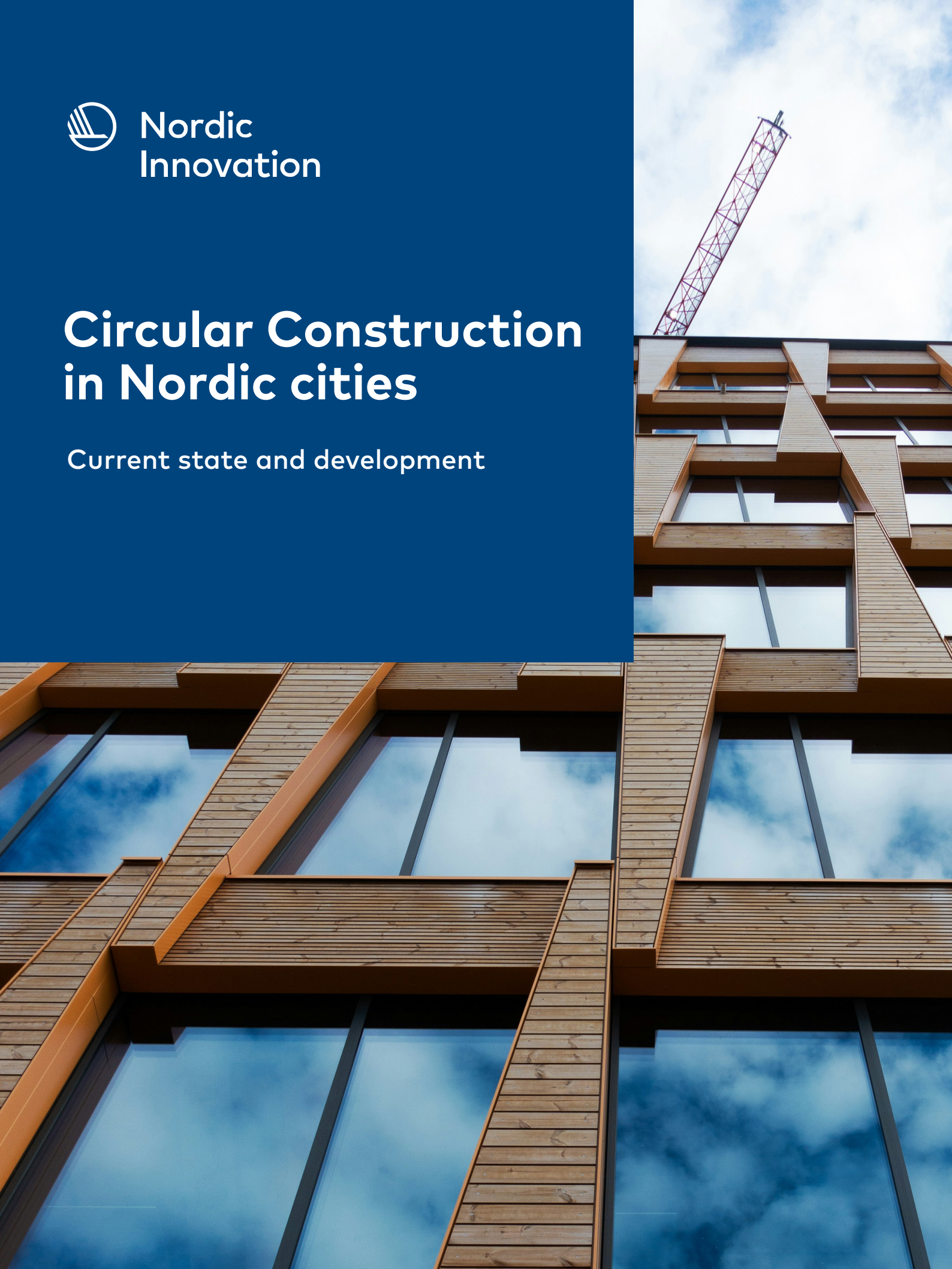
Nordic Innovation

Circular Construction in Nordic cities

Current state and development



Task force

Katri Luoma-aho, project lead
Andrea Weckman, assistant project lead
Riikka Anttonen
Joakim Suvanto
Helena Rantala
Tuukka Nissilä
Arto Toorikka, project supervisor

A steering group with representatives from Nordic Innovation and City of Tampere has assisted with proof reading and quality control of this report.

Table of contents

Terms and abbreviations

BREEAM is a sustainable building certification program (BRE Environmental Assessment Method), developed by BRE (Building Research Establishment).

The Cascading Principle Putting the use of raw materials into an order of value to create resource effectiveness. For example, wood is first made into products of a higher added value, which are then reused or recycled, and not used in energy production until the end of a natural lifespan.

EoL End of Life

EOW End of Waste

DfD Design for Disassembly

Disposal means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy.

Energy recovery refers to the conversion of waste materials into heat, electricity, or fuel through a variety of processes, such as incineration.

HVACE Heating, Ventilation, Air-Conditioning and Electricity

Landfill is the deposit of waste into or onto land. It includes specially engineered landfill sites and temporary stor-age of over one year on permanent sites.

LCA Life Cycle Assessment

LCC Life Cycle Cost

Material recovery is restoration of materials found in the waste stream to a beneficial use which may be for pur-poses other than the original use. It includes e.g. backfilling.

Preparing for re-use Checking and cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.

Recycling Any recovery operation by which waste materials are reprocessed into products, materials or substances for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Recycling and material recovery rate for construction and demolition waste is the sum of the preparing for reuse, recycling and other material recovery, including backfilling operations but excluding energy recovery, divided by all the construction and demolition waste generated excluding naturally occurring excavated material.

Recovery means any operation of which the principal result is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Recovery is divided into three sub-categories: preparing for re-use, recycling, and other recovery.

Re-use means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.

Waste prevention means measures taken before a substance, material or product has become waste, that re-duce a) the quantity of waste, including through the re-use of products or the extension of the life span of prod-ucts; b) the adverse impacts of the generated waste on the environment and human health; or c) the content of harmful substances in materials and products.

Summary

This study, commissioned by Nordic Innovation and the City of Tampere and conducted by AFRY Finland, provides an assessment of circular economy practices in the construction sector within the Nordic countries, focusing particularly on selected pilot projects in Tampere and Stavanger, as well as the general status in Stockholm and Copenhagen. Via these pilot projects, the study aims to identify expertise, challenges, and opportunities for promoting circular economy principles, and provide recommendations for city-specific, national, and Nordic levels.

The EU's Circular Economy Action Plan and Waste Framework Directive set ambitious targets for reducing material use and waste in the construction sector. The Nordic countries are aligned with these goals but face challenges in meeting them. Finland's strategic program emphasizes circular economy as a basis for national economy by 2035, with targets for reducing nonrenewable resource use and enhancing resource efficiency. Norway aims to pioneer circular economy through green value creation, emphasizing digitalization and reuse of materials in the construction sector.

In Tampere, multiple pilot projects were assessed, such as the Pohjois-Hervanta school and ReCreate Tampere. These showcase innovative circular construction practices. In Stavanger, the projects in Mosvangen kindergarten and the town hall renovation highlight efforts in sustainable building practices. Insights from the follower cities Stockholm and Copenhagen reveal a focus on circular economy, but also underscore challenges like resource limitations and organisational hurdles.

The study utilized questionnaires, interviews, and workshops to gather data, which was then analysed to assess circular economy maturity and identify bottlenecks. Tampere and Stavanger have demonstrated significant progress through pilot projects, but face challenges in scaling these initiatives. Stockholm and Copenhagen show varying degrees of circular economy integration, with common challenges related to regulatory frameworks and organisation and market acceptance.

The transition to a circular economy in the construction sector is essential for reducing environmental impact and achieving sustainability goals in the Nordic region. While significant strides have been made, broader implementation and scaling of these practices are

needed. This report offers recommendations for achieving these objectives through targeted policy measures, technological innovation, and stakeholder collaboration.

This study recommends promoting circular economy in buildings through clear goal setting, resource allocation, collaboration, earlystage circular criteria, strict circularity requirements, and progress monitoring. Nationally, laws and regulations should foster and enable innovation and reuse, while regional logistics planning should be improved, recycling and reuse markets should be stimulated, and harmonization of feasibility and product certification processes is necessary. At the Nordic level, a unified voice for circularity in the EU, collaboration, knowledge sharing, and advocating for circularity and resource efficiency can boost the building sector's circular economy.

By addressing the identified challenges and leveraging the existing strengths, Nordic cities can lead the way in sustainable construction and circular economy practices.

Introduction

The construction sector is estimated to use approximately 50% of all materials and generating over a third of the waste within the EU (European Commission 2020). The Nordic countries, like the rest of the EU, grapple with the challenge of underutilized construction waste and transitioning towards circularity in sector, failing to meet the ambitious recycling targets set for 2025. Given the sheer volume of materials used and waste produced by this industry, a paradigm shift toward circular practices within construction is essential. By designing for circularity, reusing construction products and opting for renovation instead of demolishing, the sector can mitigate the environmental impact associated with manufacturing and transporting new materials, as well as managing demolition waste. Numerous initiatives are already in motion, spanning inventive solutions, business strategies, and legal mandates across the Nordic region.

This work is part of a Nordic Innovation project focused on circular economy in construction within the Smart City Network. The Nordic Smart City Network is a cooperative venture that unites five Nordic

nations and 20 cities within the Nordic region. Their shared objective is to explore the Nordic approach to crafting cities that are both sustainable and liveable (Nordic Smart City Network 2024).
The goal of this study is to create a comprehensive overview of the expertise related to circular economy in two Nordic cities: Tampere and Stavanger. This study aims to clearly describe relevant stakeholders in this field and propose concrete actions and areas for development for promoting circular economy practices in each city. Additionally, the study will provide a broader snapshot of the circular economy situation across the Nordics, leveraging data from collaborating cities Stockholm and Copenhagen.

The key objective of this study is to assess the circular economy expertise in the selected Nordic cities, identifying strengths and areas for improvement. By analysing the expertise, insights into the challenges and bottlenecks hindering circular development will be described. The study will yield city-specific and Nordic recommendations for better integrating circular economy principles. This will be done by exploring ongoing and past circular economy projects in the project cities, and highlighting the lessons learnt.

The study also briefly examined the circular economy landscape across the Nordics, evaluating if other cities are further ahead in circular initiatives and how do markets perceive circular economy practices. Similarities and differences between the cities and countries will be highlighted in this report.

This study forms§ a holistic view of circular economy maturity and challenges in the Nordic region, informed by interviews and research. Furthermore, the study will present recommendations for promoting circularity at different levels: city, national, and Nordic. The study also takes into account contextual factors, such as evolving regulations and national interpretations of EU directives.

This study was carried out on behalf of the Nordic Innovation and City of Tampere by AFRY Finland.

2 Circular economy in the Nordic countries

2.1 Circular economy strategies and legislation related to buildings and construction

2.1.1 EU and the Nordics

The Nordic countries follow EU targets, strategies and legislation in advancing the transition to circular economy in the buildings and construction sector (Nordic Council of Ministers 2023). EU level regulations concerning the sector include the Circular Economy Action Plan and the Waste Framework Directive. Construction and buildings sector is recognized as using approximately 50 % of all materials and generating over 35 % of waste within the EU. A significant reduction in materials-based emissions can thus be achieved by improving materials efficiency.

The European Commission has adopted the Circular Economy Action Plan in 2020 as part of the European Green Deal agenda. It aims to support the transition towards a circular economy to help reduce the use of natural resources, create sustainable growth, and achieve the EU climate targets. Among other things, the plan addresses product design, circular economy processes, sustainable consumption, and circular resource use, and 35 actions are listed for the attainment of the objectives. (European Commission 2024a)

Steps provided in the action plan concerning the construction and buildings sector include: (European Commission 2020)

- **Sustainability Performance of Construction Products:** Efforts have been made to assess and improve the environmental impact of construction materials and products. This includes promoting sustainable sourcing, reducing emissions, and ensuring better resource efficiency.
- **Durability and Adaptability of Built Assets:** The focus is on designing and constructing buildings that last longer, are adaptable, and can be repurposed. This involves using durable materials, modular designs, and considering future needs.
- **Life Cycle Assessment in Public Procurement:** Public procurement processes now integrate life cycle assessments to evaluate the environmental impact of construction projects. This helps prioritize sustainable options and reduces the overall ecological footprint.

- **Revised Material Recovery Targets:** The plan revisits targets for recovering materials from construction and demolition waste. By improving recycling rates and reducing landfill disposal, the sector contributes to circularity.

- **Initiatives to Reduce Soil Sealing:** Soil sealing refers to covering natural land with impervious surfaces like asphalt or concrete. The action plan encourages measures to minimize soil sealing, preserve green spaces, and enhance urban biodiversity.

The EU Waste Framework Directive (2008/98/EC) includes definitions for waste, recycling, and recovery and sets targets for re-use and recycling of waste materials. It states that waste should be treated according to a waste hierarchy in which the prevention of waste generation altogether is considered the preferred option (Figure 1). The other options are, in decreasing order of preference, preparing for re-use, recycling, recovery, and disposal. The directive also sets end-of-waste criteria that specify when certain waste fraction is not considered waste anymore but becomes a product or secondary raw material instead. (European Commission 2024b)

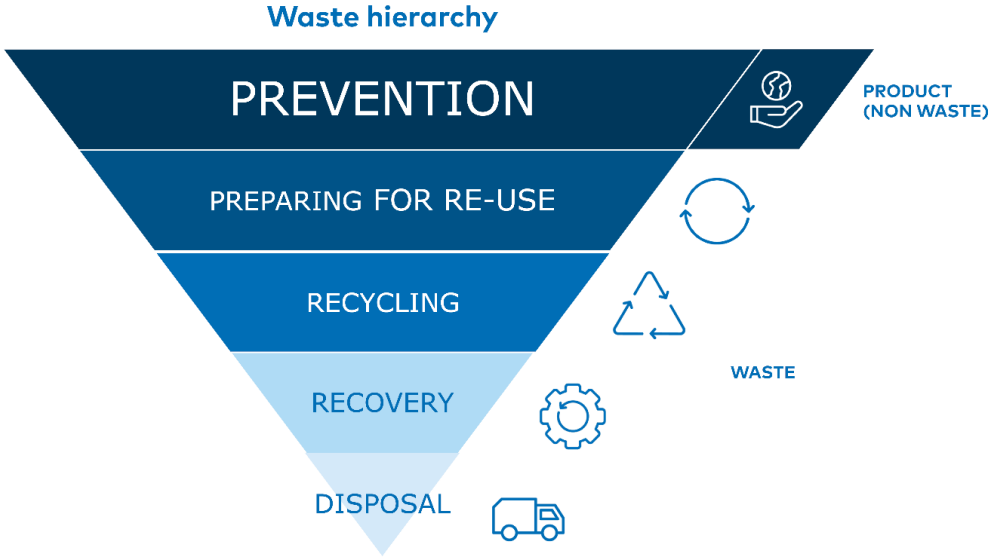


Figure 1. EU Waste Hierarchy according to the EU Watse Framework Directive.

environmental impact and to promote the transition to a circular economy. It includes all waste generated in the construction and demolition of buildings and infrastructure and contains materials such as concrete, bricks, wood, glass, metals, and plastic. (European Commission 2024c)

The target set in the Waste Framework Directive was to increase the preparing for re-use, recycling, and material recovery to a minimum of 70% of non-hazardous construction and demolition waste by weight by 2020 (European Commission 2024c). Based on national statistics, the current recovery rate is only 43%, 44%, and 55% for Sweden, Norway, and Finland, respectively, while rates of 82% and 92% have been reported for Iceland and Denmark (Nordic Council of Ministers 2023). This means that most of the countries are not reaching the recovery target. Other targets set in the directive include enabling the removal of hazardous substances, promoting the selective removal of materials, and reducing waste generation (European Commission 2024c).

The Nordic cooperation works towards the vision of the Nordic region as the most sustainable and integrated region in the world in 2030. To meet the goals of the Nordic vision, three priorities are pursued: a green Nordic region, a competitive Nordic region and a socially sustainable Nordic region. This study supports the strategic priority, "A green Nordic region", that focuses on promoting green transition and working towards carbon neutrality and a sustainable circular economy. The strategy includes the goal "Resource-efficient and non-toxic cycles" and the Nordic vision program "Nordic Sustainable Construction" and "Nordic Network for Circular Construction". (Nordic Innovation 2024)

The Nordic Smart City Network is created in collaborations with Nordic Innovations and Climate-KIC. The Nordic Smart City Network objective is to explore the Nordic approach to crafting cities that are both sustainable and liveable. The network shares experiences and best practices, aiming to make the cities better for the citizens (Nordic Smart City Network 2024). In this study, the cities Tampere (Finland) and Stavanger (Norway) joined as partners to explore the circular economy maturity and challenges in the Nordic region in the building sector. Additional to these cities, Stockholm (Sweden) and Copenhagen (Denmark) supported the study as so-called Follower Cities, i.e. not as a project partner, but participated in the study by

contributing to the results.

In addition to EU level targets and legislation, the Nordic countries have their own regulations concerning circular economy. Some of these are introduced in the fol-lowing two subsections for Finland and Norway.

2.1.2 Finland

EU regulations set the basis for Finland's legislation related to circular economy, but stricter national level strategies and regulations also exist (Nordic Council of Ministers 2023).

To facilitate the transition from linear economy to a circular one, Finland has prepared a strategic programme to promote circular economy. The vision introduced in the strategic programme is to make circular economy the basis of national economy by 2035. The transition is seen as an opportunity to strengthen the economy and to increase employment concurrently with decreasing resource use and the related environmental impacts. However, the transition is considered to require a comprehensive change in societal level planning and decision-making as well as in attitudes and behaviour among companies, households, and consumers. (Finnish Government 2021)

The real estate and construction sector plays a significant role in circular economy as it uses a major share of all steel, concrete, wood, and plastic used in the whole country. Keeping these materials in use as long as possible helps in decreasing the related emissions. The effect becomes even more pronounced in the future as the energy sector becomes less carbon-intensive and an increasing share of buildings' life cycle emissions originates from production of materials. (Finnish Government 2021)

Considering that real estate and construction sector is one of the least digitalized sectors, there is a great potential for new innovations. A significant increase in investments in new technological solutions in the sector has already occurred. (Finnish Government 2021a)
One of the targets in real estate and construction sector is to make carbon neutral circular economy a priority and to significantly decrease the resource-use-based emissions by 2035. The action plan towards achieving the target includes the following steps

(Finnish Government 2021b):

- Using economic incentives to advance circular economy solutions
- Establishing a network of circular economy experts.
- Creating digital solutions to support the reduction of environmental impact.
- Developing the regulation of construction and zoning to support circular economy.
- Increasing the efficiency of space utilization.
- Developing procurement criteria that supports circular economy.

In addition to the strategic programme to promote a circular economy introduced by the Finnish Government, Sitra, the Finnish Innovation Fund, has published a road map to the circular economy. The road map has been created to help Finland to make the transition to circular economy and consumption based on the use of services. It targets the challenges posed by climate change, overconsumption of resources, and biodiversity crisis. The road map contains four strategic goals to achieve the targets: (Sitra 2024)

- Reshaping competitiveness and vitality by placing circular economy solutions at the core of the economic growth strategy.
- Shifting to low-carbon energy along with promoting the efficient use of energy.
- Valuing natural resources as scarcities instead of relying on their limitless availability
- Harnessing everyday decisions to act as catalysts for change. Cutting carbon footprint requires a new kind of approach to ownership.

All sectors need to address the issues. The government, towns and cities, businesses, and citizens all have their own roles. Examples of concrete actions provided in the road map include using public procurement to accelerate the circular economy, developing tools for manufacturing industry to help companies transition to circular economy, and creating circular economy criteria for the construction sector. (Sitra 2024)

One of the most important regulations concerning the buildings and construction sector in Finland is The Finnish Land Use and Building Act. The act is currently being revised, and the new Building Act is coming into force in January 1st, 2025. The revision aims to combat climate change, advance circular economy, improve the construction quality, improve the proficiency of construction projects, and support the digitalization of the built environment. Also, actions to cut down the administrative burden and bureaucracy, clarify the right of appeal, and clarify the liability of the main implementer will be included. (Ministry of the Environment 2024a) The new Building Act will set the preparation of a construction and demolition waste survey as a requirement for construction and demolition projects. (Finnish Government 2022a)

The Building Act is supplemented by decrees concerning specific waste streams. These include a decree on the utilization of certain waste materials in earthworks without an environmental permit process (Finnish Government 2017) and a decree on the End of Waste procedure for concrete waste (Finnish Government 2022b). The End of Waste procedure makes it possible to remove the waste status and to utilize the crushed concrete as aggregate in construction, earthworks, and concrete production, and as fertilizer, soil conditioner, liming material, or plant substrate.

The 2021 revision of the Finnish Waste Act aims to decrease the amount of waste and to increase reuse and recycling. The different waste fractions are required to be sorted and collected separately, and the sorted fractions are not allowed to be land-filled or incinerated. In construction projects, it is required to minimize the amount and toxicity of waste generated during the project. Usable parts and materials must be collected and reused whenever possible, and separate collection must be arranged for main material fractions such as concrete, asphalt, untreated wood, and metal. Hazardous waste must also be collected separately and treated properly. The minimum target for construction waste utilization is 70% by weight, excluding soil, rock, and hazardous waste. (Ministry of the Environment 2024b)

2.1.3 Norway

The Government's ambition is for Norway to become a pioneer in circular economy by creating policies that support the development of green value creation and competitiveness. Construction and buildings sector has been identified as one of the sectors having the greatest potential for circularity and competitiveness. The "Norway's strategy for developing a green circular economy" was launched by the Norwegian Ministry of Climate and Environment in 2021, stating that the government will support local authorities to promote circular economy by, among other things, providing better guidance on the re-use of materials and updating national requirements. Cooperation with construction and buildings sectors has already been initiated to enhance digitalization and data distribution of product information, which further facilitates to identify products with highest re-use potential. The strategy underlines the role of actions of the central government itself to promote shift to circular economy by showing example in its own operations, in addition to which, it can support solution-oriented innovations by directing the market to promote circular economy through various policies and regulation (Norwegian Ministry of Climate and Environment, 2021b). For example, transport and manufacture of construction products emissions are either taxed, under other regulatory measures, or will be regulated under the EU Emissions Trading scheme. This means that construction product choices, such as using Norwegian timber, can have a positive impact on Norway's greenhouse gas inventory through being accounted as removals in the land use, land use change and forestry (LULUCF) sector. The ambitious target aims to decouple Norway's waste generation from economic growth and to maximize re-cycling and energy recovery. (Norwegian Ministry of Climate and Environment 2021a)

The Norwegian construction and buildings sector has adopted many progressive climate-friendly and circular economy initiatives. Using fossil oil to heat buildings was prohibited as early as in 2012, and under the Regulations on technical requirements for construction works, installing fossil fuel-based heating systems in new (buildings) is also prohibited. In addition, the present Government intends to facilitate a transition to fossil-free construction sites by 2025. (Norwegian Ministry of Climate and Environment 2021a)

Norwegian laws and regulations related to construction and buildings sector include regulations on technical requirements for construction

work (Byggteknisk forskrift), the waste regulation (Avfallsforskriften), and the Pollution Control Act (Forurensningsloven). The minimum technical requirements for construction and buildings are given in the Byggteknisk forskrift (Direktoratet for byggkvalitet 2024). The requirements related to construction waste include minimizing the quantity of waste generated during the construction project and choosing materials suitable for reuse and material recovery. In addition, a waste management plan shall be prepared, a minimum of 70 % of waste shall be collected separately and treated appropriately, and a final report describing the realized disposal of waste shall be prepared in specific larger projects. The technical regulations states that projects regarding demolition and rehabilitation must perform mapping of hazardous waste before demolition and from all building fractions that shall be removed. The projects must also perform mapping of materials that are suitable for reuse. Reporting of the results is required, but there are no requirements for the utilization of the materials suited for reuse. All new buildings must be planned and built for easy disassembly in the future, in order to increase the reuse of materials and thereby reduce the waste from demolition projects.

In the waste regulation, regulations on the recycling and treatment of waste are provided (Avfallsforskriften, FOR-2004-06-01-930). Regarding construction and buildings sector, the waste regulation sets limits for hazardous substance content in concrete and bricks to be reused in construction and sets requirements to the documentation of such materials so that the whole reuse process is transparent and traceable. It also provides regulations on storage, transport, and handling of hazardous waste.

2.2 Circular economy on a partner city level

2.2.1 Tampere

In Finland's strategic programme to promote a circular economy, municipalities are seen as having a key role in advancing the transition. Municipalities can promote the efficient use of resources by planning and zoning policies that favour longlived, resource efficient, and modular building. They can also set circular economy criteria for plot leasing and develop resource efficient policies for coordinating soil masses. (Finnish Government 2021)

City of Tampere has committed to promote climate and biodiversity and aims to become carbon neutral by the year 2030. The target is pursued through, among other things, carbon neutrality in acquisitions, construction, space use, and services. Advancing the transition to circular economy is part of the city strategy. (City of Tampere 2023)

The Tampere circular economy plan states that the city has a significant role in creating a society based on circular economy. The principles of circular economy should be integrated in the city's strategies and policies to allow a functioning cooperation between the public and private sectors. This will enable the development of new business activity and thus have a positive impact on the local economy. Circular economy is seen as having a key role in combining the advancement of both the economic and the environmental targets. The city is at once an actor, an enabler, a director, a partner, and an educator. (City of Tampere 2022a)

Tampere has also published a road map to support reaching their carbon neutrality target by 2030. It includes concrete plans and goals for the construction sector. The city plans to improve the energy efficiency of its own buildings and to use 80% carbon neutral energy in its properties. The share of wooden buildings out of all new apartment buildings will be increased from 10% in 2021 to 20% by 2030. In addition, the efficiency of space use will be increased, carbon neutrality criteria will be applied in all phases of construction projects, recycled materials will be utilized whenever applicable, low-emission fuels will be used in construction equipment, and instructions will be created to help all actors in tak-ing the environmental aspects into account in construction projects. (City of Tampere 2022b)

2.2.2 Stavanger

As stated in the Climate and Environmental Plan 2018-2030 adopted by the Stavanger City Council in 2018, around 11 % of local GHG emissions in Stavanger originate from stationary energy such as material use in buildings, municipal technical systems and construction work, and energy use in industrial installations.

Objectives related to energy and material use in building and construction sector include increasing the proportion of local renewable energy sources and cutting GHG emissions from buildings and construction sites by 80 per cent by 2030 and by 100 per cent by 2040.

In order to meet these objectives, the city of Stavanger is committed to; 1) set stricter environmental standards for new municipal buildings; 2) obtain an over-view of energy sources and consumption patterns throughout the city and, in collaboration with building owners, work to replace fossil energy with fossil-free or emission-free energy; and 3) phase out all fossil-based energy sources in municipal buildings by 2020, and on municipal building and construction sites by 2021. (Stavanger Kommune 2018)

3 Assessment methods

In this study, several methods for gathering and assessing data were used. An assessment framework was developed in order to evaluate the implementation of circular practices in the cities. For additional information, interviews were conducted with key persons both in the two project cities and in the two follower cities. The interviews gathered insight into how circular economy practices are implemented in the cities, and what the successes and challenges, as well as the lessons learned are from the cities' point of view. Also, a questionnaire was sent to follower cities in the Nordic Smart City Network. In Tampere, a work-shop of the preliminary results was held, bringing together both city representatives from different departments and representatives from the construction sector.

The insights obtained by using the assessment framework tool, from the interviews and questionnaire and the workshop have been utilized in describing the pilot projects and the general situation in the cities, and in analysing the successes and challenges of the projects.

3.1 Assessment framework and initial data

The initial data received from the cities was evaluated using a specific framework developed for assessing the level of circular economy in construction and building sector of the cities. The framework is an excel-based tool which uses specific checklists from various themes to screen the level of circular economy maturity in different stages of the life cycle. The tool maps the situation from zoning and land use to the project planning, tendering and finally to the implementation phase. If applicable, the assessment was also extended to include consideration of circular economy in the use phase and in the End-of-Life phase.

In addition to different life cycle stages, the framework tool assessment was organized by themes including the following:

- reasons and objectives of the projects related to circular economy
- the use of LCA/LCC in project planning, tendering process and implementation.
- the role of communication and the use of IT related to circular economy.
- challenges faced in the project related to circular economy.

The project data was screened at AFRY by using the framework tool. Observa-tions and conclusions were compiled in AFRY's internal workshops and possible open questions were gathered to be completed in the interviews.

3.2 Questionnaire and interviews

As part of the assessment, a questionnaire was prepared to create a city-specific understanding of the status and future prospective of circular economy of construction and buildings in the following Nordic cities: Copenhagen, Helsingborg, Helsinki, Oslo, Reykjavik, Stockholm, Syddjurs, Århus. The question-naire consisted of 15 questions, 10 of which were mandatory including both multiple choice and open questions focusing mainly on mapping the state of on-going and upcoming pilot projects, but also the reasons for the possible absence of projects. The aim was also to find out the respondents' views on the most effective measures to promote circular economy and to prioritize the related objectives. The questionnaire was sent by e-mail to contact persons in the Smart City Network. Only two responses to the questionnaire were received.

Interviews were conducted to supplement the data received from each of the pilot projects and the questionnaires. One interview was held in Stavanger and five in Tampere. The interviewees were mainly city employees who had the main responsibility or another essential role in carrying out the pilot projects in question. In Tampere, one interview was held with the construction company. In the follower cities, two interviews were conducted with three sustainability strategists in Stockholm and one interview was held in Copenhagen with a sustainability strategist and contact person for the Smart City Network. The interviews were conducted based on predefined questions and free format discussion. The interviews aimed to answer follow-up questions about the pilot projects and questionnaire results, as well as to understand how circular economy principles and practices are implemented in the daily work in the cities.

The interview and survey questions are provided in Appendix 1.

3.3 Workshop

The stakeholder engagement workshops were planned to foster interaction in each city and gather input on circular construction practices, aiming to enhance collaboration and communication within the sector. Workshops were to be organized in each city, but due to lack of resources in the cities, only one was organized in Tampere. The workshop provided important insights for the analysis of the pilot project success factors, challenges and especially for the co-development of concrete actions to overcome the challenges identified.

4 Circular construction pilot projects in the project cities

This study focused on describing the status of circular building in the Nordic cities by studying the ongoing circular pilots. For Tampere and Stavanger, selected pilots were assessed on a more detailed level, by looking at e.g. tendering and other documents and requirements. For the follower cities, Stockholm and Copenhagen, based on interviews, a more general status was assessed, and pilots were regarded on a more general overview level. The majority of circular building pilot projects, and all the projects regarded in this study, focused on material recycling and material reuse. Only a small part of the projects and resources is directed to e.g. circular design and other aspects of circularity.

4.1 Pohjois-Hervanta school, Tampere

The old Ahvenisjärvi school in Tampere was to be demolished, and a new building will be constructed according to circular economy principles. The demolition of the old school was in progress at the time of this study, and the construction of the new school building started in spring 2024 (City of Tampere 2022c).

The aim of the project is to gather data for circular economy possibilities and to learn what must be done differently in the demolition phase to be able to reuse the building elements. Life cycle assessment and life cycle costing were utilized in the project planning phase, and a demolition survey was conducted for the old building to investigate the reuse potential of the building materials. Parts found to be possibly reusable include the air conditioners, some of the newer windows and doors, and a steel shelter that can be refurbished.

However, although a demolition survey has been carried out, it's focus is highly traditional and concentrates on material recycling rather than on reuse with higher material value. The demolition survey revealed that the structural elements cannot be reused but may be usable in earthworks elsewhere. Interim storing has posed challenges in the project as the need for it had not been considered early enough, but only in the planning phase. This has challenged also utilizing the demolished concrete at site and, together with lacking indication of utilization requirement, caused the concrete to be taken elsewhere for utilization.

The demolition phase involved a circular economy operator who has done material surveying of construction elements and movable furniture. Some of the furniture has been donated or sold at auction through a public digital platform (Kiertonet). This has been perceived economically unproductive and laborious even though donation can be seen to have some positive social impacts.

The project has involved dialogue with designer to facilitate reuse of elements and workshops in the implementation planning phase to promote design for disassembly (DfD) in the new building. However, DfD was perceived difficult by the designers and raised questions like how to put demolition instructions in design drawings and how to predict decades from now how the demolition methods and practices will develop? Designers found it easier to focus on designing building parts to be accessible (openable) so that HVACE can be renewed and

repaired when necessary. This would help to change the renovation construction into more of an interior renovation type of a work. The project is expected to gain experience especially on the extension of the life cycle by improving repairability.

The challenges in the project also relate to design of the new building as it has not been designed with the reuse in mind. However, design solutions of the new building do include the use of materials with high recycled content.

The goals, key findings, successes and challenges of the project are described in Table 1.

Goals	• Gathering data for circular economy possibilities • Finding solutions for the reuse of building elements • Extending the building's life cycle by design choices • Utilizing Design for Demolition principles
Key Findings	• Demolition surveys can promote circular economy, but the current practice is found to be non-ideal. • Transition to circular economy requires a shift in the conception of property and its management. • Investigating the reuse potential of building materials is resource intensive.
Successes	• Ease of renovation has been considered in the design of the new school building. • Although the concrete from the old building could not be reused, it will be crushed and utilized in another project in the city.
Challenges	• The structural elements of the old building were found to be unsuitable for reuse. • Design for Demolition was found to be difficult to put into practice. • Interim storage of dismantled materials has been a challenge. • Reuse planning was started too late in the process.

4.2 ReCreate, Tampere

City of Tampere is part of the international ReCreate project coordinated by Tampere University and funded by EU Horizon 2020. The project is not actually the city's own project, but a four-year international development project carried out in cooperation with different stakeholder groups like educational institutions. One of the case studies is in Tampere which is why the city is an official partner in the project.

The project aims to find ways of removing concrete elements without damaging them and reusing them in new buildings as part of a profitable business. It also targets some of the obstacles hindering the transition, such as legislation and lack of business models and national value chains.

Pilot projects are carried out in four countries, Finland, Sweden, the Netherlands, and Germany, in which buildings scheduled for demolition are instead dismantled, and the precast concrete elements are used as structural parts in new buildings. The pilot project in Tampere consists of dismantling an apartment building, refurbishing the building elements, and finding ways of reusing the elements in constructing, for example, new parking spaces and yard areas.

The project in Tampere investigates how the used concrete elements could be removed intact and reused and what it takes to make reuse a profitable business. As ReCreate is an EU-funded project, only deliverables published at the time of this study were available as initial information. The information was supplemented by interviewing a city employee whose working time is partly divided into ReCreate project management. The same employee resource has also been used in the development of the circular economy plot lease criteria in the Kissanmaa-project.

According to the interview results, the main focus of the project is to promote scaling of reuse. The biggest challenges in the project have been both the proof of eligibility and the interpretation of dismantled elements as waste. Thus, a need has been identified for increasing information and clarifying the practices. These discussions with the authorities have been the most important and an essential part of the project from the city's point of view. The discussion about waste legislation and End of Waste-regulations has involved several authorities from the city of Tampere, the city of Kangasala and from the Ministry of the Environment. As a result, the Ministry of the Environment issued a statement on

the interpretation of reuse and classification as waste. The statement clarifies that cleaning and detaching reusable concrete elements according to a pre-made plan, combined with the quality of actions performed at the intermediate storage site, indicate that these actions are not directed towards waste, but rather towards products. The same quality requirements apply to reusable concrete elements as to equivalent new building products. So, the reusable elements are not in any phase considered as waste and can therefore be reused without an EOW-process. Concrete elements can become waste, however, if their technical suitability for new construction deteriorates or if other factors emerge that reduce the likelihood of their intended reuse. In terms of proof of eligibility, the challenges have been considered together with Helsinki's circular economy clus-ter and Building Control Services (RAVA).

The goals, key findings, successes and challenges of the project are summarized in Table 2.

Goals	• Studying the reuse potential of removable concrete elements • Making dismantling and reuse economically profitable
Key Findings	• The project has yielded useful information for the city to be utilized in its processes. • Need for more knowledge among municipalities has been recognized. • Authorities need clearer procedures related to reuse. • Reuse must be considered already at the design phase. • Creating market and demand for reuse of building elements must be encouraged.
Successes	Communication with public authorities to clarify the procedures related to reuse of building elements
Challenges	Dismantled building elements have basically been considered to be waste by the environmental authority

4.3 Kissanmaa circular economy themed plot leasing, Tampere

A circular economy themed plot leasing was carried out in Kissanmaa, Tampere in 2022 (City of Tampere 2022d). The project focused on an apartment building property that was leased to an applicant based on circular economy criteria. The proposal had to include a concept level plan of how the construction project carried out on the property would utilize building elements and materials according to circular economy principles.

In the Kissanmaa circular economy themed plot leasing process, the city, as usually, made the decision based on the land use strategy, but in Kissanmaa the city additionally ranked companies based on the CE concepts proposed. Similar concept processes have been used with different themes in years, e.g. in 2023 the theme was energy efficiency. During the process the applicants were obliged to deliver objectives and a concept level plan of how they would utilize building elements and materials according to circular economy principles in the construction project. In addition, the calculation of the carbon footprint and hand-print during the lifecycle of the building was required as a criterion for plot lease added to a normal land lease process. The project was not carried out as a competitive tendering but more on a concept level.

The concept plans were evaluated based on quality and innovation. Reuse of the building elements in their original applications was given the highest grade (The cascading principle). The plan introduced in the winning proposal included the use of dismantled concrete elements and recycled wood, bricks, and windows from other buildings.

In the process, the applicants were given the freedom to present the circular economy solutions they deemed fitting. Although a broad definition of circular economy posed challenges with comparability, it was seen as a positive way to set demands as it allowed for large variation of proposals and offered valuable insight into how circularity is seen by contractors. The message from the contractors was also very positive. These kinds of incentives are seen as very important enablers of the circular economy: incentives increase the courage to embark on circular economy projects, which in turn increases experience and competence and reduces the risks in the future.

How the solutions and CE concepts are to be implemented and monitored by the contractor will be evaluated as a part of the building

permit application process. However, according to the city's representative the authorities' possibilities to monitor the implementation and achievement of the goals during the construction and use phase are limited.

Some challenges arose from the fact that circular economy had not been considered in the zoning process: there were no space reservations for interim storage. The project had also had challenges with the quality of the demolition materials, and for example, the bricks originally planned to be reused could not be utilized due to their poor quality. The proof of eligibility of the materials has been based on sitespecific evaluation and, according to the contractor's representative, has worked well in the project.

The project faced a delay in implementation when the donor building was destroyed by fire. The material testing and demolition plans prepared for the donor building are therefore unusable and currently a new donor building is being sought for the project. This will pose some challenges also on the update and comparison of CO2-calculations between the concept and implementation phase.

As a result of the project, the city started considering separating the plot transfer and leasing from land policy in the future, so that the plot transfer could be carried out as a tender competition. The goals, key findings, successes and challenges of the project are described in Table 3.

Table 3. The goals, key findings, successes and challenges of the Kissanmaa plot leasing project.

Goals	• Executing a plot lease process utilizing circular economy criteria. • Creating a market for low-carbon and innovative construction practices.
Key Findings	• There is a demand for this kind of market-based procedures. • Monitoring how well the circular economy objectives and plans are met is necessary but may pose a challenge. • Clear policies and procedures regarding the circular economy aspects of construction projects are needed. • Digital marketplaces for reusable materials are needed.

Successes	• The circular economy criteria have gained significant interest and are being further developed. • The procedure was evaluated positively by contractors.
Challenges	• Circular economy aspects were not considered during zoning, and e.g. the size of the property has posed a challenge for interim storage. • Rating of the concept plans was not seen as being transparent enough.

4.4 Tampere soil data bank

Tampere soil data bank project aims to gather data on soil types and quantities from both public and private sites. The data will be transferred to a map app to be used by anyone. The project is not directly related to circular economy but gives information to and acts as an example for creation of building materials focused data banks.

The project differs from other Tampere's projects as it is more of a development work related to a digital tool needed to manage soil masses at city's construction sites. The development work was started with an external consultant to generate a QGIS-based tool that would allow data input and enable mass data tracking and follow up both on the map and in QGIS-reports. The city's interim storage areas were supposed to be integrated into the tool. However, the result did not meet expectations. The reason for this was an incomplete definition of client's need and partly also unrealistic expectations in relation to the software used. Hence, the tool has not been taken into use, but has only been tested on a small scale in the city's infrastructure projects. The development work is supposed to be continued by simplifying the tool. At the moment, the city of Tampere has purchased a tailored commercial application for monitoring the reception information of masses. The purpose of digital solutions in mass monitoring is to generate up-to-date information on the future excavations, track their transportation destinations and to monitor the proportions of masses land-filled vs. the ones utilized in soil construction. This study suggests that if platforms were developed regionally and collectively among several municipalities, the costs and risks would be distributed, and more could be achieved with less.

The role of soil mass management is crucial for achieving the objectives of lowcarbon construction. According to the interview, the biggest obstacle for integrating the soil mass management more efficiently in the city's processes is the lack of data on the soil quality. In the current situation, the soil quality is usually revealed at the construction site because preliminary surveys related to the soil quality have not originally been part of the "planning-as-usual", and there is ambiguity about the responsibilities related to conducting these types of surveys. Soil masses have also normally been the responsibility of the contractor which has made considering the issue in advance even more challenging.

The management of masses is also related to other types of materials deriving from construction sites, mainly demolition waste. Cooperation is carried out with Tilapalvelut, an organization responsible for development and maintenance of public properties in Tampere. The cooperation has involved screening possible nearby targets for utilization of demolition materials, mainly demolished concrete to be used as concrete crush. A more sophisticated utilization and upcycling of demolished materials is rather seen as the business of private operators as it requires significant resources. For this reason, also the storage network of materials cannot be very complex as the management and quality control of it would become too demanding.

In addition to the need of preliminary information on soil quality, the role of interim storage areas was brought up in the interview as one of the biggest requirements for the implementation of the circular economy. Within the dense urban structure, the lack of space causes problems. The interview also emphasized the importance of dialogue between the parties well in advance. A timely dialogue and preliminary investigations guarantee the best chance of success. In Tampere, the networks are already quite well formed but despite foresight and cooperation, matching schedules is still what determines success at the project level.

The goals, key findings and challenges of the project are described in Table 4.

Goals	• Creating a data bank containing geographically specific data on types and quantities of soil masses located on public and private properties. • Supporting the coordination of soil masses and promot- ing sustainable building practices.
Key Findings	• There is a need for clear division of responsibilities regarding the reuse of soil masses. • Timing of supply and demand between separate projects is difficult without a responsible actor. • A national or regional level digital platform might reduce costs and serve the needs better than local endeavours. • Need for environmental permit for interim storage is hindering the processes, which could be avoided by proper coordination.
Challenges	The developed app has not been used as it did not meet the expectations

Table 4. The goals, key findings and challenges of the Tampere soil bank project.

4.5 Mosvangen kindergarten, Stavanger

The construction of a kindergarten in Mosvangen in Stavanger is a pilot project focusing on circular economy and sustainable building practices. Solid wood will be used in the loadbearing structures. The construction site will be emission-free, and according to calculations, the building will cause 72% less greenhouse gas emissions compared to conventional buildings. Solar energy will be produced on the roof of the building, and the house is designed to produce more energy during its lifetime than is used to produce the materials and build, operate and demolish the building. The building will be certified at BREEAM-NOR level Outstanding.

The city project manager coordinating the project was interviewed. At the time of this study, the project is still in its planning phase, and construction has not yet started. Even so, the BREEAM standard will set the circular targets for the building. The pilot project will focus on maintaining the foundations and concentrating on low-emission

materials and energy-efficiency. The building Mosvangen kindergarten is planned to act as a donor building as well. The goals, key findings, successes and challenges of the project are described in Table 5.

Goals	• Building according to circular economy practices and implementing an emission free construction site. • Using solid wood in the load-bearing structures. • Producing more energy than is used by the building during its lifetime. • Based on principles outlined in the city's climate plan.
Key Findings	The project is not yet in the construction phase, which means that the observed impacts and practices cannot yet be verified.
Successes	• Goals related to circular economy and the achieved benefits are clearly and comprehensively defined. • BREEAM targets and their surveillance have been included in the Environmental Follow-up Plan.
Challenges	No clear challenges were identified or outlined based on provided data. Based on interviews there might have been some degree of lack of resources for monitoring and project management.

Table 5. The goals, key findings, successes and challenges of the Mosvangen kindergarten project.

4.6 Stavanger town hall

One of the pilot projects in Stavanger is the renovation of the Town Hall. The Stavanger town hall is being extensively renovated and rebuilt. The building will be a passive house with an energy rating of A, BREEAM-NOR certification. The project aims to be the region's first fossil-free building site. 75% of the concrete is planned to be reused. Solar cells will be installed on the roof and facades, and the town hall is to become the "Norway's smartest building".

Many of the materials from the original 1963 building were planned to be re-used, such as the terrazzo stairs, lamps, railings, bricks, brick walls, and a wall clock. The original essence and feeling of the building were to be retained by combining the characteristic historic features with modern use of materials and technology. Stavanger Town Hall consists of two separate building bodies, which both were originally planned to be preserved. However, the concrete structures of the low-rise part were found to be so weak that they had to be demolished, and a new body is being built instead. Elements of solid wood are being used.

In this study, the city project manager coordinating the project was interviewed. The townhall project has advanced to the building stage, and the interview focused on how the circular practices are being implemented in the project, but also in Stavanger in general.

In the townhall project, the solutions in the tender competition phase were pre-determined internally by city officials in cooperation with architects. Thus, the contractor's contribution was limited to the implementation. In the contract competition criteria, the scoring was based on experience in renovation con-struction. In addition to the site manager and BREAAM monitoring personnel, the contractor was required to appoint a specific person to monitor the circular economy in particular. The circular economy ambition is largely set by the BREEAM standard. Finding resources for setting and monitoring ambitious circu-lar targets has been recognized as a challenge.

The main circularity target in the townhall project was to maintain the load-bearing structures and by this way reduce the material footprint. The materials from townhall are not predetermined to be used in any other project. The city of Stavanger has a large facility with personnel available for the interim storage of demolition materials. Norway currently has a couple of public digital platforms available for the use

of circular economy. The city of Stavanger has started a request for proposals in order to get its own digital application in use during next year. The goals, key findings, successes and challenges identified in the project are described in Table 6.

Goals	• Implementing the region's first fossil-free construction site and creating one of the country's smartest buildings. • Preserving the load-bearing concrete structures. • Based on principles outlined in the city's climate plan.
Key Findings	• Majority of sustainability goals and measures derive from BREEAM. • The requirements were set, and the plans made for the project mostly by the city itself, leaving little room for the contractor to innovate. • Much of the emphasis is given on achieving a fossil-free construction site and a high rate of waste sorting.
Successes	• Objectives are clearly set and exceed the minimum legal requirements. • Most of the demolition waste (approximately 96%, according to city representative) was successfully sorted on-site. • Load-bearing structures of the high-rise part of the building were preserved and are being reused in the new town hall.
Challenges	• The structural elements of the low-rise part of the building were found to be too weak for reusing and had to be demolished. • A lack of personnel resources.

Table 6. The goals, key findings, successes and challenges of the Town Hall project.

5 Circular construction in the follower cities

Supplementary interviews were conducted with Stockholm and Copenhagen. The interviewees were sustainability strategists who worked with circular economy issues in several ways.

5.1 Stockholm

In Stockholm, the development of the circular economy is strongly focused on the Royal Seaport area. The city has a specific politically determined vision for the area which serves as a higher level agenda for more practical level goals. The goals have been set in cooperation with developers and numerous stakeholders. This has involved a diverse dialogue with developers to ensure commitment to the goals and to increase understanding of the requirements and related practicalities (e.g. if and when certificates are needed). The goals have been included in plans to provide guideline for contractors. Some freedom has been set also for contractors in implementation and on how to achieve the set targets.

In the Royal Seaport, the circular economy focuses on soil masses due to their significant amount and high level of contamination. Renovation methods have been considered together with contractors. Tendering processes focused on finding the best costclimate solutions. Goals have been set in the project area e.g. for the maximum permitted amount of construction waste as well as for energy use, waste and wastewater treatment and heat recovery.

In addition to Royal Seaport, the city has various other circular economy projects as well and a specific organizational team (Centre for Circularity) that works to promote the reuse and circularity of plastics and building materials. The Centre for Circularity works as a support function for other departments and coordinates the implementation of the City's action plan for circular construction. The team recognizes procurement as one of the main strategies to promote circularity in construction. Practices tested and applied in procurement processes include examples like "save as much material as possible" type of tendering and scoring bonuses for each saved kg of CO2.

Other areas of focus at Centre for Circularity also include waste statistics digitalization, planning process implementation, logistics and legal issues related to circularity as well as creating markets for reused materials. Waste digitalization involves development of data collection to improve the quality of statistical information on construction waste on a national level. The team has also worked with experimental activity related to social aspects in terms of offering work training in refurbishment and logistics. Stockholm is planning to upscale this activity to also include construction materials.

Specific resources (personnel) are also directed to monitor the achievement of goals by controlling and guiding developers on practical issues like, for example, how to carry out energy and climate calculations correctly and what documentation and certificates need to be submitted.

The lack of facilities has always been a challenge to circularity also in Stockholm. At the moment, the city has a construction consolidation centre outside the city and a new reuse centre being established. At the consolidation centre the main focus is on soil masses and infra products (e.g. stones), but there's some opportunity to store and sell surplus new construction materials, also to consumers. The new reuse centre could possibly also offer sanitaryware for reuse.

The challenges of circularity in Stockholm roughly divide in technical, organizational and financial issues. Many of the challenges are overlapping in nature.

Technical ones include ambiguities in warranty issues and strict demands from product legislation. At the moment, there are no clear common processes for determining the eligibility and applicability (i.e. type approval) of materials. This leads to the need for improvisation and requires personal ambition from project leaders to promote reuse. However, there is a national level development going on in terms of type approval and quality assurance (www.ri.se). Technical suitability has also been challenged by the poor quality of the materials due to the lack of maintenance of existing buildings.

Issues with approval also link to challenges with responsibilities between a donor and a recipient building, which are a large barrier to reuse at the moment. At the project level, some products have been successfully approved (e.g. concrete beams). Some companies are also providing guarantees for reused products but so far this has been a pilot type of an activity. But given the rapidly evolving markets, innovation within the industry and updated legislation, these issues are expected to be resolved in near future. Infrastructure products and soil masses are easy to reuse as they require no product certificate.

There are also challenges with the overall implementation and quality of construction. Energy and emission calculations by contractors are usually checked couple of years after commissioning the building. Quite often the plans and implementation do not match. For example, new passive houses have not met the

requirements set for them due to errors in construction processes. This has led to a dialogue and investigation of the causes of failures. It has been recognized that in order to ensure continuous improvement at city level, it is important to identify the possible mistakes connected to urban planning. The aim is also to educate city administration and urban planners on how, for example, solar panels should be placed, or how preservation and transformation can lead to huge gains in climate impact or in resource efficiency.

Financial challenges include issues such as the lack of existing circular business models. Demonstrating the monetary value of circular economy is the goal also in Stockholm but has been challenging to scale so far. Most likely the emergence of a monetary benefit will become easier as learnings from circularity make it easier to gain profits in the next project. Recent increase in material prices has also contributed to the increasing value of preserving materials. Good examples are shared but project partners are prone to hesitation and prefer traditional in case of any financial uncertainty.

One of the biggest organizational challenges links to getting everyone involved. This is also the reason for starting the Centre for Circularity in Stockholm. Circular Economy is not natural for municipal actors, so it is challenging to make people change their ways of organizational decision making. Circularity would naturally also require breaking the silos between departments. For example, it is identified that cooperation with zoning needs more attention. A good way seems to be to appoint a "circularity" person within each department to ease up the communication, as specific departments tend to have their own work language which can lead to instructions coming from outside being perceived as ambiguous.

Organizational challenges also concern various practical issues. For example, consolidation centre can be used for storing and selling companies' own materials. However, also the use of own materials involves a lot of new procedures like how invoicing is handled, etc. All this is seen as extra work and keeps the companies stuck in their traditional practices. The perception of the people working with circularity is that the command needs to come from high enough to make organizations responsible for meeting the goals of municipal climate plans.

Other organizational challenges include the lack of life cycle thinking which easily leads to a wrong focus. The Environmental Program of Stockholm only recently highlighted for the first time the

importance of avoiding demolition. Focus is strongly on operational carbon instead of embodied, meaning the impacts from the use of materials are neglected.

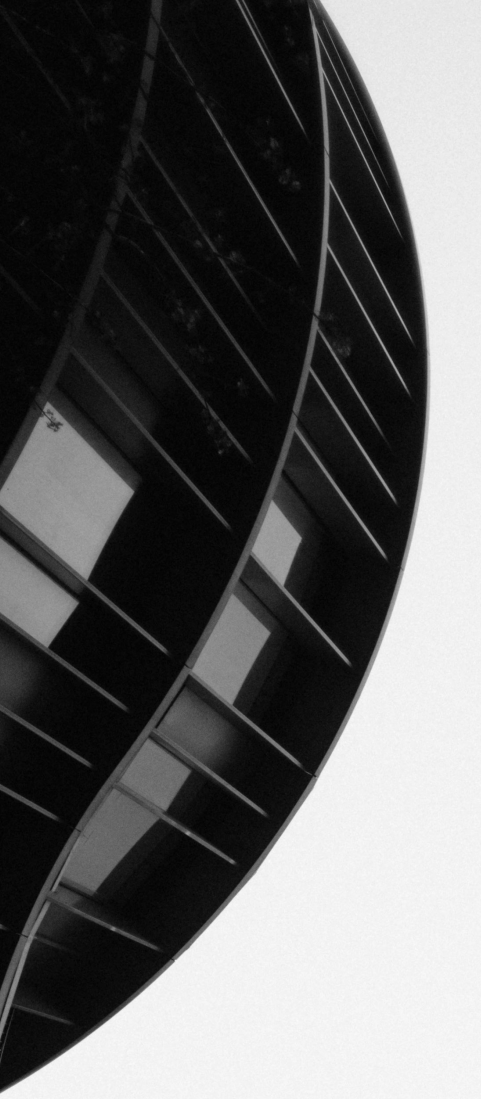
There are also issues with the city planning department concerning building permit processes that require information on the appearance of a new building well in advance. In circular construction, it is often challenging to determine what materials will be available at the time of construction. This highlights the importance of developing practices to identify and investigate donor buildings in advance but also calls for more flexible zoning and permitting processes. It has been identified that zoning plans could, for example not strictly describe actual colours and materials but more of a range of colours and main material to give room for variance during implementation. Zoning processes should also always clearly define the possible intentions for circularity.

5.2 Copenhagen

In Copenhagen, circular initiatives have been and are taking place. The focus of circular activity is mainly on resources and materials, i.e. keeping materials in use and extending life cycles by renovating and repurposing.

Copenhagen is actively seeking circular solutions from the early stages of urban planning. A handbook for circularity is used in all municipal projects, setting targets for procurement, certifications systems, circular design and sustainability in the use phase of buildings. Projects ongoing in Copenhagen include the topics of reusing concrete beams, circular design and design for disassembly (DfD). Copenhagen was also the leading partner city in the EU Horizon project Circular Construction in Regenerative Cities (CIRCuIT) that aimed to bridge the implementation gap between theory, practice and policy and showcase how circular construction approaches can be scaled and replicated. Another ongoing project aims to develop a tool for calculating carbon emissions for different urban scenarios. This tool will help to assess the environmental impact of design choices and guide decisionmaking in dialogue with investors.

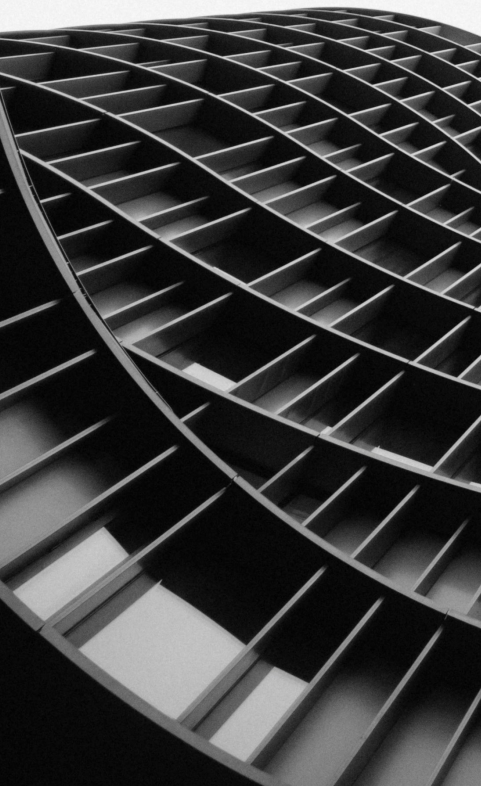
A new national law is being processed, requiring predemolition resource screening for buildings larger than 250 square meters. The screening will identify available resources in demolitions,



promoting reuse and recycling instead of disposal. In Copenhagen this is already in place, and the predemolition survey is usually completed by a continuous dialogue with demolition teams, waste and recycling companies, and contractors, aiming to maximize resource recovery with high value reuse and recycling, i.e. pursuing the cascading principle.

The main goal in the City's sustainability strategy is to reduce carbon emissions. The new Climate Plan for Copenhagen 2025-2035 will include strategies supporting circularity, for example, by reducing need for new construction, setting a limit value for CO2/m2 for new buildings, improving maintenance practices to minimize resource exchange, using materials with lower climate impact, including reused, recycled, and biobased materials, and designing for easy deconstruction and adaptability for future use.

In urban planning, Copenhagen engages in dialogues with investors, emphasizing circular solutions. While there are no direct demands, the city uses a sustainability tool to explore circularity options during local planning. In Copenhagen, the municipality does not really own land area. Land ownership can determine the ability to require circular practice. Private owners may have their own sustainability goals, but the main driver usually is economic profit. Land area is scarce, and while the city has a municipal storage area, there is no indoor storage for building material in the city, but a storage is in progress outside the city borders.



For municipal projects, the city project leader coordinates environmental and sustainability targets in construction projects. For projects over 1000 m2, DGNB certification is demanded, setting the ambition for circular targets. For smaller new buildings, there are separate targets, for example requirements for early LCA scenarios, and targets for energy, water, and biodiversity. The DGNB certification system is a lifecycle base sustainable certification system developed by the German Sustainable Building Council (DGNB Deutsche Gesellschaft für Nachhaltiges Bauen). The certification system is used internationally and is available in different variants for buildings, districts and interiors.

While the political atmosphere is supporting climate actions which include circular action, the concrete initiatives are not always popular and conflicts about the priorities increase. Other identified barriers to promoting circularity in construction are organizational, i.e. internal processes and collaboration. Also lack of reuse processing techniques

and facilities, lack of quality assurance schemes and insufficient data remain challenges in Copenhagen. There is a lack of personnel for promoting and coordinating circular economy in the city's projects, and the available resources are often spent for distributing information. The overall focus of the sector is deemed to be on investment cost instead of lifecycle costs, which often can hinder circular solutions. Another challenge, and a difference from many other Nordic cities, is that land is scarce, and the municipality does not own the land, therefore policies such as circular plot transfer or lease criteria are not relevant tools to drive circular action in Copenhagen. The importance of preserving the existing building stock and converting it to meet the modern needs is highlighted in Copenhagen.

6 Results – successes and challenges

Circular building projects are ongoing in most Nordic cities. The focus of the projects is mainly material recycling. The main drivers for circularity are climate ambition and targets, waste recycling targets and cost-efficiency. Pilot projects are a good way to increase knowledge and to test new ideas and ways of doing things. The most important thing in pilot projects are the lessons learnt; what worked well, what needs to be improved, and how to continue from here. The knowledge and experience need to be implemented in the operational models in the city; it can be how the tendering is done, how a building is transformed, or setting requirements and targets for circularity. Even though this is recognized as the most important step, this is where work still needs to be done in all cities.

This study relied on lessons learnt in the pilot projects in the cities. From a life cycle perspective, the results obtained from the evaluation tool remained limited due to the early stage of the projects. From the pilot projects involved, only two (townhall in Stavanger and ReCreate in Tampere) had progressed to the implementation phase during this study. The other ones remained mainly either in the planning or in the tendering phase.

Suggestions for the next steps regarding implementation of circular construction are provided for the city of Tampere and are based on results from the workshop. For the other cities no workshops were held and thus steps for improve-ment were not defined.

6.1 Tampere

The city of Tampere has approached circularity in four reviewed pilot projects by enabling collaborative and innovative solutions from different stakeholders and developing operational interfaces. Internal development has also been part of the pilots, and one pilot project focused on developing a tool for the management of soil masses and aggregates within the city.

Based on AFRY's findings from assessing the pilot project data, interviewing pilot representatives, and holding a workshop with a wide range of representa-tives from the city of Tampere, the following characteristics can be pointed out:

1. Tampere's pilot projects are of very different types and the city's role in them varies.

2. Tampere is politically committed to promoting circular economy in construction. Challenges have been identified in the pilot projects and results have been used to improve some aspects of processes. However, they have been managed separately and the effectiveness could be improved significantly if:

   a) The City's department-specific goals were concrete, and city's civil management would be held accountable for promoting circular economy (binding top-level goals and grassroot activities).

   b) The projects would have clear and concrete goals that align with the city's climate roadmap and circular economy action plan.

   c) Circular economy would be incorporated across all phases of pro-jects: from the preparation of project plans to the use stage and further to the dismantling at the End of Life.

   d) There would be an extensive dialogue regarding circular economy (and sustainable development more broadly) among those partic-ipating in the projects (in different stages and roles. This way extensive expertise could be more extensively utilized and practical challenges tackled.

   e) The city would have designated organization-specific responsibilities and human resources committed to the incorporation of circular economy in projects.

Many key challenges and opportunities for circularity have been identified during the pilot projects. This provides valuable information for the next steps towards effective circularity. ReCreate and Kissanmaa projects have brought up challenges regarding official practices and authorities but also led to pioneering solutions.

One key problem with city's own projects aiming for reuse is that usually "a donor and a receiver building" do not meet because of different timetables and problems with the information flow. This needs to be solved for reuse to be en-abled before commercial activities are commonplace.

Tampere has generated ways to innovate in collaboration with many stakeholders. For example, Kissanmaa circular economy themed plot leasing has gained a lot of interest, perhaps because it is relatively easy and inexpensive for the city, but the results can be valuable by demanding and enabling innovative and effective new solutions.

Based on the viewpoints presented above and collaboration in the workshop, the following suggestions for the next steps in Tampere are presented:

1. Define sites or projects in the investment and construction programs outlining where and how the implementation of circular economy is to be carried out.

2. Implement a pilot project, which starts from the plan preparation and continues to the use of the building (or buildings) and allocate resources to the monitoring of the entire path even before the start. The key part is a pilot focusing on reuse, which includes "a donor and a receiver building". The goals of the pilot project are to create an operating model that can be replicated and to outline parameters by which the implementation of circular economy within an organisation's projects can be measured. The pilot's goals must be concrete, for example a checklist-type of an operating model that everyone can easily follow.

3. Require the construction managers to report to the building committee on the implementation of the circular economy in the construction program's objects, e.g. on an annual basis. This would provide an opportunity to review the situation and the course of development.

4. Develop pre-demolition surveys and related functions in such a way that they offer a better opportunity to genuinely promote the reuse of building parts (adequate foresight and the quality of the surveys need to be considered).

5. Look for partners and ways to jointly develop digital platforms enabling the beneficial use of surplus materials. Spread the message on different forums, that at least national level cooperation is needed.

6. Commit civil management to the implementation of circular economy.

7. Establish concrete goals and boundary conditions (i.e. specific conditions or constraints that influence the project), for the resourcing of construction projects, considering circular economy and life cycle efficiency in relation to investment costs.

8. Continue to promote internal dialogue within the city to promote circular economy in construction: focus on developing a common understanding of circular economy in the city, determining the means to achieve it and most importantly refining the roles of different actors to implement the means.

6.2 Stavanger

The pilot projects in Stavanger involve the renovation of the city townhall as well as demolition and construction of kindergarten in Mosvangen. The townhall project has advanced further in timeline and offers also concrete information from the implementation. The projects are both based on BREEAM which largely determines the level and focus of circular economy.

In the townhall project, the solutions in the tender competition phase were predetermined internally by city officials in cooperation with architects. Pre-demolition studies were carried out in which reusable building parts were surveyed and the feasibility of reuse was estimated. Thus, the contractor's contribution was limited to the implementation. In the contract competition criteria, the scoring of tenders was weighed 50 % on price and 50 % on competence and plans for emission-free worksite, recycling of materials and preservation of vegetation. This tendering process resulted in that the lowest price still won, as the contractor also gained quite a high score in the competence scoring. The focus for both projects is mainly on emissions; emission-free worksites, maintaining the foundations and concentrating on lowemission materials and energy-efficiency. The materials to be reused are not assigned to a project but will be stored. The city of Stavanger has started a process for developing a digital tool for circularity.

At the city's employee level, one of the biggest challenges to the implementation of the circular economy, and sustainability in general, is perceived to be the reluctance of management level to allocate the necessary personnel resources to it.

Based on AFRY's findings from going through the pilot project data and interview-ing pilot representatives the following characteristics can be pointed out:

1. Stavanger is politically committed to promoting circular construction as a part of their climate plan.

2. The environmental dimensions of both projects are based on principles outlined in the city's climate plan.

3. Both projects are guided by goals set forth by country-specific BREEAM-certification and most of the follow up is based on BREEAM-requirements.

4. The main responsibility of following the implementation of BREEAM and other environmental aspects was acquired through an environmental consultant. Furthermore, the project manager and construction manager followed the success of reaching the goals on their own levels.

5. According to city representatives most of the Town hall demolition waste (approximately 96 %) was successfully sorted on-site.

6. Preservation of the load-bearing structures of the highrise part of the Town hall has a big impact on environmental footprint and circular economy goals.

7. Based on provided initial data and interviews, the following challenges were observed and identified:

   a. There is lack of provided clear documentation regarding for example scoring of received tenders and implementation of BREEAM related objectives. This may be a challenge only for this study, but it is recommended that documentation processes are looked over.

   b. The structural elements of the low-rise part of the Town Hall building were found to be too weak for reusing and had to be demolished.

   c. Lack of personnel resources.

The study shows that Stavanger in committed to climate and circular goals, and the pilot projects show high ambition in targets and results. How the goals and targets are implemented and monitored is not included in this study, partly due to a lack of personnel resources to contribute to the study. This may have contributed to that the full potential and results of the projects is undetected in this study.

With the information at hand, however, it recommended to evaluate the availability of resources for driving circular economy in construction in Stavanger and to see that CE targets are demanded and monitored in all stages of the projects. Increased communication and dialogue both internally and externally are also recommended. For the projects, setting high ambition and targets, and then giving contractors freedom in proposing solutions is a recommended way to give room for both innovation and the expertise of the contractors. It is recommended to focus on monitoring the progress of the targets according to a clearly defined and transparent scheme.

6.3 Stockholm

The City of Stockholm has many ongoing circular economy projects. The establishment and work of the Centre for Circularity is a step towards meeting the resourcing need for driving circular action. Another lesson learnt in Stockholm is that by appointing a circularity person within each department, the communication and therefore implementation is better compared to when targets come from "outside", i.e. other departments. Even so, the main focus still tends to be on optimization and recovery of materials, and cost savings during the opera-tional phase. Circular construction and buildings are focusing on resource efficiency which means efficient use of material and energy. There is still work to be done in reusing and closing the loop for most materials, and there is a way to go when it comes to collection and quality assurance of data.

Currently there seems to be some level of misconception perceived in Stockholm that circular economy of construction is the same as climate impact. Deci-sions tend to be constantly focused on the end part of the life cycle and scaling of new practices is difficult. This is seen also in project financing: money is per-ceived to be available for recycling but not for reuse. Contractors focus on minor issues like electric vehicles instead of "big fish" like material recovery and transforming buildings or building new buildings with reused or recycled material.

In terms of circularity, the aggregates and bulk circulate well but building materials do not, because there are big challenges with the type approval issues. At the moment, <1% of projects use reused materials. Functioning markets for some materials exist but there is no high enough demand for reused materials. The goal is to increase demand, which hopefully brings pressure to create business models in the future.

Circular economy is strongly linked to financial sustainability. Currently, the market faces a price distortion due to its inability to set an appropriate price for virgin resources that takes into account their environmental impacts. This hampers the competitiveness of circular economy solutions as it is often challenging to show financial benefits of circularity in the current markets.

Central challenges for Stockholm are a lack of skills and knowledge, organisational challenges such as cooperation between departments, and reliance on a few driven people both in the city and in certain companies to drive circular ac-tion forward. Making financial benefits more transparent, and developing skills and knowledge is recommended to promote the circular economy of construction and buildings in Stockholm. Also, the development and implementation of city-wide strict requirements for circular construction that are now being tested in pilot areas, is recommended.

6.4 Copenhagen

In Copenhagen, the emphasis seems to be on the active dialogue between the city and the investors, developers and contractors. Copenhagen actively seeks circular solutions from the early stages of urban planning. Circular principles are embedded in municipal projects, including procurement, certification systems, circular design, and sustainability considerations during the use phase of buildings. The focus is mainly on meeting climate targets and on keeping resources in use. Renovation and repurposing are prioritised over demolition and new construction, which is really the most sustainable alternative. Where new construction is built, the target is set on circular building and building for the future.

The challenges found in this study are the limited resources for circular building, conflicts on what concrete action to prioritise when e.g. investment costs and circular solutions don't meet, and the lack of technical solutions and facilities for reuse. This study recommends continuing the culture of active dialogue and taking the lessons learnt from the sector and from previous projects into implementation. More clear goals for circularity may be advised.

6.5 Differences and similarities

In this study, some clear differences and a lot of similarities between the cities became apparent. Some of the differences may be due to differences in city resources and size, in existing building stock and available land area and in culture. The cities have shared challenges related to resources, technical issues, data needs, logistics and market demand, and challenges with prioritization.

All four cities in this study (Tampere, Stavanger, Stockholm, and Copenhagen) show a clear commitment to promoting circular economy principles in construction, with varying degrees of success and focus. Each city has undertaken pilot projects to test and implement circular economy practices, gathering valuable insights and identifying challenges. There is a common emphasis on collaboration with various stakeholders, including city officials, developers, contractors, and environmental consultants, to drive circular economy initiatives. All cities face challenges related to the reuse and recycling of building materials, such as logistical issues, lack of demand for reused materials, and technical difficulties. Emission reduction and sustainability are integral parts of the circular economy strategies in all cities, often guided by specific environmental plans or certification systems. The need for clear, concrete goals and accountability mechanisms is a recurring theme, indicating that more structured approaches could enhance the effectiveness of circular economy initiatives.

In all cities, one of the biggest challenges to the implementation of the circular economy, and sustainability in general, is resource allocation and organizational commitment. It is sometimes perceived by personnel to be a reluctance of management level to allocate the necessary personnel resources to circularity. This was especially visible in Stavanger, as even time allocation for this study was scarce. Also, in Tampere and Copenhagen resourcing was mentioned as a main challenge, and although committed, there is a need for more clear goals and better prioritization of circular actions. In Stockholm though, this barrier has

been recognized, and changes in the organization have been made, e.g. the support function Centre for Circularity as well as circularity and/or sustainability experts in the different departments. However, still also in Stockholm it was perceived that a few driven individuals push circular actions forward.

The focus area for circularity varies between the cities. In Tampere, the focus is on recycling, innovation and stakeholder collaboration. In Stavanger, the projects were specific and with strong focus on BREEAM and climate targets. In Stockholm, numerous ongoing concrete projects focus on resource efficiency and material recovery and embedding circular principles in urban planning and procurement, while in Copenhagen the emphasis is on active dialogue with investors and developers.

Pre-demolition surveys are done in all cities in this study. In Stavanger, pre-demolition studies were carried out to survey reusable building and to estimate the feasibility of reuse, which differs from the pre-demolition surveys in Tampere, and Finland in general, where the feasibility study for reuse is usually not done. In Stavanger, the targets and monitoring were also clearly stated, which is an important part of driving and coordinating circular action.

Copenhagen emphasized active dialogue between different stakeholders, which is an important step in increasing and improving cooperation and functional value chains and networks. Dialogue models are encouraged to be implemented in the other cities as well. Copenhagen also differs from the other cities in this study by the fact that the focus is more on renovation and transformation, due to the reality that land is scarce. Scarce land area excludes the CE tools related to zoning of new areas but seems to be effective in driving the focus away from mass recycling and directing it to the sustainable use of the existing building stock and its circular use in the future.

In Tampere, circularity is being promoted in strategies and roadmaps, as the city advocates for incorporating circular economy into all phases of projects. These organizational targets and the gathered focus seem to drive circular pilots, innovation and testing of new ideas forward, but even so, this study identi-fied a need for better integration and implementation of circular economy goals across all project phases and especially a need for improved internal dialogue and resource allocation.

7 Conclusions and recommendations

While Tampere, Stavanger, Stockholm, and Copenhagen share a strong commitment to circular economy principles in construction, each city has unique approaches, challenges, and focus areas. The d ifferences in their strategies and implementation reflect their individual contexts, but common themes such as the need for clear goals, better resource allocation, and enhanced collaboration are evident across all cities.

The Nordic cities have started to implement circular building, but there is still much work to be done. This study highlights only a few cities and only some of the ongoing circular projects, and the conclusions are drawn on a limited set of data and contact persons. The findings, however, are supported by similar studies in the sector. The knowledge and awareness of sustainable and circular practices are on the rise, with a growing emphasis on circularity, material efficiency and planning for the future. To achieve circularity, construction should not only be focused on the circulation of materials, but also on the longevity and value of materials in use. In practice this means considering the longevity of a building's active use phase(s) both for the current building stock and for the to-be-built buildings.

The solution for the sector is proactive crosscutting action, that takes into consideration all phases of a building: planning, construction, use, maintenance, renovation, and when needed demolition (Figure 1Figure 2). If one phase lacks circularity, efforts in the others are rendered less impactful or even useless.

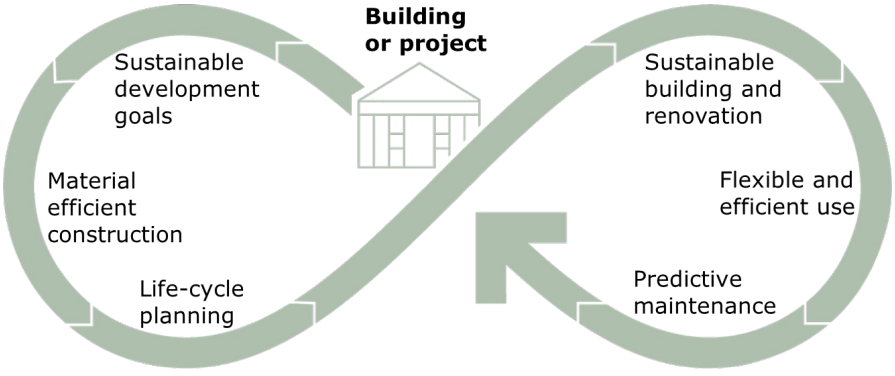


Figure 2. Circularity needs to be taken into consideration all phases of a building: planning, construction, use, maintenance, renovation, and when needed demolition, otherwise the efforts in the other stages are less impactful.

The projects and results in this study infer that the circular efforts still are a piecemeal, focusing on individual topics and targets, instead of being compre-hensive. It is important to pay attention to the entire lifecycle. Currently, the focus is mainly on the end stages and material recycling, or on a few challenges (e.g., emissions-free construction sites). Projects are usually temporary, both construction and renovation pilot projects, but also projects building networks and sharing knowledge. A crucial point is what happens when a project ends, are the lessons learnt implemented as part of normal practices, or do things return to the way they were.

Organization is crucial, when one of the biggest challenges in all cities is that work happens in silos: everyone is responsible for their own area, additional efforts are perceived to threaten finances and schedules, and new practices aren't fully implemented. Information on targets and measures should be everywhere, not just with one person or department. Currently, there's a strong individual commitment driving things forward in e.g. Stavanger and Stockholm, when emphasis should be on joint responsibilities and collaboration. As money is often the main driver, bonuses and other incentives should be more tied to the circular economy targets.

Another identified major challenge stemming from organization is timing. The logistics of reusable and recyclable materials, between different operators across different projects and different timeframes, is difficult due to a lack of infrastructure enabling temporary storage and near to non-existent marketplaces for different operators to source and deliver these materials. Also, the lack of an inventory and data of available resources within the current building mass poses obstacles for the efficient use and reuse of buildings and building materials.

Conflicting interests regarding timeframes, costs etc. between different real estate owners mean that whilst there could be suitable donor and receiver projects across different operators, the implementation of circular economy could benefit from a third-party facilitator.

This study strongly highlights the importance and sustainability of preserving and renovating existing building stock, building less, and maintaining more. This requires considering the lifecycle costs in investments. There are examples that show that economic profit can go hand in hand with circular action, and these can be learnt from.

This study recommends promoting circular economy in the cities by setting clear targets and goals, allocating resources, focusing on collaboration and dialogue, setting circular criteria in early stages, setting requirements on circularity and monitoring the progress. On a national level, legislation and regulation need to be able to allow for new innovations and recycling, logistics need to be planned on a regional level, markets for recycling and reuse need to be encouraged and processes for feasibility and product certification need to be harmonized. On the Nordic level, circular economy in the building sector can be promoted by a unified voice for circularity in the EU, by promoting collaboration, sharing knowledge and lessons learnt between the countries, and by advocating the im-portance of circularity and resource efficiency in the Nordics.

Recommendations on the city level, but also national and the Nordic level include:

1. Policy and Regulation:

- Promote and harmonize national regulations concerning reuse of construction products to not just enable but strongly encourage and streamline circular economy practices.
- Enhance incentives for adopting circular economy solutions in construction projects.

2. Innovation and Digitalization:

- Invest in technological innovations to improve material reuse and waste management.
- Develop digital tools for better tracking and management of construction materials.

3. Stakeholder Engagement:

- Foster collaboration among government, industry, and academia to promote circular economy.
- Establish networks of circular economy experts to share best practices and drive initiatives.

4. Public Awareness and Education:

- Increase awareness about the benefits of circular economy in construction.
- Provide training and resources to industry professionals to implement circular practices effectively.

8 References

Avfallsforskriften, FOR-2004-06-01-930. Lovdata. Available at: https://lovdata.no/dokument/SF/forskrift/2004-06-01-930/*#*

City of Tampere 2022a. Tampereen kaupungin kiertotaloussuunnitelma. Available at: https://www.tampere.fi/sites/default/files/2022-09/tampereen_kiertotaloussuunnitelma_2022.pdf

City of Tampere 2022b. Hiilineutraali Tampere 2030 – Tiekartta. Available at: https://www.tampere.fi/sites/default/files/2022-10/hiiline-utraali_tampere_2030_tiekartta-paivitys_2022.pdf

City of Tampere 2022c. Ahvenisjärvi school project plan. Available at: https://tampere.cloudnc.fi/fi-FI/Toimielimet/ZSivistys_ja_kulttuurilautakunta/Kokous_5102022/Ahvenisjarven_koulun_hankesuunnitelma(284032)

City of Tampere 2022d. Housing and real estate board meeting, notes. Available at: https://tampere.cloudnc.fi/fi-FI/Toimielimet/Asunto_ja_kiinteistoumllautakunta/Kokous_12102022/Asuntotontin_837133185110_Kissanmaa_vara(284858)

City of Tampere 2023. Tekemisen kaupunki – Tampereen strategia 2030. Available at: https://www.tampere.fi/sites/default/files/2022-05/FINAL_Tampereen%20strategia%202030_saavutettava_0.pdf
Direktoratet for byggkvalitet 2024. Byggteknisk forskrift (TEK17) med veiled-ning. Available at: https://www.dibk.no/regelverk/byggteknisk-forskrift-tek17/2/2-1

European Commission 2020. Circular economy action plan – For a cleaner and more competitive Europe. Available at: https://op.europa.eu/en/publication-detail/-/publication/45cc30f6-cd57-11ea-adf7-01aa-75ed71a1/language-en/format-PDF/source-170854112

European Commission 2024a. Circular economy action plan. Available at: https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

European Commission 2024b. Waste Framework Directive. Available at: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

European Commission 2024c. Construction and demolition waste. Available at: https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en

Finnish Government 2017. Valtioneuvoston asetus eräiden jätteiden hyödyntä-misestä maarakentamisessa. Available at: https://www.finlex.fi/fi/laki/alkup/2017/20170843

Finnish Government 2021a. Valtioneuvoston periaatepäätös kiertotalouden stra-tegisesta ohjelmasta. Available at: https://valtioneuvosto.fi/paatokset/paatos?decisionId=0900908f8071a6e1
Finnish Government 2021b. Uusi suunta – Ehdotus kiertotalouden strategiseksi ohjelmaksi. Available at: https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162654/VN_2021_1.pdf?sequence=1&isAllowed=y

Finnish Government 2022a. Hallituksen esitys eduskunnalle rakentamislaiksi ja siihen liittyviksi laeiksi, HE 139/2022. Available at: https://valtioneuvosto.fi/paatokset/paatos?decisionId=0900908f807d311e

Finnish Government 2022b. Valtioneuvoston asetus betonimurskeen jätteeksi luokittelun päättymisen arviointiperusteista. Available at: https://www.finlex.fi/fi/laki/alkup/2022/20220466

LINK Arkitektur 2024. Smart buildings with a historic buzz. Available at: https://linkarkitektur.com/en/project/stavanger-town-hall

Nordic Council of Ministers 2023. Reuse, recycling and recovery of construction and demolition waste in the Nordic countries. An inventory of facilities and tech-niques on the Nordics including an outlook on other European countries. Available at: https://pub.norden.org/temanord2023-544/temanord2023-544.pdf

Nordic Innovation 2024. Nordic Innovation website. Available at: https://www.nordicinnovation.org/about-nordic-innovation

Nordic Smart City Network 2024. Nordic Smart City Network - website, accessed 14.6.2024. Available at: https://nscn.eu/

Norwegian Ministry of Climate and Environment, 2021a. Norway's Climate Action Plan for 2021–2030. https://www.regjeringen.no/contentassets/a78ecf5ad2344fa5ae4a394412ef8975/en-gb/pdfs/stm202020210013000engpdfs.pdf

Norwegian Ministry of Climate and Environment, 2021b. Norway's strategy for developing a green, circular economy. https://www.regjeringen.no/contentassets/a116f209e493471bb26c81cf645152a3/kld_strategi_sirkularokonomi_sammendrag_eng_0507.pdf

Ministry of the Environment 2024a. Rakentamislaki ohjaa kestävää rakenta-mista. Available at: https://ym.fi/rakentamislaki

Ministry of the Environment 2024b. Jätelaki ja asetukset – mikä muuttui, mi-ten toimin? Available at: https://ym.fi/jatteet/jatelaki

ReCreate 2024. Project website. Available at: https://recreate-project.eu/

Sitra 2024. The critical move – Finland's road map to the circular economy 2.0. Available at: https://www.sitra.fi/en/projects/critical-move-finnish-road-map-circular-economy-2-0/#the-challenge

Skanska 2021. Tulevaisuuden kerrostalossa hiilijalanjälki on pienempi – uudel-leenkäytettävät elementit tarjoavat paljon mahdollisuuksia. Available at: https://www.skanska.fi/tietoa-skanskasta/media/artikkelit/tulevaisuuden-kerrostalossa-hiilijalanjalki-on-pienempi-uudelleenkaytettavat-elementit-tarjoavat-paljon-mahdollisuuksia/

Stavanger Kommune 2018. Climate and Environmental Plan 2018-2030. Available at: https://www.stavanger.kommune.no/siteassets/renovasjon-klima-og-miljo/miljo-og-klima/climate-and-environmental-plan-stavanger-2018-2030---final-version.pdf

Stavanger kommune 2024a. Poppeltunet på Mosvangen: Barnehage, dagsenter og avlastningsboliger. Available at: https://www.stavanger.kommune.no/bolig-og-bygg/byggeprosjekter-ny/byggeprosjekter-mosvangen/

Stavanger kommune 2024b. Rehabilitering av rådhuset. Available at: https://www.stavanger.kommune.no/bolig-og-bygg/byggeprosjekter-ny/radhuset/#prosessen-fram-mot-totalrenoverert-r-dhus

Tampere University 2024. ReCreate. Available at: https://www.tuni.fi/en/research/recreate

Appendix 1. Interviews and survey

Survey

The survey was done in forms, and in addition to basic information (City, Role) the following questions were asked:

1. Does the city have ongoing projects related to circular construction and buildings?
2. Number of projects (both finished and ongoing).
3. Please, briefly describe the projects separately (project name, time, content and objectives).
4. Please, prioritize the following circular economy related objectives of the projects (from the most important (1) to the least important (5)).
5. Please, describe your choice briefly.
6. Are there upcoming circular economy projects planned in the future? Please, describe briefly.
7. In the absence of projects, what are the reasons?
8. Please, describe your choice briefly.
9. In which ways the city could most effectively promote the circular economy of construction and buildings?
10. Has the city set objectives for the circular economy in construction and buildings?
11. Open comments.

Interviews

The interviews were open discussion interviews, based on the following scheme:

CIRCULAR ECONOMY (CE) IN THE CONSTRUCTION SECTOR WITHIN A CITY OR MUNICIPALITY

GENERAL/PROJECT SITUATION:

Ongoing projects related to CE? Number & emphasis?

What are the essential people/interest groups to be interviewed / invited to workshops?

What are the biggest challenges at the moment?

What would be the best practices to promote CE?

Is there a policy for transferring learnings to future projects?

FOCUS:

Is there some emphasis on some specific area? (e.g. mass balancing and use of surplus soils, green/secondary construction materials, energy & materials during use, reuse/ recycling at EoL)

TIMING & SCOPE:

At what stage the city usually involves CE / the requirements for CE are set in construction projects? (e.g. zoning, needs assessment, project planning, tendering, implementation, use, EoL)

PRACTICES (planning and tendering):

Has the city set objectives for CE in construction?

Has there been an interaction / effects between the goals and the zoning?

Are the projects evaluated on a basis of LCA/ LCC/whole service life?

How are the circular economy goals seen in the plans on a practical level?

Has the city done reuse of materials as such or with little upgrading?

Are there demands for secondary materials?

Are they accurately marked on the plans? (what/where/quality requirements)

Has the city involved DfD? or optimatization of structures?

Was CE criteria used for valorisation in tendering process? How?

How the CE goals, rewards and sanctions were defined in requests for tenders?

PRACTICES (implementation & EoL):
How is the achievement of goals monitored during the project? Specific resources for this?

Is the city somehow mapping and controlling the generation and handling of construction waste?

Has the city developed/involved sharing platforms (for materials, information etc.)? Are there facilities and resources available for intermediate storaging and logistics?