

Strategies and methods for implementing CE in construction activities in the Nordic countries



Nordic Council
of Ministers



Contents

Preface	3
Terms and definitions	4
Executive summary	5
1 Introduction	10
1.1 Background	10
1.2 Objectives and scope	14
1.3 Methodology - value chain approach	14
1.4 Guidance for the reader	16
2 National and local CE strategies for C&DW	18
2.1 National strategies	18
2.2 Municipal and local strategies	26
3 Screening and selection of cases	28
3.1 Screening of cases	28
3.2 Selection criteria	29
3.3 Selected cases	30
4 Digital solutions in the construction and demolition sector	33
4.1 Digital solutions – what are they?	33
4.2 Nordic digitalisation strategies	34
4.3 Digital solutions to support development of a circular economy	36
5 Drivers and barriers presented in cases for the implementation of CE in the construction sector	44
5.1 Local CE strategies to boost a circular economy	45
5.2 Digitalisation as a tool to boost a circular economy	50
5.3 Technical specification – barriers to business	51
5.4 Supporting and improving quality	57
5.5 Business models for reuse - barriers and drivers	60
5.6 Market pull - Policy instruments to support market uptake	62
5.7 Reuse and recycling targets and indicators	64
6 Policy recommendations	66
Annex 1 Screening of cases	68
Annex 2 Selected cases	83
Annex 3 Local strategies and networks to promote CE	118
Annex 4 Digitalisation cases	122
About this publication	127

Preface

This document is the report on the project entitled **"Strategier och metoder för implementering av cirkulär ekonomi i byggverksamheten i Norden - Kartläggning av goda exempel och hinder"** financed by the Nordic Council of Ministers and the **Nordic Working Group for Circular Economy (NCE)**. The project was initiated in March 2020 and finished in October 2020.

The project work was followed by a Nordic Steering Group consisting of the following members:

- Tiina Karppinen, Finnish Environment Institute
- Camilla Sederholm, Finnish Environment Institute (until May 2020)
- Christoffer Back Vestli, Miljødirektoratet, Norway (until September 2020)
- Jon Fonnli Larsen, Miljødirektoratet, Norway (from September 2020)
- Per Ravn Hermansen, Ministry of Research and Environment, Greenland

The project was coordinated by VTT from Finland. The project group consisted of the following persons:

- Margareta Wahlström, VTT Ltd, Finland (project manager)
- Malin zu Castell-Rüdenhausen, VTT Ltd, Finland
- Thilde Fruergaard Astrup, Danish Technological Institute, Denmark
- Anke Oberender, Danish Technological Institute, Denmark
- Carl Jensen, RISE, Sweden
- Pernilla Johansson, RISE, Sweden
- Eirik Rudi Wærner, Multiconsult Norge, Norway

November 2020

Project group

Terms and definitions

BASTA	BASTA is a system to make conscious product selections with the aim of phasing out substances of concern – for example building owners, contractors, architects, structural engineers or individuals
BREEAM	Building Research Establishment Environmental Assessment Method (BREEAM) from the UK's BRE
BIM	Building information modelling
C&DW	Construction and demolition waste
CE	Circular economy
CE-marking	administrative marking that indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area
CLP	Classification, Labelling and Packaging Regulation. Regulation (EC) No 1272/2008 of the European Parliament and of the council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006
Construction product	any product which is produced for incorporation in a permanent manner in construction works, including both buildings and civil engineering works
Construction works	includes both buildings and civil engineering works
CPR	Construction Products Regulation
DOP	Declaration of Performance
EN	European Norm
EoW	End-of-Waste
EPD	Environment Product Declarations
ETA	European Technical Assessment
EU harmonised standard	European standard (EN), prepared under the mandate of the European Commission or the EFTA
EPR	Extended Producer Responsibility
GPP	Green Public Procurement
Hazardous substance	a substance that is assigned a hazard statement code when classified using the CLP Regulation
Hazardous waste	a waste that due to its (intrinsic) chemical or other properties poses a risk to the environment and/or human health. Waste listed as hazardous in the European List of Waste are marked with an asterisk
LCA	Lifecycle Analysis
LEED	US Green Building Council's Leadership in Energy and Environmental Design
NACE	Nomenclature of Economic Activities (the European statistical classification of economic activities used by Eurostat)
REACH	European chemicals regulation concerning Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
VAT	Value Added Tax
waste	any substance or object the holder discards, intends to discard or is required to discard. Generally relates to waste materials where the ultimate end point is disposal rather than recycling
WFD	Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Waste Framework Directive)
WMP	Waste Management Plan
WPP	Waste Prevention Plan

Executive summary

A circular economy (CE) in the construction sector offers significant possibilities for saving natural resources and energy, while also reducing greenhouse gas emissions. Half of the Earth's raw materials are used in construction and nearly 40% of the energy consumption is used during the service life of buildings, but a considerable amount of the energy consumption relates to raw material extraction and the manufacturing of construction products. Furthermore, of the total generated waste within the EU, 30% comes from the construction sector.^{1 2}

Denmark, Finland, Norway and Sweden have prepared, or are preparing, a national strategy for a circular economy, which sets the overall targets for a circular economy in each of the countries. These local and national strategies give guidance on the way towards a circular economy and provide measures to reach the set targets in the strategies. Putting theory into practice via strategies can be a good means for the transition towards a circular economy in the construction sector. Municipalities can set requirements for CE solutions in the construction sector by requiring, e.g. the use of recycled and/or recyclable construction materials in construction, the application of design for disassembly principles in construction and requiring resource mapping, and reuse and recycling in the demolition phase, etc.

The aim of this study was to identify and present cases and experiences from the implementation of CE concepts at the local level in the Nordic communities with a focus on construction, renovation and demolition. Information was mainly collected from Denmark, Finland and Sweden and to a limited extent from Norway due to the small budget available for the Norwegian partner in this project.

The project evaluates how the national strategies in the Nordic countries have an influence on the implementation of CE concepts at local levels. Barriers and drivers for the uptake of CE solutions are analysed, and enabling factors that could support the implementation of circular economy concepts and identified barriers in norms, legislation and guidelines are described. In addition, the identification and evaluation of digital methods and solutions (e.g. the classification and statistical documentation of waste amounts and materials) that may help in establishing effective markets for secondary raw materials have also been included. The focus has been on waste material streams, and actions that mainly target other objectives such as water or energy consumption during the use phase are excluded.

The study shows that several of the identified local strategies focused not only on the circular economy but in many cases on climate effects as well. Similar to the national strategies, the local strategies were rather generally formulated. Denmark is a good example, where tools, such as requirements for sustainable construction have supported the implementation of local strategies drawn up based on national strategies in constructions in the municipality. The local strategy documents describe clear goals and list concrete actions to be considered in demolition work and resource savings in new construction (by reuse and recycling of materials).

-
1. World Green Building Council. 2019. New report: the building and construction sector can reach net zero carbon emissions by 2050 <https://www.worldgbc.org/news-media/WorldGBC-embodied-carbon-report-published>
 2. Council of European Union. 2019. Circular economy in the construction sector - draft Council conclusions. Document 13270/19 dated 18 October 2019.

In the data mapping of the cases, 115 cases were collated from Denmark, Finland, Norway and Sweden for further analysis. This was done based on our knowledge of existing relevant examples and cases, e.g. via our network, prior work and contacts. The data was supplemented with a desktop study, screening of projects, seminars, and company information, as well as interviews with relevant stakeholders.

Many cases could not be linked directly to a national or local strategy. In the cases presented in this report, we can see that many business opportunities seem to have been created through the influence of national and local strategies. The cases showed that the circular economy had been implemented, e.g. with the help of funding from research and innovation funding programmes, local funding programmes or were linked to the national waste management plan aiming for waste prevention and improved recycling. The identified cases were characterised with respect to which part of the value chain they focus on, and some key topic areas they covered. In some cases, several parts of the value chain were covered, but for most cases the focus was on the end-of-life solutions. New business models were often included in the cases.

In this report, 14 cases were selected for further description and analysis. The following criteria were considered when selecting relevant cases for the scope of the project:

- the action should fit the concept of a circular economy
- the selected action should have been demonstrated in an operational environment and implemented (impacts visible in short/long term)
- the action should be relevant for the policy objectives (national or local strategies), meaning that the selected action should contribute to material/product management (saving of resources)
- the selected actions should have a significant impact on resource savings
- the chosen cases represent different stages of the value chain (i.e. raw material extraction, material production).

Additional criteria considered were:

- background data available/documented
- cases from all four countries are presented
- novelty and multiplicability of the solution
- useful data for analysis of barriers, bottlenecks.

The cases chosen to be presented and analysed in this report all contribute to a rethinking of the traditional value chain and aim to form a loop, where the lifespan of buildings is increased, the products are efficiently reused and materials are recycled. A rough presentation of how the cases fit the circular approach is illustrated in Figure 1.

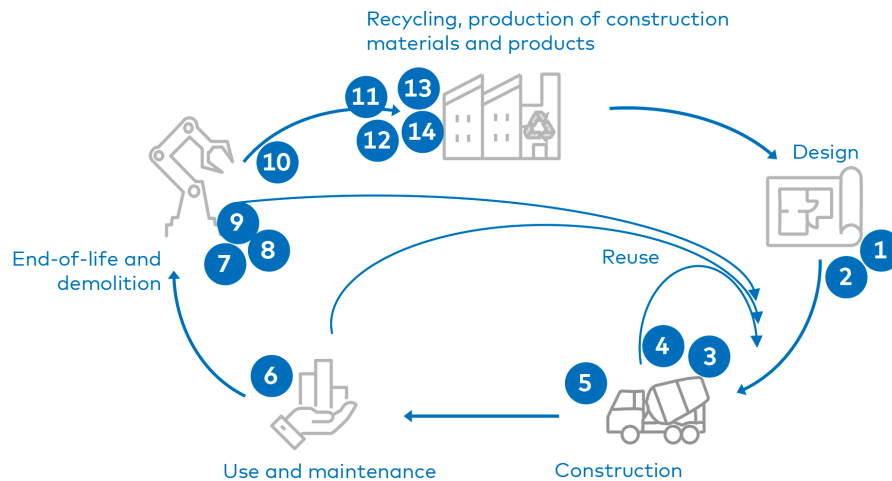


Figure 1: The chosen cases and how they fit in the value chain of the construction sector

The design phase is key to facilitating sustainable material use, easy maintenance, easy change of intended use and increased lifespan. FM-Haus (1) makes modular, easy to disassemble and reconstructable buildings, whereas Blixens (2) represents the design (and construction) of an office building by using environmentally sustainable solutions, such as reused and recycled materials. Identified drivers for the design phase were mainly local and national building strategies.

The construction phase should focus on material efficiency. Netlet (3) and ConZerW (4) work with reducing waste generation on construction sites, Netlet via collecting surplus materials for sale, and ConZerW via digital tools tracking waste generation and optimising material use. Byggeri København (5) is the City of Copenhagen's developer unit, presenting several cases with a CE focus. Identified drivers for the construction phase were national waste reduction strategies (implemented via taxes and costs for waste management), local ambitious strategies, and political focus on circular economy.

The use and maintenance phase should be maximised and prolonged. Drone technology (6) for material inventory presents the use of drones for material inventory prior to demolition. Although only one case is represented in this phase, many others have activities for a prolonged lifespan. A prolonged lifespan for buildings is mainly driven by economic incentives and local strategies aiming to prevent premature demolition activities.

The end-of-life and demolition phase determines the fates of the generated waste materials, and should focus on maximising recycling rates. Kompanjonen (7), Loopfront (8) and Vuorenranta (9) all focus on the salvation of building products for resale, all with differing business strategies and methods for implementation. Circular solutions for wood waste (10) also presents three companies working with different types of wood (waste) encompassing different reuse and recycling solutions and different business cases. The end-of-life activities are highly driven by national and local CE strategies, but in many cases also require some type of

external funding to work.

Recycling and the production of construction materials and products closes the material loop of the construction sector. Innovative recycling technologies or collection systems are needed for smaller waste fractions to be recycled. The recycling of plasterboards (11) and increased circular use of flat glass (12) are research projects aiming to find self-sustaining systems, which can increase the recycling rates of these materials. End-of-waste (EoW) status for concrete waste in Finland (13) represents a case where the recyclers are striving to get a formal end-of-waste status for concrete waste in Finland, and Circular concrete (14) is a cooperation between two Danish companies that have succeeded in the development of a certified concrete. Drivers for recycling are national recycling targets and also economic incentives via the cheaper raw material.

Barriers and drivers were analysed in all cases and grouped according to different topics. Some examples of the identified barriers and drivers are listed in Table 1.

Table 1: Drivers and barriers for the implementation of a CE in construction, as identified in the project

Topic	Driver	Barrier
Links to local strategies and Green Public Procurement	– Green Public Procurement for construction work (use of recyclables, reusable products) and demolition work (pre-demolition audit, sorting)	– Lack of concrete criteria in local strategies – Difficulties for constructors to find acceptable products suitable for the construction at the right time
Digitalisation as a tool to boost the circular economy	– digitalisation supports the flow of information, traceability of waste, digital material passport provides information on product content and historical data on use	Building Information Models (BIM) are lacking in old constructions – reliability of data depends on several other factors such as regulation, the users/data providers acceptance and willingness to report, the level of quality control and resources spent on the interpretation of reported data
Technical specification for construction products	– CE-marking provides a uniform system for documentation and testing – use of certification and end-of-waste (EoW) concept improves quality and trust for recyclables	– requirement for CE-marking of construction products, but scope of harmonised standards may exclude reuse and recycling – EoW procedures still under development
Supporting quality and collection	– using waste materials to preserve the environment	– low prices of virgin materials hamper the recycling of waste materials (e.g. flat glass, gypsum)
New business models for reuse	– marketplaces promote reusing products – potential to include in market platforms Environmental Product Declaration (EPD) data to be used in LCA – products may have historical value (design from the 1940s, handmade windows) – cost savings, quality of products equal to new products (e.g. kitchen equipment).	– unclarity in CE-marking, liability, waste or product status – storage of products and materials – in big commercial building projects difficult to use single reusable products – image ("new products are better") – lack of market--new business models needed (consultation, reverse logistics) – In reuse of products the logistics in dismantling products from construction must be synchronised with the delivery of the reusable product to the end-users. Otherwise, there is a need for storage of products
Market pull	– the economic drivers to direct construction and demolition for reuse and recycling are: green public procurement, the taxation of virgin materials, landfill taxes and landfill bans on recyclable materials	– abundance of virgin materials (e.g. wood, aggregate in some Nordic countries), low prices
Others (examples)	– need for awareness raising notified in education	– lack of knowledge/ negative attitudes by architects, client – lack of coordination between actors – reuse: need to be planned in process

Based on the barriers identified, the project group gave 10 policy recommendations:

1. For the implementation of CE goals at the local level: guidance documents and especially concrete criteria recommended to support the achievement of CE solutions in practice.
2. The use of Green Public Procurement (GPP) both for construction and demolition work to support the reuse and recycling of construction and demolition waste. Especially GPP in construction promotes closing the loop.
3. Nordic input into the CE on the definition of material-specific targets, with special focus on how waste hierarchy can be better implemented. This means the distinguishing of waste prevention, reuse and high-grade recycling from downcycling, backfilling.
4. Securing that the Nordic aspects are considered in the revision work of the Construction Products Regulation, and linked harmonised product standards for CE-marking as products are traded between countries.
5. A need for the development of digital competences in the entire value chain.
6. The promotion of End-of-Waste (EoW) and certification concepts – exchange of information (elements, e.g. traceability concepts).
7. Actions for securing market pulls for CE solutions
8. Funding systems for start-up companies, new technology demonstrations
9. Education in (applied) universities on CE solutions in construction
10. Education of professionals in business (constructors, designers, authorities, consultants)

1 Introduction

1.1 Background

A circular economy in the construction sector offers significant possibilities for the saving of natural resources, energy and reducing greenhouse gas emissions. Half of the Earth's raw materials are used in construction and nearly 40% of the final energy consumption is used during the service life of buildings, especially from the use and maintenance of buildings, but also in the production of construction products and materials from raw materials. Furthermore, 30% of generated waste is from the construction sector in the EU.^{3 4}

In a circular economy (CE), raw materials are not taken out of their cycles, they remain in the economy for as long as possible through efficient and smart use. Their value is also preserved by optimising their reuse and recycling. The circular economy, however, involves much more than just recycling; it requires a fundamental rethinking of value chains and business models, of product design and the overall economic systems in which they are applied to achieve the lowest environmental impact.

In the built environment, this would mean buildings and construction elements are designed to be easy to adapt, easy to dismantle and are hardly ever demolished. Building materials or building elements would be quickly and efficiently reused, which again would result in high-quality materials being maximally utilised in a closed loop and almost no material would end up as waste. Hazardous materials such as asbestos and tar would be removed from the material cycle.

The total construction and demolition waste (C&D waste) generation in the Nordics in 2018 was approximately 13.5 Mtonnes and represents a high potential for circular economy (Table 2). The waste generation in the construction sector in the Nordics is illustrated in Figure 2.

-
3. World Green Building Council. 2019. New report: the building and construction sector can reach net zero carbon emissions by 2050 <https://www.worldgbc.org/news-media/WorldGBC-embodied-carbon-report-published>
 4. Council of European Union. 2019. Circular economy in the construction sector - draft Council conclusions. Document 13270/19 dated 18 October 2019.

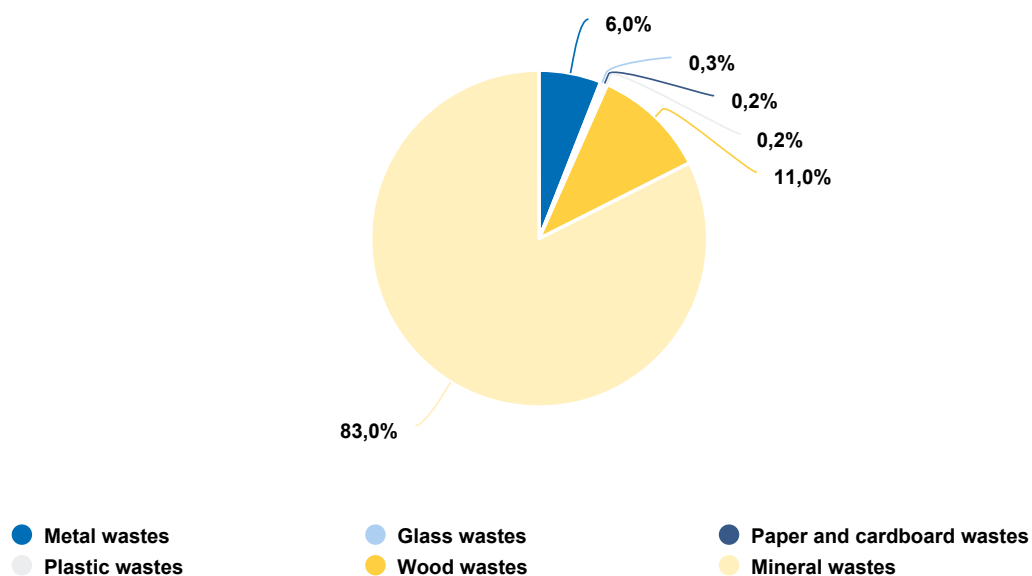


Figure 2: Waste generation in the Construction sector in the Nordics (Eurostat, 2020). Shares as percentages

Table 2: C&D Waste generation in the Nordic countries (Eurostat, 2020⁵). Waste amounts in tonnes in 2018.

	Denmark	Finland	Norway	Sweden	Iceland
Metal wastes	407 000	170 000	125 000	80 000	0
Glass wastes	28 000	600	10 000	6 000	500
Paper and cardboard wastes	3 000	300	21 000	0	0
Plastic wastes	5 000	300	20 000	800	100
Wood wastes	163 000	400 000	245 000	637 000	0
Mineral waste	4 127 000	1 250 000	2 428 000	2 877 000	609 000
Total	4 735 000	1 822 000	2 850 000	3 600 000	610 000

5. Eurostat data for 2018 was used and the CDW definition includes W061, W062, W063, W071, W074, W075 from NACE F and W121 across all NACE activities.

The recovery rate of mineral C&D waste (when soil waste is excluded) is rather high in all the Nordic countries (especially Denmark and Finland). However, high recovery rates are, to a large extent, based on a high degree of backfilling or low-grade recovery (downcycling). Although the degree of reuse, recycling and recovery varies for different types of C&D waste, in general it can be said that there are still needs for improving the recycling and reuse in order to implement a circular economy.

Currently, many bottlenecks hamper the transition to a circular economy in the built environment. These are often linked with past or current building practices as well as difficulties in establishing effective markets for reused and recycled building materials. The main barriers related to establishing markets for recyclables are, e.g. the price, quality and quantities of the secondary raw materials and also unclarities in both the technical and environmental conformity assessment of products containing waste related materials as raw materials (e.g. scope of harmonised standards for CE-marking).

High-quality recycling and reuse require greater efforts compared to energy recovery and low-grade material recycling. Strategies for the implementation of a CE need to be facilitated by the right business models such as product-service combinations and policy instruments. To make an economy truly circular, it is necessary to take additional measures by focusing on the whole lifecycle of construction products in a way that preserves resources and closes the loop. Actions must be taken at every stage of the value chain, covering materials production, design, construction, use, and finally also end-of-life.

Box 1. EU policies and strategies related to the circular economy with a focus on construction

The first Circular Economy Action Plan (CEAP 1) was published in 2015. It mentions Construction and demolition as a priority area in 2015 and lists three actions required for the achievement of a circular economy:

- Waste Management Protocol: this aims to ensure the recovery of valuable resources and adequate waste management in the construction and demolition sector.
- Waste Audit Guideline: pre-demolition guidelines to boost high-value recycling as well as voluntary recycling protocols aimed at improving quality and building confidence.
- EU Level(s) – A European reporting framework for sustainable buildings: this aims to facilitate the assessment of the environmental performance of buildings.

The New Circular Economy Action Plan (CEAP2)⁶ was launched in 2020 (one of main blocks of the European Green Deal). CEAP2 also mentions the construction sector as a focus area and it presents as one key measure to “make sustainable products as a norm in Europe”. It is built on EU previously published strategies on Circular Economy Action Plan from 2015 and the Circular Economy Package from 2018 (including EU Strategy on Plastics in a Circular Economy⁷). The European Green Deal and CEAP both focus on EU Climate Strategies⁸ for a low-carbon economy.

The CEAP is an overarching policy that also covers waste legislation. It is therefore not possible to distinguish between policies related only to waste legislation or circular economy concepts.

Furthermore, the European Green Deal mentions the Zero Pollution Ambition (ZPA) for a toxic-free environment. The ZPA especially addresses a need to rapidly address the risk posed by hazardous chemicals and, more specifically, very persistent chemicals, encourage initiatives that ensures that products are designed to be safe – free from hazardous chemicals – and circular/sustainable by design and support actions for clean material loops.

6. <https://ec.europa.eu/environment/circular-economy/>

7. https://ec.europa.eu/environment/waste/plastic_waste.htm

8. https://ec.europa.eu/clima/policies/strategies_en

1.2 Objectives and scope

The aim of this study was to identify and present experiences from the implementation of circular economy concepts in the construction sector in the Nordic countries. Furthermore, the role of strategies and digital solutions, and whether they have a true impact on the transition towards a circular economy at a municipality or local level in the Nordic communities was investigated. Barriers and drivers for the uptake of circular economy solutions are analysed, and enabling factors that could support the implementation of circular economy concepts and identify barriers in norms, legislation and guidelines are described. Action that mainly targets other objectives such as water or energy consumption during the use phase are excluded.

More specifically the objectives of the study were as follows:

1. To identify and present the main national and local strategies of the Nordic countries and to evaluate how the national strategies have an influence on implementation of CE concepts at different levels
2. To identify and present a set of good examples of the implementation of circular economy concepts in the construction sector in the Nordics
3. In more detail present a set of cases along the circular value chain and analyse the main drivers and barriers related to these cases
4. To map which digital solutions are applied or expected to be applied as tools to boost a circular economy in the Nordic countries.
5. To analyse barriers and drivers for the uptake of a circular economy in the Nordics

Information was mainly collected from Denmark, Finland and Sweden and to a limited extent from Norway due to the small budget available for the Norwegian partner in this project.

1.3 Methodology - value chain approach

In a circular economy, buildings, construction products and materials are not taken out of their cycles, and their value is preserved by prolonging their lifetime, as well as optimising their reuse or recycling. The circular economy requires a rethinking of value chains and business models in order for materials to remain in the economy for as long as possible. The cases chosen in this report all contribute to a rethinking of the traditional value chain, aiming to form a loop, where the lifespan of buildings is increased, the products are efficiently reused and materials recycled. The value loop of the construction sector is illustrated in Figure 3.

To close the loop, it is important to focus on the whole value chain, from material production, to construction, maintenance, demolition, waste management and recycling. Some of these phases are keys to waste prevention and keeping the materials in use for as long as possible, while others are necessary when the constructions have met end-of-life and the materials and products must be reused or processed for recovery.

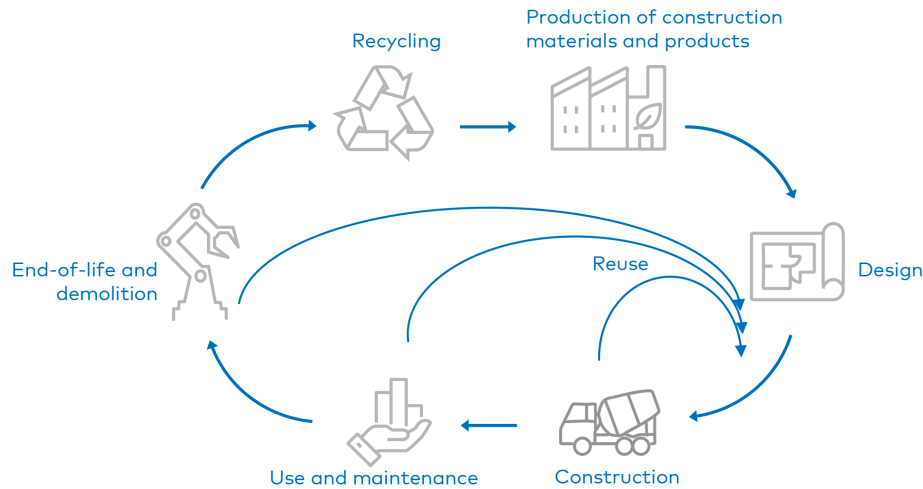


Figure 3: The value chain of the circular construction sector

The production of construction materials and products (partially) based on secondary raw materials offers great potential for reducing the use of virgin materials. At the same time, it offers the possibility to focus on the reusability and recyclability of materials and products, when they have reached end-of-life status. Furthermore, the durability and lack of hazardous substances present in materials and products has a great impact on their longevity and potential for reuse and recycling.

The design phase (not included in the loop figure) is key to facilitating sustainable material use, easy maintenance, easy change of intended use and increased lifespan. Material choices should focus on the use of secondary raw materials, but also on renewable and recyclable materials. Maintenance should opt for flexible, upgradable, repairable and adaptable structures, allowing the construction to perform ideally in many different stages of use. Flexible change of use is key in increasing the lifespan of the construction by reacting to changes in demand. Increased lifespan is key to keeping materials in the loop for longer.

The construction phase is of key importance when focusing on material efficiency. Principles and ideas laid out in the design phase must be implemented by the most suitable choice of materials, construction method and technical solutions. At construction sites, waste generation should be minimised and taken care of appropriately. Take-back solutions for surplus materials, collection of spill and leftover materials can facilitate the reuse and recycling of building materials. By using tools for building information management (BIM), and material passports, the following life stages of a building, e.g. maintenance and pre-demolitions audits prior to demolition can be facilitated, as also the recovery of waste and materials at end-of-life. This increases the value of the construction materials throughout the entire lifecycle.

Use and maintenance phase should be maximised and prolonged if possible. By maximising the use of the construction, i.e. the use intensity, the need for building

other constructions for some activities can be prevented. Increased use intensity of buildings includes, e.g. flexible functionality for different users at different times of the day. The increased lifespan of a building also reduces the demand for new constructions and keeps the materials in the loop for longer. Rehabilitation, repairing, as well as strengthening and retrofitting structures are means to achieving a longer lifespan. The BIM and material passports should also be updated during maintenance to maintain and increase the material value throughout the lifespan of the building.

The end-of-life and demolition phase determines the fates of the generated waste loop – where waste material can be recycled into a new product or sent to waste disposal. Recycling efficiency is very much dependent on the quality of the feedstock, where barriers for recycling include contaminants of both foreign and hazardous materials. Buildings and constructions that are demolished now are typically from periods when problematic substances such as PCB, asbestos and lead were commonly used in construction, and circular design principles and construction methods were not applied. Therefore, demolition practises (including pre-demolition audits, resource inventories, the removal of hazardous materials prior to selective demolition) are key to maximising the material value and recyclability of the waste arising from demolition; the EU Construction and Demolition Waste Management Protocol⁹ includes good practices for demolition works. Selective demolition and efficient site sorting prepare materials for reuse and recycling and enhances the recovery and recycling of waste, while tracing systems further contribute to the quality assessment and certification of C&DW streams, increasing the material value of the waste.

The recycling phase closes the loop. Recovered materials can be used for the production of construction materials and products.

1.4 Guidance for the reader

In order to identify and present good examples of strategies and methods for a circular economy, we have shortly reviewed national strategies with relevance to circularity, circular/sustainable construction, waste management, and digitalisation in the Nordic countries. Furthermore, we have reviewed examples of strategies at the municipality and project level. An overview of the strategies and methods that we have selected for this report can be found in Chapter 2 and Annex 1.

We have carried out a screening of cases, companies, and projects that address strategies and methods for the implementation of a circular economy at the municipality level. We also collected examples for digitalisation in the construction and demolition sector. This has been done based on our initial knowledge of existing relevant examples and cases, e.g. via our network, prior work, and contacts. This has been supplemented with a desk study, screening of projects, seminars, company information as well as contact to and interviews with relevant stakeholders.

A long list of cases, identified as building on the concept of a circular economy, was collected during the first screening round. The main aim was to find a very diverse collection, representing cases from different stages of the value chain and also different stakeholders and customers. While compiling this list, no specific focus or

9. European Commission "EU Construction and Demolition Waste Protocol", available online from https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en (2016)

requirements were considered, the aim was to find a broad selection on which to build the selection criteria to narrow down the list. A long list of the examples and cases that were identified can be found in Annex 2.

The presented cases act mainly as examples of different types of cases, aiming to present cases from all the studied countries and from all phases of the value chain. The cases are not chosen based on performance or superiority, and good examples which are not analysed in this study are not excluded because they are considered weaker. For each selected case a fact sheet was developed, highlighting the links to strategies, materials and technologies in focus, phases of the value chain, whether there was a focus on digitalisation, as well as lessons learned. For all cases, drivers and barriers were elaborated on, with a focus on the innovation potential and potential for replicability and if there are any specific factors which contributed to the success of the concept. The fact sheets can be found in Annex 2.

A list of cases that address digitalisation can be found in Chapter 4.

There is a great deal of focus on digitalisation and digital solutions that can assist in the documentation, classification, statistical documentation of waste flows and in establishing effective markets for secondary raw materials. In chapter 4, we have addressed a few selected approaches to digital solutions.

Based on the experience from the different selected cases and our knowledge of drivers and barriers to circular economy, we have identified the most successful drivers that could support the implementation of circular economy strategies and methods. This can be found in chapter 5.

Chapter 6 contains policy recommendations that are based on the findings in this project.

2 National and local CE strategies for C&DW

We have reviewed national strategies with relevance to circularity, circular/sustainable construction, waste management, and digitalisation in the Nordic countries. Furthermore, we have reviewed examples of strategies at the municipality and project levels. This chapter presents an overview of the national and local strategies, with some national strategies presented in more detail in Chapter 2.1 and a long non-exhaustive list of local strategies presented in Annex 3.

In this section, we list key national strategies with links to the circular economy and give examples of local strategies. However, national strategies for digitalisation are reviewed in Chapter 4. The local and national strategies guide the way towards a circular economy and provide measures to reach the targets set out in the strategies. However, this can be done in many ways. In the cases presented in the Annexes, it can be seen that many business opportunities are created through national and local strategies. Thus, putting theory into practice via strategies can be a good means of transitioning towards a circular economy in the construction business.

2.1 National strategies

The circular economy in the construction and demolition sector can be addressed in different types of strategies. Table 3 below presents an overview of the national strategies of the Nordic countries, including a link to the strategy for further information. In order to present the range and examples of targets for circularity in the construction and demolition sector in Nordic strategies, we have selected a few examples of different types of strategies and present them in the following pages.

Table 3: Summary of national strategies and plans (some strategies and action plans are presented in more detail in box 2).

Presence of national strategies	Denmark	Finland	Norway	Sweden
Waste Management Plan (WMP)	Yes ¹	Yes ²	Yes ³	Yes ⁴
– Is there a specific section on construction and demolition waste (CDW) in the WMP?	Yes	Yes	Yes	Yes
– Objectives with respect to CDW?	Yes	Yes	Yes	Yes
National Waste Prevention Plan (WPP)(national/regional) in place?	Yes ⁵	No ⁶	No ⁷	Yes ⁸
– Is there a specific section on prevention measures of CDW in the WPP?	Yes	-	Yes	Yes
– Objectives of the document with respect to CDW?	Yes	-	Yes	Yes
National material efficiency or resource efficiency strategy in place?	No	Yes ⁹	No	No
– Is there a specific section on CDW?	-	No	-	-
– Objectives of the document with respect to the construction sector and CDW?	-	No	-	-
Other strategic document/plan in place with specific mention of CDW and/or material resources relevant to the construction sector and CDW (as resource, e.g. reuse, End-of-Waste status)?	Yes ¹⁰	Yes ¹¹	Yes ¹²	Yes ¹³
– Objectives of the document with respect to the construction sector and CDW?	Yes	Yes	Yes	Yes
Other strategic documents/plans in place with relevance to CE focus not only on CDW (e.g. climate strategies, sustainability strategies, non-tox strategies)?	Yes ¹⁴	Ongoing ¹⁵	Ongoing ¹⁶	Yes ¹⁷
– Objectives of the documents and relation to sustainability strategies impacting the operational environment of the construction sector?	Yes	Yes	-	Yes
Relevant building and construction strategies (e.g. with relevance to material use, indoor air quality, procurement)?	Yes ¹⁸	Yes ¹⁹	-	Yes ²⁰

1. Danish Government (2013): Denmark without waste. Recycle more – incinerate less (in Danish) https://mst.dk/media/mst/Attachments/Ressourcestrategi_DK_web.pdf and Danish EPA (2014): Denmark without waste. Resource plan for waste management 2013-2018 (in Danish). Guidelines from the Danish EPA no. 4 <https://www2.mst.dk/Udgiv/publikationer/2014/05/978-87-93178-55-7.pdf>

2. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160889/SY_01en_18_WEB.pdf?sequence=1

3. <https://www.regjeringen.no/no/dokumenter/meld.-st.-45-20162017/id2558274/?ch=1>

4. Nationell plan och avfallsförebyggande programmet 2018–2023 – att göra mer med mindre <http://www.naturvardsverket.se/Om-Naturvardsverket/>

Publikationer/ISBN/6900/978-91-620-6946-9/

5. Danish Government (2015): Denmark without waste II. Strategy for waste prevention (in Danish) https://mst.dk/media/90395/danmark_uden_affald_ii_web_29042015.pdf

6. The National Waste Management Plan also includes the waste prevention plan.

7. The National Waste Management Plan also includes the waste prevention plan.

8. Nationell plan och avfallsförebyggande programmet 2018–2023 – att göra mer med mindre <http://www.naturvardsverket.se/Om-Naturvardsverket/>

Publikationer/ISBN/6900/978-91-620-6946-9/

9. The National Material Efficiency Programme – Sustainable Growth through Material Efficiency https://tem.fi/documents/1410877/3323088/Sustainable_growth_through_material_efficiency/fd454ebd-49a7-4675-af0d-a897b5aec87a

10. The Danish Government (2018): Plastic without waste – The Government's action plan on plastics (in Danish). https://mfvm.dk/fileadmin/user_upload/MFVM/Publikationer/NY_Regeringens_plastikhandlingsplan_full_version_FINAL_O123-2019.pdf One of the initiatives in the action plan is aimed at the construction sector (development of voluntary partnerships within selected sectors, e.g. the construction sector).

11. Plastics roadmap. <https://muovietiekartta.fi/in-brief/>

12. The Norwegian government has announced a circular economy plan to be released in the end of 2020. <https://www.byggemiljo.no/nasjonal-handlingsplan-for-bygg-og-anleggsavfall-2017-2020-nhp4-er-klar/>

13. Resource and waste guidelines for construction and demolition <https://byggforetagen.se/app/uploads/2020/01/190520-Resurs-och-avfallshantering-vid-byggande-och-rivning.pdf>

14. The Danish Government (2018): Strategy for circular economy. More value and improved environment through design, consumption, and recycling https://www.regeringen.dk/media/5626/strategi-for-cirkulaer-oekonomi_web.pdf. The Danish Government (2013): Strategy for intelligent public procurement https://www.regeringen.dk/media/1278/strategi_for_intelligent_offentligt_indkoeb.pdf. The national strategy for intelligent public procurement focuses, among other aspects, on increased use of tools for calculating the total cost of ownership and sustainability in public procurement.

15. The Finnish Government is currently preparing a strategic programme to promote a circular economy (to be finalised during 2020. <https://ym.fi/en/strategic-programme-to-promote-a-circular-economy>

In 2016, the Finnish Innovation Fund (Sitra) in collaboration with Ministries of the Environment, Agriculture and Forestry and Economic Affairs and Employment, the business sector and other key stakeholders, compiled a roadmap to a circular economy <https://media.sitra.fi/2017/02/28142644/Selvityksia121.pdf>

16. <https://www.regjeringen.no/no/tema/klima-og-miljo/forurensning/sirkular-okonomi/id2700997/>

17. Molio Byggeriets Videnscenter. 2020. Industriens Fond og Realdania vil styrke brugen af ny teknologi i byggebranchen (pressrelease dated 25.6.2020) https://fossilfrittsverige.se/wp-content/uploads/2020/10/ffs_bygg_anlaggningssektorn.pdf

<https://via.ritzau.dk/pressemeddelelse/industriens-fond-og-realdania-vil-styrke-brugen-af-ny-teknologi-i-byggebranchen?publisherId=13560015&releasId=1359597118>.

18. Danish Ministry of Transport, Construction and Housing (2019): Strategy for digital construction work <https://www.trm.dk/publikationer/2019/strategi-for-digitalt-byggeri/>

19. Wood Building Programme. <https://ym.fi/puurakentaminen>

20. Focus on wood construction https://www.regeringen.se/49ee7f/contentassets/37f07802672c45078a20d3a375e82c25/20180626_inriktning-for-trabyggande.pdf

Box 2. Examples of national strategies listed in Table 3

National waste management plan – Sweden

The Swedish national waste management plan and the waste prevention plan have been merged into one plan which covers the time period 2018–2023. Set targets in the plan include the UN global sustainability goals, as well as those in the waste framework directive, EU climate and energy package and the climate and energy framework, as well as the general national targets stating "sustainable management of resources" and "sustainable waste management", etc. Many of these targets apply to (but not exclusively) to the generated construction and demolition waste. The only target applying exclusively to the construction and demolition waste is the one in the waste framework directive stating that *"Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste..."*. The plan also states that the goal is to decrease the amounts as well as the hazardousness of construction and demolition waste, but it is not stated to what extent.

Measures needed to be taken to reach the set targets are fairly vaguely described in the plan, but it is stated that "to prevent the generation of waste during construction, management and demolition, the Swedish Environmental Protection Agency, the National Board of Housing, Building and Planning and The Swedish Construction Federation collaborate in guidance campaigns, information and education initiatives" to improve the management of constructions and demolition waste. This requires, among other things, that material inventories of buildings before demolition be more comprehensive in order to make it possible to identify materials and products for reuse, waste that can be recycled, and hazardous waste so that it can be disposed of in an environmentally acceptable way. Furthermore, it is required by law that that wood, minerals (such as concrete), bricks, tiles, metals, glass, plastics, and gypsum be sorted at construction and demolition sites.

The 70% recycling and reuse target of construction and demolition waste is followed up by the Swedish Environmental Research Institute together with Statistics Sweden through the consortium SMED on behalf of the Swedish Environmental Protection Agency.

National waste management plan – Finland

From recycling to a circular economy, the National Waste Plan to 2023. Finland's WMP is currently under revision, extending the targets and ensuring compliance with the revisions of the Waste Framework Directive. The plan consists of both a waste management plan and a waste prevention plan, as well as a plan for reducing the harmfulness of waste. The current WMP sets out a target state to achieve by 2030, when the following should be achieved:

- High-standard waste management is part of the sustainable circular economy;
- Material-efficient production and consumption save natural resources and mitigate climate change;
- Volumes of waste have decreased from the present. Reuse and recycling have risen to a new level;

- The recycling market works well. Reuse and recycling create new jobs;
- Valuable raw materials present at low levels are also recovered from recycled materials;
- Material cycles are innocuous and increasingly less hazardous substances are used in the production;
- In the waste sector there is high-quality research and experiments and competence in waste issues is at a high level.

The targets and measures aim to control the rise in waste quantities and to boost recycling. The measures aim to create opportunities for introducing new circular economy approaches and economically viable business concepts. The plan presents financial and administrative policy instruments, as well as a range of voluntary tools.

Construction and demolition waste is one of four key areas set out in the WMP. The key impacts will be the intensified reuse and recycling of construction products and components, thereby saving virgin natural resources. In order to reach the set targets, the WMP presents a set of actions and measures to support the transition. The targets set for the C&DW are:

- Reducing the volume of construction and demolition waste
- Raising the material recovery rate of construction and demolition waste to 70%
- Increasing the material recovery of construction and demolition waste while managing related risks
- Achieving greater accuracy and correctness in statistics on construction and demolition waste

Resource efficiency strategy – Finland

Finland has a dedicated resource efficiency strategy in place. The National Material Efficiency Programme – Sustainable Growth through Material Efficiency¹⁰ was designed to put ideas from the 2012 Rio+20 Sustainable Development Conference and the EU's Sustainable Consumption and Production Action Plan into practice. It was published in 2013 and was updated in 2018¹¹.

The aim of Finland's National Material Efficiency Programme is to promote sustainable growth through material efficiency, and simultaneously strive for economic growth, the smart utilisation of natural resources and disengagement from adverse environmental effects. The programme's objective means that the material efficiency of companies will increase in a way that will ensure the optimisation of material use and its reduction so as to cut down on its adverse environmental impacts, and ensure responsible operating practices and the increased competitiveness of companies.

10. Finnish Ministry of Economic Affairs and Employment. 2014. National Material Efficiency Programme – Sustainable growth through material efficiency.http://tem.fi/documents/1410877/3323088/Sustainable_growth_through_material_efficiency/fd454ebd-49a7-4675-af0d-a897b5aec87a (English)

11. Finnish Ministry of Economic Affairs and Employment. 2018. Sustainable growth through material efficiency Update of the National Material Efficiency Programme 2017. Publications of the Ministry of Economic Affairs and Employment 5/2018.http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160559/TEMjul_5_2018_Kestavaa_kasvua.pdf?sequence=1&isAllowed=y (Finnish)

National action plan for waste prevention in the construction sector – Norway

The National Action Plan for construction and demolition waste is a voluntary initiative for increased source sorting and waste reduction in the construction industry. The entire chain of actors in the construction industry participates in the work: builders, designers, contractors, waste transporters, and handlers. The programme was started in 2000, and the first action plan was implemented in 2001. Initially, the goal was to increase material recycling and gain control of hazardous waste. However, in 2017, waste reduction and reuse were included as new goals.

When the program was started, about 80% of all waste went to landfills, and much was also burned on construction sites. Today, very little goes to landfills, and the recycling rate is high. However, the amount of waste has not been reduced. The regulations have been extended to include requirements for waste plans, requirements for resource sorting on construction sites, and requirements for the environmental mapping of buildings to be demolished or rehabilitated. In 2020, there will also be rules for the utilisation of concrete in construction projects. The government is referring to this action plan in their waste management plan.

Roadmap to a fossil-free competitiveness – the construction and civil engineering sectors – Sweden

To tackle the challenge of enabling the transition to a fossil-free Sweden, a joint roadmap for the construction and civil engineering sectors has been developed to direct and demonstrate how this can be achieved by the sector and its actors throughout the value chain in collaboration with politicians and other decision-makers. The plan describes a successive decrease in greenhouse gas emissions reaching net zero emissions by 2045. To enable this transition, the following five key factors have been identified:

1. collaboration, leadership and knowledge;
2. long-term conditions that enable investment and conversion to climate neutral materials and processes;
3. a development from linear to circular processes;
4. access to and efficient use of bio-based raw materials, and
5. public procurement as a catalyst for transition.

The construction and civil engineering sector have agreed on 26 points of actions for key actors in the value chain, politicians and authorities to enable the transition. One of those points of action applicable to construction and demolition waste is the change in rules and legislation for waste classification to promote circular business models as well as an increased reuse and recycling of excavated masses, building and demolition materials.

Resource and waste guidelines for construction and demolition – Sweden

The Swedish Construction Federation has published guidelines with the aim of improving resource efficiency and waste management within the construction and demolition industries. The guidelines are a tool for fulfilling the legal requirements, considering the waste hierarchy, contributing to achieving Sweden's environmental objectives, and for meeting general expectations from society for an increased

circular economy in terms of the industry's material and waste management. In some cases, therefore, the guidelines exceed the requirements in the legislation.

The guidelines contain the construction industry's agreement on how the management of resources and waste should be performed by 1) procurement and material inventory prior to demolition; 2) reuse, source sorting and other waste management services during demolition, including the procurement of a demolition contractor and planning, source sorting, and 3) other waste management services during construction, including the procurement of a construction contractor.

Examples of what the guidelines contain are:

- all actors in a construction or demolition project shall participate in the planning process to manage the material and waste in a circular way.
- material and reuse inventories shall always be carried out prior to demolition.
- a material and waste management plan should be developed for all construction and demolition projects.
- hazardous and electrical waste should first be removed as far as possible and then handled separately and disposed of in a safe manner.
- products for reuse and waste should be sorted according to the basic level for construction and demolition. If the waste is sorted into fewer fractions, this must be specifically justified.
- waste for landfilling or post-sorting should be minimised.

The Strategy for a circular economy – Denmark

In September 2018, the Danish Government adopted the strategy for a circular economy, "More value and improved environment through design, consumption, and recycling"¹². The Strategy supports the acceleration of a circular development. A total of DKK 116 million has been set aside to implement the strategy's 15 initiatives, which relate to six focus areas.

The six focus areas are:

1. strengthen enterprises as a driving force for a circular transition
2. support the circular economy through data and digitalisation
3. promote the circular economy through design
4. change consumption patterns throughout the circular economy
5. create a proper functioning market for waste and recycled raw materials
6. get more value out of buildings and biomass

Two initiatives are of specific relevance for the construction sector. These initiatives are:

Initiative no. 13: developing a voluntary sustainability class in the Danish building regulations. The aim of this initiative is to increase the resource efficiency in constructions, and to increase the extent and value of the reuse and recycling of building materials. June 2020, a voluntary sustainability class was launched, focusing on climate, lifecycle costing and indoor climate, among others. The class will be tested in the coming two years in cooperation with the construction sector. The results of the test period may create the basis for introducing the use of a

12. https://www.regeringen.dk/media/5626/strategi-for-cirkulaer-oekonomi_web.pdf

sustainability class as a requirement in the building regulations.

Initiative no. 14: expanding the use of selective demolition. The aim of this initiative is to expand the use of selective demolition when buildings reach their end-of-life. The overall objective is to promote the reuse and high-grade recycling of building materials and reduce the loss of value related to demolition. The Danish EPA has launched a project which runs from 2019 to 2021. The project analyses the environmental and socio-economic consequences of increased selective demolition, and aims to suggest standardised demolition plans and relevant education for the involved stakeholders in a demolition process.

The strategy for digital construction – Denmark

In 2019, the Danish Ministry of Transport, Construction and Housing, launched a strategy for digital construction¹³.

The strategy encompasses 18 initiatives within five focus areas. The focus areas are the following:

1. Better use of digital tools
2. Open formats and common standards
3. Better use of data
4. Digital competences for the entire value chain
5. More sustainable construction through digitalisation.

Three initiatives are related to focus area no. 5 on sustainability:

- a. further development of the two Danish software tools, "LCCbyg" and "LCAbyg" to ensure a better integration with, e.g. BIM. LCCbyg and LCAbyg are used for the assessment of a building's life cycle costs and environmental impacts, respectively.
- b. compilation of knowledge collected through the performance of lifecycle assessments (LCA) and lifecycle costings (LCC). An assessment will be performed to identify how a database for calculations and documentation of sustainable construction can be established.
- c. development of the technical basis for passports for buildings and materials. The overall aim of the passports is to create better documentation and traceability of the content and location of materials in buildings to enable a more resource efficient handling of the building during renovation or when it reaches its end-of-life phase.

13. <https://www.trm.dk/publikationer/2019/strategi-for-digitalt-byggeri/>

2.2 Municipal and local strategies

We have identified a number of strategies and methods or tools at the municipal and/or project levels that can be found in Annex 3. The list gives some examples from Denmark, Finland, Norway and Sweden, and illustrates differences in scope and focus. This list is neither exhaustive nor does it rank the strategies in any way, it merely identifies a few strategies out of many. Several of the strategies and methods that we have identified have been published in the past few years, and experiences from cases have not necessarily been published yet.

However, as we can see, most municipalities seem to have strategies to promote a circular economy and sustainable development and to boost activities which are preferable from an environmental perspective. These strategies may be combined or separated from other strategies, and either focus on CE activities or environmental issues holistically. In addition to the CE strategies of the municipalities, funding and networks are also seen as local strategies promoting a CE in this context. Several of the local/regional strategies focus on low-carbon economy including CE aspects in the action plans.

We have found examples in which local CE strategies aim at supporting businesses, promoting environmentally sustainable activities and reaching the target set in national strategies. Local strategies commonly seem to have a more concrete solution for meeting targets, such as planning and requirements for public procurement, e.g. in the "The Carbon-neutral Helsinki 2035 Action Plan"¹⁴, or Gothenburg's requirements for procurement for circular flows in construction and demolition. Local strategies are often a continuation of the national strategies with similar targets, but they often include more detailed practices and responsibilities for reaching the targets. Additionally, they may also entail a more practical follow-up system for ensuring the realisation of set targets.

As planning and permitting of construction and demolition are under municipal control, this gives the municipality a good tool for creating incentives to move towards more circular solutions. Some cities also have quite intensive construction activities themselves, allowing them to highly impact the choice of technologies and material solutions in construction via Green Public Procurement. As can be seen in the case of the strategy of Helsinki in the box below, the city will use both planning and construction activities to reach the set targets.

14. https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/HNH-2035/Carbon_neutral_Helsinki_Action_Plan_1503019_EN.pdf

Box 3. The Carbon-neutral Helsinki 2035 Action Plan

The objective of the Helsinki City Strategy 2017–2021 is to make Helsinki carbon-neutral by 2035. This goal will be achieved by reducing the greenhouse gas emissions in Helsinki by 80%, and also by compensating outside the city. One of the most significant sources of greenhouse gas emissions in Helsinki is the heating of buildings.

In the strategy, Helsinki presents 58 actions to meet the emissions reduction targets through construction and buildings.

- Improve the energy efficiency of buildings
- Introduce smart energy systems to further reduce energy consumption
- Reduce emissions in its procurement of construction materials
- The city's construction company will use biofuels in machinery by 2020
- The lifecycle emissions from the city's construction and infrastructure projects will be minimised
- The city will pilot and move towards energy-plus construction
- Using recovered materials in groundworks
- Increase the proportion of recycled materials in construction
- Land-use and planning to support carbon neutrality

The City will promote wooden construction through detailed planning

3 Screening and selection of cases

3.1 Screening of cases

During our initial screening, we collated 115 cases from Denmark, Finland, Norway and Sweden for further analysis. This has been done based on our initial knowledge of existing relevant examples and cases, e.g. via our network, prior work and contacts. This has been supplemented with a desk study, screening of projects, seminars, company information as well as contact to and interviews with relevant stakeholders.

Although this is a long list of cases with relevance to circular economy in the construction and demolition sector, it is by no means exhaustive. We know that there is a lot of focus on the implementation of a circular economy in the sector, and throughout the past years this has resulted in a large number of projects, initiatives, new companies, etc. and the list of cases illustrates this.

We know that there are bottlenecks that hamper the successful implementation of a circular economy, and they are associated with different phases in the value chain as well as material-specific challenges. The identified cases have therefore been characterised with respect to lifecycle phases and some key topic areas covered. Figure 4 illustrates the lifecycles covered in the mapped cases, by showing the share of lifecycles included in the cases. In some cases, several lifecycle stages were covered. In the data mapping, most cases were found for end-of-life solutions. Many cases related to the development of new business models. A summary of all the cases mapped in Denmark, Finland, Norway and Sweden are presented in Annex 1.

We also collected examples for digitalisation in the construction and demolition sector. See Chapter 4 for more information.

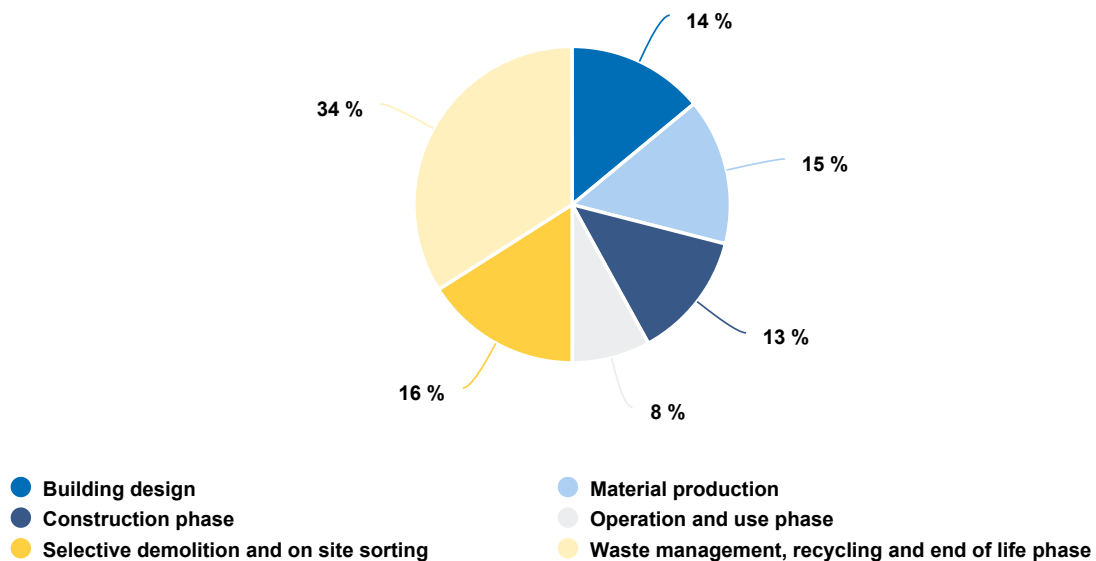


Figure 4: Nordic cases on good practices in construction: Lifecycles covered in the cases

3.2 Selection criteria

The scope of this report does not carry out a comprehensive analysis of all the identified cases and examples in terms of their potential to contribute to the implementation of circular economy and waste policy objectives. Instead, the scope is to identify some examples suitable for deeper analysis that illustrate the links between circular economy and the management of material resources for the built environment.

The following criteria were considered when selecting relevant cases for the scope of the project:

- The action should fit the concept of a circular economy.
- The selected action should have been demonstrated in an operational environment and implemented (impacts visible in short/long term).
- The action should be relevant for the policy objectives (national or local strategies), meaning that the selected action should contribute to material/product management (saving resources). Actions that mainly target other objectives such as water or energy consumption during the use phase are excluded.
- The selected actions should have a significant impact in resource savings.
- The chosen cases represent different stages of the value chain (i.e. raw material extraction, material production).

Additional criteria are the following:

- background data available/documented
- cases from all the four countries are presented

- novelty and multiplicability of the solution
- useful data for analysis of barriers, bottlenecks

3.3 Selected cases

Based on the selection criteria described above, we selected 14 cases. All the cases can be found in the Annex 2. For each selected case we have prepared a two-page presentation that covers some basic information on the type of case and its focus with respect to circular economy. We have included information on the possible links to national or local strategies and methods, and have specified which materials, technologies, or digital solutions may have been used. We have also indicated which phase in the circular economy value chain is of relevance for the case and which other focus areas might have been addressed.

The description of the case includes a brief introduction to, e.g. concepts, objectives, illustrations, or photos. Under "Lessons learned", a short discussion of drivers and barriers is given, and we have pointed out aspects such as potentials for, e.g. replicability, and factors that have contributed to the success of the case.

The reader should bear in mind that the selected cases are examples of how barriers and challenges to the implementation of a circular economy can be addressed. There are many aspects that influence the implementation of the circular economy, including economics, technology, and the market, all of which must play together and be supported by regulation as well as standards. These aspects cannot be expected to be exactly the same in different countries, so one solution that works in one place may not necessarily work in another country, or for a different material.

The cases chosen in this report all contribute to a rethinking of the traditional value chain, aiming to form a loop, where the lifespan of buildings is increased, the products efficiently reused and materials recycled. All the cases represent more than just one phase in the value chain. Figure 5 is a coarse representation of where the cases best fit the value chain phases in order to illustrate the circularity approach.

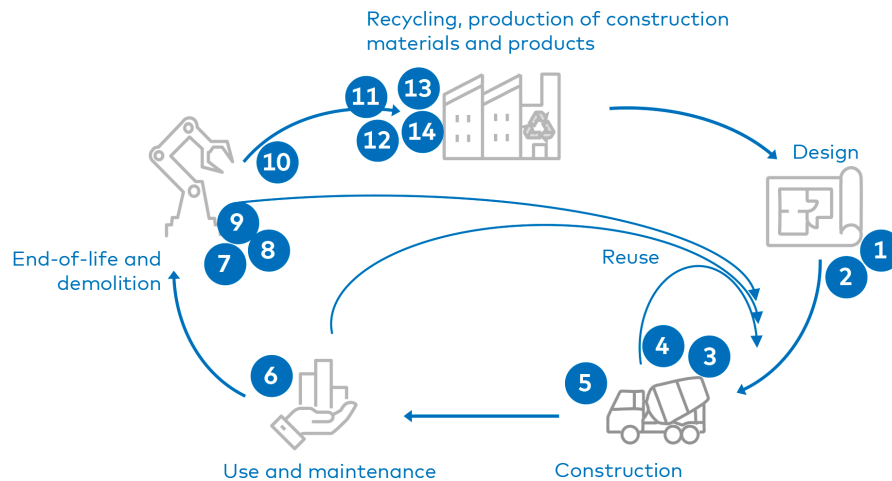


Figure 5: A coarse presentation of where the cases are presented in the value chain of the circular construction sector

- 1 Modular, easy to disassemble and reconstructable buildings are presented in **case 1 – FM-Haus**, which is the producer of wooden constructions that are intended for a temporary and/or unknown length of use. The constructions are demountable and reconstructable, including possibilities for changes in size and intended use.
- 2 **Construction of Blixens, an office building in Aarhus**, where environmental sustainability was a pervasive theme in the building's design, both in the form of energy optimisation, water collection for toilet flushing and garden irrigation, as well as recycling materials in tile facades, wooden floors and wall cladding, furniture, etc.
- 3 **Netlet Oy** collects surplus materials and products from construction sites. The materials and products are then sold at their outlet store, thus reducing waste generation and contributing to the salvation of virgin materials and products. These products and materials have traditionally ended up as waste at the construction sites.
- 4 **ConZerW** aims to achieve waste-free construction sites by developing digital process tools, which enable to track the source of waste from construction activities, implement potential optimisation measures and evaluation methods that support collaboration between partners in planning, procurement and logistics activities related to the construction site.
- 5 **Byggeri København** is the City of Copenhagen's developer unit under the Finance Administration, and is responsible for the construction of schools, day-care institutions and cultural and leisure facilities. The City of Copenhagen has for several years worked ambitiously with sustainability in construction and civil engineering. This has been expressed in plans, policies, and strategies such as KBH2025 Klimaplanen and five editions of "Miljø i Byggeri og Anlæg" (MBA) since 1999. Among other things, the efforts of the City of Copenhagen have resulted in a number of construction projects which focused on recycled building materials, and in 2020 Byggeri København presented several new projects, which will focus on circularity.
- 6 **Drone technology for material inventory** presents the use of drones for pre-demolition material inventories. The collected information enables more efficient dismantling of valuable materials and products, and supports selective demolition.
- 7 **Kompanjonen is a commercial actor whose business ideas** help companies in the Swedish construction and real estate sectors to buy, sell and handle building products for reuse.
- 8 **Loopfront** provides new solutions for circular activities, thus making reuse easy and profitable. Loopfront is a multi-sector collaboration platform made to empower building owners and the construction industry – removing barriers for reuse of building materials and furniture. In

Loopfront, users can register materials and inventory in existing buildings or those planned for demolition, and with the Market function it is possible to reserve materials for reuse – or make them available to other organisations.

- 9 In **Vuorenranta**, a non-profit organisation was given the opportunity to dismantle interior products prior to the demolition of a home for the elderly. The focus was on reusable products and materials (interiors, stone facades, windows, kitchen equipment, garden stones etc.) that have second-use value. Marketing and resale were done at the recycling centre run by the non-profit.
- 10 **Circular solutions for wood waste**. Three different companies work with different types of wood (waste) encompassing different reuse and recycling solutions and different business cases.
- 11 **Recycling of plasterboards**, an ongoing Swedish R&D project aiming at increasing the material recycling of plasterboards by developing new business models and streamline the reverse logistics etc.
- 12 **Increased circular use of flat glass**, an ongoing Swedish R&D project aiming at finding a self-sustaining system or recommending legislation to create a producer-responsible system paying for the collection and recycling of the material. The project (when this report was written) will also propose techniques for sorting the glass and possible logistic solutions.
- 13 **End-of-waste status for concrete waste in Finland** represents a case where the recyclers are striving to get a formal end-of-waste status for concrete waste in Finland. By achieving end-of-waste status, the concrete is no longer a waste, but a product which can be used as aggregate in earth construction and concrete production.
- 14 **Circular concrete** – The companies RGS Nordic and DK Beton have joined forces in order to create a sustainable concrete solution across the value chain. It was done with financial support from the Danish Environmental Protection Agency's MUDP (Miljøteknologisk Udviklings- og DemonstrationsProgram) funds. The solution implies that the recycling of concrete waste in new concrete is quality-assured, that the new circular concrete is delivered as certified concrete, and that the market can be served on an industrial scale.

4 Digital solutions in the construction and demolition sector

This chapter describes which digital solutions are applied or expected to be applied as tools to boost a circular economy, more specifically reuse and high-grade recycling in the Nordic countries. The focus is on solutions that enable the digitalisation of data and waste flows. The chapter introduces and defines what are generally regarded as digital solutions.

4.1 Digital solutions – what are they?

Digital solutions cover new technologies and approaches in the construction and demolition sector. The solutions range from simple solutions, such as registering and tracking information in Excel or other types of databases, to more advanced solutions that rely on data pools, the internet, or big data.

Digital solutions include a variety of solutions such as visualisation, planning, coordination, communication, production, and systems for surveying and monitoring. Digital solutions may also cover 3D prints, sensors, drones, and robots, depending on the definition applied.

Generally, the level of digitalisation is low in the construction and demolition sector in the Nordic countries, and the economic and environmental potentials of increased digitalisation are considered significant^{15, 16, 17}.

Currently, it is primarily architectural firms, engineering companies and the large contracting companies that use BIM (Building Information Model) and similar digital tools in their work.

Many solutions, however, are under consideration or at early development stages. We have presented a few examples of digital solutions in Box 4, other examples are described in more detail in the following sections, and further examples can be found in Annex 4.

-
15. Danish Technological Institute (2018): Build 4.0 provides new possibilities for the construction sector (in Danish).
 16. Danish Ministry of Transport, Construction and Housing (2019): Strategy for digital construction work (in Danish). <https://www.trm.dk/publikationer/2019/strategi-for-digitalt-byggeri/>
 17. Molio Byggeriets Videnscenter. 2020. Industriens Fond og Realdania vil styrke brugen af ny teknologi i byggebranchen (press release dated 25.6.2020) <https://via.ritzau.dk/pressemeddelelse/industriens-fond-og-realdania-vil-styrke-brugen-af-ny-teknologi-i-byggebranchen?publisherId=13560015&releaselId=13595971>

Box 4. Digital solutions applied in the Nordic countries – examples

- Banedanmark, an agency belonging to the Danish Ministry of Transportation and Housing, has developed an IT projection model to keep track of future needs of spare parts for the railway signal systems in the sections not yet renovated. This was done in relation to the replacement of the current railway signal system. Elements removed from the renovated sections are stored for future use, thereby facilitating reuse and optimising stock¹⁸.
- A robotic recycling system ("Zenrobotics") was developed in Finland and has since 2014 been used commercially. The system is used for sorting mixed C&D waste and separating waste into categories such as metals, wood (different grades), bricks, concrete, stones and plastic, thereby replacing manual sorting. The system relies on robot technology and AI/deep learning. A fully automated materials recovery facility for C&D waste (with an annual capacity of 120 000 tonnes) is built and will be in use in Vantaa, Finland, by the end of 2021¹⁹.
- In Sweden, BASTA, Byggvarubedomningen and SundaHus provide online systems encompassing information on the chemical content of construction materials and products^{20, 21, 22}. The requirements are based on REACH²³ and CLP²⁴. The systems are for anyone who wants to make conscious product selections with the aim of phasing out substances of concern.
- When the building "BLOX" was constructed in Copenhagen, "BIM 5D" was used to visualise the project and time plan, and to calculate the amounts of materials needed and the financing. The benefits with "BIM 5D" included: reduced material spillage, optimised production, and economic savings. In the project the expected spillage of reinforcement was reduced from 5–10% to 1%²⁵.

4.2 Nordic digitalisation strategies

Most Nordic countries have developed digitalisation strategies with the aim of expanding the use of digitalisation.

Table 4 provides an overview of country-specific digitalisation strategies, identified challenges and focus areas.

18. https://pro.ing.dk/wastetech/artikel/nyt-prognosesystem-sikrer-banedanmark-genbrugsguld-millioner-6556?utm_source=newsletter&utm_medium=email&utm_campaign=wastetech

19. <https://www.recycling-magazine.com/2020/09/15/zenrobotic-helps-remeo-to-build-the-next-generation-materials-recovery-facility/>

20. <https://www.ivl.se/om-oss/dotterbolag-och-internationellt-arbete/basta-online-ab.html>

21. <https://byggvarubedomningen.se/>

22. <https://www.sundahus.se/>

23. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02006R1907-20140410>

24. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32008R1272>

25. https://www.licitationen.dk/article/view/601228/digitale-vaerktojer-gav-millionbesparelse_pa_blox

Table 4: Digitalisation related strategies in the Nordic countries.

Country	Norway	Finland	Denmark	Sweden
National digitalisation strategy (yes/no) Specific focus on the construction and demolition sectors? (yes/no)	No	Yes. A vision for 2030 and a strategy to promote the digitalisation of the built environment was published in 2019. A group of experts conducted the strategy work during 2018 and 2019 commissioned by the Ministry of the Environment. The strategy work was given the name <i>Rasti</i> ("Standardisation of information management in the built environment - Assessment of the present situation and a proposal for measures")	Yes. Denmark has a strategy for digitalisation in the public sector (" <i>A stronger and more secure digital Denmark</i> ") launched in 2016, and a strategy aimed at the building sector (" <i>Strategy for digital building work</i> ", in Danish) launched in 2019.	Yes. " <i>For a sustainable digitalised Sweden – a digitalisation strategy</i> " (in Swedish). The strategy was published in 2017. The strategy does not focus specifically on the construction and demolition sector.
Sector level digitalisation strategy covering the building and construction sector (yes/no)	Yes. " <i>BYGGNETT. A strategy for the future digital building sector</i> " (in Norwegian). The strategy is developed by the Directorate for building quality ("Direktoratet for byggkvalitet" (DiBK)), an agency and competency centre for building policy.	Yes. RYHTI is a project aiming at holistic data management of property and the construction sector. Digitalisation is one of the key principles in the ongoing renewing of the Land Use and Building Act.		
Identified challenges	Variable prices and quality, lack of data and documentation / information not digitalised, complex building projects, lack of coordination between authorities, different digital competences.	Fragmented information, lack of data and documentation / information not digitalised, complex building projects, lack of coordination between authorities, different digital competences.		
Focus areas	Increase coordination between, e.g. public and private sector, develop methods and processes supporting digitalisation, competency development, simplify regulation, development of user-friendly IT-tools.	The Ministry of Environment has the overall responsibility for regulation and politics concerning the construction and demolition sector. A project <i>KIRA-digi (2016–18)</i> focus on reducing the fragmented information in the C&D sector by organising the data from the sector in a new umbrella platform, which should cover different scales of the built environment, from land use to buildings and materials. Another focus area is related to BIM. The aim is that all new public buildings should have a BIM model. A BIM model will not be mandatory for renovations, besides historical renovations. See Roadmap – <i>Rasti</i> – detailed level.	The Strategy for digital building work encompasses 18 initiatives within five focus areas. 1) Better use of digital tools, 2) open formats and common standards, 3) better use of data, 4) digital competences for the entire value chain, 5) more sustainable construction through digitalisation. For more details about the strategy, please see Box 2 – Examples of national strategies.	Digital competency development, safe and secure handling of data, data-driven innovation, improvement of the digital infrastructure and digital management.

4.3 Digital solutions to support development of a circular economy

As the focus in this report is on digital solutions that boost circularity, and more specifically on reuse and high-grade recycling, in the following section, the focus is on digital solutions that enable the documentation of waste flows and enhance the treatment of C&D waste through traceability and marketplaces.

4.3.1 The documentation of waste flows via national waste statistics for C&D waste

Norway

In Norway, the mapping of national C&D waste flows is based mainly on data from waste plans from projects in the municipality of Oslo which are scaled to cover Norway as a whole. The mapping to a lesser extent also depends on data from other municipalities. Waste generated from renovations is based on the turnover of building products and the market size. Waste from construction activities (bridges, quay facilities and similar) is not included. Waste amounts are probably underestimated.

Finland

In Finland, data on C&D waste generation and treatment is collected on a yearly basis by the YLVA environmental monitoring system (formerly VAHTI) register Compliance Monitoring Data System) and complemented with data on mineral waste generation, which is estimated based on the usage of mineral materials in construction activities²⁶. The data is supplied by the company generating the waste in a data system managed by the Finnish Environment Institute.

Sweden

In Sweden, the national waste statistics for C&D waste are based on annual environmental reports from waste management facilities and industries of a certain size and environmental impact (cf. "Miljöbalkens 26 kap. 20 §"). The data is reported in a digital format at "Svenska Miljörapporteringsportalen". The waste management facilities report the received amounts, the type of construction and demolition waste (EWC 17 xx xx), and its treatment. If the facility processes the waste, e.g. by sorting, the facility is obliged to report the generated waste fractions, their amounts, and how the waste fractions (secondary waste) are treated (final treatment)²⁷.

The C&D waste received at waste management facilities are classified according to defined material codes which to a great extent are unique for each facility. Upon arrival at the facility, C&D waste is registered with a specific material code based on the treatment the waste is subjected to. In the environmental reporting, the material codes are translated into EWC (European waste catalogue) codes, based on a translation guide²⁸.

26. https://ec.europa.eu/environment/waste/studies/deliverables/CDW_Finland_Factsheet_Final.pdf

27. <http://www.naturvardsverket.se/upload/stod-i-miljoarbetet/vagledning/avfall/vagledning-for-utokad-rapportering-av-bygg-och-rivningsavfall-2018-12-20-version-8.pdf>

28. <https://www.naturvardsverket.se/Stod-i-miljoarbetet/Vagledningar/Avfall/Bygg--och-rivningsavfall/Utokad-rapportering-for-mottagande-anlaggningar/>

As the waste management companies are only obligated to report C&D waste (EWC 17 xx xx), other waste fractions and related amounts from the sector such as oils, packaging, and electronics are based on information from construction and demolition companies through surveys. The waste amounts reported by the construction and demolition companies are scaled up to the national level based on the yearly turnover of the company in question.

The national waste statistics are presented using EWC stat codes, which are more aggregated waste categories compared to the EWC codes. For example, the EWC code 17 08 02 *gypsum-based construction materials* is aggregated into EWC Stat code 12 *Mineral waste* in the waste statistics.

The national waste statistics are carried out by IVL Swedish Environmental Institutes and Statistics Sweden through a consortium called SMED on behalf of the Swedish EPA.

Denmark

In Denmark, data on C&D waste generation and treatment is collected annually through the National Waste Data System (ADS) in the Danish EPA. All waste operators must report to the Waste Data System, according to the Statutory order on the Waste Data System²⁹. The waste operator must report data on the amount of waste, the relevant EWC code, national codes indicating if the origin of the waste is households or business, and treatment of the waste and R-code or D-code to differentiate between recovery and disposal operations. Based on the reports, yearly waste statistics are developed.

4.3.2 Systems for applying for building and demolition permits

Applying for building or demolition permits can be done digitally in most Nordic countries. However, it depends on the actual municipality which solution is offered (paper vs. digital, and the type of digital solution). Naturally, the systems are adapted to support the national (or even local) regulations and of course language.

In Sweden, several municipalities use the digital solution "Minut bygg"³⁰, whereas in Denmark most municipalities use the digital solution "Byg og Miljø"³¹. In Finland, the digital solution "Lupapiste" , is used for building and demolition permits, demolition notifications and waste shipment. If you apply for a demolition permit in Denmark, the system reminds the applicant about the requirements of sending a waste notification to the municipality. In Sweden, no such interlink seems to exist. This is also the case for Finland. In the box below, the digital solution applied in Norway is described in more detail.

29. Bekendtgørelse om Affaldsdatasystemet. BEK nr. 1742 af 13. december 2018.
<https://www.retsinformation.dk/eli/lta/2018/1742>

30. <https://sokigo.com/produkter/minut-bygg/>

31. <https://www.bygogmiljoe.dk/>

Box 5. Norway launches new digital solution for building and demolition permission applications

In Norway, a new digital solution has been launched for building and demolition permission applications. The new solution substitutes ByggSøk, which was launched in 2003. The new solution is customised to different target groups and automatically checks if the application meets the regulation requirements. The case work time in the municipalities is expected to be considerably lower compared to the current system, and similar expectations apply with respect to the users of the system. In total, a yearly saving of NOK 250 Mio. is expected³².

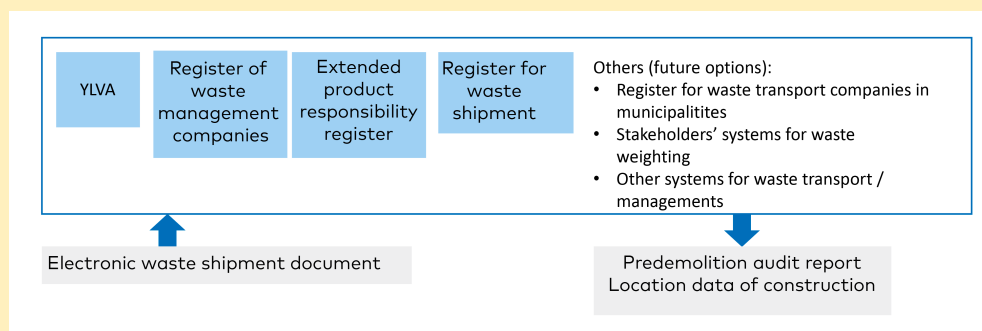
Whereas the new digital solution is expected to be more user-friendly and accordingly reduce costs related to building and demolition permission applications, a submitted notification of the expected types and amounts of C&D waste is no longer a prerequisite for a demolition permission as was the case for applications in ByggSøk. It is too early to determine what type of effect this will have on high-grade recycling or reuse. It reduces, however, the municipalities' knowledge about C&D waste generation in the concrete case, and thereby the municipalities' opportunity to affect the treatment of the waste.

Currently work on the digitalisation of administrative reporting in Finland is under development. The idea is that data is only reported once and the traceability is improved by linking different data systems (see text box below³³):

Box 6. Plan for improving administrative reporting in Finland electronically

Digitalization possibilities in waste information systems

- Improvement of traceability
- Confidence in waste data and improvement of quality
- Simplification of reporting - data only reported one time
- Improvement of access to data



32. <https://dibk.no/om-oss/Nyhetsarkiv/byggsok-stenger-hosten-2020/>

33. Kinnunen, R. 2020. Seminar presentation in Purkumisen uudet tuulet.

4.3.3 The traceability of waste

To ensure the correct management of C&D waste and to support the priorities of the waste hierarchy, the traceability of C&D waste is important. The origin of the waste, e.g. a specific building being demolished, as well as information about the demolition process and how the materials were subsequently managed, is crucial for traceability. A valuable tool in this respect is pre-demolition audits.

A pre-demolition audit can be used to both identify hazardous substances and assess the materials to be removed from the building or infrastructure, and consequently assess their potential value prior to the demolition or renovation activity. There are mandatory requirements for waste audits in Denmark, Finland, Sweden and Norway³⁴.

In the box below, another example of a means to enhance traceability of C&D waste is described.

Box 7. Enhanced traceability of C&D waste flows – amendments to the Danish waste statutory order

Since 2012, Danish building owners have been obliged to notify the municipality about C&D waste generation in cases where more than 1 tonne of C&D waste is generated or more than 10 m² of the building is renovated or demolished³⁵. The notification must be submitted at least two weeks before the beginning of the work. It must contain information about, e.g.: expected waste amounts, expected waste types, expected management of the waste, and the result of the pre-demolition audit (survey/screening of hazardous substances in the building). The notification can in most municipalities be done digitally by using "Byg og Miljø"³⁶ or similar digital tools³⁷.

Despite this requirement, many building owners do not notify the municipality about C&D waste generation, particularly in smaller renovations and demolitions. As a consequence, but also to enhance the traceability of waste from renovations and demolitions, i.e. to enable tracing the waste flows from the renovation/demolition site to the waste management facility, amended provisions went out for consultation in the beginning of September 2020.

The following amendments are suggested: the notification must "follow" the waste, i.e. the notification will receive a sequential number issued by the municipality; the waste carrier must hold a copy of the notification, and the waste management facility must digitally report the sequential number and the waste received to the municipality.

34. Wahlström et al. (2019): Improving quality of construction & demolition waste – Requirements for pre-demolition audit. TemeNord 2019:508. Nordic Council of Ministers.

35. <https://www.retsinformation.dk/eli/lt/2019/224>

36. "Byg og Miljø" is an online portal for construction and environmental permits. As part of this waste notifications can be filled in and send to the municipalities: <https://www.bygogmiljoe.dk/>

37. <https://www.bygningsaffald.dk/Default.aspx?ReturnUrl=%2f>

4.3.4 Materials and buildings passports

Another means of increasing the traceability of C&D waste is to introduce materials and buildings passports. A materials passport contains information about building materials, e.g. the chemical content. A buildings passport registers the building materials used in a building, e.g. types and amounts. By combining the two passports in a database, valuable information is available for renovation or demolition purposes.

The overall aim of establishing materials and buildings passports is the following:

- Improve the possibility of recycling and reuse of building materials
- Prevent C&D waste from renovation and demolition activities
- Reduce renovation and demolition costs
- Increase removal of hazardous substances from the building before it becomes waste

No fully developed system exists yet, but various activities are taking place across Europe related to the development of the basis for materials and buildings passports. Some of these activities are described in the box below, based on Smith et al. (2019)³⁸. This publication is also referred to for a thorough overview of the ongoing activities.

Box 8. Materials and buildings passports – examples of projects and activities

- Europe (BAMB) – Building as Materials Banks³⁹. A project performed under Horizon2020 involving 15 partners from Europe. BAMB sought to create a central platform for materials and buildings passports in Europe. Potential obstacles: it should be possible to link the platform to BIM but no BIM standard exists. In general, there is a need for standardised data for, e.g. products and EPDs (Environmental Product Declarations) to link the platform with data from other sources. The business model of existing databases may also be an obstacle (e.g. if not in open format).
- Sweden. Several activities of relevance for materials and buildings passports. Examples are "Byggvarudeklarationen, BVD" which declares the chemical content in products, logbooks of construction work, e.g. related to "Miljöbyggnad, SundaHus Miljödata and BASTA.
- Norway. NOBB ("Norsk Byggevarerebase") – a digital product portal, BYGGDOK – a digital tool for collecting information about buildings, ECOproduct – for assessment of building materials' environmental footprint.
- Denmark. Ongoing project carried out on behalf of the Danish Transport, Construction and Housing Authority (Trafik- Bygge- og Boligstyrelsen). The project will finish by the end of 2020 and aims to identify recommendations on how building and material passports can be implemented in Denmark.

38. Smith, K. H., Andersen, S. C. & Astrup, T. F. (2019). Analysis of buildings and materials passports (In Danish). Study performed for the Danish Transport, Construction and Housing Authority. DTI.

39. <https://www.bamb2020.eu/>

4.3.5 Exchange of surplus materials from construction, demolition, and renovation activities

Electronic platforms or digital marketplaces are often described as important means for an efficient exchange of surplus materials related to activities from construction, demolition, and renovation. In the Nordic countries, several digital marketplaces have been developed, aimed especially at exchanging materials for reuse. In the box below, examples of digital marketplaces in Nordic countries are listed.

Box 9. Digital marketplaces for the exchange of C&D waste materials for reuse

Finland

- **Materiaalitori**⁴⁰, a platform which is managed by the Finnish state-owned company Motiva Ltd. The platform is developed for the exchange, sale and purchase of waste materials, side-streams and leftovers, and is linked to an act in Finnish waste legislation.
- **Rakennusoutlet.com**⁴¹ is a digital platform for the resale of leftover materials from construction sites.

Sweden

- **Kompanjonen.se**⁴² provides a digital platform for buyers and sellers to meet. Resale of used interior building materials and products.
- **ReAppli**⁴³, development of an app for reuse of white goods from renovation projects.

Denmark

- **Genbyg**⁴⁴, Denmark's largest construction market for used building materials. Genbyg was established in 1998 and specialises in the purchase and resale of used building materials, such as doors, windows, lamps, floors, door handles, and timber.
- **ProffOutlet.com**⁴⁵ is a new Danish web shop that sells new surplus goods from wholesalers, DIY stores and manufacturers.

Norway

Loopfront⁴⁶ is currently a closed system for the registration and exchange of reusable materials.

40. https://www.motiva.fi/en/solutions/material_efficiency/materiaalitori

41. <https://www.rakennusoutlet.com/>

42. <https://www.kompanjonen.se/>

43. https://www.recyclingnet.se/article/view/655953/fastighetsbolag_satsar_pa_aterbruk_av_vitvaror

44. <https://genbyg.dk/>

45. <https://proffoutlet.com/>

46. <https://www.loopfront.com/en/company/about>

There are also examples of companies working with the reuse of construction and demolition material that rely on their homepage as a means to advertise and sell their products⁴⁷.

4.3.6 Utilising the benefits of digitalisation

As mentioned in the beginning of this chapter, the level of digitalisation is generally low in the construction and demolition sector in the Nordic countries. Various initiatives, however, are designed to increase the level of digitalisation. In the box below, a Swedish initiative is described.

Box 10. Smart Built Environment – a Swedish initiative to utilise the benefits of digitalisation

Smart Built Environment is a program based on a joint nationally established strategic innovation agenda⁴⁸. More than 50 businesses and organisations participate in the programme, either through funding and/or participation. Among these are the government research funders Formas (the research council for sustainable development), Vinnova (Sweden's innovation agency), and the Swedish energy agency.

The programme was launched in 2016 and will run up until 2028. The aims of the programme are to take a holistic approach to the opportunities digitalisation can bring, and to catalyse the dissemination of new opportunities and business models across the built environment sector, which is currently fragmented consisting of a large number of stakeholders and processes.

The goal of the program is to achieve by 2030:

- 40% reduced environmental impact in new construction and renovation
- 33% reduction in construction time from planning to finished project
- 33% reduction in construction costs
- Renewed business logic - new value chains and business models

Smart Built Environment have a yearly call to support research and development projects in collaboration with industry, universities, research institutes and other parts of society. They have four thematic areas that applications should relate to:

- Information infrastructure
- Value chains and business models
- Innovation and new applications
- Knowledge and expertise

47. Find examples in the following publications: https://www.teknologisk.dk/_/media/79283_Markedspalter%20for%20genanvelse%20og%20genbrug%20af%20byggematerialer%20-%20Sp%20F8rgeunders%20F8gelse.pdf and http://grafisk.3xn.dk/CAC/CircleHouseLab_GreenPaper01_Bygnings-ogMaterialepas.pdf

48. <https://www.smartbuilt.se/om-oss/>

Within Smart Built Environment, a project regarding the sharing of data within the construction sector has been initiated⁴⁹. The goal of the project is a well-described nomenclature in the area of data sharing, principles and recommendations for future technical solutions as well as proposals for methods and processes for data sharing that include ownership, classification, responsibility and trust. The ambition is for these deliveries to be accepted by actors in the community-building process.

49. <https://www.smartbuilt.se/projekt/informationsinfrastruktur/delning-av-data/>

5 Drivers and barriers presented in cases for the implementation of CE in the construction sector

This section focuses on analysing success factors, drivers, and barriers especially related to the cases mapped in this study. We know that the successful implementation of a circular economy is hampered by many bottlenecks – barriers related to the reuse and recycling of waste materials in construction as well as barriers related to the production, design, and construction of buildings.

The following list includes aspects that have been analysed in recent literature from different perspectives:

- EU, national and local policies as well as targets setting the frames for the operational environment: recycling targets in regulations, financial instruments.
- The variety of products and materials used in the construction sector. The reuse and recycling potential of these depends on the material (some materials with well-functioning market, e.g. steel), supply and demand (e.g. reusable components), environmental quality (potential content of hazardous materials or substances, separation process in demolition, recycling processes), technical quality, price (also abundance of virgin materials like wood and aggregate).
- Market for recovered materials (established market for some materials like metals, material availability, systems/technologies in place, technical requirement on construction products)
- Actors (who pays what, role of legislator in pull of market through financial support for reuse/recycling or bans): how are costs covered by actors (e.g. building owners, demolition company, recyclers, constructors, governmental supports)?

Drivers and barriers especially related to recycling construction and demolition waste have been presented in several studies (e.g. Williams 2020⁵⁰, Wahlström et al. 2020⁵¹, Wahlström et al. 2019⁵², Bio by Deloitte 2017⁵³, Deloitte&Utrecht University, 2017⁵⁴, Environmental Project No. 2076, 2019⁵⁵) and previous EU projects (EU HISER; EU IRCOW) and briefs⁵⁶. Circular building concepts have been presented in earlier

-
50. Williams, R. 2020. Emerging Challenges of Waste Management in Europe - Limits of Recycling. Trinomics. <https://trinomics.eu/wp-content/uploads/2020/06/Trinomics-2020-Limits-of-Recycling.pdf>
51. Wahlström, M., Bergmans, J., Teittinen, T., Bachér, J., Smeets, A., Paduart, A., 2020. Construction and Demolition Waste: challenges and opportunities in a circular economy. EIONET-report - ETC/WMGE 2020/1. <https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-reports/construction-and-demolition-waste-challenges-and-opportunities-in-a-circular-economy>
52. Wahlström, M., zu Castell-Rüdenhausen, M., Hradil P, Hauge Smith, K., Oberender, A., Ahlm, M., Götbring, J., & Bjerre Hansen, J. 2019. Improving quality of construction & demolition waste - Requirements for pre-demolition audit, TemaNord 2019:508 <http://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-5502>
53. Bio by Deloitte, VTT et al. 2017. Resource efficient use of mixed wastes improving management of construction and demolition waste <https://publications.europa.eu/en/publication-detail/-/publication/78e42e6c-d8a6-11e7-a506-01aa75ed71a1/language-en>
54. https://circulareconomy.europa.eu/platform/sites/default/files/171106_white_paper_breaking_the_barriers_to_the_circular_economy_white_paper_vweb-14021.pdf
55. <https://mst.dk/service/publikationer/publikationsarkiv/2019/mar/establishing-effective-markets-for-secondary-building-materials/>
56. European Environmental Agency (EEA). 2020. Construction and demolition waste: challenges and opportunities in a circular economy. Briefing. <https://www.eea.europa.eu/themes/waste/waste-management/construction-and-demolition-waste-challenges>

Nordic reports (Høibye & Sand 2018⁵⁷; Munck-Kampmann et al. 2018,⁵⁸ Ahola et al. 2017⁵⁹).

Section 5.1 examines how strategies support the implementation of a circular economy in some cases, and also identifies barriers that need to be overcome or that still hinder business growth and especially. The section explores why the selected cases have been successful in overcoming these barriers. Additionally, drivers and barriers are examined more generally.

5.1 Local CE strategies to boost a circular economy

In the cases presented in this report, we can see that many business opportunities seem to have been created through the influence of national and local strategies. Thus, putting theory into practice via such strategies can help in transitioning to a circular economy in the construction business. Municipalities can set requirements on CE solutions in different ways, e.g. in a strategy, in guidelines or even specific requirements for construction projects. This can include, e.g. the demolition phase of constructions, focusing on resource mapping prior to demolition, the use of selective demolition and reuse, and recycling of waste. CE solutions can in the construction phase focus on the use of materials that are recyclable, dismantlable and can set focus on the documentation of material content, e.g. in material passports. However, as reported in Chapter 2, local strategies or roadmaps towards a circular economy have just recently been published, and experiences from cases have not yet been published in the Nordic countries.

We have identified examples where tools, such as requirements for sustainable constructions, have supported the implementation of local strategies in construction in the municipality, e.g. the cases of *Byggeri København* and *Blixens, Århus*. However, the implementation of the strategy requires support in practice for the individual projects and project managers responsible. There is a need to structure the work such that circularity is prioritised, since there are a number of different ways to address circularity in construction projects (e.g. reuse of materials contra design of disassembly). In both cases, the municipalities have developed tools and requirements for construction projects. *Byggeri København* has developed a tool called "*Byggeri Københavns håndbog i cirkulær Økonomi*" (see the case in Annex 2 for more information). See Table 5 below for examples of requirements.

57. Høibye L. & Sand H. 2018. Circular economy in the Nordic construction sector. Nordic Council of Ministers. <http://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A1188884&dswid=5261>

58. Birgit Elin Munck-Kampmann, Inge Werther and Lena Holm Christensen. 2018. Policy Brief: Recycling in the Circular Economy. How to improve the recycling markets for construction materials, biowaste, plastics and critical metals. Nordic Council of Ministers. <http://norden.diva-portal.org/smash/get/diva2:1269435/FULLTEXT01.pdf>

59. Ahola, K., Salmenperä, H., Ryding, S-O & Busch, N.J. 2017. Circular Public Procurement in the Nordic Countries. TemaNord 2017:512. <http://norden.diva-portal.org/smash/get/diva2:1092366/FULLTEXT01.pdf>

Table 5 Examples of requirements for public building and construction projects presented in "Miljø I Byggeri og Anlæg 2016" (MBA2016)⁶⁰ and Aarhus⁶¹.

City	Issue	Specification
Copenhagen City	Title: Sustainability in Construction and Civil works	Essentially, Sustainability in Construction and Civil Works applies to six project areas commissioned or supported by the City of Copenhagen: - city of Copenhagen, Development Department - social housing - housing renewal - city of Copenhagen, Construction projects - Copenhagen Courtyard gardens - craftsman services
	Requirements included (examples)	Requirements concern e.g. materials, resources, and waste. Noteworthy with respect to this are requirements for, e.g.: - harmful chemicals in materials - assessment of reusable building components (resource mapping of constructions to be demolished) - identification of environmentally harmful substances prior to demolition - recycling of materials - plan for sorting of building waste
	LCA as an assessment tool	In new building projects, a life-cycle assessment (LCA) of building elements has to be conducted in order to qualify the choice of designs with the least possible environmental impact. See the requirements for more information.
Aarhus	Title (translated): Requirements and Recommendations for Environmentally Sustainable Construction (including energy aspects)	The publication contains requirements that need to be followed, and recommendations that may be appropriate to follow. The publication covers all of the municipality's buildings. The requirements and recommendations cover ten areas, among which are requirements for materials, e.g.: - for the most important parts of the construction, only natural and / or recyclable materials such as concrete, natural stone, wood, bricks, steel, glass, etc. are to be used. - building materials that can only be disposed of at the end of their service life should be avoided as far as possible. - asbestos, formaldehyde or other pathogens not allowed to be present in the building materials used. - avoid products that contain substances that are on the Danish Environmental Protection Agency's list of undesirable substances. - maintenance-friendly products must be chosen. Avoid products which, after a short number of years, need to be replaced because they cannot be maintained. In renovation work or maintenance degradable building parts can easily be replaced without it having a significant impact on other parts of the building. - materials that are easy to clean must be chosen, with minimal use of cleaning agents.// - in the construction project, a period must be set aside for the release of volatile substances from materials before use. Construction projects rehousing has been established at the same time may deviate from the requirement - see the requirements for more information.

60. <https://www.kk.dk/miljoe-byggeri-anlaeg>

61. Miljø- og energirigtigt byggeri i Aarhus Kommune", <https://www.aarhus.dk/media/22741/miljoe-og-energirigtig-byggeri-i-aarhus-kommune.pdf>

5.1.1 Requirements in public procurement

Byggeri København, as a major developer for Copenhagen, has looked into the possibilities for setting requirements for recycling building materials in tender documents. It was politically decided by the City of Copenhagen that from 2020 *Byggeri København* shall address and work with a circular economy in all construction projects. This focus is not only on criteria and requirements for a circular economy (e.g. reusing and recycling building material) in tender documents. It will also be implemented in projects for *Byggeri København* that are carried out via strategic partnerships, where no project-specific tenders are made.

As the public sector is the single largest property developer, the requirements on the public sector via Green Public Procurement policies both in construction work and demolition have a great impact on the competitiveness of the CE cases analysed in this study. For closing the loop, especially the use of public procurement in construction is also highly linked to policies for promoting markets for recovered materials from demolition work.

Setting the right kind of requirements in procurements is one challenge (i.e. requirements for reuse/recycling in general contra reuse/recycling of specific materials contra general requirement for a circular economy). However, another challenge we have identified relates to the market's readiness. As pointed out in case 2 – Blixens - it can be difficult to find the right materials that could live up to the municipality's requirements and expectations if the market is not ready. Furthermore, the choice of solution and materials often implies prioritisation – for a number of solutions with recycled materials cheaper solutions with virgin materials were available, however, the recycled materials have in return added value in the form of aesthetics, and a good working environment, etc.

In Finland, a guideline⁶² for Public Green Procurement in demolition was published in 2019 by the Finnish Ministry of the Environment. The target group for the guideline are the public authorities that set requirements on contractors working with demolition. Steps in the Public Green Procurement in demolition work is presented in Box 11. In 2020, the Finnish Ministry of the Environment and the real estate association RAKLI signed the first Green Deal agreement in the construction industry⁶³. In this context, it can also be mentioned that Innovative Public Procurement (KEINO⁶⁴) was established by several Finnish Ministries in March 2018. KEINO offers a wide variety of services free-of-charge to its customers and stakeholders from municipalities to cities and counties, and includes the governmental procurement units, e.g. fields such as construction and energy.

62. Kuittinen, M. 2019. Circular economy in public demolition projects. Procurement guide. Publ. of the Ministry of Environment 2019:31. <http://urn.fi/URN:ISBN:978-952-361-038-5>

63. The agreement focuses on sustainable demolition (resource mapping in pre-demolition auditing) and, above all, encourages the construction industry to invest in solutions that support the circular economy (also spreading of information on available materials in the Materiaalitori-market place governed by Motiva, see Chapter 6.6). [https://www.ym.fi/fi-FI/Ajankohtaista/Tiedotteet/RAKLI_ryn_ja_ymparistoministerion_solmim\(54710\)](https://www.ym.fi/fi-FI/Ajankohtaista/Tiedotteet/RAKLI_ryn_ja_ymparistoministerion_solmim(54710))

64. KEINO is a network-based Competence center for Sustainable and Innovative public procurement in Finland. <https://www.hankintakeino.fi/en/about-keino>

Box 11. Green Public Procurement for ordering demolition work and pre-demolition audit for resource mapping

Green Public Procurement (GPP) is a voluntary instrument intended to be used by municipalities to improve the recycling of C&D waste arising from the demolition of public buildings. In the Finnish guideline, potential criteria to be taken into public procurement processes are proposed. One of the suggested criteria relates to the scope and content of the pre-demolition audits, e.g. including plans for the reuse or recycling of C&D waste. In addition, criteria related to the competence of the waste auditor are proposed.

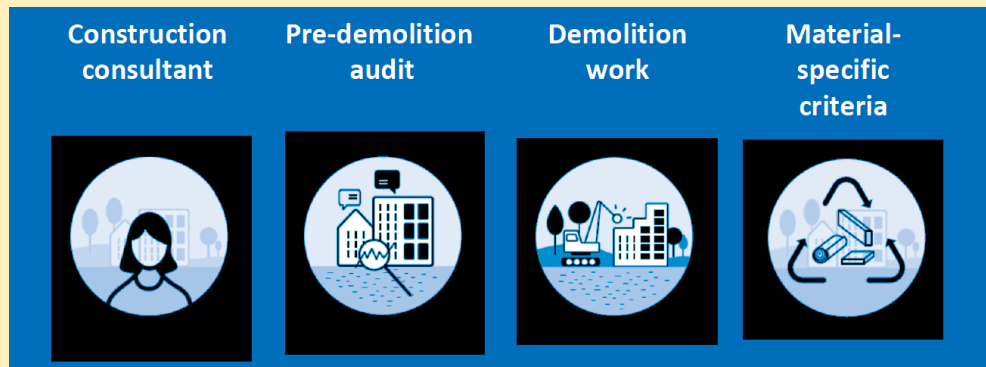


Figure 6 Scheme of different steps (reference: Kuittinen, Kinnunen, 2019).

Step 1: Construction consultant representing the purchaser's or property owner's interests in demolition at different stages. The consultant ensures the flow of information related to a circular economy between all project partners. Checking the quantities of waste and their managements sites.

Step 2: A pre-demolition audit is an activity organised by the owner of the building or infrastructure resulting in the inventory of materials and components arising from the future demolition or renovation projects, and their management and recovery options. A pre-demolition audit consists of two parts:

- a. The identification of materials and components (both hazardous and non-hazardous) that will be generated during the demolition or refurbishment. It defines both the nature and the estimated quantity of the materials streams that will come free after demolition (high-risk or low-risk materials)
- b. Additional information about which materials should if possible be separated at the source, which materials can/cannot be reused or recycled, and how. It may also suggest solutions for the waste management plan, etc.

Step 3: Best practices in demolition work (e.g. in Finland defined in guidelines) including sorting primarily on-site, actions for minimising the environmental burdens of the work (e.g. dust emissions), and incentives for identifying utilisation of waste.

Step 4: Criteria for various material and waste streams for enabling their processing according to the waste hierarchy and beyond normative minimum requirements. If possible, construction structures and components should be dismantled for reuse.

Table 6 presents examples of criteria presented by two municipalities (Hyvinkää in Finland with criteria set for a specific construction case and Gothenburg in Sweden with GPP criteria on construction and demolition work) for circular economy solutions in construction. The criteria are also to be linked to strategies for low-carbon economy (energy-saving solutions) and non-toxicity.

Local green public procurements act as the main driver for Netlet, a Finnish company collecting surplus materials from construction sites for resale. Cities within the sphere of the collection services of Raksanouto increasingly require constructors to eliminate surplus materials ending up as waste. National wood-building targets serve as a driver for FM-Haus, but this is not in relation to the reconstruction ability of the concept. The reconstructability concept does not rely on any specific strategy, the drivers are mainly related to the economic benefit from temporary constructions.

Table 6 Examples of green public procurement criteria for circular economy solutions in the selection of construction materials/products published.

Municipality	Focus	Example of CE criteria for selection of construction materials/products
Hyvinkää, Finland (project case)	CE procurement in construction for a school building (Hyvinkää is part of Finnish Sustainable Communities (FISU) with strategy for implementation of solutions to reduce greenhouse gas emissions and improving communities' resource efficiency.	"The materials used are either recyclable or can be safely eliminated at the end of the building's lifecycle. The building has been constructed so that it can be dismantled, or either reconstructed elsewhere or recycled at the factory. Materials are environmentally friendly and so lower the carbon footprint of the building. While around 10–15% of building materials normally end up as waste, in this project, this was limited to 5%¹." Examples of solutions: • modular construction • Nordic Swan labelled materials with low emissions
Gothenburg, Sweden (guideline)	Green procurement in construction and demolition work (goals for 2030) ²	Overall targets: • prolonging the lifespan of buildings/construction components • resource efficiency in material use • minimising the use of virgin materials • in renovation and demolition recovered products and materials are directed to reuse or recycling • construction enables repair, disassembling, reinstallation • products in construction are easy to reuse and recycle The recommendations include areas to be further developed, such as: responsibilities, competences, examples of reusable products, good practices, assessment tools etc.

¹ https://procuraplus.org/fileadmin/user_upload/Procura__case_studies/Procuraplus_case_study_Hyvink%c3%a4%c3%a4.pdf

² Goals for 2030

In summary, the following observations were made:

- Local strategies on CE-solutions have just recently been published, and experiences from cases have not yet been published in the Nordic countries. Local/regional strategies often focus more on low-carbon economy ideas than CE actions.
- Overall targets are in many cases general.
- Specific requirements for construction projects and tools for day-to-day work can help stakeholders in meeting overall targets.
- The use of Green Public Procurement (GPP) both for construction and demolition work (especially in construction) promotes directly closing the loop.

5.2 Digitalisation as a tool to boost a circular economy

Chapter 4 described the digital solutions applied in the construction sector, and focused especially on the documentation of waste flows and traceability.

Generally, the level of digitalisation is low in the construction sector in the Nordic countries compared to other sectors, and the economic and environmental potentials of increased digitalisation are considered large.

It is primarily architectural firms, engineering companies, and the large contracting companies that use digital solutions, such as BIM (Building Information Model) and similar digital tools in their work.

Reliable waste statistics and reliable data on reuse, recycling, material recovery, etc., cannot directly boost a circular economy. However, reliable data is a prerequisite for measuring if launched initiatives are to have any effect.

The documentation of C&D waste flows and the development of national waste statistics are done differently in the Nordic countries. In Norway, data on C&D waste generation is mainly based on data from Oslo, which is scaled up to the whole of Norway. In the other Nordic countries, C&D waste generation and treatment are either based on reporting from waste management facilities and/or the companies generating the waste. Different digital solutions are applied for reporting and management of the reported data, but the systems also rely on inputs reported manually to the systems.

It has not been possible within the scope of the project to assess which of the approaches provides the most reliable data. It is clear, however, that the type of digital system used is important, but the reliability of the data depends on several other factors. These include: regulation, the user's/data provider's consent and willingness to report, the level of quality control, and resources spend on the interpretation of the reported data.

As direct reuse is not considered a waste management activity, reuse is not accounted for in national waste statistics.

The traceability of waste, i.e. the origin of the waste, the treatment it has undergone, etc. is a critical parameter in order to have confidence in the quality of the waste, technical as well as environmental. Pre-demolition audits are foreseen as important tools with respect to increasing traceability, as such audits can be used to identify hazardous substances and map resources prior to demolition. Digitalisation

may play an important role in supporting the flow of information, from when the audit is performed, to when the hazardous substances are removed, and the building is demolished and separated into relevant waste types. In Denmark, amended provisions were sent out for consultation in September 2020 proposing waste notifications (which can be seen as light versions of pre-demolition audits) to always "follow" the waste, the waste-carrier must hold a copy of the notification, and the waste management facility must digitally report the sequential number and the waste received to the municipality. In this case, digitalisation is part of the solution, but in the end, traceability also depends on parameters such as high-quality pre-demolition audits, the thorough removal of hazardous substances and hazardous waste, and the correct sorting of the waste. At the project level, ConZerW is tested. ConZerW aims to achieve waste-free construction sites by developing digital process tools. These tools track the source of waste from construction activities, implement potential optimisation measures and evaluation methods that support collaboration between partners in planning and procurement and logistics activities related to the construction site. In addition, the project will demonstrate a full-scale solution in a pilot project and communicate the results to builders, contractors, suppliers, politicians and the media.

Buildings and materials passports which are already used in different forms in some countries (or under possible development in others) are also considered a means to increase traceability as knowledge of the building is/would be available through the building's service life via the passports. Establishing and operating these passports, which are essentially large databases, depends heavily on the right digital solutions, including common data standards and open formats.

Both cases – the traceability of waste and building/material passports – obviously also depend on stakeholder's acceptance and use of the systems to be effective.

The findings above indicate that digitalisation plays an important role in achieving circularity. However, digitalisation cannot stand alone as several framework conditions are just as important.

5.3 Technical specification – barriers to business

Establishing an effective circular economy is closely linked with bridging the gap between the waste and building sectors. This, in turn, relates closely to requirements for documentation and technical specifications of materials. When looking more closely at the rules and standards for the technical documentation of building materials, it is important to distinguish between the reuse and recycling of materials, as there are important differences.

5.3.1 Reuse and CE-marking

We have identified several cases that focus on the reuse of building materials. These cases have been presented in Annex 2 and include case 3 "Netlet Oy" (surplus materials and products in construction works), case 10 "Circular solutions for wood waste", Norway (concrete hollow core slabs, glulam beams and other wooden materials, concrete for landfill) and case 5 "Kompanjonen", Sweden (interiors from

construction). The reuse of elements and structures (concrete, steel, wood) were not covered in any of the selected cases, but they have been assessed in previous studies, e.g. ReUSE-project⁶⁵, EU PROGRESS project⁶⁶).

National circular economy strategies emphasise the importance of reuse and are a strong driver in promoting reuse solutions in preference to recycling, e.g. through public green procurements. Also, the Waste Framework Directive sets waste prevention and preparation for reuse as the highest priority in the waste processing hierarchy.

Although the reuse of building materials is a clear way of extending their service life, saving resources as well as CO₂, reuse is currently limited to the reuse of interiors/furniture from buildings. However, we can see that reuse can create business opportunities in local communities, e.g. distribution of salvaged materials.

In some cases, it is also cheaper to dismantle buildings part-by-part and sell the components than to demolish buildings conventionally and to process the waste.

Even though examples for reuse of building materials exist, it is not common practice in the Nordic countries. The obstacles to widespread reuse have been documented in the literature and many practical case studies (e.g. ReUSE-project, PROGRESS project).

There are several challenges related to reuse. They include costs, acceptance/perception, logistics, planning, and selective demolition. However, the technical documentation of reused building materials plays a very central role.

The CE-marking of building products are covered by the Construction Product Regulation (CPR) and have also to be documented in accordance with national building regulations. However, current rules for CE-marking do not cover reusable structures and components (see Box 12 below with information on Construction Products Regulation⁶⁷ and CE-marking). This was a special concern raised in several of the cases presented in Annex (e.g. the Loopfront-case 8).

65. https://www.researchgate.net/publication/270105210_Re-use_of_structural_elements_Environmentally_efficient_recovery_of_building_components

66. <https://projectsites.vtt.fi/sites/progress/>

67. CPR concerns "any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works." The aim of the CPR is to remove barriers to the trade of construction products between member states in the European Economic Area.

Box 12. Construction Products Regulation and CE-marking

The Construction Products Regulation aims to remove barriers to the trade of construction products between member states in the European Economic Area. To achieve this, the CPR requires that harmonised test methods be used in the performance declarations of building products in order to remove trade barriers between member states. The CPR does not intend to harmonise existing national regulations and requirements concerning the actual construction work. Member States and public and private sector procurers are free to set their own requirements on the performance of buildings and construction works and therefore performance levels of products.

The CPR defines seven so-called basic requirements for construction work (BWRs⁶⁸). Test procedures for the testing of the basic requirements are described in the harmonised product standards (e.g. for sampling and testing in type-testing and factory-production control).

The Construction Products Regulation requires that all construction products put on the market for which there is a harmonised standard must (with some exceptions) be CE-marked. However, the scope of the harmonised standards is for manufactured new products and does not cover reusable products. Moreover, the harmonised standards are not applicable for reused products. Typically, the harmonised standards require the factory production control which is not possible for reusable products as the producer of the product cannot be liable for the product to be reused (and can in practice not be carried out for reused products).

Note! Also for the recycling of waste materials in new products, the use of recyclable materials is not usually included in the scope and may not be suitable for materials containing recycled materials. Furthermore, CE-marked products can only be CE-marked once.



Figure 7 The CE-marking indicates a product's compliance with EU legislation and so enables the free movement of products within the European market. However, not all products must bear the CE marking, only product categories mentioned in specific EU directives on the CE-marking.

⁶⁸. BWRs defined in CPR are as follows: 1. Mechanical resistance and stability 2. Safety in case of fire 3. Hygiene, health and the environment 4. Safety and accessibility in use 5. Protection against noise 6. Energy economy and heat retention NEW: 7. Sustainable use of natural resources

A project carried out in 2019 took a closer look at possibilities for the documentation of reused building materials. The project⁶⁹ has investigated what regulations (including harmonised standards, ETA, national legislation, etc.) exist in Denmark, the Netherlands, Belgium and the United Kingdom for companies that want to document and use recycled building materials.

As reuse is encouraged by national strategies and green public procurement in the Nordic countries, an increase in markets for reusable products is expected. However, this calls for a clarification of the rules regarding CE-marking and other alternative solutions for documentation, an effort that could benefit Nordic stakeholders.

Clarifications needed with respect to the CE-marking of reusable products in particular and reuse of building products more generally:

- In case the reusable product is used for another purpose (application area): a process/scheme to CE-mark reusable product (methods, traceability systems, etc).
- The development of a simple declaration system for reusable products (e.g. doors) for which there is no need for CE-marking, e.g. to declare essential requirements for safe use (e.g. fire resistance, bearing properties).
- Rules for the maintenance of the product status if the product is used for the same purpose in accordance with the scope of the harmonised standard. This means that CE-marking can be done as for original products. However, this requires that alternative systems to cover factory production control in harmonised standards be developed. Documentation on use conditions and traceability are also needed.
- How to address environmental and health aspects for reusable products (e.g. indoor risk due to material deterioration due to use conditions (e.g. moisture), uses of chemicals that were acceptable but now banned).
- Clarification of the stakeholder who has liability for reusable products (role of the owner of the product, end-user, re-seller, producer?).
- When a material or product is in surplus at a construction site it has not been used, but it may have undergone transport, storage and may have become damaged at the construction site. Thus, it is no longer under the original warranty of the producer, but the CE marking is still valid.

5.3.2 Recycling and CE-marking of construction products

Two cases concerning the recycling of concrete waste are described in Annex (cases 13 and 14). In both cases the CE-marking could be done because the standards allow for the use of recyclable aggregates.

Construction products containing recycling material need to comply with requirements for products produced from virgin materials only. Here the scope of the standardisation plays an important role as the harmonised standards often exclude the use of recyclable materials or are unclear. This is a barrier for recycling if CE-marking and linked testing is required (see Box 12).

A few standards, e.g. European standards, such as EN 206: Concrete –

69. "Nabotjek: Dokumentation for genbrugte byggevarer" https://erhvervsstyrelsen.dk/sites/default/files/2020-05/NABOTJEK%20-%20Dokumentation%20for%20genbrugte%20byggevarer_samlet.pdf

Specification, performance, production and conformity; and EN 12620: Aggregate for concrete, allow for the 20-30% replacement of aggregate in concrete. Their use in different applications is regulated by national standards. Up to 20% of the substitution of virgin aggregates with concrete waste is not considered to lower the new concrete's properties or influence its workability, e.g. in requiring more water in mixing. The use of aggregate from sorted, processed concrete waste is common practice especially in Central Europe, but it is less used in the Nordic countries.

Case 14 – Circular concrete – illustrates how the recycling of concrete waste into new concrete could be implemented in practice. In this case, concrete waste as aggregate in new concrete is certified in accordance with EN 12620:2002+A1:2008.

5.3.3 Case examples for proofing quality for recycling

Concrete waste (if excavated soil at construction sites is not included) is the dominant fraction generated in demolition. Both small and large actors are involved in recycling and recovering concrete waste. Certification and change of waste status, i.e. the use of End-of-waste-criteria, are both drivers for promoting high-quality recycling as they address challenges related to the confidence in secondary material quality (traceability and documentation). Both the certification and EoW concept require professionalism along the value chain. We have identified two cases that address certification and end-of-waste, respectively – case 14 – Circular concrete and case 13 – end-of-waste status for concrete waste.

The certification of concrete waste

Case 14 – Circular concrete – is a product developed by the companies RGS Nordic and DK Beton. The solution implies that recycling concrete waste into new concrete is quality-assured, that the new circular concrete is delivered as certified concrete, and that the market can be served on an industrial scale.

Through the project, massive work has been done to control traceability, so significant amounts of virgin materials can be replaced with old concrete. Hitherto the use of recycled concrete has typically required a dispensation. So far, it has only been used on a small scale.

With the development of certified aggregate has come a technical, environmental, regulatory and market basis for crushed-concrete waste from demolition projects. Crushed-concrete waste can now be used as certified aggregate in the production of certified ready-mixed concrete where it represents a valuable source of raw material.

Certification requires more effort, and is useful especially for materials intended for high-grade recycling.

The End-of-Waste concept for reclaimed concrete

The End-of-Waste (EoW) concept means that a specific waste fraction can cease to be a waste under certain criteria given in the Waste Framework directive. If the criteria are fulfilled, the material will no longer be classified as a waste and it will instead become a product subject to free trade and use (although for specific purposes). If no EoW legislation has been given at the EU level, member states can

develop national EoW legislation for a certain waste material or make a case decision as part of the environmental permit. In the latter case, the material and conditions are limited to the case described in the environmental permit. Different routes for achieving an EoW status are illustrated in Figure 8.

As procedures for End-of-Waste concepts for concrete waste are lacking at the EU level, EoW criteria can be introduced at the national level by national legislation. In 2018, the Finnish Environmental Institute got instructions from the Finnish EPA to develop an EoW concept for reclaimed concrete. A proposal for a national EoW concept for reclaimed concrete is now ready for a national enquiry (situation October 2020). Today, national EoW decisions are lacking in the Nordic countries.

In the development work of a national EoW concept for reclaimed concrete, especially the use of the reclaimed concrete in groundwater needed special attention as there is a general ban on polluting the groundwater.

A lesson learned was that the environmental criteria used for the assessment of compliance for certain applications cannot be the basis for the assessment. EoW criteria for reclaimed concrete not linked with a specific application were developed for the EoW status assessment. When used in certain applications, the reclaimed concrete needs as a product to comply with existing product standards and requirements. However, in case the reclaimed concrete is used as a construction product, the EoW draft proposal sets some requirements for information to be included in the Declaration of Performance (DoP) document (the alkalinity (pH 11) and the need for a 2 m distance to groundwater table are to be included in DoP).

EoW concepts create confidence in the EoW waste. In national EoW systems, national conditions for waste characteristics and use can be taken into account. The EoW concept is built on the same elements as certification, the main difference being the reporting requirements of certified concrete according to waste legislation. The Finnish EoW scheme developed requires quality control by a third party. Using the EoW concept is expected to reduce regulatory burdens with reporting obligations, improve the quality of the reclaimed concrete, and especially to change the image of waste materials.

In member states with EoW criteria, professionalism in the whole recycling chain setting clear responsibilities for each stakeholder involved is required. Furthermore, documentation or records of the EoW material processing and quality testing are required. This means that the EoW concept is demanding for small-scale operations with input materials coming from several providers.

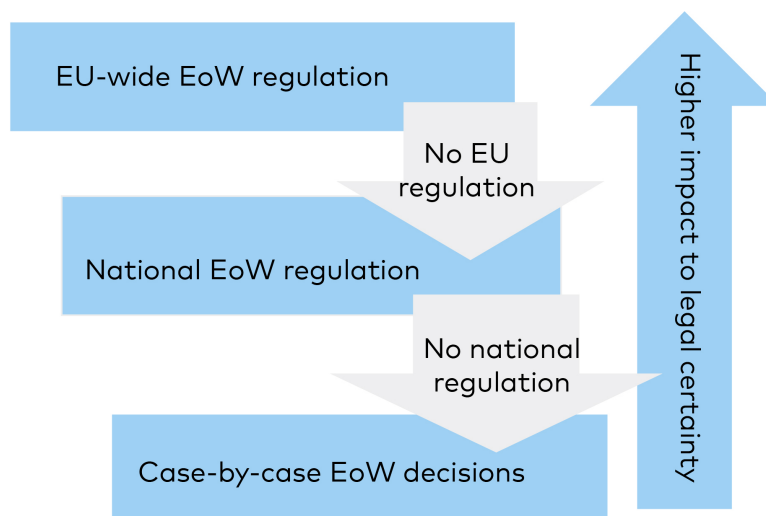


Figure 8 Different routes for achieving End-of-Waste status.⁷⁰ If a C&D waste aggregate obtains EoW status and ceases to be waste it becomes a product and fulfils the requirements for virgin materials.

5.4 Supporting and improving quality

5.4.1 Introduction

Doubts about quality (especially the variability in the quality of demolition waste) were raised in the literature and interviews as one key aspect that hampers recycling, especially its purity if a tight quality-control system is not applied. The required quality of the recovered material depends on the targeted application. Typically, high-quality (no impurities, good technical and environmental properties) are needed for high-grade recycling (as well as reuse). Concerns about the quality (e.g., impurities, material degradation) and the potential presence of hazardous materials, such as paint and glues, lead to a lack of confidence or trust in the recovered waste streams. Many composite elements in the existing building stock cannot easily be recycled because the materials are difficult to separate from each other or the elements are coated with agents containing hazardous substances.

One of the barriers noted with stakeholder contacts (e.g. representatives from municipalities working with tenders) in this project relates to the current lack of information on high-grade recycling and reuse options that can be requested in construction work. Information on achievable criteria under realistic conditions related to reuse and high-grade recycling would support the preparation of procurement documents.

70. Turunen, T. 2018. *The concepts of waste and non-waste in the circular economy. PhD dissertation.* https://erepo.uef.fi/bitstream/handle/123456789/19850/urn_isbn_978-952-61-2920-4.pdf?sequence=1

An overview of applicable standards and impurities in recyclable materials has been published in a European project PARADE⁷¹. A further assessment of the document for the Nordic conditions is needed (materials used in the Nordic countries, types of applications, climate aspects). Especially the environmental properties of recycling materials need to be specified, also including potentially harmful substances that may be present from the use phase. Especially regarding the reuse of interiors (e.g. panels) requirements for indoor quality need to be taken into account.

The material availability, besides reliable information on quality, is also presented as an important aspect to be considered. For example, in Finland, concrete waste cannot be economically transported further than 20 km from the demolition site. The transport from the demolition site to the processing plant also lowers the benefits of CO₂ savings.

A potential driver in the future is the potential material-specific recycling targets for construction and demolition waste under consideration by the Commission. The revised Waste Framework Directive states that, by 31 December 2024, the Commission should consider setting reuse and recycling targets for C&DW and its material-specific fractions.

5.4.2 Case examples: effective waste sorting and collection as a tool

One (among several) prerequisite(s) for establishing effective markets for reused or recycled materials is the security of supply of the right kind of materials. Effective identification, sorting and collection of building materials can support this. Case 11 – Recycling of plasterboards and case 12 – Increased circular use of flat glass illustrate this (see also Annex 2).

Flat glass recycling is technically possible and especially the potential for CO₂ savings is high as recycled glass needs 30% less energy than virgin materials do in production. Today, however, packaging glass dominates this recycling route.

In demolition and refitting, glass is primarily put into landfills. This is due to several reasons: there is no demand from glass producers for recycled glass from the construction and demolition sector, there is low interest in the construction and demolition sector for a more circular handling of glass, there is no system in place for recycling, there is no technique for separating glass from framings, and there are no instructions describing which glasses are suitable to sort and which glasses need to be separated. Dismantling reusable products, structures, and elements prior to demolition delays the demolition process and also increases storage needs. In several cases, landfilling is seen as a more cost-effective solution for the demolition company as the material is bulky and cheap.

The major issue is the pricing of glass. The sand used as the raw material when producing flat glass is very cheap. This gives a small price range for extra handling such as separating glass from frames, granulating and washing, and logistics.

The cost for landfilling in Sweden is approximately EUR 100 /tonne, and a glass producer can pay up to EUR 60 /tonne depending on the quality of the glass. This is the margin for the extra sorting and transporting of materials. The Swedish government is currently reviewing legislation demanding the sorting of glass

71. Jef Bergmans, Petr Hradil, Alena Sičáková, Zuzana Struková, Jozef Junák, Jiabin Li . 2019. Recyclability and reusability of key waste streams: PARADE. Best practices for Pre-demolition Audits ensuring high quality Raw materials. <https://cris.vtt.fi/en/publications/recyclability-and-reusability-of-key-waste-streams-parade-best-pr>

(alongside other materials) which will ease the transition to a circular system.

The easiest technique for separating glass from framing is to collect it with minimum damages in containers, then transport it to a recycling facility where the glass can be separated, crushed and packed for shipping to a glass producer. The separating and crushing are preferably done by an excavator with a claw attached, on a brushed concrete or asphalt area, to minimise the risk of personnel injuries and contamination of the glass from infusible (such as stone, ceramics) materials, and optimising lead-time.

The glass needs to be free of metals and infusible materials as they can harm the production of glass and cause great loss of production and in worst case stop the production entirely.

Plasterboard is a common building material. Therefore, much waste is generated from this material during construction, demolition and refurbishment. It is possible to use recycled gypsum boards as secondary raw materials in new plasterboards, and manufacturers want to increase the amount of recycled raw material in their products. Although plasterboards are often sorted in a separate waste fraction at construction and demolition sites, only a small portion of the gypsum waste is recycled into new plasterboards.

In Sweden, only one producer of gypsum boards receives secondary raw materials and only at one production site. The transport distances to this plant are often quite long from the collecting sites of the building and demolition waste which leads to high costs in the logistics chain. Also, the individual volumes of collected waste in different parts of the value chain are often small. In the project, a solution of regional collecting sites is tested and evaluated to increase the volume of waste and coordinate the transport.

The waste must be sorted into a fraction that is clean enough to meet the quality demands of the producer of the secondary raw material. However, some contamination of the material, such as wallpapers on the demolition waste, are accepted. In the project, sorting instructions are developed, tested and evaluated.

Today, the waste fraction is often sold as soil improver instead of being used in new gypsum boards. The project also investigates if this process can be motivated on Swedish soils.

The project is a study in collaboration with RISE Research Institute of Sweden and commercial companies throughout the value chain, including the material producer, building materials distributors, construction companies, recycling companies, and a company that processes the waste into a secondary raw material.

5.4.3 Technology development project for the use of drones for resource mapping

A drone is a cost-efficient tool to quickly assess available materials (steel, concrete, wood), components (e.g. windows) in a structure that is to be demolished, especially information about materials or conditions in not easily-accessible construction parts can be collected. Drones can also be used to plan and monitor renovation work (waste to be generated, material needs, work progress, accessibility). Drone technology is especially useful in cases where no BIM information is available from a construction as it can be used to estimate the amounts of different materials (steel, concrete, wood) in a pre-demolition audit needed for planning the waste management.

During and after the demolition, information on available spaces for sorting and storage of different materials can be made available with the help of drone tests. Calculations of heaps (e.g. crushed concrete, soils) can be carried out with high accuracy by using 3D-imaging calculations.

If drones are equipped with different kinds of special sensors (e.g. multispectral or hyperspectral cameras or laser scanners), it is possible to identify different materials and their quality (e.g. degradation, moisture content) and information on connections regarding reusable components. However, this has not been used on a larger scale yet.

In the future, this technology can be a standard tool for planning work, quality controls and material tracing on demolition sites.

5.5 Business models for reuse - barriers and drivers

5.5.1 Digital marketplaces for reusable products and recyclable materials

There is often a lack of information among stakeholders about generated materials and components that can be reused or recycled. Digital marketplaces are internet platforms intended for the professional exchange of waste and production side-streams from companies and organisations. Several platforms are available.

In case 5 – Kompanjonen – it is reported that the financial, social and organisational barriers were found to be more difficult to overcome compared to the technical barriers. In a survey answered by actors throughout the value chain, the following significant challenges were identified, and observations made:

- There are substantial restrictions throughout the renovation process as there is a lack of knowledge and information related to the reuse of construction products. For example, increased knowledge is needed about how the economic benefit of reuse is calculated from the perspective of the real estate owner as well as the tenant.
- The market for reused material is hampered due to a general perception that there are limited financial incentives for reuse and that the dismantling for reuse of interiors takes longer than conventional demolition.
- The potential of reuse is reduced due to habitual behaviour, that is working according to existing procedures.
- The linear and established business models do not benefit, and are not adapted for increased reuse.
- Reuse requires a longer lead time as well as new ways of working which take time and effort to learn and implement. This barrier often also includes overlooking the fact that the reuse aspects must be considered early in the renovation process.
- There are limited numbers of storage facilities and there are challenges in the logistics planning.
- There are few actors such as specific reuse actors but also architects working in the field with reusable building products.
- There is a limited supply of reusable building products of known quality.
- There is a lack of available information about the contents of the products and the traceability of this information over time. Because, for example, regulations on hazardous substances according to EU legislation REACH (EC / 1907/2006)

is continuously updated, there is no guarantee that a product approved and certified today will meet the requirements at the time the product is subject to reuse.

- There is a need for the dissemination of results and useful examples from completed projects.
- There is a need for well-documented product information such as name of manufacturer and product name, date of manufacture and date of purchase, the material and chemical content of the product, characteristics such as strength, fire class and acoustic qualities, and technical drawings.

Loopfront (case 8) is a multi-sector collaboration platform made to empower building owners and the construction industry by removing barriers for the reuse of building materials and furniture. In Loopfront, users can register materials and inventory in existing buildings or those planned for demolition. Technical information (such as CE, Environmental Product Declarations (EPDs), BIM files and manufacturers information) is easily gathered in one place – always accessible from all devices. Collaboration and planning functions accommodate logistics, such as demounting, transportation and storage. And with the Market function it is possible to reserve materials and products for reuse or make them available to other organisations. All circular activities are tracked, making reports on waste, emissions, and financial savings available at all times. Loopfront provides new solutions for circular activities – making reuse easy and profitable.

Unclearities noticed in the cases: waste/product status liability of product, need to pay Value Added Taxes (VAT), role of owner and end-user in proofing of quality, need for CE-marking.

5.5.2 Streamlining the reuse processes

As the reuse of building materials is still in its nascent period of development, there is considerable potential to streamline the reuse processes to make easy accessible reusable products such as inner doors and inner walls (glass panels). Similarly, lighting can be made more competitive compared to building products based on virgin materials. This includes increasing the awareness and competence in reuse among actors throughout the value chain and considering reuse aspects earlier in, e.g. the renovation process. Moreover, it also means developing continuous and comprehensive reuse inventories to increase the supply of reusable building products, developing more efficient reverse logistic solutions, and providing storage solutions, etc. all of which are considered key aspects needed to be developed and streamlined.

Just like traditional manufacturing, the concepts of lean production⁷² could to some extent (even though the conditions are different) be applied to for the reuse processes to make them more streamlined and efficient. Kompanjonen, a Swedish reuse partner provides the construction and real estate sector services and competence to facilitate reuse. This includes reuse consultation throughout the value chain, e.g. the renovation process, reuse inventories, selling and buying reusable building products for clients such as real estate companies, building companies as well as architects.

72. Lean production is an approach to management that focuses on cutting out waste, whilst ensuring quality. This approach can be applied to all aspects of a business – from design, through production to distribution. Lean production aims to cut costs by making the business more efficient and responsive to market needs.

In addition to the environmental aspects with reduced waste volumes and reduced climate impact, reduced costs for waste disposal and shorter time of delivery are highlighted as incentives and drivers for increased reuse. Reduced costs for reused materials are also highlighted as an argument when this can be offered.

In the reuse of products, the logistics in dismantling products from construction must be synchronised with the delivery of the reusable product to the end-users. Otherwise, there is a need for storage of the products which creates extra costs related to the products and materials and, thus, increases the resale price.

As part of the HYPPY project - case 14 - the attitudes for reusable products have also been assessed based on a citizen questionnaire by a "sister project" carried out by SYKLI, the Environmental School of Finland. The following barriers need attention (Uotila 2020⁷³, preliminary results):

- lack of knowledge/negative attitudes by architects and clients
- lack of coordination between actors
- old products require more effort in planning and installation
- new products are cheaper and better than recyclable products
- concern about potential emissions to indoor air.

5.5.3 Reuse as part of employment activity

In case 9 - the HYPPY-case, another less commercial business model was assessed. The new business model was tested to direct dismantlable interior products to reuse from a home for the elderly called "Vuorentaan vanhainkoti" that was set for demolition in 2019. Prior to demolition, a mapping of reusable interior products and materials was carried out by a professional team working at the recycling centre run by the Luotsi foundation. The Luotsi Foundation is a non-profit organisation working towards a better community with the mission to provide training, support, education, and employment programmes to unemployed people.

The focus was only on reusable products and materials (interiors, stone facades, windows, kitchen equipment, garden stones, etc.) that have a second-use value. The identified objects were dismantled or disassembled by a professional team, and the transport, product sorting, marketing and management at the recycling centre was carried out by the trainees at the Luotsi Foundation.

The recovered products and materials were then advertised through several channels (Facebook, direct contacts to potential people interested in the recovered materials) and sold via the recycling centre. The products were subject to VAT.

5.6 Market pull - Policy instruments to support market uptake

Markets for recycled materials depend on the quality, the price and the material availability. In many of the cases it has been concluded that the main obstacle for the reuse and recycling of C&DW is economic due to the often too low price of virgin materials (e.g. aggregate, wood, glass and gypsum). The economic boundaries hamper the possibilities for upgrading and re-processing. In Finland and Sweden, the

73. Uotila, T. 2020. Hyppy-case. Preliminary results from enquiry. Presented in HSY seminar.

abundance of wood and aggregate in particular limit the interest in recycling these materials. Furthermore, the sorting and processing needs of demolition waste to secure high-quality material for recycling or dismantling for reusable products increase the demolition costs.

In the cases and contacts with the stakeholders, the need for supporting drivers has been mentioned. Potential economic drivers to direct construction and demolition for reuse and recycling are: Green Public Procurement, the taxation of virgin materials, landfill taxes, and landfill bans on recyclable materials. Here, the introduction of policy instruments such as sanctions or fees as well as subsidies to promote reuse and recycling need to be further considered. Today, inert materials used or recycled in landfills are excluded from the landfill tax, e.g. in Finland and Sweden. In Finland, the taxation base is currently under discussion and proposed to be enlarged. One option under investigation concerns the taxation of all waste materials on landfill area despite their use on landfill area.

The requirement on the reuse of construction products or the recycling of construction and demolition waste in Public Green Procurement in new products used in construction will increase the market value of the recovered materials.

Case 10 – Circular solutions for wood waste (as well as case 14 – Circular concrete) highlighted the need for funding programmes and initiatives that promote new business start-ups and other entrepreneurial initiatives for bringing ideas to the market. So, while strategies greatly help in raising awareness of a topic, they typically only contain intentions and recommendations. They need to be followed up by concrete initiatives that ensure implementation in practice.

In the future, sustainability aspects in the building sector may increase the recycling of recovered materials. "Green" materials with recycled content or environmental benefits are often given credit in voluntary environmental rating systems for new or existing buildings. Examples of developed protocols are: Level(s) from the European Commission, the Building Research Establishment Environmental Assessment Method (BREEAM) from the UK's BRE, and the US Green Building Council's Leadership in Energy and Environmental Design (LEED). The protocols can be used by investors, designers, general contractors and real estate operators for proving the sustainability of a building. Reuse in particular could be considered to a greater extent in these certification systems for buildings and city districts.

Green public procurement is needed both in construction and in demolition. However, green public procurement in construction sets more specific requirements on the use of waste-related materials and thus promotes recycling more directly than green public procurement in demolition.

Also – the development of building legislation to promote reuse such as the requirement of using a minimum amount of reused building products in new constructions and mandatory reuse inventories before demolition. This solution also includes requirements for municipalities and state-owned companies to work with and consider the reuse aspects to a greater extent, such as setting reuse targets, considering reuse in public procurements as well as introducing reuse aspects in ownership directives etc.

5.7 Reuse and recycling targets and indicators

Achieving CE targets in waste management is often measured based on the recycling rate which is calculated as the ratio of recycled waste amount to generated waste amount. There is no distinction between preparation for reuse, high-grade recycling, and downcycling (including backfilling). The waste framework directive sets a target of recycling 70% (by weight) of non-hazardous construction and demolition waste. By 2024, the Commission shall consider material-specific targets for key streams. Should backfilling be excluded from calculating the recycling rate? Should climate impacts related to the manufacturing of the materials and products be considered (e.g. embodied energy defined as the energy linked to the production of construction products and materials from raw materials)? Here, the Nordic countries could further explore and test different indicators and their impacts.

A recycling target for an entire industry creates incentives to recycle materials that have a large impact on the targets and risks reducing the incentives to recycle materials that have a small impact. For packaging waste, separate targets are set for the different materials, incentivising the recycling of all packaging materials in use. For packaging waste, most EU Member States have an Extended Producer Responsibility scheme, where the producers are responsible for the waste management and reaching the recycling targets for the packaging waste.

A discussion is needed on the possibilities to demand an Extended Producer Responsibility (EPR) for some construction products and/or materials (e.g. flat glass, plasterboards). In practice, EPR schemes work such that the producers are responsible for the waste management of their products, and also reaching set recycling targets. It is very common that the producers are organised into an executing entity, the Producer Responsibility Organisation, PRO, and pay a fee based on the products they put on the market; the sum of the fees should cover the expenses of the waste collection and treatment for the end-of-life products becoming waste. The PRO is then responsible for reaching national waste recycling targets. Under an EPR scheme, producers may be fined if they fail to reach the set targets. EPR schemes are seen as very efficient means of reaching recycling targets as the costs for recycling are embedded in the cost of the product instead of forming a separate waste management fee for the consumer.

Waste prevention is not part of waste management (e.g. reuse and recycling) and is therefore not included in statistics, and there are currently no indicators for waste prevention even if waste prevention highly supports the circular economy goals. In several cases (e.g. Netlet, FM HAUS) there is a lack of a system to include waste prevention in environmental reporting. In the Netlet case, the surplus materials are managed as products, not waste. In the case of modular construction (FM HAUS), it is not clear how to address the avoided waste generation. Reuse means that a product retains its product status and waste generation is prevented, but waste prevention is not measured in the waste statistics.

When it comes to indicators for recycling, it is important to consider the quality aspect and distinguish between low-grade recycling and high-grade recycling. The certified concrete waste as well as EoW concrete can be used in new concrete as an example of high-grade recycling. In high-grade recycling, the physical and chemical properties of a material are retained and used again whereas in low-grade recycling, the recovered materials are useable but have been downgraded and the original

properties have been lost.

The recycling of gypsum from plasterboards is presented as a case example.

Recovered gypsum can technically be recycled into new plasterboards, but there is only one plant in Sweden receiving plasterboard waste. The use of gypsum waste as soil improver is currently under investigation. Discussions on material-specific targets for, e.g. gypsum sets the need for clarification on whether use in other applications can be calculated as high-grade application.

6 Policy recommendations

Based on the identified drivers and barriers in the selected cases analysed in the previous sections, the following actions to support Nordic ambitions for circularity, low-carbon economy and non-toxicity are recommended:

Focus area	Policy recommendations	Recommendations for further work
Local CE strategies at the sub-national level (municipality level)	1. For implementation of CE goals at the regional level: guidance documents and especially concrete criteria recommended to support achievement of CE solutions in practice (actions at municipal level)	• Development of a methodology and collection of examples of how to evaluate the impacts (economic, environmental, social) from CE actions • Assessment on how also other strategies (e.g. low-carbon economy, non-toxicity) can be linked with CE strategies in the construction sector
Green Public Procurement	2. Use of GPP both for construction and demolition work are tools to support the reuse and recycling of construction and demolition waste. Especially GPP in construction promotes closing the loop. (actions at municipal level)	• Collation of information on best practice based on existing technologies and systems (including boundary conditions) that could be used as background information for case-specific green public procurement tenders
Indicators for CE actions	3. Nordic input to the European Commission on the definition of material-specific targets, with special focus on eco-design and how the waste hierarchy can be better implemented. This means distinguishing between waste prevention, reuse and high-grade recycling, and downcycling, backfilling (actions at national level in cooperation with EU), and also including indicators on eco-design, such as recycled material content and recyclability.	• Specification on conditions when materials/products have product or waste status (through examples), improve the liability of reusable products • Impact assessment via use of other than mass-based indicators (e.g. LCA approach: CO2 savings in different management options) • Development of potential criteria for measuring achievement of CE goals in projects at local level (e.g. for GPP tenders)
Reuse and CE-marking	4. Securing that the Nordic aspects are considered in the revision work of the Construction Products Regulation and linked harmonised standards for CE-marking as products are traded between countries (actions at the national level in cooperation with Nordic countries)	• Collation of Nordic expertise on challenges and potential solutions for different reusable products • Examples of unclarities to be discussed: – Liability: end-user, re-seller, producer – Inclusion of reusable components in harmonised standards – Process to CE-mark reusable products (methods, traceability systems, etc) • Identification of cases/situations with no need to require CE-marking (input to Commission's consultation)

Focus area	Policy recommendations	Recommendations for further work
Digital solutions	5. A need for the development of digital competences in the entire value chain	• Development of “best practice” guidelines for performance of reliable waste statistics • Survey identifying how waste traceability is most efficiently ensured • Development of common data standards, open formats, etc. to support the development of materials and buildings passports
Conformity assessment/ acceptance procedures	6. Promotion of EoW and certification concepts – exchange of information (elements, e.g. traceability concepts) (action at national level)	• Guidance document or overview on how to test and assess reusable structures and elements and products containing waste materials (focus on key streams) • Catalogue of high-grade recycling and reuse possibilities implemented in the Nordic countries (target group: designers, municipalities, etc.) • Identification of potential legal barriers
Promoting the market for CE solutions	7. Actions (e.g. fiscal) for securing market pulls for CE solutions (action at national level) 8. Funding systems for start-up companies, new technology demonstrations (actions at municipal, national and EU level)	• Impact study on potential solutions: e.g. use of certification schemes, EoW concepts, green public procurement, taxation of virgin materials, ban for landfilling of recyclable materials, marketplaces, Extended Producer Responsibility (EPR) • Lessons learned in Nordic countries to ensure a well-functioning market (removal of potential barriers)
Awareness-raising on CE solutions in construction	9. Education in (applied) universities on CE solutions in construction (actions at municipal and national level) 10. Education of professionals in business (constructors, designers, authorities, consultants) (actions at municipal and national level)	• Catalogue of success stories • Protocols, procedures, competence

Annex 1

Screening of cases

Table A1.1. Summary of findings from Denmark, Finland, Norway and Sweden. Topics covered in the different cases. A list of cases analysed is collated in Annex 2.

Total	Total
	115
Building design	29
Material production	30
Construction phase	27
Operation and use phase	16
Selective demolition and on-site sorting	33
Waste management, recycling and end-of-life phase	68
Requirements for reuse etc., or requirements for zero chemicals	17
Logistics	24
End-of-Waste legislation	6
Business models and business development	38
Standardisation	6
Use of digitalisation	15
Public procurement and overall economy	13
Climate and CO ₂	14
LCA/LCC requirements	10

Table A1.2. Mapping of cases in Denmark, Finland, Norway and Sweden.

Note! Please contact national authors of this report or the project coordinator for links with further information. Unfortunately, we were not able due to technical reasons to add the links for further information.

	Country	Title and place	Project type	Description of project	Project focus
1	DK	Blixens (initially OPS Aarhus). Aarhus municipality.	Commercial	Construction of an office building for 950 employees in the municipality. Aarhus municipality is owner of the building and sustainability has been an important factor in the project. The building was constructed 2016-2018 and when the project was put out to tender, circular economy was a relatively new term. As such, circular economy is not mentioned directly in the tender, but the project team has aimed at using as much recycled, or reused materials as possible in the building.	Sustainability, reuse, recycling.
2	DK	Byggeri København	Construction projects for the City of Copenhagen	Byggeri København is the City of Copenhagen's developer unit under the Finance Administration, and is responsible for the construction of schools, day care institutions and cultural and leisure facilities. The City of Copenhagen has for several years worked ambitiously with sustainability in construction and civil engineering. This has been expressed in plans, policies, and strategies such as KBH2025 Klimaplanen and five editions of "Miljø i Byggeri og Anlæg" (MBA) since 1999. Among other things, the efforts of the City of Copenhagen have resulted in a number of construction projects, where recycled building materials were in focus, and in 2020 Byggeri København presented several new projects, where the circular economy will be the focus.	CO ₂ -savings, resource savings; LCA/LCC
3	DK	Construction of Sydhavn recycling centre, Copenhagen	Commercial	Construction of a new recycling centre in Copenhagen with aggregates from demolition of an old chimney at the Amager plant. The Centre won on March 28, 2019 the Sustainable Concrete Award, awarded by Danish Concrete. Construction is shaped as an infinity sign to symbolise the cycle of materials. Sydhavn Recycling Centre is operated by both the Amager Resource Centre (ARC) and the City of Copenhagen, where ARC operates the recycling station and the visitor service, and the City of Copenhagen stands for Multihuset with start-ups, workshops, meetings and discussions, shop, sale of waste streams and teaching for school classes.	Recycling of concrete, reuse, logistics, CO ₂ , standards, legislation, education, entrepreneurship and sustainability at the recycling centre.
4	DK	"Fra Missonshus til værtshus", Middelfart municipality	Demonstration project, 2017-2018	Collaboration between DM&E and Middelfart municipality where bricks from an old missionary house were used for re-construction of a pub.	Resource mapping, careful/selective demolition, reuse.
5	DK	"Bæredygtig bundlinje Bornholm", "Byg360" and "Materialeværket" ("Sustainable bottom line", "Build360" and "Material plant"), The Island of Bornholm	Three initiatives based on public-private partnerships.	"Bæredygtig bundlinje Bornholm" involves companies focused on becoming more sustainable economically as well as environmentally. "Byg360" and "MaterialeVærket" are two interconnected projects focused on sustainable demolition of old buildings aiming to reuse as many materials as possible. Other focus areas are new business opportunities at Bornholm within demolition and sale, and construction.	Sustainability, demolition, reuse, recycling, networking, business development, CO ₂ .

	Country	Title and place	Project type	Description of project	Project focus
6	DK	Bedre brug af byggeaffald ("Better use of C&D waste"), Kolding municipality	R&D	C&D waste is perceived as a valuable resource. The aim of the project is to develop new business models for better use of C&D waste in close collaboration with the companies participating in the project. The project runs for three years and is financially supported by the EU.	Developing of new business models.
7	DK	Marina City som eksempelprojekt ("Development of Marina City"), Kolding Municipality	Commercial (and initiative for concept not yet developed)	The new quarter in Kolding, Marina City, is being developed as a case example of circular economy within the construction sector. Marina City is being developed as a partnership between Kolding Municipality, Kolding marina and Kolding harbour. Marina City will be a sustainable quarter and become certified according to DGBN criteria for urban areas.	DGNB certification and development of a lab for circular initiatives.
8	DK	Certified circular concrete - Use of certified aggregates from recycled concrete to production of certified concrete (RGS Nordic and DK Beton)	Started as an R&D project, but the aggregates are now certified and produced on a commercial basis	Production of concrete for use in indoor constructions. Aggregates produced from old concrete can substitute 20 % of the stones used in new construction concrete.	Quality, concrete standards, traceability of old concrete.
9	DK	"Stablen" - Tender from Horsens municipality	Tender (the building shall be finished by summer 2023)	"Stablen" is intended as a building with a focus on the reuse of building materials and circular economy. The building shall - among other things - house classrooms for teaching in waste and resources, a "repair cafe", and a shop that sells used building materials. It should be constructed of re-used materials.	Reuse, education, circular economy.
10	DK	Demolition of Storstrømsbroen - Tender from Vejdirektoratet	Tender (the bridge shall be demolished before mid- 2027)	Storstrømsbroen is to be demolished and a new bridge established. It appears from the demolition tender that the focus is on the mapping of resources, reuse, recycling or recovery of concrete, granite and iron, local use of waste resources from the bridge and management of hazardous waste.	Mapping of resources, reuse and recycling, local perspective.
11	DK	Compas ReDo, Hedensted municipality	Initiative financially supported by Hedensted municipality	Compas ReDo was established in the beginning of 2019 as a "second life material station". Several small companies/start-ups are part of Compas ReDo. The material station receives waste materials from companies and recycles or reuses the materials. Traceability is important, and accordingly Compas ReDo do not accept waste from public recycling centres.	Reuse, circular economy, entrepreneurship.
12	DK	TrÆls	Start-up	Part of Compas ReDo (see above). Construct furniture of old wooden pallets and sells or rents out the furniture to festivals, etc.	Reuse, traceability
13	DK	næste	Commercial	Small company that construct sheds based on reused wood and tiles.	Reuse, resource efficiency, sustainability
14	DK	GENTRÆ	Partly commercial, partly financed by Realdania	The project aims at introducing reused materials in the Danish DIY centres. Currently, the project focuses on wood used at construction sites for interim purposes. The reused wood is sold in STARK (DIY centre and project partner).	Reuse of wood from interim uses (boards, battens, poles) at construction sites.
15	DK	Circle House	R&D	Construction of council flats based on circular principles. The project runs from 2017-2023 and involves more than 60 companies. The project is supported financially by the Danish EPA and Realdania.	Design-for-disassembly, reuse, recycling, legislation

	Country	Title and place	Project type	Description of project	Project focus
16	DK	Fischer Lighting (company name)	Commercial (technological solutions for CE)	Fischer Lighting produces modular LED solutions built on existing fixtures, but offering all of the functionality, lighting quality and energy saving technology expected from state-of-the-art LED.	Reuse of old light fittings
17	DK	Peikko (company name)	Commercial (technological solutions for CE)	Peikko produces (among other things) bolted connections with the aim of enabling future disassembly of buildings. Peikko is partner in the Circle House project.	Design-for-disassembly
18	DK	Really (company name)	Commercial (technological solutions for CE)	Recycling of end-of-life textiles into solid textile boards and acoustic textile felts.	Recycling of textile
19	FIN	S-Market, Urjala, Finland	Commercial	The original structure of the S-market was erected in the 1980s in Tampere and was relocated for reuse in 2009 in Urjala, 60 km away. The owner of the existing discount store building (~2 000 m ²) in Tampere, Finland, SOK, planned to replace it with a new Prisma hypermarket (~10 000 m ²). At the same time, SOK also intended to build a new supermarket of similar size in Urjala (about 60 km from Tampere). It was decided to design the new building with a target that part of the main structural components of the disassembled building could be reused in the new location. The existing building was built in the 1980s. The main structure consists of composite RHS columns and RHS steel trusses. The walls were made of prefabricated concrete elements and the roof was built in-situ with trapezoidal sheeting, mineral wool insulation and bitumen membrane. The building was deconstructed and re-assembled between 2008 and 2009.	Reuse
20	FIN	Circular city village, Helsinki	R&D/Commercial	Reuse of elements (wood, tiles, concrete, metals) in wooden housing structures within the Helsinki region. City Village CO-10 Oy, founded in 2019 and based in Helsinki, represents a sustainable development start-up company that combines experience and expertise in ecological construction and community living. The CO-10 principles bring together issues related to construction, housing, property management, services and global responsibility through research, planning, design, and extensive collaboration and co-development.	Reuse
21	FIN	FM-Haus	commercial	Design of modular demountable constructions. Design for deconstruction or disassembly enables reuse of building parts without damaging others and without a loss of quality or value.	Reuse
22	FIN	Raahe	municipality	Raahe (2008-2010). Partial deconstruction of apartment blocks (at the back) and reuse of panels for carports	Reuse
23	FIN	Rantarousti School/ Tyrnävä	municipality	Choice of material for construction of school wall	New construction

	Country	Title and place	Project type	Description of project	Project focus
24	FIN	Tarpaper recycling Oy	municipality	Tarpaper Recycling collects roofing felt waste from waste management companies, demolition worksites, roof contractors, and roofing felt manufacturers all around Finland. The quality of both received and produced material is closely monitored with respective guidelines and sampling tests. Tarpaper Recycling processes roofing felt into new raw material for asphalt production. The name of the end product is BitumenMix and it can replace approximately one third of the virgin bitumen needed to manufacture asphalt. With BitumenMix, 60 kilograms of CO2 is saved per every produced tonne of asphalt. The end product is close to asphalt made of virgin material and its durability is high due to its material tenacity.	Recycling
25	FIN	Laakso Hospital/ Helsinki	municipality	Favouring of recycled material and reused elements, longevity of materials/elements	New construction
26	FIN	Hyvinkää municipality	municipality	Use of recyclable materials, or materials that can be dismantled later for further use	New construction
27	FIN	Raksanouto+B42	commercial	Service to pick up leftovers (material, products, equipment) from construction sites and sell the products further for 50-80% of the original prices	New business models
28	FIN	FIRA	commercial	Logistics system on material management at construction site to avoid material losses	Optimisation in management of material uses
29	FIN	CIRCUIT - HSY: city symbiosis	R&D project	1) urban mining, 2) prolongation of building lifetime, 3) flexible planning of new constructions for reuse/ recycling	Industrial symbiosis
30	FIN	CITYLOOPS - Mikkeli XAMK	R&D project	Development of an internet-based market place for promoting exchange of materials, structures, and equipment. Supplementally, estimation of amounts and planning of demolition work promoted by use of a XAMK drone-based tools	Technology development
31	FIN	PEIKKO	commercial	Dismantling of concrete elements for reuse	Construction
32	FIN	HISER: wood-plastic composite panels	Technological solutions for CE	Production of wood-plastic composites (WPCs). WPCs are a material mainly composed of crushed wood from construction and plastic waste.	
33	FIN	Isover-Saint Gobain Glass wool	Technological solutions for CE	85% recycled glass bottles	
34	FIN	Knauf Oy glass recycling	Technological solutions for CE	Glass wool produced using glass bottles as a raw material (80% of raw materials)	Recycling
35	FIN	Knauf Oy gypsum recycling	Technological solutions for CE	Gypsum boards from construction can be returned to the manufacturer for recycling.	Recycling
36	FIN	Suomen Selluvilla-Eriste Oy cellulose wool	Technological solutions for CE	Recycled paper	Recycling
37	FIN	Termex-Selluvilla cellulose wool	Technological solutions for CE	Recycled paper	Recycling
38	FIN	UltraTouch Recycled Denim Insulation	Technological solutions for CE	Recycled jeans	Recycling

	Country	Title and place	Project type	Description of project	Project focus
39	FIN	Ekoexpert EkoCollect	Technological solutions for CE	Collection of blow wool, grinding of wool insulation, storage on site and blow installation of wool	Recycling
40	FIN	Uusioaines Oy foam glass	Technological solutions for CE	100% recycled glass bottles	Recycling
41	FIN	Rudus concrete aggregate	Technological solutions for CE	100% recycled concrete	Recycling
42	FIN	WOOL2LOOP	Technological solutions for CE	The recycling of mineral wool waste into geopolymers: WOOL2LOOP provides new smart demolition and sorting technologies, combined with a novel analysis method for mineral wool waste that enables separating the material based on its suitability for alkali-activation. Geopolymer technology, on the other hand, makes it possible to use mineral wool waste as a valuable resource for new ceramic or concrete-type products as pioneered by the University of Oulu, Finland.	Recycling
43	FIN	ICEBERG	Technological solutions for CE	Recycling of wood waste into new products	Recycling
44	FIN	Hemprefine hemp concrete	Technological solutions for CE	Hemp fibres + lime	Recycling
45	FIN	Fisu - Finnish Sustainable Communities. Network of communities	Network	Fisu (Finnish Sustainable Communities) is a network of Finnish municipalities committed to working towards becoming carbon neutral and waste-free, and curbing over-consumption by 2050.	Network
46	FIN	Canemure - Towards Carbon Neutral Municipalities and Regions	Network	The aim of the project is to promote smart low-carbon transport, increase the production of decentralised renewable energy, and improve the energy efficiency of buildings. In addition, support is provided for climate sustainable urban planning processes and conditions created for low-carbon production and consumption.	Network
47	FIN	Circwaste	Network	CIRCWASTE is a project that promotes the efficient use of material flows, waste prevention and new waste and resource management concepts. All actions contribute toward implementing the national waste management plan and directing Finland towards a circular economy.	Network, awareness
48	FIN	"Circwaste-Pori CE activities and waste reduction in the construction sector"	R&D, pilot	Activities under Circwaste in Pori: LCA on 5 buildings -LC-thinking in procurement -Carbon footprint of two houses -Applying pre-demolition audits according to MoE instructions -Recycling of plastic packaging from construction site -Development of material bank for spare parts and materials -Improved communication among stakeholders in the construction sector	
49	FIN	Web guides for C&DW management	Communication & awareness raising	Web guides on good practice in recycling of household construction & demolition waste from refurbishment by waste companies, e.g. HSY	Awareness
50	FIN	Web-page collection points	Communication & awareness raising	Web-page for navigating to recycling centres and collection points	Collection

	Country	Title and place	Project type	Description of project	Project focus
51	FIN	Building Performance Indicators	Calculation tool	Building Performance Indicators by Green Building Council Finland. A calculation tool for measuring the environmental and energy efficiency of buildings, their lifecycle costs, and also occupant well-being. The results can easily be presented in the Building Passport, either for the pre-design or occupancy phase.	Impact assessment
52	FIN	Guide on utilisation of crushed concrete	Communication & awareness raising	Guide on utilisation of crushed concrete in Helsinki region; Comprehensive guidance for design, building and maintenance of infra structures utilising crushed concrete instead of virgin raw materials	Guidance
53	FIN	Guidance on lifecycle management of constructions and buildings	harmonisation, digitalisation	Guidance on lifecycle management of constructions and buildings, Covers sustainability aspects, process, tools and methods, demolition, reuse and recycling	Sustainability
54	FIN	Hiedanranta Construction of a new smart and sustainable city district in Tampere	Construction, in implementation	The new city district of Hiedanranta will create homes for 25,000 residents, and 10,000 jobs. Hiedanranta will come to comprise a smart and sustainable city district that provides its residents with a smooth daily life and improves their quality of life by utilising new digital solutions. Hiedanranta is located at a distance of about four kilometres from the city centre.	Case
55	FIN	Construction of a new smart and sustainable city district in Tampere	Construction, in implementation	The new city district of Hiedanranta will create homes for 25,000 residents and 10,000 jobs.	
56	FIN	Circular Economy Aspects of Construction in Municipalities project ("RANTA")	awareness raising	The project focused on demonstration of enhanced utilisation of the building materials and land masses based on case studies in buildings and construction areas owned by the municipalities. In addition, the project focused on increasing understanding of the process and by example developing circular economy-based criteria for public procurement of building demolition.	Resource mapping, public green procurement
57	FIN	REUSE	R&D	Utilisation of C&D waste and materials in the construction industry	Business models
58	FIN	RAKLI	Education, professional training	The clinic RAKLI project aims to support city developers to define goals, criteria, and solutions for implementation of CE principles in local regions in order to strengthen the vitality of the regions. Furthermore, the aim is to create roadmaps and networks for achievement of goals.	Developer of new business models in society (examples: KERA; VIIKKI; Hiedanranta)
59	FIN	Plastics Roadmap Pilot Projects	Project (guidance)	Guidance on assessing the use of plastics in buildings, finding alternative solutions and materials; pilot projects on management on construction site	Efficient management of plastics in buildings

	Country	Title and place	Project type	Description of project	Project focus
60	FIN	Kieppi	Partnership Model for Sustainable Neighbourhoods	The goal of the KIEPPI Partnership Model for Sustainable Neighbourhoods project is to develop Kera in Espoo, Hiedanranta in Tampere, and Tiedepuisto in Turku into sustainable neighbourhoods that generate new jobs and business based on the circular economy and sharing economy. The project will create a carbon-neutral neighbourhood platform model, where the material flows required for the growth of cities circulate in a way that is as closed and resource-efficient as possible. The project will facilitate the development and bringing together of new circular economy solutions that support the development of the districts involved into sustainable and attractive areas	Actions/cases for development of new CE business models
61	FIN	KERA	demonstration	The development in the region focuses on Espoo's goals of permanently becoming the most sustainable city in Europe and becoming carbon-neutral during the 2020s, and smart and clean solutions hold a central role in achieving these goals. Several concrete actions, such as repurposed buildings are demonstrated,	Development of KERA region in Espoo
62	FIN	HYPPY reutilising building parts and materials for municipalities	demonstrations	The HYPPY project aims to promote such activities, where used building parts or objects inside a demolished building could be readily re-used.	Reuse
63	NO	Reuse of concrete slabs	R&D project	Initial inspections have been carried out by the concrete technologist, supplemented by testing the concrete's compressive strength and carbonation to determine the condition and technical characteristics of the hollow core slabs. These were later verified with full-scale testing. Constructive castings were removed, the elements were cut loose and transported back to the factory, where they are to be adapted in the plan for the Oslo Metropolitan Guard and stored pending installation. This work was carried out in accordance with job descriptions that are interdisciplinary between the different partners. For each interface, checklists are filled, which document the critical aspects and the necessary documentation is passed on to the next paragraph. The project will provide many practical experiences with the possibilities and challenges of reuse of hole decks. The project is a collaborative project between Statsbygg, Omsorgsbygg, Contiga, Skanska, Veidekke, OBOS, the Control Council and NTNU Omsorgsbygg, Statsbygg, Skanska, Contiga and Veidekke with support from Enova.	Reuse
64	NO	Avfallsfrie byggeplasser (Waste free construction sites)	Commercial	This project focuses on reducing construction waste by ordering pre-cut materials, ready-made modules and take back schemes for products with incorrect dimensions or other flaws.	New business models
65	NO	Nasjonal Handlingsplan for bygg- og anleggsavfall (National Action Plan for Construction and Demolition waste)	Voluntary agreement	NHP was established in 2000 as a voluntary collaboration between the actors in the building and construction sector. In the last four years, circular economy, waste minimisation and reuse have also been implemented.	Industrial symbiosis

	Country	Title and place	Project type	Description of project	Project focus
66	NO	Foamrox	R&D project	Development of sustainable prefabricated constructions for tunnels. The goal is to manufacture a product, which replaces concrete and PE-foam. The product is based on recycled glass.	recycling
67	NO	Høine tegl	R&D project	Extracting and upcycling used clay brick for resilient, authentic, local and sustainable building façades. Clay bricks with cement mortar is hard to disassemble, but it is possible to cut them in three, to create three new façade covers. This cladding façade is 99 times better for the environment. And the authentic material is popular among architects around the world. This business can create hundreds of local jobs in Norway, Sweden and Denmark.	Waste minimisation
68	NO	ConZerW Construction Site Zero Waste	R&D project	The main objective of ConZerW is to achieve waste-free construction sites by developing digital process tools, which enable tracking the source of waste from construction activities, implement potential optimisation measures and evaluation methods, that support collaboration between partners in planning, procurement and logistics activities related to the construction site.	New business models
69	NO	Loopfront	R&D project	Loopfront is a multi-sector collaboration platform made to empower building owners and the construction industry – removing barriers for reuse of building materials and furniture. In Loopfront, users can register materials and inventory in existing buildings or those planned for demolition. Technical information (such as CE, EPDs, BIM files and manufacturers information) is easily gathered in one place – always accessible from all devices. Collaboration and planning functions accommodate logistics, such as demounting, transportation and storage. And with the Market function you can reserve materials for reuse – or make them available for other organisations. All circular activities are tracked, making reports on waste, emissions, and financial savings available at all times. Loopfront provides new solutions for circular activities – making reuse easy and profitable.	New business models
70	NO	Precut gypsum boards	R&D project	Gypsum boards are cut in exactly the correct dimensions through new processes and digitalisation, in order to reduce waste generation on site. The goal is to develop the system for other building materials as well, so that the amount of waste can be more than halved in the long run.	Precut gypsum boards
71	SE	Centrum för cirkulärt byggande – bygg- och fastighetssektorns gemensamma arena för cirkulärt byggande	Commercial/ initiative not fully implemented	The Centre for Circular Construction (CCBuild) is an arena, where industry players meet and collaborate on recycling and circular material flows during construction, demolition and management. The arena offers networks, knowledge and digital services that strengthen the market for circular products and services in the construction and real estate sectors.	Reuse

	Country	Title and place	Project type	Description of project	Project focus
72	SE	Kompanjonen	Commercial	Kompanjonen offers a number of services related to the reuse of building materials (mainly interiors such as doors, inner walls etc.). Examples of services provided are reuse consultation, sales and purchase of building materials and products, material inventories, selective demolition for reuse, storage, etc.	Reuse
73	SE	LM	Commercial	The construction company LM uses loose wool insulation instead of conventional boards	Waste minimisation
74	SE	Loop Rocks	Commercial	The construction company NCC started Loop Rocks in the summer of 2016 to create a market for secondary materials, primarily stone, soil and various filling materials. Through a digital interface both supply and demand are made visible and construction projects can be matched in this way. Loop Rocks have closed down their business due to poor profitability.	Material recycling
75	SE	GBR golvåtervinning	Commercial	GBR Golvåtervinning is a collection system that is free of charge for the plastic flooring industry members in Sweden. Flooring companies installing floors, gather the floor residues generated, which are then collected. A large proportion of the collected floor is milled down to granules and becomes new floors, while the remaining energy is recycled. Nowadays, mainly PVC and polyolefins floor residues are collected and recycled from many major suppliers in the Swedish market.	Material recycling
76	SE	Byggpall	Commercial	Recycling system for wood pallets.	Reuse
77	SE	Constructivate	R&D	Constructivate was part of the research programme Mistra Closing the Loop II. The project aims to: achieve more resource efficient recycling of construction and demolition waste. The project is led by Chalmers Industrial Technology and in the project 17 Swedish project partners from academia and the value chain participate in construction and demolition. The goal is both to develop technical solutions and to identify obstacles and opportunities for increased recycling of construction and demolition waste. Legislation, regulations, logistics and business models are included in the development. Two streams of material have been identified as extra interesting to follow: Concrete and plastic because these are recycled to a small extent today.	Material recycling

	Country	Title and place	Project type	Description of project	Project focus
78	SE	FISSAC	R&D	The FISSAC project involves stakeholders at all levels of the construction and demolition value chain to develop a methodology, and software platform to facilitate information exchange, that can support industrial symbiosis networks and replicate pilot schemes at local and regional levels. The model will be based on three sustainability pillars: Environmental (with a life-cycle approach), Economic, and Social (taking into consideration stakeholder engagement and impact on society). Our ambition is that the model we create can be replicated in other regions and other value chain scenarios. FISSAC aims to demonstrate the effectiveness of the processes, services, and products at different levels.	Sustainability
79	SE	100 gruppen	commercial/ (Network)	100 Gruppen was formed after a successful seminar on "The furniture and material choices of the future for indoor environments" in the fall of 2015. The 100 participants showed great interest in pushing the issue further in organised form. Manufacturers and suppliers of interior design products and interior designers agreed that a common platform was needed to simplify the development, for everyone involved, towards a circular economy in the most cost-effective way possible. The common interest is that sustainability should pay off, regardless of whether you are a supplier or a customer.	Sustainable interiors, digital solutions, circular business models
80	SE	Cradlenet	commercial/ (Network)	Cradlenet is a Sweden's platform for knowledge of, and networking around, circular economy. Cradlenet's work aims to accelerate Sweden's transition to a circular economy. The network creates good meetings between companies, organisations and people to provide inspiration, energy, and knowledge about the latest in the subject. All seminars are open and we offer members of Cradlenet unique networking meetings, where the opportunity for in-depth knowledge, workshops and discussions is provided. Cradlenet's dissemination of information also takes place in the media, on social media, the website, and through Cradlenet's newsletter. Cradlenet also works with political influence to speed up the transition and support the politicians in their work with circular economy. Members from the construction sector also participate in the network.	Circular economy
81	SE	Backsippan	Commercial	In 2014, Backsippan preschool, which is built on circular principles, was opened. The school was selected to be presented at the World Sustainable Building 2014 in Barcelona, as a good example of sustainable construction. CEFUR (Center for Research and Sustainable Development), in Ronneby has a great focus on circular principles and is behind Backsippan, but also other initiatives within the municipality.	Material recycling
82	SE	Modexa (company name)	Commercial	Modexa renovates old kitchens, while preserving the cores.	Interiors, kitchen cupboards
83	SE	BAMB- Buildings As Material Banks	R&D	BAMB creates ways to increase the value of building materials. Dynamically and flexibly designed buildings can be incorporated into a circular economy, where materials in buildings sustain their value.	Material recycling and reuse

	Country	Title and place	Project type	Description of project	Project focus
84	SE	OMREDA	Commercial	Consultant who advises on renovation with the aim to preserve as much as possible of the interior and exterior. Omreda is her trademark. There are many examples at www.omreda.se	Reuse
85	SE	Cirkulära produktflöden i byggsektorn, Stockholm	R&D project and demonstration	Circular product flows in the construction sector - recycling of building materials on an industrial scale. This research project took place between 2017 and 2019.	Reuse and material recycling
86	SE	REuse and REcycling of C&D waste materials and structures in energy efficient pREfabricated elements for building REfurbishment and construction (RE4)	R&D, incl. demo	Research project financed by H2020, which was completed in February 2020. Innovative systems and processes for more efficient sorting of construction and demolition waste, for different material fractions such as mineral based, plastics, and wood, etc.	Material recycling and reuse
87	SE	Manufacturing of environmentally friendly particleboards from wood waste	R&D	The project idea is to create commercially sustainable environmentally friendly innovative models (variants) of particleboard based on wood waste using different natural adhesive systems, and compare their mechanical-, physical- and environmental properties with the European Standards, and conventional particleboards.	Wood waste
88	SE	Sweduce- EPS recycling	R&D	The purpose of the project was to create the conditions for the recycling and reuse of used frigolite. The project has had difficulty in achieving a recycling volume according to the project target and the selected recycling technology has not been successful with higher energy consumption than the previous prototype.	Recycling and reuse of expanded polystyrene
89	SE	RE:think	Commercial	Parts included in the RE:think certification: //-Annual review of waste producing companies waste management to ensure economical and sustainable solutions. After the review, improvement suggestions are given linked to the criteria achieved. //-Digital education in circular economy and the UN's Global Goals. //-An annual rating of the company's resource efficiency. //-ReThink certificates / diplomas with the current level that waste producing companies can use in their sustainability work. //-Together with certified customers, RagnSells supports various innovative projects that work for circular solutions and a sustainable planet.	Waste management
90	SE	Byggigen	Commercial	Market place for reused building parts such as doors, windows, roof tiles etc.	Reuse
91	SE	Bergo flooring	Commercial	Plastic floors from 100% recycled plastics	Recycling
92	SE	Tarkett/Desso	Commercial	Cradle to Cradle certified office mats in recyclable materials. Some models clean the air.	Recycling
93	SE	The ecological building store	Commercial	Building store selling natural materials	Selling of building parts in natural materials (i.e. stone, bricks, flax etc.)

	Country	Title and place	Project type	Description of project	Project focus
94	SE	Hus till hus (house to house)	Commercial	The company conducts refurbishment and sell building products and recycled building materials for house renovations.	Reuse
95	SE	Leva husfabrik	Commercial	Individually customised houses constructed from environmentally friendly materials (mainly wood).	Use of renewable raw material
96	SE	Hållbara hus	Commercial	Cell isolation made in cellulose based materials.	Isolation in cellulos based materials
97	SE	Malmö återvinningsdepå	Commercial	Receives and sells reused building materials.	Reuse
98		Enhanced waste collection for increased recycling of plaster boards. RISE	R&D	In this study, the barriers and opportunities for increasing the amount of secondary raw material to reach the gypsum producers are studied and some innovative solutions are tested. These include coordinated collection systems, new technologies for more efficient sorting and transport, and the development and communication of sorting guidelines. The project includes several actors from the industry, as it is important that both material manufacturers, construction companies, recycling companies and transport companies cooperate.	Recycling of C&D waste to new gypsum plaster boards.
99	SE	Recycling of construction waste (Byggåtervinningen)	Commercial	The municipality of Halmstad receives and sells used building materials and parts such as tiles, doors, windows etc.	Reuse of construction materials and parts.
100	SE	Insulation material	Commercial	The circular economy has its own environmental certification - Cradle to Cradle. The Swedish company Woodfiber Träisolering is the first Swedish product to be approved	Use of renewable raw material.
101	SE	BASTA	Commercial	In BASTA systems, suppliers and manufacturers of construction products register the products that meet the requirements for content of substances with dangerous properties in the BASTA or BETA criteria. The information in the system is reviewed by third parties and quality assured through regular audits of affiliated suppliers and manufacturers.	Phasing out substances with hazardous properties from construction and civil engineering products.
102	SE	Byggvarubedömningen	Commercial	Byggvarubedömningen assesses building-related products based on their chemical content, environmental impact during the lifecycle and, by extension, social impact at the supplier stage. This is done to promote product development towards a non-toxic and well-built environment, and a responsible supplier chain.	Phasing out substances with hazardous properties from construction and civil engineering products.
103	SE	SundaHus	Commercial	SundaHus offers services to property owners to make environmentally conscious material choices etc.	Phasing out substances with hazardous properties from construction and civil engineering products.

	Country	Title and place	Project type	Description of project	Project focus
104	SE	Traceability 4 Circularity	R&D	The overall focus of the project is to elicit knowledge about the requirements for a new digital & physical marking system for product traceability. For this, the plan is to identify existing knowledge gaps, requirements, constraints from stakeholders in the product value chain (i.e., OEMs, suppliers, distributors, recyclers). We will use ROCKWOOL (partner on this project) as a case study to develop an initial understanding of this research question.	Product traceability
105	SE	Preschool "Hoppet" in Gothenburg	R&D	The City of Gothenburg will investigate and build as far as possible the fossil-free preschool Hope. The project is part of creating the conditions for achieving Gothenburg City's goal of a climate-neutral city with a sustainable and equitable level of greenhouse gas emissions in 2050.	The construction of a fossil-free preschool
106	SE	The handbook "Hazardous substances" in a mobile app	Commercial	The goal is that the developed app will facilitate management of hazardous waste in the workplace, and at the same time be perceived as simple and user-friendly.	Identification of hazardous materials prior to demolition
107	SE	Repipe, RISE	R&D	The project will demonstrate how plastic pipes that today go to energy recovery, can instead be collected and material recycled.	Recycling of plastic pipes.
108	SE	Ökad cirkulär användning av planglas, RISE	R&D	The project aims to develop a functioning system model for the collection, recycling and reuse of flat glass in Sweden. Glass from demolitions and window replacements as well as waste from industries and construction should be part of a circular process, instead of being landfilled.	Recycling of flat glass
109	SE	InFutUReWood. RISE	R&D	Technical solutions for recycling wood from existing buildings, how experience in demolition can help to design wooden buildings for circulation, sorting of recycled wood from timber, designing new products of dismantled wood.	How to build today to enable circulation of wooden houses in the future?
110	SE	Increased resource efficient utilisation of secondary raw materials in constructions	R&D	Strategic project from SIP RE:Source, focusing on factors that are potential obstacles (barriers) and enablers for increased resource efficiency for increased recycling or reuse of secondary raw materials. Factors were (but not exclusively) business models, public procurement, logistics, regulations, statistics and standardisation.	Increased recycling and reuse of secondary raw materials in construction and building materials. Outcome was for raw materials in general, with some focus on concrete and energy ashes.
111	SE	Construction of Glöstorpskolan in Göteborg. Peab, ROCKWOOL, Suez	Commercial	Construction waste of mineral insulation (Rockwool) from a construction of a school, are reused instead of ending up as landfill.	Recycling of mineral wool
112	SE	Mould growth on reused timber	R&D	Handling and selection of wood materials intended for recycling - what to keep in mind to avoid mould-damaged material.	Quality of recycled wood

	Country	Title and place	Project type	Description of project	Project focus
113	SE	Office building Epic. Skanska.	Commercial	Recycled materials from old houses and construction waste from own activity are used in a new building. 77 195 recycled PET bottles in sound-dampening cloth, 35 221 meters of window frames and beams from demolition projects in the wood panel, 16 tonnes of concrete from the Copenhagen metro in the floor and 17 tonnes of bricks from Epic's own facade in the floor.	Use of recycled materials in a new building
114	SE	Procurement requirements for circular flows in the construction and demolition process. Göteborgs stad & Vinnova.	R&D	The aim was to increase the knowledge of how public procurement can drive towards a circular construction and demolition process, and to make recommendations and proposals for circular procurement requirements. This was achieved by formulating a future scenario, mapping the current situation and analysing the GAP based on the knowledge and experience of public actors, the construction industry and research. The results were re-formulated in conditions necessary to achieve a circular construction and demolition process and recommendations, addressed to public organisations.	Public procurement
115	SE	Circular material (mineral masses)	Commercial	Asphalt crusher for asphalt manufacture, bearing and reinforcement bearings, fillers, temporary roads. Gravel sand of crushed concrete, which provides good bonding of ground stone and inhibits weed growth. Macadam, shingle and sand in different fractions. Walls, terraces, and other structures in gabion systems. Biocarbon for trees and plantings	Recycling of mineral masses

Annex 2

Selected cases

The presented cases act mainly as examples of different types of cases, aiming to present cases from all studied countries and from all phases of the value chain. Therefore, the cases are not chosen based on performance or superiority, and good examples that are not analysed in this study are not left out because they are considered weaker.

1. FM-Haus Oy

Type of project	Commercial, in practice
Project focus	Modular demountable wooden constructions
Link to strategy	National waste management plan Resource efficiency strategy
Materials/ technologies in focus	Wood Design for disassembly, design for reconstruction and reuse Temporary constructions
Focus on digitalisation	no
Phases of the circular economy covered	Building design Construction phase Operation and use phase
Other topics with relevance for the strategies and methods	Requirements for reuse Business models and business development Climate and CO ₂ LCA/LCC requirements

Description of case

Modular wooden constructions aimed for temporary and/or unknown length of use. Demountable and reconstructable. Includes possibilities for extensions and reductions of size. Fast construction time, modules are built in a factory and assembled on site. The modules can be used both for monoplane and multi-storey buildings.



The aim of the concept is to provide solutions for temporary needs, but also for fast constructions, where the need for a building is urgent. The building solutions are flexible; when there is no longer a need for the building in its current use, it can either be demounted to be raised at another site or reshaped in order to fit current needs. The idea is to reduce the need for demolition and to offer a lean concept for changing needs and thus, also reduce the environmental impacts of construction and demolition activities.

The modules are built indoors in a factory in order to minimise moisture damages during construction and also to maximise efficiency. FM-Haus Oy is both selling and renting constructions, providing both short- and long-term solutions for their customers. The regular modules can be demounted, transported and rebuilt up to five times. If there is a need for more reconstruction times, the modules would be strengthened to assure endurance.

Design for deconstruction or disassembly enables reuse of building parts without damaging others and without a loss of quality or value. Modular or demountable solutions support the circular economy goals for resource efficiency (reductions in environmental impacts, e.g. carbon footprint by resource savings) and also reduce the amount of C&DW generated.

Lessons learned

FM-Haus has created a concept, which is quite well-suited for the current regulations in Finland. Main issues hindering their business is not specific for modular

construction, but related to planning in general (building permits etc.). Specific issues related to the modular constructions, which are built at their factory, is the road transport; there are maximum height (7 m) and width (7 m) restrictions, as well as weight restrictions for the Finnish roads. Furthermore, natural obstacles, such as underpasses, may further complicate the transport. Still, the road transport does not inflict major increase in cost for the modular constructions. In fact, savings from material efficient indoor construction at the factory well compensates for the transport costs.

Related to the concept with demountable constructions, although they may be aimed for permanent purposes, the business for permanent constructions do suffer from the fact that the buildings are demountable. When planning to build schools and other services, local decision-makers prompt for choosing permanent solutions in order to guarantee future availability of services.

FM-Haus also rents the modules, leading to some issues regarding the maintenance of the constructions, since they must be fit for reuse after the lease expires. FM-Haus monitors the conditions in the constructions (moisture and temperature) via an interconnected sensor system.

Related to reconstruction of the buildings, the VAT is due upon finishing a new construction. There are no definitions of policy regarding reconstructed buildings – whether they are taxed as new buildings or not. Another issue is whether the reconstructed building must follow current construction regulations or the regulations of the time of construction. FM-Haus has a good connection to the Ministry of Environment (MoE) and they are responding positively to solving the legislative issues coming up for the concept of reconstructable modular constructions. This is a new topic for the MoE as well, and solutions are found in good collaboration with the actors in the market.

Country: Finland

Reference: <https://fm-haus.fi/>

2. Blixens – OPS Gellerup

Type of project	Construction of an office building, commercial
Project focus	Sustainability, reuse, recycling
Link to strategy	The project itself is not directly linked to any strategy, but the municipality has a strategic focus on facilitation of green transition and sustainability in building projects. However, the project received focus on sustainability because of Aarhus Municipality's requirements and recommendations "Miljø- og energirigtigt byggeri Aarhus kommune" (Environmental and energy efficient construction of buildings in Aarhus municipality).
Materials/ technologies in focus	Environmental sustainability is a pervasive theme in the building's design, both in the form of water collection for toilet flushing and garden irrigation as well as recycling of materials in tile facades, wooden floors and wall cladding, furniture, etc. In addition, the building energy optimised to use as little energy as possible by passive measures as well as solar cells and solar collectors.
Focus on digitalisation	None
Phases of the circular economy covered	Building design Construction phase Operation and use phase Waste management, recycling and end of life phase
Other topics with relevance for the strategies and methods	

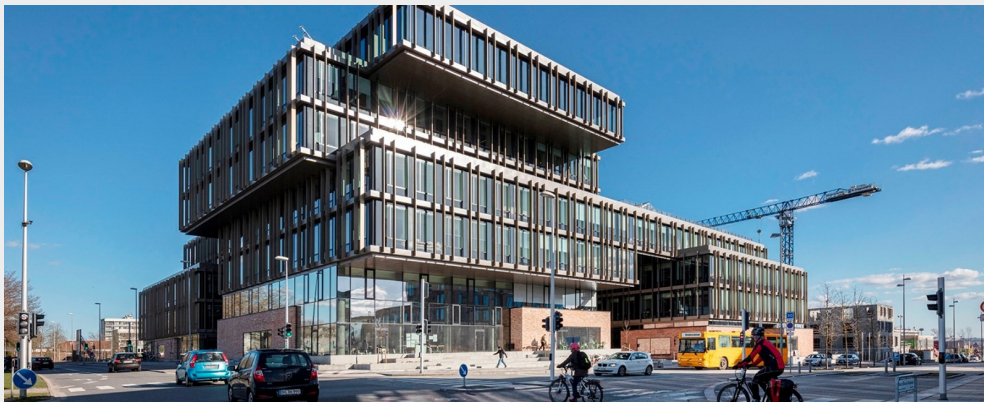
Description of case

In Aarhus municipality *Gellerupplanen* is changing. The goal is to create an area that among other things offers better infrastructure as well as greater connection with the rest of Aarhus. One of the newer buildings is *OPS Gellerup*, also called *Blixens*, which is a workplace for 950 employees from Aarhus Municipality. Aarhus municipality is the owner of the 23 000 m² building and sustainability has been an objective and focus in the project. The building was constructed 2016-2018.

Since 2013, Aarhus municipality has worked with sustainability in construction projects, supported by Aarhus Municipality's requirements and recommendations "Miljø- og energirigtigt byggeri Aarhus kommune" (Environmental and energy efficient construction of buildings in Aarhus municipality). Although circular economy was a fairly new term when the project was put out to tender and was not, as such, mentioned directly in the tender material, a sustainability framework was included in the tender document – as a result of the municipality's sustainability requirements

and recommendations – and the bidders competed for maximum sustainability at a fixed price. The project was tendered as a PPP [Public Private Partnership] project, where the winning team is responsible for both the construction of the buildings and the operation for the next 15 years. The goal was an integrated project, where the client and the winning team could collaborate on aesthetics, technology, construction, execution, operation, and total economy.

In collaboration with the winning team, opportunities were actively sought to use recycled materials in construction. Environmental sustainability is a pervasive theme in the building's design, both in the form of water collection for toilet flushing and garden irrigation as well as recycling of materials in tile facades, wooden floors and wall cladding, furniture, etc. In addition, the building energy optimised to use as little energy as possible by passive measures as well as solar cells and solar collectors.



Blixens, Gellerup, Århus (<https://arkitema.com/da/arkitektur/erhverv/blixens>)

Lessons learned

Aarhus Municipality's requirements and recommendations "Environmental and energy efficient construction of buildings in Aarhus municipality" apply to all municipal construction projects, including new construction as well as major and minor renovation projects. Although requirements and recommendations do not include the concept of "circular economy", recycling of materials - and thus in effect circular economy - is a common thread in the publication, which *makes it a valuable driver for circular construction projects* in Aarhus municipality. The requirements regarding choice of material, unwanted substances etc. can be found in the publication². The publication is easily accessible and can thus easily be used by other stakeholders as a source of inspiration in the development of their own guidelines.

Although the requirements and recommendations ensured a focus on sustainability

in the project, they could not solve some of the more practical challenges, such as finding the right materials that could live up to the Municipality's requirements and expectations. Project manager Bente Damsgaard Sejersen points out, that a choice of solution and materials often implies prioritisation – for a number of solutions with recycled materials cheaper solutions with virgin materials were available, however, the recycled materials have in return added value in the form of aesthetics, good working environment etc.

Country: Denmark

Reference:

¹ Interview with Bente Damsgaard Sejersen, Århus Kommune, 29 May 2020

² "Miljø- og energirigtigt byggeri i Aarhus Kommune", <https://www.aarhus.dk/media/22741/miljoe-og-energirigtig-byggeri-i-aarhus-kommune.pdf>

³ "Bygherrens rolle i den cirkulære økonomi", Cirkulær ressource økonomi i dansk byggeri, Teknologisk Institut 2019, https://www.teknologisk.dk/_/media/73328_Bygherrens%20rolle%20i%20den%20cirkul%C3%A6re%20%F8konomi_interaktiv.pdf

⁴ "Cirkulær økonomi i byggeri, hvad, hvorfor og hvordan", go green with Aarhus, <https://www.aarhus.dk/media/22742/cirkulaer-oekonomi-2019.pdf>

3. Netlet Oy

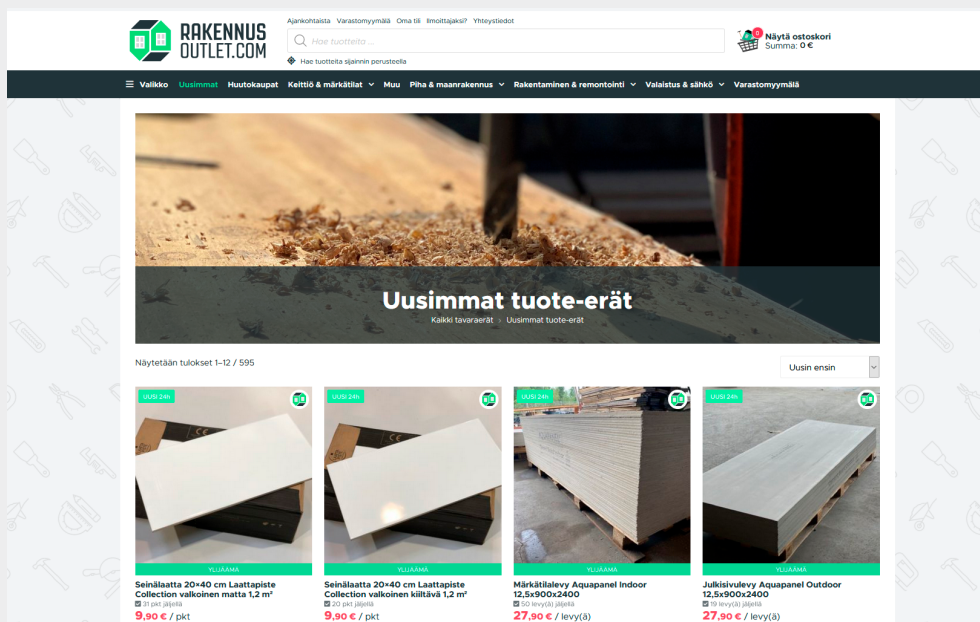
Type of project	Commercial, in practice
Project focus	Collection of surplus materials and products from construction sites, resell to customers
Link to strategy	National waste management plan Resource efficiency strategy Ramate programme
Materials/ technologies in focus	-
Focus on digitalisation	Digitalisation is used for marketing products and for web shop
Phases of the circular economy covered	Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	Requirements for reuse Business models and business development Use of digitalisation Climate and CO ₂ LCA/LCC requirements Resource mapping

Description of case

Netlet Oy is a company collecting surplus materials from construction sites for resale. Partners are the largest property developers and construction firms in Finland. Netlet only collects surplus from companies and not from private persons. This is to guarantee the products are legal, and to assure the volumes are kept at a cost-efficient level. The construction firms gain from a reduction in waste management costs, while contributing to a reduction of waste generation and environmental impacts.

Netlet Oy has a service called Raksanouto (meaning construction site pickup), which collects surplus construction products and materials from construction sites. For large construction firms and at large construction sites, it is not feasible to sell the surplus and therefore, commonly end up as waste although it may be valuable products and materials in question. Via Raksanouto, the materials and products are collected and placed for sale in Netlets shop. The shop, Rakennusoutlet.com (meaning construction outlet) has a varying selection of goods, all collected via Raksanouto.

The products sold at the outlet store do not have a manufacturers' guarantee, since it is impossible to validate proper treatment of the products at the construction site.



Lessons learned

The official status of surplus materials and products is products and not waste – Netlet is not required to have an environmental permit for waste management and the products are not covered by waste legislation. However, due to the lack of waste status, the materials, which previously have undergone recycling are not calculated as recycling, which has led to a reduction of the recycling rates of the construction companies, putting them in a poor light in the evaluation of environmental performance. Although this is seen as a bureaucratic problem for the construction companies, they are still very positive towards the business of Netlet and are happy to have a good solution for the leftovers.

The green procurement requirements of local resource efficiency strategies are serving Netlet quite well. Most cities have requirements not only on the waste treatment, but now also on the treatment of surplus materials and products, now that Netlet has made this requirement possible.

Indicators for waste prevention; an official status of the surplus materials and products, and the possibility for the constructors to get a benefit from reducing waste generation (in comparison to the recycling rate for proper treatment) would be of benefit for this type of business.

The initiative has a good replicability potential.

Country: Finland

Reference: <https://www.netlet.fi/>

4. ConZerW

Type of project	Development of digital tools for reducing waste at the construction site.
Project focus	Digitalisation tools
Link to strategy	National waste management plan Resource efficiency strategy
Materials/ technologies in focus	Digital process tools
Focus on digitalisation	Material tracing
Phases of the circular economy covered	Waste management, building design and construction phase
Other topics with relevance for the strategies and methods	

Description of case

The main objective of ConZerW is to achieve waste-free construction sites by developing digital process tools, which enables to track the source of waste from construction activities, implement potential optimisation measures and evaluation methods, that support collaboration between partners in planning, procurement and logistics activities related to the construction site.

The project will address three objectives:

1. What do the ambitions of a waste-free construction site for the players entail, and what new solutions and working methods can realise it?
2. How can optimisation systems that reduce waste by tracking the flow of resources and efficient exchange of information in the value chain, be developed?
3. How can one calculate and evaluate whether waste-free solutions contribute to real waste reduction, increased profitability, and emission reductions in the value chain?

In addition, the project will demonstrate a full-scale solution in a pilot project and communicate results to builders, contractors, suppliers, politicians and the media.

Lessons learned

The project is under execution.

Country: Norway

Reference: <https://www.sintef.no/projectweb/conzerw/>

5. Byggeri København

Type of project	Construction projects for the City of Copenhagen
Project focus	CO ₂ -savings, resource savings, LCA/LCC
Link to strategy	City of Copenhagen's strategies, including the Financial Administration's and Byggeri København's overall strategies and Byggeri København's Strategy for sustainability, "Miljø i Byggeri og Anlæg 2016", "Circular Copenhagen. Resource and waste management plan 2024" and the Danish Governments strategy for circular economy
Materials/ technologies in focus	Not linked to any particular material or technology but different means to implement circular economy in construction projects
Focus on digitalisation	None
Phases of the circular economy covered	Construction phase Operation and use phase Selective demolition and on site sorting Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	Logistics End of Waste legislation Procurement Climate and CO ₂ LCA/LCC requirements Resource mapping

Lessons learned

The Danish Government's Strategy for the Circular Economy of 1 September 2018⁵ includes a number of initiatives aimed at supporting the recycling and reuse of building materials. These include promoting circular procurement, increasing the focus on total economy in public procurement, introducing a voluntary sustainability class and selective demolition. The above initiatives are not very specific in nature. However, born of the ambitions in the Danish Government's Strategy for Circular Economy, there has been a political desire for *Byggeri København*, as a major developer for Copenhagen, to follow suit with the state, and to look into possibilities for setting requirements for recycling of building materials in tender documents ^{6, 7}.

It was politically decided^{6, 7} by the city of Copenhagen that from 2020, *Byggeri København* shall address and work with circular economy in all construction projects. This focus is not only limited to criteria and requirements for circular economy (e.g. reuse and recycling of building material) in tender documents, but will also be implemented in projects for *Byggeri København* that are carried out via strategic partnerships, where no project-specific tenders are made.

Even though the City of Copenhagen has worked ambitiously with sustainability in construction and civil engineering for several years, the strategy for circular economy and the political focus on circular economy have given even more momentum to this work.

Although *Byggeri København* prioritises its work with the circular economy on a number of municipality strategies and own strategies (please see above), there is a need to support this work in practice for the individual projects and project managers responsible. There is also a need to structure the work with prioritisation of the circular economy, since there are a number of different ways to address circular economy in construction projects (e.g. reuse of materials contra design of disassembly). By developing tools, such as a handbook for the circular economy⁴ those responsible for specific construction projects are guided and aided in their daily work with circular economy.

Country: Denmark

Reference:

¹ <https://byk.kk.dk/>

² https://www.kk.dk/sites/default/files/sustainability_in_construction_and_civil_works_2016.pdf

³ <https://byk.kk.dk/artikel/koebenhavns-kommune-inviterer-byggebranchen-til-dialogmoede-om-cirkulaer-oekonomi-i-kommende>

⁴ "Byggeri Københavns håndbog i cirkulær økonomi", version 2, 3. september 2020; contact Jens Runge, Byggeri København for more information.

⁵ Strategi for cirkulær økonomi (em.dk)

⁶ <https://byk.kk.dk/artikel/koebenhavns-kommune-inviterer-byggebranchen-til-dialogmoede-om-cirkulaer-oekonomi-i-kommende>

⁷ <https://www.kk.dk/indhold/borgerrepraesentationens-modemateriale/19092019/edoc-agenda/b2166db7-a0fc-45da-a6db-fb2a77ba81c3/b1776bd0-59cf-43d1-b4e2-84fa96b654d2>

6. Drone for material inventories

Type of project	Technological development, in demonstration for demolition site
Project focus	Tool for resource mapping and planning
Link to strategy	Guidance published by the Finnish EPA for use of pre-demolition audit for mapping of resources in demolition work Funding from EU for development of new innovative technologies in the circular economy solution in C&DW recycling
Materials/ technologies in focus	Drone technology, photogrammetry, 3D imaging
Focus on digitalisation	3D imaging
Phases of the circular economy covered	Construction phase Selective demolition and on site sorting Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	Logistics Standardisation Use of digitalisation Resource mapping

Description of case

Drone technology is typically used for performing fast aerial surveys across wide, or hard-to-reach areas. It is also a capable tool for producing reliable maps and three-dimensional data with unparalleled resolution and accuracy of the target. A method of drone-based 3D imaging has not previously been used for mapping of constructions to be demolished, or to monitor work in progress at a demolition site on a wider scale. However, the method has recently been taken into use in the construction industry to monitor construction and site conditions of new-born buildings. Drone-based 3D imaging is also used e.g. in the mining industry for mapping and quantifying volumes of pits and heaps. 3D imaging is based on photogrammetry when only a normal camera is needed as a sensor on a drone.



Photo: Aki Mykkänen

The drone-based 3D imaging technology is currently under testing in the EU Horizon 2020 CityLoops project. Buildings will be demolished and drone-based 3D-imaging of the demolition sites will be carried out constantly during the demolition process. Before the actual demolition phase, demolition sites were mapped and 3D-modelled using the same method.

Lessons learned

A drone is a cost-efficient tool to quickly assess available materials (steel, concrete, wood) and components (e.g. windows) in a construction to be demolished. Especially information about materials or conditions in not easily-accessible construction parts, can be collected. It can also be used to plan and monitor renovation work (waste to be generated, material needs, work progress, accessibility). Drone technique is especially useful in cases, where no BIM information is available from a construction as it can be used to provide estimations on amounts of different materials (steel, concrete, wood) in a pre-demolition audit needed for planning the waste management.

During and after the demolition, information on available spaces for sorting and storage of different materials can be available from drone tests. Calculation of heaps (e.g. crushed concrete, soils) can be carried out with high accuracy by using 3D

imaging calculations.

If drones are equipped with different kinds of special sensors (e.g. multispectral or hyperspectral cameras or laser scanners), it is possible to identify different materials and their quality (e.g. degradation, moisture content) and for reusable components also information on connections. However, this has not been used on a wider scale yet, due to e.g. less cost-efficient operations.

In future, this technology can provide a standard tool for planning work, quality controls and material tracing in demolition sites. The same method can be used throughout the redeveloping process of some area as well.

Limitations: Weather conditions may disturb the quality of pictures or prevent flight operations. Bad imaging leads to less reliable information, or may prevent achieving the necessary results. There are also regulations and legislation that limit drone operations.

Skill of operator: Drone pilot must have experience to handle the equipment and knowledge of regulations and aviation legislation concerning drone flying. There is also an ongoing legislation process, which will add mandatory training for drone pilots.

Typical time needed for a drone flight at a demolition site: < 1 hour plus 3–8 hours for software-based 3D modelling and reporting.

Costs: drone with normal camera < EUR 2 000, advanced systems with special sensors >EUR 10 000, software for data handling e.g. >EUR 200 per month or > EUR 5 000 as one-time payment.

Country: Finland

Reference: <https://cordis.europa.eu/project/id/821033>

7. Kompanjonen

Type of project	The business idea of the commercial actor Kompanjonen is to facilitate for companies in the Swedish construction and real estate sector to buy, sell, and handle building products for reuse.
Project focus	Reuse of building products (mainly interiors)
Link to strategy	The business idea is based on the sustainable development goal 12.5 "By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse".
Materials/ technologies in focus	The building materials in focus are inner doors, inner walls (glass panels), lighting, entrance sections, acoustic panels and ceilings etc.
Focus on digitalisation	When performing reuse inventories, Kompanjonen goes through building products and document the building products having the potential of being reused. Each building product is photographed, measured, and the quality is evaluated as well as quantified (in terms of numbers). The results are included in a reuse report for the customer. The documentation of building materials takes place in a digitalised inventory tool (app), after which the products can be uploaded for sale at a digitalised marketplace. Together with other commercial and research actors, a nationwide marketplace has been developed for buyers and sellers of reusable building materials to meet and exchange products and services. Also, the marketplace developed can be used as a real estate owner's own inventory management system of products.
Phases of the circular economy covered	Selective demolition and on site sorting Construction phase (renovation) Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	Logistics Standardisation (how reusable products are described at the digital marketplace) Use of digitalisation Resource mapping

Description of case

The services Kompanjonen offers are:

- performing reuse inventories and thereby, identifying building products possible and with a potential for reuse
- providing advice and expertise regarding reuse
- purchase and selling of building products for reuse



Photo: Kompanjonen.

Lessons learned

Kompanjonen has together with several commercial actors throughout the value chain, as well as research actors, participated in the project "Circular product flows in construction sector - recycling of building materials on an industrial scale", a project led by IVL Environmental Research Institute. Lessons learned are based on the reports published in the project, see <https://ccbuild.se/rapporter/> for more information.

The financial, social and organisational barriers were found to be more difficult to overcome compared to technical barriers. In a survey answered by actors throughout the value chain, the following significant challenges were identified:

- there are substantial restrictions throughout the renovation process as there is a lack of knowledge and information related to the reuse of construction products. For example, increased knowledge is needed about how the economic benefit of reuse is calculated from the perspective of the real estate owner as well as the tenant.
- the market for reused material is hampered, due to a general perception that there are limited financial incentives for reuse and that the dismantling for reuse of interiors takes longer compared to conventional demolition
- the potential of reuse is reduced due to habitual behaviour, which is working according to existing procedures
- the linear and established business models do not benefit, and are not adapted for an increased reuse
- reuse requires a longer lead time as well as new ways of working, which take

time and effort to learn and implement. This barrier also includes often overlooking the fact that the reuse aspects must be considered early in the renovation process.

- there are limited numbers of storage facilities and there are challenges in the logistics planning
- there are few actors, such as specific reuse actors but also architects working in the field with reusable building products
- limited supply of reusable building products of known quality
- lack of available information about the contents of the products and the traceability of this information over time. Because, for example, regulations on hazardous substances according to EU legislation REACH (EC / 1907/2006) is continuously updated, there is no guarantee that a product approved and certified today will meet the requirements at the time the product is subject to reuse.

The following solutions were identified to overcome the above challenges:

- development of building legislation to promote reuse, such as the requirement for using a minimum amount of reused building products in new constructions and mandatory reuse inventories before demolition. This solution also includes requirements for municipalities and state-owned companies to work with and consider the reuse aspects to a greater extent, such as setting reuse targets, considering reuse in public procurements as well as introducing reuse aspects in ownership directives etc.
- introduction of policy instruments, such as sanctions or fees as well as subsidies to promote reuse
- the development and introduction of a national strategy for circular economy in Sweden
- consider the reuse aspect to a greater extent in certification systems, such as LEED and BREEAM etc. for buildings and city districts.
- development of a national marketplace for reusable products to promote reuse on a large, industrial scale. This marketplace is in place today but, will be further developed
- test circular business models and encourage companies taking this initiative
- dissemination of results and useful examples from completed projects.
- well documented product information, such as name of manufacturer and product name, date of manufacture and date of purchase, the material and chemical content of the product, characteristics such as strength, fire class and acoustic qualities, technical drawings, maintenance instructions, information on possible eco-labelling as well as info on guarantees.

Country: Sweden

Reference: <https://www.kompanjonen.se/>

8. Loopfront

Type of project	Development of digital tools for registering obsolete building materials, and development of database for sales of reusable construction products.
Project focus	Digitalisation tools, database tools
Link to strategy	National waste management plan Resource efficiency strategy
Materials/ technologies in focus	All reusable building materials
Focus on digitalisation	Material tracing
Phases of the circular economy covered	Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	

Description of case

Loopfront is a multi-sector collaboration platform made to empower building owners and the construction industry – removing barriers for reuse of building materials and furniture. In Loopfront, users can register materials and inventory in existing buildings, or those planned for demolition. Technical information (such as CE, EPDs, BIM files and manufacturers' information) is easily gathered in one place – always accessible from all devices. Collaboration and planning functions accommodate logistics, such as demounting, transportation and storage. And with the Market function you can reserve materials for reuse – or make them available to other organisations. All circular activities are tracked, making reports on waste, emissions, and financial savings available at all times. Loopfront provides new solutions for circular activities – making reuse easy and profitable. (Formerly called Greenstock).

<https://youtu.be/FvXkdfVs6Q4>

Lessons learned

The platform is currently under construction. Asker municipality has saved millions in using this system for reuse of furniture when merging three municipalities into one.

Country: Norway

Reference: <https://www.loopfront.com>

9. Vuorenranta home for the elderly - reusable interior products

Type of project	New business model for reuse of interiors from building, in practice
Project focus	Reuse, interiors, new business models
Link to strategy	CE roadmap for Hämeenlinna city, part of Kanta-Häme
Materials/ technologies in focus	Business model
Phases of the circular economy covered	Construction phase Selective demolition and on site sorting Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	Requirements for reuse Logistics Business models and business development Use of digitalisation Climate and CO ₂ Resource mapping

Description of case

A new business model was tested to direct dismantlable interior products collected for reuse from a home for the elderly called "Vuorenrannan vanhainkoti" that was set for demolition in 2019. Prior to demolition, the mapping of reusable interior products and material was carried out by a professional team working at the recycling centre, run by the Luotsi Foundation. The Luotsi Foundation is a non-profit organisation working towards a better community with the mission to provide training, support, education and employment programmes for unemployed people.

The focus was only on reusable products and material (interiors, stone facades, windows, kitchen equipment, garden stones etc.) that have a second use value. The identified objects were dismantled or disassembled by a professional team and the transport, product sorting, marketing and management at the recycling centre, were carried out by the trainees of the Luotsi Foundation.



Vuorenranta Vanhainkoti to be dismantled – pavement has already been dismantled.

The recovered products and materials were marketed through several channels (Facebook, direct contacts to potential people interested in the recovered materials) and sold at the recycling centre. The products were subjected to VAT.

The project results were encouraging, the selected products and materials were of high interest to buyers (not only due to lower price, but also due to historical value, the "old" appearance). As part of the HYPPY project also the attitudes for reusable products have been assessed based on a questionnaire for citizens by a "sister project" carried out by SYKLI.

Lessons learned

The project has shown savings in demolitions, but most important is to provide good examples for reuse. Many of the products had a historical value (design from the 40's, hand-made windows) or were high-quality products equal to new products (e.g. kitchen equipment).

The aim is also to change the image of second-hand products. Experience from the HYPPY project has been presented in seminars and local newspapers.

The survey done in connection to the project revealed the following 3 factors mostly hindering the reuse:

1. lack of demand, market, low prices of new products/virgin materials, more time needed for planning, need for storage
2. lack of procedures for quality assessment
3. imago that new products are better, difficulties to learn new habits. Small construction companies are more interested in reusable products, but big construction companies only use new products or virgin materials.

Digital marketplaces covering the whole country to be used in marketing

In this case, the work was done as an activity of an employment programme and thus, the costs for salaries were not directly linked to the business case. However, in the Nordics, these type of programmes, which receive funding for their activities are commonly involved in the CE sector, often with small niche activities, such as handcrafted items made out of recovered scrap etc. Policy framing could steer these types of activities towards having a greater impact on the environment and CE activities.

Country: Finland

Reference: <https://www.luotsisaatio.fi/>

10. Solutions for wood waste – GENTRÆ, Næste, TrÆls

Type of project	Commercial
Project focus	Combination of four solutions that focus on handling of wood waste
Link to strategy	UN's sustainable development goals and circular economy in Hedensted municipality, The Danish Governments strategy for circular economy
Materials/ technologies in focus	Interim timber from construction sites; wood waste from renovation and demolition projects (as well as roofing tiles); residual/surplus wood/pallets, wood waste Reuse and recycling through four different solutions and business cases
Focus on digitalisation	Partly – GENTRÆ-App
Phases of the circular economy covered	Selective demolition and on-site sorting Waste management, recycling, and end-of-life phase
Other topics with relevance for the strategies and methods	Logistics Business models and business development Use of digitalisation (partly) Resource mapping (partly)

Description of case

GENTRÆ¹ is a circular and sustainable solution for reuse of wood from temporary constructions. Interim timber is collected at construction sites, and once it is picked up the wood is checked, adjusted and packed for resale in the construction market.

Næste² is a start-up company that designs and builds tailor-made solutions for sheds, covering design, obtaining a building permit, construction, and delivery as well as subsequent service inspections. The *Næste*-shed is built from reused materials – high-quality waste wood and roofing tiles from renovation and demolition projects are reused and given new life in a tailor-made solution.

GENTRÆ and Næste are two of the three winners of the innovation challenge "Circular Construction Challenge – Rethink waste", in 2018 and 2019 with funding from *Realdania*^{5, 6}. *Realdania* is a philanthropic association focusing on solving challenges in Danish society in cooperation with the government, the municipalities, foundations, associations, private businesses, and local, voluntary enthusiasts. The industry's focus on circular economy is, of course, also a focus that is shared by *Realdania*, and the purpose of the call was therefore, to find businesses and innovators that wanted to bring their solutions for reuse, recycling, and upcycling of waste to the market. The winning teams received substantial support in bringing their ideas to the market – funding to support prototype development, and a

mentored innovation process. Since the implementation of innovative and new solutions in practice very often requires more than just one company, there was a special focus on finding teams/consortia, that could bring the new ideas to the market.

TrÆls³ is a small company, which builds furniture and other products from old wooden pallets and surplus wood. The furniture is sold or rented out to e.g. festivals and the like. For TrÆls, traceability is essential, so that they can ensure that there are no unwanted chemicals in the wood they receive. That is why very close co-operation with their suppliers is very important to them. This also helps to ensure that materials can be obtained in the amounts and qualities needed, and they can avoid not being able to deliver due to lack of materials.

TrÆls is one of several start-up companies at Compas⁴ – an initiative of Hedensted municipality. The purpose of the initiative is to realise the municipal strategies – which is to highlight the municipality as a pioneer municipality within circular economy. It also represents a valuable and ambitious contribution to the realisation of the UN's sustainability development goals⁷. Compass shall attract start-ups who want to work with circular economy to Hedensted municipality to create new companies, products and jobs in the municipality. Requirements to become a start-up at Compas, are to work with the circular economy, have a growth mindset, and be production-oriented. Compass assists start-ups and companies to develop projects, products and services with a sustainable and circular idea.



Solutions for wood waste – GENTRÆ, Næste, TrÆls

Lessons learned

Wood is a building material that comes in many different qualities and sizes and is used in a number of applications. Where and how the materials have been used, whether they are free of pollutants, whether they can be sorted efficiently, etc. are of great importance for their potential for reuse and recycling. Finding the right material to focus on when developing a product or service, a material that can be traced and documented is therefore, an important step. Yet, it is only the beginning.

The problem comes when one wants to go from the design idea to the final product, or from the business idea to the commercial solution. Where does one go to make a

prototype? Where are the production facilities that one can use? Where does one get the materials from? Who to cooperate with? How to get funding for all of this?

Funding programmes and initiatives that promote new business start-ups and other entrepreneur initiatives, are an important element in bringing ideas to the market. So, while strategies greatly help to raise awareness of a topic, they typically only contain intentions and recommendations. They need to be followed up by concrete initiatives that ensure implementation in practice.

Country: Denmark

Reference:

¹GENTRÆ - Løsning til genbrug af træ fra midlertidige konstruktioner (stark.dk)

²<https://www.naeste.dk/>

³<https://traels.nu/>

⁴<http://compashedensted.dk/startups/>

⁵<https://realdania.dk/nyheder/2019/02/vindere-circular-construction-challenge>

⁶<https://challenges.dk/da/challenge/circularconstructionchallenge>

⁷https://www.hedensted.dk/hedensted_data/dagsorden/Udvalget_for_Politis/09-09-2019/ID2637/Bilag/Punkt_160_Bilag_2_Compas_pixi_juli_2019pdf.pdf

11. Enhanced waste collection for increased recycling of plaster boards

Type of project	R&D (ongoing)
Project focus	Recycling of plaster boards
Link to strategy	The national waste management plan and the waste prevention plan
Materials/ technologies in focus	The material focus is on plaster board materials used in building construction
Focus on digitalisation	The project does not contain any part on digitalisation
Phases of the circular economy covered	Material production Construction phase Selective demolition and on site sorting Waste management, recycling and end of life phase
Other topics with relevance for the strategies and methods	Logistics Business models and business development

Description of case

Plasterboard is a common building material. Therefore, much waste is generated from this material during construction, demolition and refurbishment. It is possible to use recycled gypsum boards as secondary raw materials in new plasterboards, and manufacturers want to increase the amount of recycled raw material in their products. Also, plasterboards are often sorted in a separate waste fraction at construction and demolition sites. Nevertheless, only a small proportion of the gypsum waste is recycled into new plasterboards.

In Sweden, producer of gypsum board receives secondary raw material. The transport distances to this plant are often quite long from the collecting sites of the building and demolition waste, which leads to high costs in the logistics chain. Also, the individual volumes of collected waste in different parts of the value chain are often small. In the project, a solution of regional collecting sites is tested and evaluated to increase the volume of waste and coordinate the transport.

The waste must be sorted into a fraction that is clean enough to meet the quality demands of the producer of the secondary raw material. However, some contamination of the material, such as wallpapers on the demolition waste, are accepted. In the project, sorting instructions are developed, tested and evaluated.

Today the waste fraction is often sold as soil improver instead of being used in new gypsum boards. The project includes a part, where it is investigated if this process can be motivated on Swedish soils.

The project is a study in collaboration with RISE Research Institute of Sweden and commercial companies throughout the value chain, including material producer,

building materials distributors, construction companies, recycling companies, and a company that processes the waste into a secondary raw material. The project has received support within the strategic innovation program RE: Source, which is funded by Vinnova, the Swedish Energy Agency and Formas.



Photo: Bok, G., Brander, L., & Johansson, P. (2018). New possibilities for reducing deposited gypsum waste from building and refurbishment projects. (RISE Rapport 2018:10). Retrieved from <http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-36323>.

Lessons learned

The project is ongoing, and therefore no final evaluation has been made yet. The conditions for recycling are good. However, it can be difficult to achieve economic profitability throughout the value chain, as the secondary raw-material economic value is low.

Country: Sweden

Reference: No webpage available

12. Increased circular use of flat glass

Type of project	R&D project
Project focus	Recycling and reuse of flat glass
Link to strategy	No
Materials/ technologies in focus	Flat glass
Focus on digitalisation	No part of the project is related to digitalisation.
Phases of the circular economy covered	Raw materials extraction Material production Selective demolition and on-site sorting Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	Logistics End-of-waste legislation Business models and business development Climate and CO ₂

Description of case

Glass is a material well suited for recycling. There is no (or minimum) degradation of the material in a recycling loop.

There are different types of glass, primarily divided into packaging glass, art glass, insulation and flat glass. Approximately 98 % of all packaging glass sold in Sweden is recycled. This gives a false image to the public that glass is taken care of. However flat glass is a bigger bulk of material and this is only being recycled in very small quantities.

This project aims at creating a system for flat glass recycling in Sweden. In demolitions and refittings, glass is primarily put to landfills. This is due to several reasons: there is no demand from glass producers for recycled glass, there is low interest in the construction and demolition sector of a more circular handling of glass, there is no system in place for recycling, there is no technique for separating glass from framings and there are no instructions describing which glasses are okay to sort and which glasses need to be separated.

The goal is to either find a self-sustaining system, or recommend a legislation to create a producer responsible system paying for the collection and recycling of the glass, similar to the one for packaging glass. The project will also propose techniques for sorting the glass and possible logistics solutions. Alternative solutions for the reuse of glass without altering the glass and breaking the recyclability will also be investigated.

Lessons learned

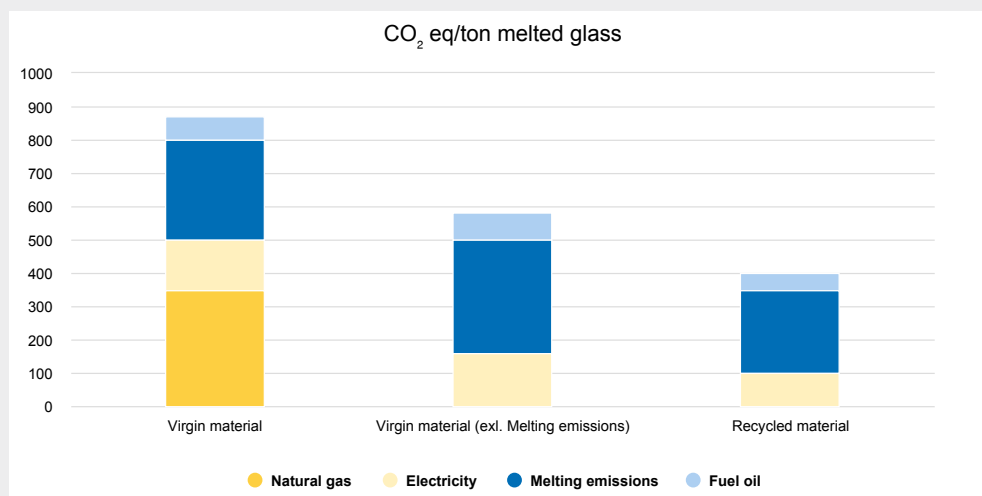
The biggest issue is the pricing of glass. The sand used as raw material when producing flat glass, as well as the produced glass are very cheap. This gives a small price range for extra handling, such as separating the glass from the frames, granulating and washing, and logistics.

The cost for putting material to landfill in Sweden is approximately EUR 100 /tonne, and a glass producer can pay up to EUR 60 /tonne, depending on the quality of the glass. This is the margin for the extra sorting and transporting of materials. The Swedish government is at the moment reviewing legislation demanding the sorting of glass (alongside other materials), which will ease the transition to a circular system.

The production of glass is very energy consuming, and recycled glass can decrease the greenhouse emissions substantially. 1 tonne of recycled glass decreases the amount of CO₂ e with 300 kg in direct emissions. Recycled glass also needs 30% less energy than virgin materials in production. Furthermore, if the amount of recycled glass becomes the main source of material in production, the temperature of melting can be decreased for even more energy savings.

To melt 1 tonne of virgin materials in a float production (standard for flat glass production) 2 000 kWh is needed, which can be decreased to 1 400 kWh with recycled glass.

There is no production of flat glass in Sweden. The closest production sites are in Germany and Poland. This will create a long way to transport the glass cullet, but the emissions of a truck driving from Stockholm to Poland, Germany or even France is lower than the savings in emissions when producing flat glass from secondary raw materials. This is without taking into account the mining and transporting of virgin materials.



Mix according to NSG integrated report 2019, CO₂eq-emissions according to Swedish Environmental Protection Agency report 2018-09-04 Vägledning i klimatklivet

In the project the easiest technique for separating glass from the framing is to collect it with minimum damage in containers, then transport them to a recycling facility, where the glass can be separated, crushed and packed for shipping to a glass producer. The separating and crushing are preferably done by an excavator with a claw attached, on a brushed concrete or asphalt area, to minimise risk of injuries to personnel and contamination of the glass from infusible (such as stone, ceramics) materials and optimising lead-time.

The glass needs to be free of metals and infusible materials, as they can harm the production of glass and cause great loss of production, and in the worst case stop the production.

Calculations done indicate that 15 000 tonnes of glass is dismantled in Sweden every year, according to Linskog, Tyréns, Översiktlig nulägesanalys av avfallsflödena inom glasbranschen, 2010. If the glass were recycled instead, it could decrease CO₂ eq emissions with 9 700 tonnes CO₂ eq/year. It is now mandatory to separate glass when demolishing a building. The glass only needs to be separated from fittings, kept clean and not contaminated with metals or infusible materials to be ready for re-melting at the nearest float glass plant. The first step is initiated where Ragn-Sells collects glass to send for re-melting as a pilot.

Country: Sweden

Reference: <https://www.ri.se/sv/vad-vi-gor/projekt/okad-cirkular-anvandning-av-planglas>

13. EoW for reclaimed concrete

Type of project	Development of legislation
Project focus	Removal of legislative barriers
Link to strategy	National waste management plan Resource efficiency strategy
Materials/ technologies in focus	Reclaimed concrete
Focus on digitalisation	Material tracing
Phases of the circular economy covered	Selective demolition and on-site sorting Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	End of Waste legislation

Description of case

One action mentioned in the Finnish Waste Management Plan, is to investigate under which conditions certain construction waste can achieve an EoW status. Some activities for a case EoW decision on reclaimed concrete was earlier started by a Finnish company, but the preparation of a case decision was "frozen" as procedures for authorities, as well stakeholders for a case EoW decisions and the guidance for needed background documents (especially quality criteria for proving no adverse environmental impacts) were lacking. In 2018, the Finnish EPA gave the Finnish Environment Institute the task to prepare the background documents for a national legislative EoW status for reclaimed concrete, as the need for national EoW for reclaimed concrete had arisen.

The Waste Framework Directive provides that, where no EoW criteria have been set at EU level, "Member States may decide case by case whether certain waste has ceased to be waste taking into account the applicable case law". EoW can be achieved through a national decision for a specific waste stream or as case EoW decision through a waste permit (conditions limited to case conditions, e.g. certain waste suppliers). One of the benefits of a national EoW approach is that national differences can be considered. However, it is important to note that when waste reaches the national end of waste status, it only ceases to be waste in that Member State. The waste is still to be considered waste in other member states, and the regulation on shipments of waste is still applicable to it. If waste obtains EoW status and ceases to be waste, it becomes a product. In this case, the use of the material will be regulated entirely by a legislation on the products.



Intermediate storage of reclaimed concrete (left), use in road base (right).

Photos: VTT.

The use of reclaimed concrete with a waste status in certain types of earth construction has since 2006, been promoted through a Government Decree (amended in 2017), in which reclaimed concrete from selective demolition in earth constructions through professional utilisation is approved for use under specified conditions through simplification of the environmental permit system. The conditions for use (type of applications) are prescribed in the decree, as well as in the requirements for the quality control system (including limit values for release and content of harmful substances). The notification procedure for waste fulfilling the requirements defined in the decree is much faster (an approval is given in 2-25 days) than in the environmental permission procedure. For example, reclaimed concrete is in road base, e.g. Rudus has supplied 7 million tonnes of reclaimed concrete for earth constructions.

The work was preceded by development of a Finnish quality standard SFS 5884 (revised 2018) entitled "Factory Production Control of crushed concrete for earth construction". Currently, the reclaimed concrete analysed according to SFS 5884 can be CE-marked.

The benefits of the EoW status of the reclaimed concrete are the following aspects:

- uniform acceptance form (no case interpretation by local authorities on whether registration requirements are fulfilled)
- acceptance of the waste reclaimed as a product (image)
- small quantities can be used
- improved quality of the reclaimed concrete

The scope of the EoW preparation for reclaimed concrete concerns both concrete waste recovered from production and waste from demolition, and covers for example use in earth construction, building construction, use in landscaping ("viherrakentaminen" in Finnish), use in concrete products and also use of fertilizer (concerns only production). The EoW approaches also enable the use of material specific criteria, whereas the Government decree covers several waste types.

A significant difference between the use of reclaimed concrete as a waste (through the Government decree) or as a product (through a national EoW decision), concerns product liability. With a waste status the waste owner is the end-user, whereas in the latter case the producer of the reclaimed concrete is liable for the quality through the declaration of product (DoP).

When reclaimed concrete is used in a virgin aggregate, such as construction

products, it has to fulfil the product requirements according to the construction products regulations and a product declaration has to be made according to the requirements in the harmonised products standards. However, the aggregate requirements concern mainly technical properties.

In the preparation of the EoW background documentation for reclaimed concrete, the focus has also been to define the quality criteria for reclaimed concrete to fulfil product status (without taking into consideration requirements for certain product applications). Here, a comparison was made between the characteristics of concrete products (especially the release of certain substances). Limit values were developed through a risk assessment, in which the leachate generated directly beneath the construction needs to fulfil the drinking water standards. Some adjustments to the calculated values were also made, taking into account maximum release values that have been reported in the testing of reclaimed concrete (lowering the limit values for EoW concrete) and also releases from concrete products (increasing limit value). As a test method, a two-step leaching test (EN 12457-3) or a percolation test (EN 14405) is used for comparison of EoW limit values.

If EoW reclaimed concrete is used as a construction product, a specific issue discussed was the use of reclaimed concrete in a groundwater area. In the background memorandum for the proposed legislation, it is proposed that the EoW reclaimed concrete can only be placed with a distance of 2 meters above the groundwater table. Another aspect, is that in the declaration of the EoW product, it has to be mentioned that the pH of the leachate of the EoW has a pH of 11. The quality assurance system must be reviewed and approved by an independent third party, at least at level 2+, referred to in Annex V of the Construction Products Regulation.

Lessons learned

A lesson learned was the need to separate the process, where the waste is classified as EoW according to given criteria and not mix this step with the criteria for product use according to existing product standards and requirements. The product criteria are not to be used as EoW criteria, even if relevant when used in certain applications. However, if the reclaimed concrete is used as a construction product, some requirements on information to be included in DoP is suggested.

There is still only limited experience of the development of a national EoW decision. The approach developed for reclaimed concrete will be used for development of EoW status for other materials (e.g. plastics from mechanical recycling).

The influence of the EoW concept on the recycling rate is not shown, but quality of material is assumed to increase. An EoW legislation is clearly one approach to promote recycling of certain waste derived materials, however, under Circular

Economy context, different parallel approaches, systems and tools are needed. There is also a need to start discussion on other tools (e.g. taxation of virgin material) to increase recycling.

Exchange of information among member states on the experience concerning the EoW concept (identified development needs, good practices etc) is recommended. There will of course be differences in the implementation of EoW criteria, which is due to the national conditions and practices.

Country: Finland

Reference:

Government Decree 843/2017 concerning the recovery of certain wastes in earth construction; English translation of Decree: <https://www.finlex.fi/en/laki/kaannokset/2017/en20170843>

SFS 5884" Factory Production Control of crushed concrete for earth construction" issued by the Finnish Standardization Organization 2018.

Jussi Kauppila, Topi Turunen, Eevaleena Häkkinen, Jani Salminen, David Lazarevic. 2018. Advantages and disadvantages of end-of-waste regulation. Reports of the Ministry of the Environment 9/2018 (in Finnish)

14. DK Cirkulær – Certified circular concrete

Type of project	Commercial
Project focus	Production of concrete for use in indoor constructions. Aggregates produced from old concrete can substitute 20% of the stones used in new construction concrete.
Link to strategy	The Governments strategy for circular economy "Circular Copenhagen. Resource and waste management plan 2024" and "Miljø i Byggeri og Anlæg 2016"
Materials/ technologies in focus	Concrete, quality, concrete standards, traceability of old concrete.
Focus on digitalisation	None
Phases of the circular economy covered	Material production Selective demolition and on-site sorting Waste management, recycling and end-of-life phase
Other topics with relevance for the strategies and methods	Logistics End of Waste legislation Standardisation

Description of case

RGS Nordic and DK Beton have joined forces in order to create a sustainable concrete solution across the value chain^{1, 2, 3}. It is done with financial support from the Danish Environmental Protection Agency's MUDP (Miljøteknologisk Udviklings- og Demonstrations Program)⁴ funds. The solution implies that recycling of concrete waste in new concrete is quality assured, that the new circular concrete is delivered as certified concrete, and that the market can be served on an industrial scale.

In this way, quality stone in structural concrete is not lost from the building's material cycle but can be used again and again with full traceability. It is circular economy in practice and well on its way to an industrial scale.



Product sheets from DK Beton and RGS Nordic

Lessons learned

Recycled materials are often in demand and highlighted as a positive factor, and there is an increasing demand from all construction parties. In the past, traceability has been an obstacle to the recycling of concrete. Through the project, massive work has been done to control traceability, so significant amounts of virgin materials can be replaced with old concrete. Hitherto, the use of recycled concrete has typically required a dispensation. And so far, it has only been used on a small scale.

Increasing focus on sustainable construction is leading to a demand for solutions that can reduce the industry's consumption of virgin resources. With the developed certified aggregate (in accordance with EN 12620:2002+A1:2008), a technical, environmental, regulatory and market basis for crushed concrete waste from demolition projects has been created. Crushed concrete waste can now be used as certified aggregate in the production of certified ready-mixed concrete, where it represents a valuable source of raw material.

The case is not directly linked to a specific strategy in circular economy. However, the political focus as well as the focus in the industry on sustainable construction and circular economy as well as the possibilities to obtain financial support for R&D activities within these areas has had a positive effect on the development of this product.

Country: Denmark

Reference:

¹<https://www.rgsnordic.com/media/2096/pressemeddelelse-om-cirkulaer-beton.pdf>

²<https://www.rgsnordic.com/cases/cirkulaer-beton/>

³<https://www.dkbeton.dk/da/dk-cirkulaer>

⁴<https://www.teknologiudvikling.dk/mudp>

⁵<https://www.rgsnordic.com/media/1303/genbrugsbeton.pdf>

Annex 3

Local strategies and networks to promote CE

This table provides a summary of good examples in the Nordic countries. Note that this compilation is not intended to provide a comprehensive list of good examples.

Title of strategy	Country	Description	Reference
"Go green with Aarhus" Climate strategy and climate plan 2016-2020, Aarhus municipality	DK	The strategy focuses with respect to buildings on the following topics: 1) renovation of existing building stock and adaption to the smart energy consumption of the future, 2) facilitation of green transition and sustainability in building projects, 3) mobilisation and strengthening of knowledge and competences in the local building industry.	https://gogreenwithaarhus.dk/
Miljø- og energirigtigt byggeri Aarhus kommune (Environmental and energy efficient construction of buildings in Aarhus municipality)	DK	Requirements and recommendations for municipal building work, public funded buildings and urban renewal projects with respect to electricity, heat, water, materials, waste, biodiversity and climate adaption. Aim: to make buildings as sustainable as possible.	https://www.aarhus.dk/media/22741/miljoe-og-energirigtig-byggeri-i-aarhus-kommune.pdf
CHP 2025 Climate Plan. Roadmap 2017-2020.	DK	The climate plan for Copenhagen municipality is based on four pillars: 1) energy consumption, 2) energy production, 3) mobility and 4) city administration initiatives. The roadmap describes 60 initiatives. As initiatives particularly related to buildings, the following can be mentioned: renovation of building envelopes, space management and total renovations.	https://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detail&id=1586
Circular Copenhagen. Resource and waste management plan 2024	DK	The plan contains three overall targets related to the recycling of household waste, CO ₂ -emissions and reuse. With respect to C&D waste, the plan focuses on the following topics: 1) reuse of construction materials from the city's properties and 2) cleaner recycling of resources in C&D waste.	https://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detail&id=1991
"Miljø i Byggeri og Anlæg 2016", Københavns Kommune (Environment in construction and civil engineering 2016, Copenhagen municipality)	DK	Environmental requirements, which apply to construction and civil works commissioned or supported by the City. The requirements will help to implement a number of political strategies, including the KBH 2025 Climate Plan, the Resource and Waste Management Plan 2018 and the Copenhagen Climate Adaption Plan. The requirements cover the following areas: electricity, heat, water, materials, indoor climate, rain water and urban nature, resources and waste, and building sites.	https://www.kk.dk/sites/default/files/sustainability_in_construction_and_civil_works_2016.pdf
Middelfart municipality (the strategy is under development),	DK	A strategy for circular economy in the municipality of Middelfart is under development. The circular economy related initiatives in Middelfart are based on three pillars: 1) construction and selective demolition, 2) learning, 3) circulation of resources. All initiatives are decided by the city council.	No reference, as the strategy is under development
Bright Green Island visionen - Bornholmermålene frem mod 2035 ("The bright Green Island vision - the goals of Bornholmers towards 2035"). Published in 2018.	DK	A vision of a sustainable and climate friendly Island community. The vision encompasses eight goals. Several goals are important for the building and demolition sector, e.g. the goal of renovating buildings sustainably by using sustainably produced materials, or reused materials.	http://www.brightgreenisland.dk/nyheder/Documents/PDF_BrightGreenIsland_vision2018.pdf
Bornholm showing the way - without waste 2032 (published in 2019)	DK	A vision of a cleaner, healthier and greener Bornholm boosting growth and development. A vision of no waste on Bornholm in 2032 - all discarded items are resources that can be recirculated. The vision paper interacts with the UN Global Goals, the Agenda 21 goals, the goals of the global climate agreement from 2015, Denmark without waste and the circular economy package. It is also interlinked to several local strategies and plans, e.g. the target of being CO ₂ neutral in 2025. Several measures will be implemented up to 2032. From 2022 measures will be implemented for construction waste (but not specified which type of measures).	https://bofa.dk/wp-content/uploads/2019/01/BOFA_mini-publication_UK_A4_160119.pdf

Planstrategi 2019, Kolding kommune ("Plan strategy 2019")	DK	The municipality aims at becoming circular and a pioneer municipality with respect to circular economy. A strategy for circular economy is under development and is expected to be published in 2020. When it comes to creating new housing, the municipality will focus on the concentration and recycling of the existing city area, instead of subdividing new/virgin areas.	https://www.kolding.dk/media/j52ib51r/planstrategi_2019_for_kolding_kommune_lokal_dek_november_low.pdf
Affaldsplan 2019-2024, Kolding kommune ("Waste management plan 2019-2024")	DK	The plan describes the municipality's goals and activities related to the prevention and effective utilisation of waste. With respect to C&D waste, the municipality will upgrade the effort for the increased sorting and removal of contaminated C&D-waste. This will be done through increased information and authority at the recycling centres.	https://www.kolding.dk/borger/affald-og-genbrug/politik-og-regulativer-pa-affaldsomradet/kolding-kommunes-affaldsplan/
Carbon neutral Helsinki 2035	FI	In the strategy, Helsinki presents 58 actions to achieve the emissions reduction targets through construction and buildings. • Improve the energy efficiency of buildings • Introduce smart energy systems to further reduce energy consumption • reduce emissions in its procurements of construction materials. • The City's construction company, Stara, will move to using biofuels in machinery by 2020. • The lifecycle emissions from the City's construction and infrastructure projects will be minimised. • The City will pilot and move towards energy-plus construction • Using recovered materials in groundworks • Increase the proportion of recycled materials in construction • Land-use and planning to support carbon neutrality • The City will promote wooden construction through detailed planning	report in finnish: https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/HNH-2035-toimenpideohjelm.pdf summary in english: https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/esitteet/HNH2035_en_summary_14022019.pdf
Turku Climate Plan 2029	Fi	The objective is to collectively implement the goal of a carbon neutral city area 2029. Implementation target of the construction sector: Sustainable construction is developed and promoted not only in pilot areas, but also extensively in the entire city area. Using wood as building material is developed, new energy solutions are implemented, and energy effectiveness is improved.	https://www.turku.fi/sites/default/files/atoms/files/turku_climate_plan_2029.pdf
Vantaa CE plan	FI	Carbon neutral 2030 Specific targets for construction sector	https://www.vantaa.fi/instancedata/prime_product_julkaisu/vantaa/embeds/vantaawwwsstructure/145955_Kiertotalouden_tiekartta_lopullinen.pdf
Kuopio resource efficiency programme	Fi	Increase energy efficiency and sustainability in construction. Increase the use of LCC analyses in construction. Increase renewable energy consumption in buildings.	https://www.kuopio.fi/documents/7369547/7583060/Kuopion+resurssiviisausohjelman/b9c68ee3-fb3a-492b-82ff-47ea882a0542
Hinku network - Towards Carbon Neutral Municipalities	FI	Hinku regions and the Hinku communities in each region jointly commit to reducing the regions' greenhouse gas emissions by 80 percent from the 2007 levels by 2030. To obtain Hinku status, the municipality or region must meet the Hinku criteria specified by the Finnish Environment Institute.	https://www.hiilineutraalisuomi.fi/en-US/Hinku/Hinku_criteria
DEVELOPMENT AND SUSTAINABILITY AGENDA FOR ÅLAND	Fi	The sustainability principles of Åland in relation to Construction and C&DW: In a sustainable society, nature is not subject to systematically increasing... 1) concentrations of substances extracted from the Earth's crust (fossil fuels, metals and minerals) 2) concentrations of substances produced by society (synthetic substances, chemicals that contain persistent substances; or natural substances that are in use in larger quantities than nature can handle) 3) degradation by physical means (over-exploitation of natural resources, including water, forests, fish-stocks or farmland; the usage of important natural environments for example building, the introduction of alien and invasive species, production that results in refuse rather than being a closed substance cycle) The means to achieve these targets, in relation to the construction sector are:	https://www.regeringen.ax/dokument/hallbarhet/hallbarhetsveckling/utvecklings-hallbarhetsagendan

		- the use of timber grown on Åland in the construction industry - the use of fossil-free energy in buildings	
Ramate programme	FI	Efficient utilisation of construction material, reducing the amount of waste generated and promoting recycling	http://www.ym.fi/fi-FI/Ymparisto/Rakennusjatteesta_arvokkaksi_resurssiksi%2829942%29
Requirement for pre-demolition audits	FI	For certain categories of buildings, the identification of hazardous materials is mandatory before any demolition work	
demolition standard	FI	Mandatory selective demolition/ plan for large demolition site	
Promoting of wood recycling	FI	Finnish Ministry of the Environment and industry, Promoting of wood recycling, development of new recycling concepts and new products from wood waste	http://www.ym.fi/fi-FI/Ajankohtaista/Tapahtuma_Puujatteen_kierratyksseen_semin%2833145%29
National Action Plan for Green Public Procurement	FI	Finland has established a National Action Plan for Green Public Procurement (GPP) guidance and criteria, some of which are directly relevant for buildings.	https://tem.fi/documents/1410877/2132296/IJH+Toimenpidesuunnitelma.pdf/3fe413eb-Ofd5-4dc3-9797-74ce98694503/IJH+Toimenpidesuunnitelma.pdf
Upphandlingskrav för cirkulära flöden i bygg- och rivningsprocessen (Procurement requirements for circular flows in the construction and demolition process)	SE	The city of Gothenburg has developed procurement requirements for circular flows in the construction and demolition process	https://goteborg.se/wps/wcm/connect/d0600675-8e9c-4522-9984-4783c65d9a07/Slutrapport+Upphandlingskrav+f%C3%B6r+cirkul%C3%A4ra+fl%C3%B6den+i+bygg-och+rivningsprocessen.pdf?MOD=AJPERES
Resurs - och avfallsriktlinjer vid byggande och rivning	SE	The city of Gothenburg has developed procurement requirements for circular flows in the construction and demolition process	https://goteborg.se/wps/wcm/connect/d0600675-8e9c-4522-9984-4783c65d9a07/Slutrapport+Upphandlingskrav+f%C3%B6r+cirkul%C3%A4ra+fl%C3%B6den+i+bygg-och+rivningsprocessen.pdf?MOD=AJPERES
(Resource and waste guidelines for construction and demolition)	SE	The construction sector together with other actors in the value chain, such as waste management companies have developed guidelines regarding what source sorting possibilities should be available on construction and demolitions sites	https://byggforetagen.se/ap/uploads/2020/01/190520-Resurs-och-avfallshantering-vid-byggande-och-rivning.pdf
In Skåne they have developed a tool to minimise the waste from construction sites	SE	A tool (guidelines) have been developed to minimise the waste from construction activities.	https://www.hutskane.nu/projekt/verktyg-for-att-minska-avfall-vid-nybyggnation/
Local roadmap for a climate-neutral construction and civil engineering sector in Malmö 2030.	SE	The roadmap consists of the following six strategies: 1. Business models, incitement and collaboration, 2: circular Economy and resource efficiency, 3. Design, process and climate calculations, 4. Climate neutral building materials, 5. Climate neutral operation and maintenance, and 6. Climate neutral construction sites and transports	http://lfm30.se/
Climate strategic program for Gothenburg	SE	In Gothenburg, we have the goal of reducing our greenhouse gas emissions to a sustainable and fair level by 2050. To achieve this goal, we in Gothenburg have developed a climate strategic program that shows how we must work long-term to reduce our climate impact.	https://goteborg.se/wps/porta/start/miljo/det-gor-goteborgs-stad/klimatstrategiskt-program/lut/p/z1/04_Sj9CPykssyOxPLMnMzOvMAfIjo8ziQwONAi2cDBONLCwCzA08gxzdZU2M3Q38vcz0wwkpiAJKG-AAjgb6BbmhigAzNGH5/dz/d5/L2dBISEvZ0FBIS9nQSEh/
Oslo municipality	NO	Oslo municipality was the European environmental city last year, and have a clear ambition to be one of the leading environmental cities in the world. The municipality builds environmentally friendly buildings, works for emission-free construction sites, and will reduce greenhouse gas emissions in accordance with the Paris Agreement	

Kongsvinger region Circular scan	NO	Two projects are carried out in circular economics for the moment. One is a so called "Circle Scan" within the construction industry in the region (situational analysis (including material flow) + circular feasibility study). The second project is derived from Circle Scan: Development of a prototype building, where at least 50 % of the material is to be reused or recycled building material, preferably wood (load bearing structure in reusable timber).	https://kongsvingerregionen.no/workshop-1-i-circle-scan-kartlegging-av-byggenaeringen-i-regionen/ https://www.o-house.no/
Longyearbyen, Svalbard	NO	Both in Longyearbyen and in Svea, there are many buildings that must be removed due to landslides and closure of mining. These are still usable and functional - though not according to today's standards for new buildings. The buildings constitute Svalbard's local bank of building materials with local identity. Removing and reusing buildings also means rebuilding and upgrading. The project looks at the principles for this.	https://lpo.no/prosjekter/rett-plass-rett-form
Reuse of concrete slabs	NO	Hollow Core Concrete slabs (HCS) from an existing building are to be reused in Oslo's new emergency medical centre. Initial inspections before deconstruction were carried out by a concrete technologist, supplemented by invasive testing of the concrete's compressive strength and carbonation to determine the condition and technical characteristics. These results were later verified by full scale testing of a sample of HCSs.	https://www.tu.no/artikler/storbylegevakten-som-skal-apne-i-2023-far-hulldykker-fra-gamelt-regjeringsbygg/490344?key=KcJW2ac9
Reuse of concrete slabs	NO	Hollow Core Concrete slabs (HCS) from an existing building are to be reused in Oslo's new emergency medical centre. Initial inspections before deconstruction were carried out by a concrete technologist, supplemented by invasive testing of the concrete's compressive strength and carbonation to determine the condition and technical characteristics. These results were later verified by full scale testing of a sample of HCSs.	https://www.tu.no/artikler/storbylegevakten-som-skal-apne-i-2023-far-hulldykker-fra-gamelt-regjeringsbygg/490344?key=KcJW2ac9

Annex 4

Digitalisation cases

Note! Information has been collected only from Denmark, Finland and Sweden.

Country	Level (national / municipal / company / project)	Type of data digitalised	Type of digitalisation/ technology used (tools)	Aim of digitalisation (project)	Project status – implemented or under development
DK	National	Data encompassed by the notification, which is required to be sent to the local municipality in renovation and demolition projects. Data examples are: waste amounts, waste types, survey/screening of hazardous substances in the building.	"Byg & Miljø" or similar platforms used by the municipalities	Correct management of the waste (the municipality approves the suggested waste management facility).	Implemented
DK	National	Notifications related to renovation and demolition projects (see above)	"Byg & Miljø" or similar platforms used by the municipalities	The waste statutory order is expected to be amended with the following digitalisation related requirements: the notification must follow the waste, i.e. the notification will receive a sequential number, the waste carrier must hold a copy of the notification, the waste management facility must digitally report the sequential number and the waste received to the municipality. Overall aim: to enhance traceability (to follow the waste flow from the demolition site to the waste management facility).	Under development
DK	National	Waste flows in Denmark	"ADS" (Affaldsdatasystemet, hosted by the Danish EPA)	Danish companies treating waste (or importing or exporting waste) are obliged to report data on the waste to ADS. Data to report: producer of the waste, type of waste (EWC and Danish codes), type of treatment. The Danish Waste Statistics are based on data from ADS. Part of the data are publicly available and can be found here: https://www.ads.mst.dk/Forms/Reports/ReportsOverview.aspx	Implemented
DK	Project	Interim wood from construction sites	App - GENTRÆ	GENTRÆ aims at introducing reused materials in the Danish DIY centres. Currently, the project focuses on wood used at construction sites for interim purposes. The reused wood is sold in STARK (DIY centre and project partner).	Implemented
DK	Company project (2013-2017)	BIM 5D (3D modelling to visualise the project. 4D modelling to visualise the time plan. 5D calculations of amounts and economy).	BIM	"5D-modellering ved Blox-byggeri". BIM 5D was used when the building "Blox" was constructed in Copenhagen. Value creation: reduced material spillage, optimised production and economic savings. In the project the expected spillage of reinforcement	Implemented

				was reduced from 5–10% to 1%.	
DK	Company	Soil amounts at construction sites	Drone technology	NCC uses drones to measure up and afterwards calculate amounts of soil at construction sites. This indicates precisely how many trucks are needed to remove soils from the site.	Implemented
DK	Company	Data from sensors in buildings (building management systems)	Sensors and IBM's Watson IoT platform	ISS integrates and analyses data from millions of sensors placed in 25 000 buildings worldwide. Data is uploaded to IBM's Watson IoT platform. Purpose of sensors and platform: to ensure optimal operation of buildings (e.g. with respect to energy and water use, and indoor climate).	Implemented
DK	Company	Traffic and subsidences at bridge	Sensors and Cognitive Digital Twins	12-meter-long steel bridge in Amsterdam with sensors measuring traffic at the bridge, subsidence in the bridge, etc. Data is constantly updated to a digital twin, which is continuously measuring the condition of the bridge. Value creation: the lifespan of the bridge is potentially increased and renovation is optimised.	Implemented
DK	Company	Supply and demand of building materials	Platform and app managed by NCC	Loop Rocks was an online platform and app managed by NCC to match surplus building and construction materials, such as gravel, soil, and sand with potential buyers. The platform was launched in Sweden in 2016, and the year after in Denmark. In 2019, it was closed down due to lack of external funding.	Implemented, but closed down
DK	Project	Waste recognition	Robot technology and AI/Deep Learning	Development of a robot that by use of AI/Deep learning can recognise electronics containing batteries. Can potentially also be used for recognition of hazardous substances in C&D waste. INNOSORT project at DTI.	Under development
DK	National (Banedanmark is an agency belonging to the Ministry of Transportation and Housing)	Projection of the need for spare parts for the railway signal system of Banedanmark	IT projection model	In relation to the replacement of the current railway signal system, Banedanmark, has developed a projection model to keep track of the future need of spare parts for the railway sections not yet renovated. The elements removed from the renovated sections are stored for future use. Value creation: reuse of elements instead of purchasing new ones, optimised stock.	Implemented
DK	National, regional and municipal level	Data on waste and resource flows	Internet portal ("Danmarks Miljøportal")	"Danmarks Miljøportal", which collects and makes available environmental data has launched a new strategy (in 2020) where focus - among others - is on circular economy. The portal will now also focus on waste and will - in close collaboration with the waste sector - create easy access to well-structured and updated data on waste flows and resources. In the long run it may create a circular data bank.	Under development
DK	Company	Data on excess building materials from wholesalers in particular	Internet platform for sale of excess building materials.	The company "Proffoutlet" runs an internet platform for sale of excess building materials. The platform works on pcs, tablets and mobile phones. The	Implemented

				sellers are wholesalers, the buyers are private persons, companies, and the public sector. The platform was established in September 2019.	
FIN	National/ municipal	electronic waste transfer document		aim to improve statistics on generated C&DW	Under development
FIN	National/ municipal	electronic notification concerning waste generated in demolition of a building, or part of a building shall include an account of the amount and type of construction waste and how it will be sorted		aim to improve information on waste generation and management	Under development
FIN	National	Materiaalitori market place	Platform managed by the Finnish state-owned company Motiva Ltd for the exchange, sale and purchase of waste materials, side-streams and left overs.	"Materiaalitori" service aims to promote the circular economy and the recovery of waste and side-streams by providing operators in the field with a platform that enables those offering and needing recycled materials to find each other. Forming such industrial symbioses is a requirement for recycling materials	implemented
FIN	National	Building and dwelling register (part of Population Information System) - background: the owners pay taxes based on registered buildings, therefore demolished buildings are removed from the database		detailed record of all residential buildings demolished yearly, information on building types, information on new buildings available from Finland Statistics, as well	Rakennus- ja huoneistorekisteriksi (RHR), information available online at: https://vrk.fi/rakennustiedot
FIN	Project	Material degradation follow-up	Modelling, on-line measuring	Accurate prediction of the material degradation, or failure is from the simulation of the physical processes in the material under the variable external conditions. One example is the decay of wood elements, which is based on internal moisture and temperature. The whole process can be simulated by the Finite Element Method (FEM) providing very accurate estimation of the decay risk and internal stresses that can lead to cracks and accelerated degradation	S. Fortino, P. Hradil, A. Genoese, A. Genoese, A. Pousette, Numerical hygro-thermal analysis of coated wooden bridge members exposed to Northern European climates, Construction and Building Materials 208 (2019) 492–505
SE	National	Data on quality of used interior building materials and products, digital platform for buyers and sellers to meet		To develop a digital marketplace for buyers and sellers to meet.	Under development
SE	Regional (Stena fastigheter)	ReAppli - En digital tjänst för ökad återanvändning av begagnade vitvaror och återkoppling av data		When Stena Real Estate renovates an apartment and the existing appliances are not to be reused, they can get a new home, from someone else. In the ReAppli app, the appliance, with information and pictures, organises a date for collection. The product is then auctioned off. The dealer who makes the highest bid receives the home appliance and can in turn sell it to someone who is looking for a second-hand appliance.	Implemented
SE	National	Traceability 4 Circularity- Find the needs and challenges for tracing, managing and transfer of the information for a plastic product by a digital			Under development

		marking's system to the whole value chains in order to accelerate the circularity of plastic products.			
SE	National (Kompanjonen)	Used building materials and products for sale including product information, such as size and quality etc.		Create a market place for secondary building products and materials	Implemented
SE	National (Loop rocks)	Market for secondary materials, primarily stone, soil and various filling materials. Through a digital interface both supply and demand are made visible and construction projects can be matched in this way. Loop Rocks have closed down their business due to poor profitability.		Create a market place for secondary materials, primarily stone, soil and various filling materials	Implemented
SE	National (Hus till hus)	The company conducts refurbishment, and sell building products and recycled building materials for house renovations. Available products are on a digital platform		Create a market place for secondary building products and materials	Implemented
SE	BASTA (BASTA online)	Information about construction materials and products such as chemical content and how each product and material relate to the requirements set by BASTA		BASTA is aimed at anyone who wants to make conscious material choices with the aim of phasing out topics with dangerous properties - including property owners, contractors, architects, building designers or private households	Implemented
SE	Byggsvaru-bedömning-en	Information about construction materials and products, such as chemical content.		Byggsvarubedömningen assesses building-related products based on their chemical content, environmental impact during the lifecycle and, by extension, social impact at the supplier stage. This is to promote product development towards a non-toxic and well-built environment, and a responsible supplier chain	Implemented
SE	SundaHus	Information about construction materials and products, such as chemical content.		SundaHus offers services to property owners to make environmentally conscious material choices etc.	Implemented
SE	The handbook "Hazardous substances" in a mobile app	Information about hazardous materials and substances in buildings	Information about hazardous substances	The hope is that the app will facilitate a serious management of hazardous waste in the workplace and at the same time be perceived as simple and user-friendly.	Implemented
SE	National (Real Estate Data Lab)	All type of data related to real estate.		The real estate data lab will establish an ecosystem and create a national platform for sharing property data between actors in the real estate industry. The purpose is to contribute both to a more standardised way of handling data between different actors, and to make data available for actors who want to develop new innovative digital services based on AI and smart analytics algorithms.	Under development
SE	National (BETCRETE 2.0)		Panorama (collaboration tool that visualises and accelerates	Gather leading actors to formulate an implementation plan for industrial	Under development

			Sweden's climate transition)	conversion to climate-neutral cement and concrete use, including resource effectiveness, increased recycling of materials and sustainable processes.	
NO	Cobuilder Collaborate	Environmental data from building components can be linked to the BIM model. The platform can also check that no materials, which do not comply to the standards of the building site enters the construction site.		Cobuilder Collaborate is a solution within the Cobuilder platform that is unique in its collaborative approach to data collection and automated data checking. It fosters data quality through the application of standards for construction product data management and general data governance. Cobuilder's Project Data Management Solution 'Collaborate' helps developers' and construction teams to set their data requirements, collect data directly from the supply chain, automatically check it against the set requirements and deliver checked data to Asset Information Models.	Implemented
NO	Loopfront	Information on reusable building materials and interior		Connects those who possess materials with possible buyers in a digital tool.	Under testing
NO	ConZerW Construction Site Zero Waste			The main objective of ConZerW is to achieve waste-free construction sites by developing digital process tools, which enable tracking the source of waste from construction activities, implement potential optimisation measures and evaluation methods, that support collaboration between partners in planning, procurement and logistics activities related to the construction site.	Under development

About this publication

Strategies and methods for implementing CE in construction activities in the Nordic countries – supporting cases

Margareta Wahlström, Malin zu Castell-Rüdenhausen, Thilde Fruergaard Astrup, Anke Oberender, Carl Jensen, Pernilla Johansson and Eirik Wærner

ISBN 978-92-893-6929-9 (PDF)

ISBN 978-92-893-6930-5 (ONLINE)

<http://dx.doi.org/10.6027/temanord2021-508>

TemaNord 2021:508

ISSN 0908-6692

Cover photo: Karl Hornfeldt

© Nordic Council of Ministers 2021

Disclaimer

This publication was funded by the Nordic Council of Ministers. However, the content does not necessarily reflect the Nordic Council of Ministers' views, opinions, attitudes or recommendations.

Rights and permissions

This work is made available under the Creative Commons Attribution 4.0 International license (CC BY 4.0) <https://creativecommons.org/licenses/by/4.0>.

Translations: If you translate this work, please include the following disclaimer: This translation was not produced by the Nordic Council of Ministers and should not be construed as official. The Nordic Council of Ministers cannot be held responsible for the translation or any errors in it.

Adaptations: If you adapt this work, please include the following disclaimer along with the attribution: This is an adaptation of an original work by the Nordic Council of Ministers. Responsibility for the views and opinions expressed in the adaptation rests solely with its author(s). The views and opinions in this adaptation have not been approved by the Nordic Council of Ministers.

Third-party content: The Nordic Council of Ministers does not necessarily own every single part of this work. The Nordic Council of Ministers cannot, therefore, guarantee that the reuse of third-party content does not infringe the copyright of the third party. If you wish to reuse any third-party content, you bear the risks associated with any such rights violations. You are responsible for determining whether there is a need to obtain permission for the use of third-party content, and if so, for obtaining the relevant permission from the copyright holder. Examples of third-party content may include, but are not limited to, tables, figures or images.

Photo rights (further permission required for reuse):

Any queries regarding rights and licences should be addressed to:
Nordic Council of Ministers/Publication Unit
Ved Stranden 18
DK-1061 Copenhagen
Denmark
pub@norden.org

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.

The Nordic Council of Ministers
Nordens Hus
Ved Stranden 18
DK-1061 Copenhagen
pub@norden.org

Read more Nordic publications on www.norden.org/publications