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Reuse of wood products left after demolition: challenges, facilitation and Green Public Procurement's role

– A Case Study for Helsinki City

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Master’s Thesis | Abstract

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Case study for Helsinki City

This study aimed to assess the challenges and ways to facilitate the reuse of construction products, focusing on wood products left after demolition. Commissioned by the City of Helsinki, this research also examined how Green Public Procurement can support these reuse practices.

The emphasis on wood materials was driven by Helsinki City's goal to attain carbon neutrality by 2035 where the expansion of wood constructions plays a vital role due to its carbon-binding properties. The theoretical framework of this thesis included concepts of a circular economy, waste, and green public procurement. The present study adopted a descriptive methodological approach and employed a qualitative methodology by implementing questionnaires and semi-structured interviews with open-ended questions to collect data. In total, experts from seven different organizations participated in interviews representing various departments of the City of Helsinki, Ministry of the Environment, University of Helsinki, XAMK, SATO Oy, Rasek Consulting Oy, and AINS Group.

The results of this study showed that all participants agreed on the need to reuse wood products left after demolition, however, they emphasized difficulties with its practical implementation due to a non-functional reuse market, high costs, unclear legal rules, lack of harmonized standards, and assessment

methods. The study showed that facilitation of the reuse can be achieved through changes in legislation to create a predictable operational environment to invest, the development of the reuse market, constant learning, and benchmarking. Moreover, results revealed that since green public procurement has significant purchasing power even though it is a voluntary tool, the inclusion criteria “reuse of wood products left after demolition” in Helsinki City’s pilot projects is crucial for collecting required data and obtaining expertise for further expansion on a larger industrial scale.

Keywords:

Circular economy, waste, Green Public Procurement, European Green Deal, reuse of wood products left after demolition, method for assessment, carbon footprint.

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1 Introduction

The construction industry plays a significant role in the world economy and is expected to reach nearly 14.4 trillion dollars by 2030 from 6.4 trillion dollars in 2020 (Statista, 2022). The construction sector generates up to 12% of the global GDP and reaches up to 5.5% of gross value added in Europe (Eurostat, 2023) via utilizing multiple raw resources, energy, and technology (Eurostat, 2023). Given the ongoing growth in urban populations, the demand for raw materials is set to increase, thereby amplifying construction activity resulting in exacerbation situation related to environmental degradation, waste management, and resource scarcity. According to the United Nations, in November 2022 the number of people exceeded 8 billion and will reach 10 billion by 2059 (Armstrong, 2022). Data analysis shows that by 2050 more than 68.4 % of the world population and 86.6% of the population from developed countries will be concentrated in urban areas (Statista, 2022).

The exponential growth of population and urbanization generates a significant share of waste which exposes a threat to public health, contaminates the environment, and affects global warming. Many cities experience difficulties not only in finding solutions to the current situation but also in building a future strategy. Nowadays, nearly half of all raw extracted materials are directed to the construction sector, which contributes to a third of the global overall waste and 40% of the global CO2 emissions (Miller, 2021). In research from the Construction Waste Market (2022), it is expected that by 2025 global construction waste can reach up to 2.2 billion tons, thus consuming 35-40% of the world's resources and energy (Benachio et al., 2020).

In the European Union, public sector entities spend approximately 16-17% of the GDP on public procurement each year, and it is getting more frequently utilized as a policy instrument, however, it remains inefficiently used in Europe with variations from 4 % in Portugal to nearly 18% in Finland (Sapir, Schraepen, & Tagliapietra, 2022). The purchases of goods and services by governments

and public organizations significantly contribute to the European economy, which is why it is important to direct public procurement to achieve one of the EU goals in the reduction of greenhouse gas emissions. Such reduction can be achieved via materials' reuse and recycling, replacing the purchase of polluting goods and services with green alternatives. Currently, there is a growing trend in various industries, including the construction sector, to be increasingly aware of social and environmental concerns (Edmondson, 2022; Murphy, 2022). To contribute to sustainable growth and low carbon emissions, existing construction practicalities utilize improved methods where products and materials can be reused, repaired, or recycled, materials can be accessed locally and energy consumption can be reduced (Ellen MacArthur Foundation, n.d.a). The aforementioned methods can be represented through the adoption of new business models, *inter alia*, "Green Public Procurement" (GPP) which drives the transition from a linear to a circular economy, energy and resource efficiency, improved design, and low-carbon footprint. Moreover, GPP practices encourage smart deconstruction enabling further reuse of dismantled parts as an alternative to tradition demolition generating a substantial amount of waste. It is considered that after demolition of traditional residential buildings nearly 25% of materials can be reused and 70 % recycled (Bohne & Wærner, 2014).

Finland is among the pioneers in implementing the goal to become carbon neutral by 2050. To support the achievement of this goal public authorities can use existing legal frameworks where environmental criteria such as reuse and recycling of materials, carbon footprint, and diversion of waste streams to circular practices can be fully utilized, including, in the industries with the highest emission rate such as construction sector, transportation, housing and energy sectors (European Commission, 2022; Pesonen, 2021.)

This thesis was commissioned by Helsinki City as a part of a circular economy project to identify challenges and possibilities to facilitate the reuse of construction products, specifically wood products left after demolition activities, as well as examine how Green Public Procurement (GPP) can support these

reuse practices for urban development of Helsinki City. The project also aims to help Helsinki City in reaching climate goals, improving material flow, reusing, and recycling opportunities for recovered materials. (Testbed Helsinki, 2023).

The theoretical framework for this thesis is based on a review of academic literature, books, and European legislation related to circular economy, waste management, GPP, and Green Deal in the construction sector. This framework also draws upon the findings from projects focused on the reuse of construction products/materials from construction and demolition (C&D) activities and associated carbon footprint assessment in the construction sector. Additionally, relevant online sources within the context of "reuse of construction products/materials and circular economy in the construction sector" have been utilized to further form the theoretical framework.

1.1 Objective and Research Questions

The objective of the current research is to investigate the challenges and possibilities to facilitate the reuse of wood products left after demolition activities. A particular focus is also on the examination of how Green Public Procurement (GPP) can support these reuse practices for the urban development of Helsinki City. So that to reach this objective, the following questions have to be answered:

- What are the key challenges in the reuse of wood products left from demolition activities?
- How to facilitate the reuse of wood products left from demolition activities?
- How can Green Public Procurement in Helsinki City support the reuse of wood products left from demolition activities?

The findings of this research can serve as valuable information not only for Helsinki City but also for other municipalities with similar prior data. Additionally, this study contributes to the European Union's research database in the field of circular economy, the reuse of construction materials, GPP; and innovative practices between businesses, R&D entities, NGOs, and municipalities in

material flow operations in relation to construction needs and zero-emission objectives. The results of this research can also be used for education purposes related to topics of GPP, reuse of construction materials, and waste management, including, systematic evaluation of possible synergy between municipalities and businesses, its associations with carbon dioxide emissions, and potential sources of revenue on a sustainable internal market. The author of this thesis can gain valuable insights from this research by understanding the mechanisms and practices of GPP and discovering strategies to optimize the value of reused construction materials for sustainable business practices. This research also provides a great possibility to collaborate with multiple stakeholders and networking, which overall can be beneficial for further development and career growth.

1.2 Thesis scope and delimitations

This thesis aims to examine the challenges and ways to facilitate the reuse of construction products focusing on the reuse of wood products left after demolition activities. Also, the research investigates how GPP can support the reuse practices for the urban development of Helsinki City. The emphasis on wood products is driven by Helsinki City's goal to attain carbon neutrality by 2035 and the expansion of wood constructions plays a vital role in this endeavor due to their carbon-binding properties (City of Helsinki, n.d.).

It is important to highlight that practical instances of reusing construction products from construction and demolition activities through GPP contracts are notably poor; therefore, the current research can be viewed as an R&D initiative, aiming to extract valuable insights from experts' opinions, literature analysis, R&D accomplishments of analogous projects, benchmarking, and case studies. Furthermore, anticipated regulatory changes in the research field are expected to impact the development of this subject, for example, further developments are expected in EU Taxonomy regarding defining which key construction activities are to be considered sustainable and eligible for

sustainable finance, including the reuse of construction products (European Commission, n.d.-e). Upcoming changes in the Construction Products Regulation (under revision) are expected to incorporate harmonized standards for different product categories, including harmonized technical specifications for reused wood products (CPR, 2011). Additionally, changes in the 'Land Use and Building Act' will introduce climate declarations with defined carbon limits (Ministry of the Environment, n.d.-b; Maankäyttö- Ja Rakennuslaki Uudistuu, 2023).

Delimitation of this research relates to the reuse of wood products left after demolition activities for urban development of Helsinki City within a GPP, specifically windows, doors, and glued wood “glulam”. The last one refers to homogeneous, combined, and split glulam, as defined in the tool “For determining the eligibility of reusable construction products” (Antti Koponen, 2023). The research refrains from exploring the scientific attributes or calculation methodologies related to the reuse of construction products, *inter alia*, the reuse of wood products and associated carbon footprint, instead, it provides a broader analysis aligned with the objective of the current thesis.

This thesis is based on a qualitative method of research via open-ended questionnaires and semi-structured interviews utilized to collect data and consists of ten parts. Chapter 1 covers the introduction, objective, research questions, thesis scope, and delimitations. Chapter 2 introduces general information about the commissioner of this research. Chapters 3,4 and 5 cover the main concepts of circular economy, waste, and green public procurement. Chapter 6 describes previous findings. Chapter 7 represents methodology. Chapter 8 analyses the results of this research. Chapter 9 covers development ideas for further research, including, reflection on own learning. Chapter 10 provides a conclusion and gratitude to the parties involved in the process.

2 Commissioner- Helsinki City

The Commissioner of this thesis is the City of Helsinki - the capital of Finland and a developed urban area with a population of nearly 1,5 million inhabitants in the region and more than 800,000 jobs. Helsinki's annual procurement volume is approximately €4 billion, making it the largest operator engaging in public procurement in Finland. A huge part of the procurement relates to the construction sector, where the average share of residential buildings is 64.3%, commercial and office buildings 22.7%, and other buildings 13.0%. (Urban Research and Statistics, 2020.) Helsinki's procurement-related carbon footprint is the largest due to its population and amounts to more than 0.81 million tons of CO2e, with the majority of emissions attributed to the construction sector (Hiilineutraalisuomi, (2019). Implementing public procurement with "green criteria" can be seen as an effective mechanism to promote the reuse of construction products and reduce carbon emissions by fostering sustainable practices and markets. Significant focus in the construction sector is on a collection of effective green criteria in the "Criteria bank" (Helsingin Kaupunki, 2021; Helsingin Kaupunki, 2023).

2.1 Helsinki City General Strategy

In December 2018, the Helsinki City Board adopted the Carbon-neutral Helsinki 2035 Action Plan, which comprises a comprehensive array of 147 strategies aimed at attaining carbon neutrality. One of the key strategies outlined in the plan is the development of a roadmap for the promotion and implementation of a carbon-neutral circular economy. This economy would be characterized by the sustainable utilization of natural resources and the maintenance of the value of products and materials through maximizing their circulation. (City of Helsinki (2020.) To reach this goal complex and extensive measures must be performed across all sectors and industries based on a thorough analysis of direct and indirect impacts on the environment, especially in the construction, energy, and transport fields (City of Helsinki, 2021b).

Helsinki City actively supports and promotes projects related to sustainability and climate change, relating to city planning, reconstructions, renovations, demolition of old buildings, and implementing green public procurement practices (City of Helsinki, 2021b). As a part of its strategy, Helsinki City actively develops multiple digital platforms to support the concept of a sustainable “smart city”, which was launched in 2013 with the purpose to preserve and minimize consumption of natural resources, diminish the negative consequences of rapid urbanization, secure energy supply and optimize waste management system (Business Finland, 2018; European Commission, 2018).

2.2 Helsinki Circular Economy Cluster

Helsinki’s circular economy cluster program aims to reduce greenhouse gas emissions in the city by 80% by 2030 compared to the levels in 1990, focusing on resource efficiency, reduction of waste, utilization of renewable materials and energy (Ministry of Economic Affairs and Employment, Ministry of the Environment, 2021; Ministry of the Environment, 2021). Along with the food and textile sectors, the main focus of the program is the construction industry where pilot projects are run regularly. One of the examples is a project “Innovation Challenge" launched specifically for the concrete sector. The project assessed the possibility of replacing cement producing up to 8% of the world's greenhouse emissions, with mineral wool left after demolition as a binder in the production of concrete (Circuit, 2021; Nieminen, 2021; Testbed Helsinki, 2022c.)

2.3 Helsinki Public Procurement

In 2015 Helsinki City set a goal that by 2020 environmental criteria would be included in all public procurement with a focus among others on energy-saving, reduction of carbon footprint, resource efficiency, and waste minimisation in the construction sector (Hasanbeigi, A., Becque, R., Springer, C., 2019). To assist in GPP a special center “KEINO” for sustainable and low-carbon public

procurement has been set up, which facilitates data sharing, provides experts, and supports a circular economy (Keino, n.d.). Within a framework of GPP, Helsinki City prepared a “roadmap” with a long-term perspective to be achieved by 2035 where the city commits to conduct a lifecycle assessment of alternative construction materials and incorporate the results into its procurement criteria (City of Helsinki, 2020a; Helsingin Kaupunki, 2023; Sitoumus2050, n.d.).

To access the reuse of building materials in construction projects a special tool was created for the Helsinki Circular Economy Cluster program which compiles product eligibility specifications as part of site-specific verification (Helsinki Circular Economy Cluster, 2023). The criteria for demonstrating eligibility are determined based on the demolished product and its intended new purpose, sometimes requiring laboratory tests or the product's user experience from the original dismantled building. Currently, the tool includes specifications for determining the eligibility for burnt brick, lime-sand brick, glulam, steel, windows, doors, and clay roof tiles; however, when employing site-specific verification, the discretion to determine the adequacy of reports largely rests with the municipal building inspector. (Helsinki Circular Economy Cluster, 2023.)

In 2020 Helsinki signed a “Green Deal Agreement” to promote “emission-free” construction sites (City of Helsinki, 2020a; Helsingin Kaupunki, 2023; Sitoumus2050, n.d.). To facilitate collection and data sharing on material flow in the construction sector, Helsinki City introduced a digital “Platform Ecosystem” project that enables the matching of supply and demand for existing materials and guides demolition companies and re-users of recovered materials to green construction practices. (Testbed Helsinki, 2022b.) A pilot initiative within the framework of “Platform Ecosystem” is a project in the Vattuniemi area that targets to utilize some of the elements and materials from demolished office buildings for new constructions (Testbed Helsinki, 2022a).

Overall, despite the active promotion of the reuse of construction products/materials and utilization of GPP practices in Helsinki, there are still

challenges related to procurement management, incorporation of green criteria to the contract, expertise of the employees, and data sharing between multiple departments (Helsingin Kaupunki, 2023).

3 Circular economy

The Circular Economy (CE) model sets a balance between production and consumption with a focus on a closed-loop system. Such an approach promotes a longer lifespan for products through various means, such as sharing, repairing, recycling, reusing, renting, and renovating (Figure 1). The CE prioritizes resource regeneration, with a focus on utilizing waste as a secondary resource and facilitating its recovery for reuse and recycling, thus fostering the extension of material lifetime through new business models, design processes, and innovations that enable the continual use of materials, thereby creating increased value. (European Parliament, 2022; Circle economy, n.d.).

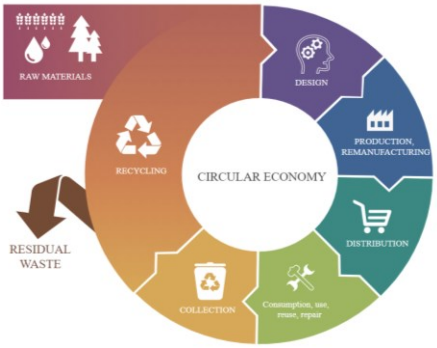

Figure 1. Circular economy (European Parliament, 2022).

The concept of a CE has emerged as a key driver for achieving sustainable economic growth and contributing to a positive shift in climate (WEF, 2021; European Commission 2021c). In the European Union, for example, in Finland, Sweden, the Netherlands, and France, the concept of CE is implemented within a framework of national development, bringing such benefits, as lowering materials costs up to €460 billion, reducing the size of landfills and associated GHG emissions up to 30 million ton per year, increasing economic profit for manufacturing sector up to €600 billion annually (Ellen MacArthur Foundation, 2013a; CIRAIG, 2015). According to the Ellen MacArthur Foundation (2013a; 2015a), by 2030, the implementation of a CE in Europe could yield substantial advantages amounting to nearly €1.8 trillion, which accounts for around 11% of

the GDP and nearly three times greater than what is achievable through the present developmental course. In Finland alone, the CE approach could potentially lead to an annual economic boost of around €2.5 billion, aligning with the government's goals to be the world's first fossil-free society by 2030 and carbon neutral by 2050 (SITRA, 2015; SITRA, 2018).

3.1 Definition and principles of a circular economy

Despite the rising popularity of the term "circular economy" it still lacks a unified understanding, potentially making the concept obsolete due to the absence of a cohesive definition and challenges in integration (Preston, 2012; Zero Waste Scotland, 2015; Kirchherr et al., 2017). Certain European countries have yet to enact laws mandating the integration of CE principles into national legislation, partly due to concerns over potential governmental interventions that might favour CE over other innovative approaches like recycling, and also due to the need for thorough examination of health risks and toxic emissions associated with CE practices before adopting such strategies at a national level (Cossu & Williams, 2015).

The term "circular economy" first emerged in Western literature around 1980, highlighting the relationship between the economy and the environment. Subsequently, it evolved into describing a "closed-loop system" with cyclic materials and resources, increased durability, and interconnected relationships. (Murray et al., 2017; Yang & Feng 2008). Common components within the framework of a CE often include waste reduction, increase of material value, and prioritizing closed-loop processes to minimize reliance on recycling (European Commission, 2015; Ellen MacArthur Foundation, 2013a; Waste Resources Action Program, 2021). Ellen MacArthur Foundation (2013a, 2013b) describes the CE as a regenerated system that relies on renewable resources, with minimal use of chemicals and waste production, focusing on a closed loop of energy and material flow. Thus, a common perception of the concept of a CE

relates to the reduction of environmental impact via minimization of resource consumption and waste production, *inter alia*, through reuse and recycling.

The CE concept is based on its principles, which are guiding rules defining and shaping the concept's fundamental ideas. According to the Ellen MacArthur Foundation (2015b), CE principles include the protection and enhancement of resources through the use of renewables, optimization of materials through recycling cycles, and the enhancement of efficiency by addressing external factors. Reh (2013) defines the CE as based on three principles: "recycle, reuse, and reduce". Pan et al. (2015) expanded the concept with two more principles: "reclamation and recovery", while Govindan and Hasanagic (2018) added, "remanufacture and redesign". Overall, CE principles are interconnected, where reduction stands atop the hierarchy followed by reuse as the best alternative to curb energy and resource usage, minimize waste, and raw material consumption (Su et al., 2013; Ghisellini et al., 2016) (Figure 2).

Figure 2. Circular economy principles (adapted from Ellen MacArthur Foundation 2015b).

Following reduction, the next principle is "reuse" which involves using materials or products repeatedly for the same purpose they were initially manufactured, which may involve reselling items to reduce waste and using by-products as raw materials (JRC, 2008). Reuse benefits the environment, due to cutting emissions and costs and can even be considered as a core of the circular economy (Stahel, 2013), however, effective utilization of reuse requires proper laws, market and consumer willingness (Lenzen et al., 2007).

The principle of recycling implies reprocessing products into new ones, serving their original or new purposes (Ellen MacArthur Foundation, 2015b; Zeb & Kortelainen, 2021). Several studies describe recycling as a critical final step, where products unable to be recovered are broken down into pieces that offer new value and functionality, curbing raw material use and waste (Kane et al., 2018; Su et al., 2013). Some researchers like Lazarevic et al. (2012) and Kane et al. (2018) highlight the benefits of recycling which is a reduction in energy consumption, pollution, and waste; meanwhile, Bartl (2015) and Moreno et al., (2015) criticize recycling for its negative environmental impact, reduced product quality, and less efficient energy consumption.

3.2 Circular and Linear Economy

Throughout history, people believed in a "Cowboy economy" - an endless space within of which we could freely move when resources were scarce, thus mostly inhabiting thriving regions that relied on cheap global resources favoring companies consuming energy and materials (Boulding,1966). Consequently, companies that maximized resource consumption (“linear economy”) held the competitive edge, resulting in waste and neglect of recycling (Sariatli, 2017; Ellen MacArthur Foundation, 2013a). However, such a linear approach “production-use-disposal” is unsustainable as it ignores Earth's limits of natural resources, causing pollution and exploitation (Figure 3).

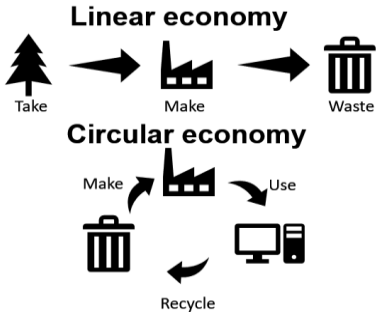

Figure 3. Linear and circular economy (adapted from Stark, 2019).

Despite being in practice for over 150 years, a linear economy model is not sustainable as it treats the environment as a waste repository, depleting resources with little recycling or reuse (Pearce & Turner, 1991). Significant population growth, rising consumption, and resource scarcity led to questioning the linear economy, giving rise to the CE concept, also known as the "cradle-to-cradle" vision based on alternative cyclical flows: biological and technical. In the first one, materials like food and wood return to nature through anaerobic digestion and composting thus generating renewables; in the technical cycle, products are meant to be repaired, reused, restored, or recycled (Ellen MacArthur Foundation, 2013a; Ellen MacArthur Foundation, 2015a*;* Sariatli, 2017). Such a CE approach extends raw material lifecycles, benefiting society, the economy, and the environment (EPRS, n.d.). McKinsey & Company asserts that by 2030 CE model can yield over €1.8 trillion in annual profit and a reduction of CO2 emissions by 48% (McKinsey & Company, 2016; Ellen MacArthur Foundation, 2015c).

Common characteristics of a CE include low material consumption, reduced pollution levels, and high resource efficiency (Murray et al., 2017). The Ellen MacArthur Foundation (2013a; 2015b) defines key characteristics of a CE as eliminating waste by valuing resources and optimizing material cycles for reuse. The “Systems thinking” approach is one of the key characteristics of a circular economy, which involves understanding how components interact and function as a system along with recognition of the full potential of materials until they are fully utilized. (Figure 5)

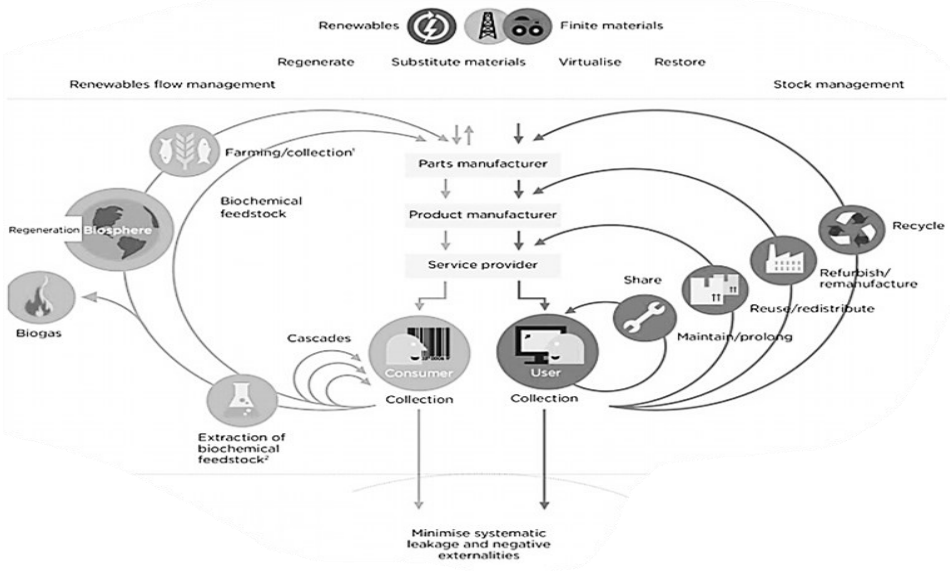

Figure 4. Circular economy characteristics (EMF 2015b).

Transitioning to the CE introduced by the Ellen MacArthur Foundation in "ReSOLVE" model suggests six main actions, amid of which are shift to renewables, ecosystems' regeneration and resource recovery; promotion of sharing, repairing, and reuse; optimization and automation of supply chains, minimizing waste in a products' cycle; promotion of closed-loop systems for finite material recycling and renewable return; shift to virtual materials (e.g., digital books, online offices) (Ellen MacArthur Foundation 2013a; Ellen MacArthur Foundation 2015a). However, for a successful shift to a CE, effective product design is vital. The European Commission stresses that nearly 80% of environmental impact arises from a product design. The establishment of favourable conditions, including consumer education, collaborative efforts to minimize environmental impact, regulations, and financial incentives, are essential, along with the development of reverse communication networks to ensure manufacturers are prepared to take back products at the end of their life cycle. (Sitra 2018*;* Bakker & Hollander, 2013.)

As an EU Member, Finland is a leader in achieving a carbon-neutral circular economy and aims to reduce raw material consumption to 2015 levels by 2035 (SITRA 2021). Emphasis is put on close collaboration between the government

and municipalities to reduce natural resource usage, promote reuse and recycling of materials, and establish a carbon-neutral CE. Key strategies include product design, innovation, and cooperation among all stakeholders, particularly in the construction and energy sectors. (Työ ja elinkeinoministeriö, 2021.)

3.3 Green Deal and Circular Economy Alignment

The European Green Deal (EGD) constitutes a comprehensive policy framework designed to facilitate Europe's transition toward a sustainable trajectory, culminating in the attainment of climate neutrality by 2050. The benchmark year is 1990 when emissions were estimated at approximately 5 billion tons of CO2 equivalent. The trajectory to achieve net-zero emissions by 2050 involves a 20% reduction target for 2020, compared to the 1990 baseline, and a more ambitious 40% reduction target for 2030. However, a revised objective has been set for a 55% reduction target by 2030 to bridge the disparity between the projected progress of EU Member States in 2030 and their envisioned position (European Council of the European Union, 2023; European Committee of the Regions, Gløersen, et al., 2022).

The EGD encompasses the Circular Economy Action Plan (CEAP), which provides the framework for the European Commission's extension of eco-design directives under a 'sustainable product policy legislative initiative', which extends beyond energy-related aspects (European Commission, n.d.-i; Bader, 2021). One of the concerns addressed within this legislative framework is construction products which greatly contribute to the total amount of EU waste and GHG emissions via resource extraction, manufacturing, and building activities. Since enhancing material efficiency through reuse has the potential to mitigate approximately 80% of GHG emissions, the European Commission has established targets to augment it within the construction industry and thereby decrease its environmental footprint on a global scale. (European Commission, n.d.-l; Bader, 2021.)

3.4 Assessment of Carbon Emissions from Construction Products

Assessing carbon emissions aligns with CE principles by considering the entire lifecycle of construction products. Due to the significance of the building construction sector in causing various emissions which can include besides carbon dioxide (CO2), such gases as methane (CH4) and nitrous oxide (N2O), known as greenhouse gases (GHG), the whole life cycle of the products from design and extraction of raw materials to end-of-life and disposal has to be assessed (Klöpffer & Grahl, 2014; IPCC, 2014; EPA, n.d.a). Life cycle assessment can be done via the commonly used Life Cycle Assessment (LCA) method, which can evaluate various impacts, including climate change and resource depletion (Klöpffer & Grahl, 2014). Climate change is assessed through the Global Warming Potential (GWP) calculation over a period of 100 years, which quantifies GHG emissions in CO2-eq using the “Carbon Footprint” (CF) analysis of a product or service which is the total CO2-eq it contributes to GWP (Klöpffer & Grahl, 2014). For example, CO2’s GWP is always 1 as a reference gas; CH4 equals 27-30 units of CO2 over 100 years; N2O is 273 units of CO2 over 100 years (EPA, n.d.-b). Conversely, the term 'Carbon Handprint' represents positive climate impacts (Pajula et al., 2021).

To become a low-carbon building, there has to be a substantial decrease in the carbon footprint and notable carbon handprint, which can be achieved, *inter alia*, via the initial planning, design process, and reuse of products/materials (Kuittinen & le Roux, 2017). It is noteworthy that the construction sector, which accounts for nearly 39% of global carbon emissions, with 11% attributed to “embodied carbon” (total GHG emissions produced throughout the entire life cycle of a product or material, from its creation to disposal), play a significant role in reaching “carbon neutrality” (a balance between emissions and sinks) and “carbon negativity” (achieving net carbon removal surplus) which is vital for mitigating climate change (Weir et al., 2023; World Green Building Council, 2019). Various methods and tools are utilized to calculate emission data in the construction sector which result in disparities and variations in data quality.

Some suggest addressing these challenges via the utilization of Environmental Product Declarations (EPDs) that adhere to EN 15804 to ensure receiving verified and comparable environmental impact information for construction materials and products (Bionova, 2017; Rakennustieto, 2021). At the moment, in the EU, carbon footprint calculations are not mandatory in the construction sector. However, the Level's methodology helps to measure the resource efficiency of the buildings, including resource-efficient utilization of materials, and provides a common framework with core criteria for the entire building lifecycle which can be used in different countries, aligning with LCA methodology following the EN 15978 standard and the EU Taxonomy for new buildings over 5000m² (Regulation (EU) 2020/852).

In Finland, the carbon footprint assessment enforcement set for 2025 in the new “Land Use and Building Act (Ympäristöministeriö, n.d.-b). The upcoming calculation method will consider all lifecycle GHG emissions (embodied and operational ones), along with the evaluation of carbon handprint according to EU standards, which involves, among others, GHG avoidance through material reuse and recycling, utilization of durable building materials with organic or technical carbon content, as well as carbon sequestration in products made from concrete. (Kuittinen & Häkkinen, 2020; Ministry of the Environment, n.d.-a). In the meantime, it is possible to take voluntary actions by using standardized carbon footprint calculations or pursuing certifications like RTS, LEED, or BREEAM (Kuittinen & le Roux, 2017; Bionova, 2017). Additionally, voluntary actions can be supported by the Green Public Procurement mechanism that encourages the reuse of construction products/materials left after demolition activities.

4 Waste in a Circular Economy

The European parliament set a goal, that by 2020 at least 70 % of construction and demolishing waste has to undergo reuse, recycling, or some material recovery (Directive 2008/98/EC, 2008). Many EU member states have already reached that goal via the improvement of waste management systems through the increase of recycling and recovery, though it affected the reduction of materials' quality (Braungart M., & McDonough W.,2002). However, some alternatives can help to preserve the quality of the materials in the construction sector that are reaching their End of Life (EoL). Such alternatives are reuse and remanufacture which have to be encouraged and improved, because the closer to direct reuse, the higher the potential cost savings in materials, labour, energy, capital, and associated environmental factors (Ellen MacArthur Foundation, 2013a; Ellen MacArthur Foundation, 2013b).

4.1 Definitions

The Waste Framework Directive (WFD) in Article 3 (1) defines waste as "any substance or object which the holder discards or intends or is required to discard" (WFD, 2008). Within the hierarchy of WFD (Figure 5), waste prevention holds the highest priority and refers to actions taken before something becomes waste to reduce the waste quantity and harmful substance content, environmental, and health impacts (WFD, 2008). Furthermore, WFD in article 3 defines categories of "reuse" and "preparing for reuse", where the first one relates to the process of using products or components that are not considered waste for their original intended purpose and the second one relates to inspecting, cleaning, or repairing discarded products which became waste enabling their direct re-use without additional processing (WFD, 2008). In the hierarchy of WFD recycling takes a third place after preparing for reuse and encompasses reprocessing of waste materials into products or substances for original or other purposes but excludes energy recovery, fuel production, or backfilling (WFD, 2008). The fourth desired action in WFD involves recovery

processes, which means utilizing waste for a useful purpose by replacing other materials in specific functions within a plant or the broader economy (WFD, 2008). Finally, the least desired action is disposal, which refers to any operation that does not involve recovery, even if it incidentally reclaims substances or energy in the process (WFD, 2008).

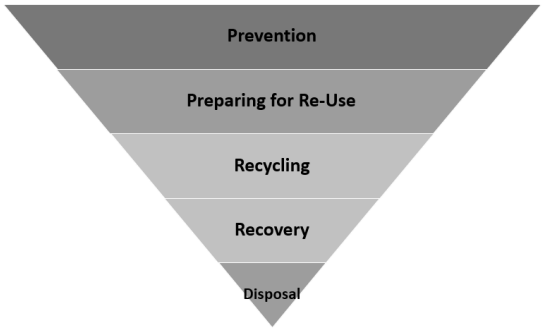

Figure 5. Waste hierarchy (adapted from WFD, 2008).

From the perspective of WFD reuse has an edge over recycling, which can be explained by little GHG emissions and less required processes; however, recycling is more common and has received detailed consideration through specific standards, whereas the aspect of reuse has not been explored within the same parameters. From a legal perspective the reuse from a circular point of view comes under the “prevention” and “preparing for reuse” categories according to the waste hierarchy. During the reuse under the “prevention” category, construction products/components that are not waste are used again for the same purpose; however, reuse under the “preparing for reuse” category implies that products/components that are waste have been checked, cleaned or repaired so that they can be reused after and the new purpose of their use might vary from a previous one (WFD, 2008; Zatta, 2019).

WFD (2008) also defines a situation “End of Waste” (EoW) when the waste ceases to be waste when it is followed by the completion of recovery, including, recycling operation after which it obtains the status of a secondary product. EoW status can be granted only if the product serves a specific purpose, there is a demand for it on the market, it complies with technical standards, and it

does not have a negative environmental or health impact (WFD, 2008). The EoW concept is relevant from the perspective of the “reuse” category when the construction products have to be reused again or when the purpose varies from the initial one (Zatta, 2019). Similar to the circular economy strategy prioritizing reuse as the best option for utilizing products or materials for the same purpose, the hierarchy of waste in WFD focuses on prevention as the best alternative to disposal, followed by preparing for reuse and recycling (Figure 6).

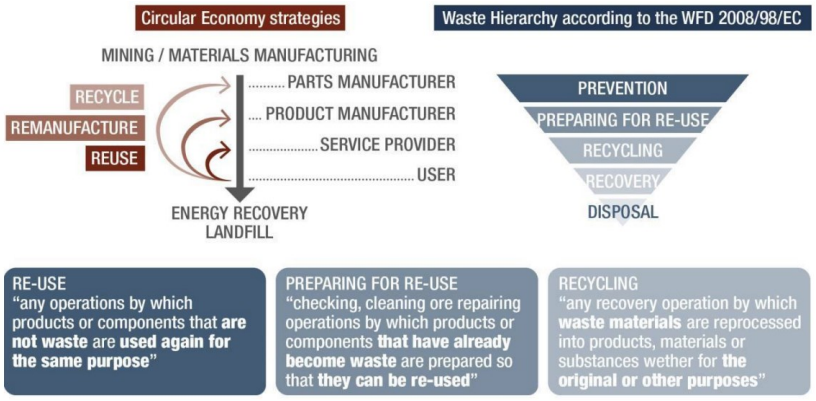

Figure 6. Circular economy and waste hierarchy (Ellen MacArthur Foundation, 2013a; WFD, 2008; Zatta, 2019).

Given the focus on the reuse of construction products in this thesis, it's crucial to define the term “construction products”. According to Designing Buildings (2022) “construction products” are finished items available for purchase, e.g., doors, and windows; “construction materials” are defined as raw, unprocessed substances, e.g., sand, salt; and “building components” are defined as building parts prefabricated off-site and assembled on-site, e.g., concrete panels, steel frames. Construction Products Regulation (CPR) N305/2011 in article 2 (1) defines “construction products” as any product or kit placed on the market intended for permanent inclusion in construction works, affecting their performance and meeting basic construction requirements (Regulation (EU) No 305/2011 [CPR], 2011). “Intended use” of construction products is defined in “harmonized technical specifications” representing standards and European Assessment Documents that have been harmonized for specific purposes

(CPR, 2011). In Finland, section 4 of the “Laki eräiden rakennustuotteiden tuotehyväksynnästä 954/2012” (2012) describes a “construction product” as an integral part, component, structure, or equipment in a construction work, including installation components, which meet defined in “Land Use and Building Act” technical requirements. Given the lack of uniform definitions for “construction products”, this thesis will utilize the CPR (2011) definition for the purposes of this research.

Regarding “construction and demolition waste” (C&D), which historically has often been disposed on landfills posing environmental risks, there is no unified definition. According to Circuit (2023), C&D waste comprises materials generated during construction or demolition, along with surplus items due to over-ordering or inaccurate estimates, common examples include insulation, concrete, wood, metal, soil, gypsum, cement, paints, adhesives, and more. Law Insider (n.d.), defines C&D waste as solid waste originating from building, repairing, or demolishing structures and land clearing; this waste typically includes concrete, wood, glass, asphalt, and more, but excludes clean fill, industrial or municipal solid waste generated during residential or commercial activities. European Commission (n.d.-h) defines C&D waste as debris from construction, demolition, infrastructure work, and road maintenance, which comprises diverse materials like concrete, bricks, wood, glass, metals, and plastic.

C&D waste is generated during construction, maintenance, disposal phases and is commonly classified into building, road, and excavation segments (The Brainy Insights, 2022; Team Finland, n.d.; European Commission, n.d.-g.). For market purposes, construction waste can be categorized by type into excavation waste (soil, sand, gravel, rock, clay), roadwork waste (concrete, asphalt, paving stone, etc.), demolition waste (concrete, roofing, wood, etc.), and complex waste (plastics, metals, paper, carton) (Transparency Market Research, n.d.). Further, the construction waste market categorizes materials into various types, which include wood waste (e.g., plywood, painted wood,

treated and manufactured wood, pallets); metal waste (ferrous and non-ferrous metals); asphalt-brick-concrete waste (ABC); ceramic waste (toilets, sinks, tiles); plastic waste (plastic pipes, vinyl siding), and others (textiles, carpet, mattresses, tires, glass) (Transparency Market Research, n.d.).

4.2 Legal Landscape for the Reuse of Construction Materials

European Demolition Association (2022) highlights that the demolition sector in Europe is going to expand and to promote sustainability, it is recommended that at least 50% of the materials in a new building derive from sources that involve recycling, reusing, or responsibly sourced renewable materials. Within this 50%, a minimum of 15% should be obtained from reused components, another 15% from recycled materials, and the remaining 20% can be a blend of reused, recycled, or responsibly sourced materials (European Demolition Association, 2022).

The legal landscape for the reuse of construction products left after demolition, including reuse of wood products left after demolition, is very complex, including European and Member State Levels. The European level includes three hierarchical sub-levels. The top and the highest sub-level start with an *umbrella on sustainable goals*, including green transition, reporting requirements, monitoring framework, and tools (see Figure 7).

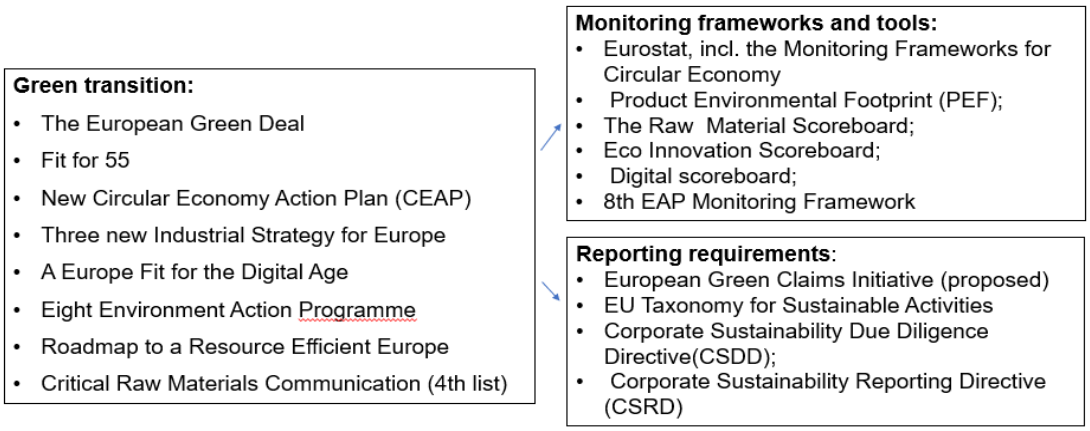

Figure 7. EU sustainable umbrella (Nordic Innovation, 2023)

The second European sub-level includes *strategies and frameworks specific to construction*, which includes among the others common EU indicators of the resource efficiency of buildings -Level(s) (Ministry of the Environment, n.d.-d). (see in Figure 8).

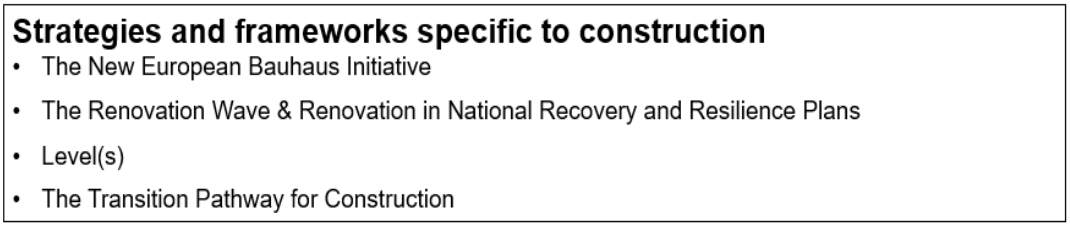

Figure 8. EU construction strategies (Nordic Innovation, 2023).

The lowest European sub-level includes *regulation on construction and construction demolition waste*, which covers energy performance, waste management, and technical specifications (CDW) (see Figure 9).

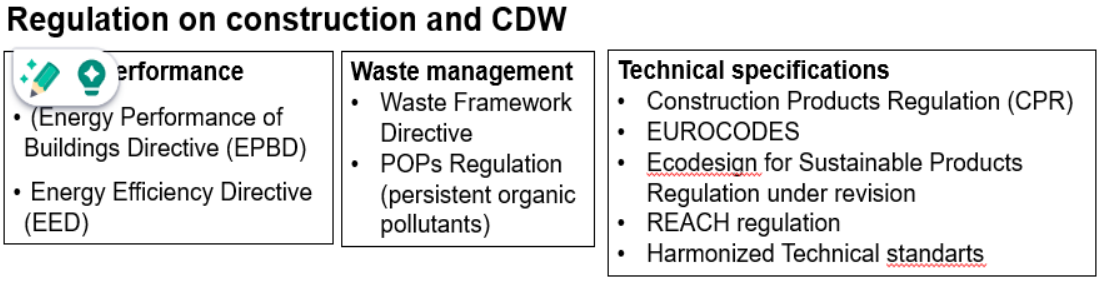

Figure 9. EU construction regulations (Nordic Innovation, 2023).

The Construction Product Regulation (CPR), which is under revision, sets the performance requirements for construction products, while harmonized European standards (hENs) set common assessment methods and criteria for construction products' performance related to essential characteristics including aspects like fire resistance, absorption, contact with drinking water, controlling the release of hazardous substances into indoor air and the environment (CPR, 2011; European Commission, n.d.-g). CPR offers mandatory and optional assessment procedures to get the CE ("Conformité Européenne") mark, which

demonstrates the product's alignment with the declared performance. If a product falls under a harmonized standard, the manufacturer must create a Declaration of Performance (DoP), which confirms that the product complies with construction requirements and safety standards throughout its life cycle (Zatta, 2019; CPR, 2011).

The DoP is crucial for obtaining the CE mark, signifying compliance with the CPR's technical language and assessment system. If a product is not covered/fully covered by the harmonized standard, there's no need for a DoP or CE mark and manufacturers may choose an alternative in the form of receiving the European Technical Assessment (ETA) via Technical Assessment Bodies (TAB) using the European Assessment Document (EAD) (Zatta, 2019; CPR, 2011).

There is also a third option named “mutual recognition” when the product is not covered by hENs or ETA. This option implies that the product can be freely marketed across all Member States if no national requirements are justified by health and safety concerns; however, products falling solely under mutual recognition are not permitted to bear the CE mark under the CPR (Zatta, 2019; CPR, 2011; Finnish Safety and Chemicals Agency (Tukes), n.d.-a).

According to the Waste Framework Directive (WFD), if a construction product's future use remains the same, it is governed by CPR as any product; however, if its purpose changes, it is treated as waste, complying with norms until recovery operations ensure its End of Waste status, subjecting it to CPR compliance (WFD, 2008).

Besides the European level, the reuse of construction products is also regulated on a *Member State level* which is the lowest in the hierarchy, providing Member States specific possibilities and limitations for reuse (see Figure 10).

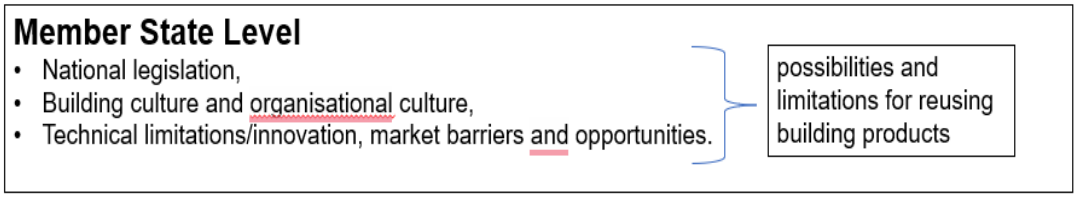

Figure 10. Member State approach for construction products (adapted from Nordic Innovation, 2023)

In Finland, local practice involves controlling reuse on a national level, except when substantially modified reusable product is considered new under the CPR, thus requiring CE marking. Finnish national procedures for approval of construction products not covered by CE, hENs, or ETAs, include Type Approval, Verification Certificate, and Certification of Production Quality Control (Laki eräiden rakennustuotteiden tuotehyväksynnästä 954/2012, 2012). In addition, the building supervision authority may require On-Site Certification, to ensure product safety and fit (Ministry of the Environment, n.d.-c).

The aforementioned legal framework is not a comprehensive overview. Additionally, there is also an EU Construction & Demolition Waste Management Protocol which promotes urban mining and highlights material reuse as the top strategy due to its environmental advantages over recycling (EU Construction & Demolition Waste Management Protocol, 2016). The protocol covers pre-demolition audits, waste identification, separation, collection, logistics, processing, quality management, policy improvements, and clarifies relevant definitions. The European Commission's 2018 guidelines offer the methodology for conducting this assessment, including phases, stakeholders, and material inventory for waste assessment (European Commission, 2018). According to the EU Construction & Demolition Waste Management Protocol (2016), European standards that apply to regular materials are also applicable to those from construction and demolition waste (CDW).

4.3 Challenges in the legal reuse of construction products

In the construction industry, the design phase is crucial for minimizing environmental costs and the building industry explores Design for Disassembly (DfD) to boost sustainability, focusing on easy disassembly and single-material components for recycling and durability (Greenfield, 2017; COM/2014/0445, 2014) Bakker et al., 2014). DfD involves planning for the reintegration of materials at their End of Service Life (EoSL), enabling responsible material management. However, in practice more than two-thirds of EU residential buildings were built in the period 1945-1970 without considering construction and demolishing waste as potential resources; furthermore, the absence of urban building element databases exacerbates challenges, leading to delays in material sourcing (BPIE, 2011; Ajayabi et al., 2019; Gorgolewski, 2019).

The reuse of building materials promotes innovation and sustainability, however, in practice, the legal framework has challenges due to the ambiguous categorization of reclaimed elements which is not based on the actual performance of the elements but depends on how the materials were collected during demolition (Zatta, 2019). This scenario leads to a complex situation where elements may be subject to different regulatory frameworks, making it difficult for stakeholders to understand the legal requirements (Zatta, 2019). Reclaimed elements do not always conform to existing harmonized standards and CPR requirements for the CE mark due to their origin outside traditional manufacturing processes and limited information on their technical specifications (European Commission, 2016). Currently, there are no harmonized standards to be applied to reused products which is due to a lack of assessment methods, possible changes in characteristics due to product use, lack of proper documentation, absence of product history, and shortage of control methods specified in standards to access reused products' characteristics (Nordic Innovations, 2023).

There are no specific rules in the CPR for assessing reclaimed products, which ultimately leads to a situation where the reuse is encouraged, but the main construction product standards do not address it explicitly, creating confusion and a lack of clear guidance (Zatta, 2019). The CPR procedures focus on products' safe use in construction, not the product itself, leaving Member States to regulate performance and safety based on their specific needs.

Despite recognizing the significance of reusing construction materials after demolition, the current version of CPR does not promote the reuse of construction products. For example, CPR does not cover the redistribution of reused products and it lacks specific assessment procedures for reclaimed construction products. Moreover, CPR does not regulate the situation for reused products that were manufactured before it came into force and products whose performance was changed during their use (Testbed Helsinki, 2021; Nordic Innovation, 2023).

The requirements of the CPR apply when products are introduced to the market within the European Economic Area (EEA), but this presents challenges because the information usually originates from deconstruction processes rather than manufacturers. Another perspective suggests that CPR requirements do not tightly regulate reused construction products, as they are often intended for local use within a specific area (Seys, 2017; Zatta, 2019). Despite potential debates, it remains a necessary requirement for all suppliers to ensure that buildings are safe and have minimal environmental impact (CPR, 2011; Zatta, 2019). Notwithstanding favourable assessments, some end users are prejudiced against 'second-hand' quality which remains a significant hurdle in the reclaimed building market; additionally, norms exacerbate this problem as worries about "waste" and “safety” increase with acknowledged EoW (End-of-Waste) status.

A common misunderstanding is that reused construction products should have the CE mark, even though in fact, the CE mark does not cover reused products.

A CE mark does not imply automatic compliance with national construction regulations and a CE-marked product is suitable if it meets national requirements and aligns with site-specific design solutions. The suitability of a construction product for a specific purpose must be evaluated based on the construction works and relevant building regulations, for example in Finland with “the Land Use and Building Act” and the decrees relevant to the Act (Finnish Safety and Chemicals Agency (Tukes), n.d.-b).

5 Green Public Procurement

Public procurement refers to the process of procuring goods and services by government organizations or public sector entities (OECD, n.d.). Public procurement has a significant purchase power in the EU and dominates certain sectors of the market, for example, construction and public transport. The decisions made within public procurement's framework can have a significant impact on the promotion of goods and services with little environmental impact and the development of environmentally friendly technologies and products. This influence is significant, even though GPP is a voluntary tool with variable adoption by Member States. (European Commission, n.d.-b).

5.1 Definition

Green Public Procurement (GPP) is defined as a "policy tool" that promotes sustainable purchasing practices with reduced environmental impact through a selection of criteria based on the keyword "environment" and its variations (Rainville, 2016; Rosell, 2021). In literature, concepts of Sustainable Public Procurement (SPP) and Circular Procurements are interconnected to GPP, however, these concepts are different and go beyond consideration of only environmental impact (Sapir et al., 2022).

SPP can be defined as a method through which public authorities seek to achieve value for money in terms of creating advantages not only for the organization, but also for society and the economy, meanwhile minimizing and avoiding possible damage to the environment. In other words, public organizations during the procurement of goods and services want to achieve an optimal balance between three fundamental pillars of sustainable development - economic, social, and environmental (Safdie, 2023; United for Efficiency [U4E], n.d.). On the other hand, GPP can be defined as a process via which public organizations procure goods and services with reduced environmental impact

throughout their life-cycle analysis (European Commission, 2008; United Nations Environment Program, 2021.)

While SPP considers the economic, social, and environmental impact of procurement, GPP focuses on the environmental aspect. The grounds of the definitions for SPP and GPP is the idea of “Value for money”, which is evaluated not only at the moment of purchase but encompasses the total expenses in connection with the “use-maintenance-disposal” cycle. (European Commission, n.d.-a; Morton, Perfrement & Perera, 2009; Life Cycle Initiative, 2016.)

Similar to GPP, Circular Public Procurement (CPP) has a focus on sustainability, resource efficiency, and uses a life-cycle approach, considering the environmental impact of products and services during the entire lifespan, and not only during the production and use phases (Greener, n.d.; Circulars – ICLEI, 2022; Ellen MacArthur Foundation, n.d.-b). Both approaches encourage collaboration among stakeholders, including public authorities, suppliers, and consumers, to drive innovation in procurement strategies (European Commission, 2017). Though GPP and circular procurement share some similarities they differ in objectives and methods, for example, GPP integrates environmental criteria for sustainability, while circular procurement transforms the value chain for resource efficiency and waste reduction (Fedato, n.d.; European Commission, 2017); GPP evaluates products based on environmental performance, while circular procurement also emphasizes durability, repairability, reusability, and recyclability (Ellen MacArthur Foundation, n.d.-b).

Despite differences between GPP and CPP, there has been a growing trend towards considering CPP as a comprehensive GPP, where special attention is given to such features as the circularity of the products and services, which can be explained by the overall transition towards circular economy practices (Tátrai & Diósi-Kovács, 2021).

5.2 GPP Requirements

Public procurement balances supply and demand, prioritizing "value for money," which doesn't always mean the cheapest option but rather meeting requirements, including environmental aspects. Incorporation of GPP criteria requires prior market analysis regarding available products, solutions, technologies and can be implemented at any building and procurement stages (Table 1), for example, in subject-matter, technical specification, selection-exclusion-award criteria, in contract performance clauses (Rosell, 2021; Cheng et al., 2018; European Commission, 2016).

Table 1. GPP criteria across building stages (adapted by the European Commission, 2016)

	Building stage	**GPP criteria**
A	Feasibility study & pre-planning	include the initial assessment of the project including its environmental impact
B	Design phase	consider the use of sustainable materials, renewables, and energy efficiency
C	Construction & installation	involve effective resource management, waste reduction, sustainable construction practices with the utilization of materials with low environmental impact.
D	Operation & Maintenance	include efficient use of materials and overall monitoring of their environmental impact.
E	Renovation & refurbishment stage	focus on the integration of energy-saving systems and utilization of best practices
F	End-of-life stage	promote responsible practices of demolition including recycling and handling the waste in a sustainable way.
G	Project specific criteria	can include requirements relevant to a specific project, for example, partial utilization of demolished materials for the construction of a new building

In 2017 the Finnish Ministry of Environment published a 'Green Public Construction - Procurement Guide,' which highlighted the need to implement GPP requirements to make public procurement more environmentally friendly. It stressed the significance of the Life Cycle Assessment (LCA) method for assessing environmental impacts and urged the adoption of CE principles to enhance resource efficiency and alignment with Sustainable Development Goals (SDGs). It emphasized the need for collaboration across the value chain and incentives to suppliers to drive innovation in their efforts to meet higher

standards, thereby achieving better scores. Transparency was advocated to promote accountability, allowing for the evaluation of environmental factors in decision-making. (Kuittinen & le Roux, 2018).

To increase transparency and engage with participants regarding GPP requirements, authorities can publish prior notices, detailing criteria and consultation processes. This engagement aligns with GPP principles of clear, verifiable, and justifiable environmental criteria, common across Member States, grounded in a life-cycle approach and scientific evidence. For example, the City of Helsinki publishes Contract notices through the Hilma service, where suppliers can access procurement details and submit bids or proposals, thus, enabling the City of Helsinki to identify suitable suppliers, compare offers, and select the most advantageous one based on predetermined criteria. Notice publication in Hilma is obligatory for contracts above the EU and national thresholds and voluntary for contracts below the EU and national thresholds (Hilma, n.d.). Additionally, the City of Helsinki follows its own guidelines during the public procurement practices with a focus on responsible procurement practices for a climate-smart sustainable city, providing a possibility to directly purchase the product or service from the most appropriate supplier in minor procurements (City of Helsinki,2020b).

Since 2008, the Commission has developed over 20 GPP criteria, which are continuously updated and reviewed. (European Commission, 2016; European Commission, n.d.). For example, GPP criteria in the construction sector assess the environmental impact of a building and its components focusing on energy, material, water, waste, and emissions. Currently, criteria exist for office buildings, and a working draft is in progress for the design, construction, renovation, demolition, and management which can be applied not only to office buildings but also to social housing and the private sector (Donatello et al., 2022; European Commission, n.d.-c). GPP criteria combine "core" and "comprehensive" parameters. "Core" parameters address major environmental impacts, applicable to all authorities with minimal verification and costs.

"Comprehensive" parameters target the greenest products and require more verification and costs. (European Commission, 2023).

Apart from EU's level GPP criteria, national or regional criteria may exist for various product and service categories, including labels from impartial third-party organizations, such as, "EU Ecolabel", "Energy Star" or "EU Energy label," (European Commission, 2023; European Commission, 2016; EU Ecolabel,2023; Magnadóttir et al., 2017). For example, in Finland, under Finnish Act 1397/2016 "On Public Procurement and Concession Contracts", public authorities are required to promote sustainable procurement practices by including the use of eco-labels and sustainable criteria in tender specifications (Act on Public Procurement and Concession Contracts, 2016). Furthermore, under Act 1397/2016, public funds are encouraged to voluntarily incorporate "carbon reduction" criteria in building projects, with a recommendation to utilize a minimum of 10% recycled or reused materials and calculate the life-cycle carbon footprint throughout the procurement process (Hasanbeigi et.al., 2019; Act on Public Procurement and Concession Contracts, 2016; GBC-Finland, 2015; Kuittinen & le Roux, 2018.)

GPP tenderer selection relies on suppliers' technical and professional resources, confirmed through the European Single Procurement Document (ESPD), which indicates compliance with criteria like experience, qualifications, references, certificates, and environmental management systems, e.g., EMAS, and ISO. (Regulation (EC) No 1221/2009, 2009; Directive 2014/24/EU, 2014; European Commission, 2016).

5.3 GPP Contract Clauses and Contract Award

Considerations related to environmental impact can be included directly into contract clauses provided that they are applied to all the bidders and linked to a contract's subject matter (Directive 2014/24/EU, 2014; Directive 2014/25/EU, 2015). According to Ahola (2012), including environmental criteria in the

contract's title can help tenderers to define what is required and important for the contract performance. Kähler (2013) and Hirvonen-Ere (2019), suggest so that the environmental clauses are effective, they have to be monitored and supported by positive and negative incentives which go beyond general compliance with environmental law. In the event of subcontracting, it is essential to consider the principles of joint liability as outlined in Articles 71 (Directive 2014/24) and Article 87 (Directive 2014/25) which ensure adherence to environmental clauses and potential substitution of subcontractors in cases of non-compliance (Directive 2014/24/EU, 2014; Directive 2014/25/EU, 2015).

Public authority evaluates tenders based on the MEAT (most economically advantageous tender) method and in the case of GPP environmental impact is also considered for contract award (European Commission, 2016). Environmental criteria in GPP can be set in "technical specification" as a minimal requirement and in award criteria as a preference. It is also possible to define in the specification a minimal performance level for tenderers ("performance-based specification") with the allocation of additional points during the award stage, as well as consider labels, EMS, certificates, and life-cycle costing (LCC) for assessment. In both cases, exclusivity for one supplier should be avoided unless there are exceptional circumstances and provisions for the possibility of using "equivalent" are indicated (Sustainable Procurement Platform, n.d.; Directive 2014/24/EU, 2014; Directive 2014/25/EU, 2015; European Commission, 2016). According to Rainville (2017), "knock-out" criteria can be set in technical requirements, while criteria that encourage voluntary performance enhancements and expand the variety of solutions and potential suppliers can be set in the award stage.

Whereas technical specifications assessment is performed on a "pass/fail" basis, award criteria are scored and tenders offering the best environmental solutions can get more marks depending on the weighing system determined by the contracting party (European Commission, n.d.-b). Award criteria have to be clearly "defined and be verifiable", meaning that well-informed and diligent

tenders can understand criteria in the same way and public authority has means to check the accuracy of the information provided by tenderers, which is especially important to prevent “greenwash” and false claims (Directive 2014/24/EU, 2014; Directive 2014/25/EU; European Commission, n.d.-b.) Award criteria have to be announced in advance and provide a possibility for different operators to participate in a tender, thus, preventing discrimination and unhealthy competition (*Concordia Bus Finland Oy Ab, v Helsingin kaupunki and HKL-Bussiliikenne*, 2002; Directive 2014/24/EU, 2014; European Commission, 2016).

Life-cycle cost (LCC) calculation method and information given by tenderers have to be reflected in procurement documents and can be evaluated via the utilization of different tools, which consider the costs along the whole lifespan of the product, specifically, purchase and operating costs; end-life and external costs (Directive 2014/24/EU, 2014; European Commission, 2016; European Commission, n.d.-d; European commission, 2016). The list of tools that can be utilized for LCC calculation is not exhaustive and among the others include, for example, “The European Commission’s common method for LCC in construction”; assessment of CO2 emissions under “the SMART-SPP project”; LCC tool by the Swedish Environmental Management Council (SEMco); LCC within the “BUY SMART” project (European Commission, 2007; Tepper, 2017; Swedish environmental management council [SEMC], 2011; IEA, 2017). However, in practice, the use of LCC methodology is a complex task as it varies depending on services, works, or products, and in most cases, it is under the jurisdiction of Member States which results in significant challenges for its systematic implementation, except of, for example, Clean Vehicles Directive requirements (Pouikli, 2021).

Overall, though GPP is a voluntary mechanism where Member States can define the extent to which it is applied, it is a critical tool for promoting green practices in public procurement, *inter alia*, in the reuse of construction products and carbon footprint mitigation (European Commission, 2023).

6 Previous findings

Successful examples show that including in the public procurement contract “green clauses” which prioritize reuse and refurbishments already on the design stage, along with strong collaborations with local contractors and active involvement of residents can significantly increase the share of reused materials/products during the construction work (Jones & Shalley, 2016; Bullitt Center, n.d.). Findings show, that, compulsory green requirements and a supportive legitimate framework for the construction sector can provide more legal certainty and be considered an effective tool to increase the enforceability of the relevant provisions, encourage the reuse of construction products, and contribute to a greener future (European commission, 2016*;* Pouikli, 2021*).*

In France within a framework of GPP, several criteria have been utilized to facilitate the circulation of reclaimed building elements in North-western Europe by 50% (FCRBE). There has been created an inventory of reusable available materials with an assessment of the market demand for them and then materials were categorized based on their reuse potential from the most promising to those with limited potential. Further, technical specifications set minimum targets for high-reuse materials (category A) based on reclamation audit results, and contractors were incentivized by award criteria to exceed these targets or reclaim materials from other categories. Ultimately, the winning bidder offered the best value for money, meeting or surpassing minimum targets and demonstrating substantial field experience. (Green Public Procurement: good practice library, 2022.)

Missing data leading to differences between the EU countries is considered to be one of the obstacles in GPP, for example, in the online database for tenders “TED” system (Tenders Electronic Daily) it is estimated of nearly 25% of missing data (Rosell, 2021). Another obstacle is the lack of transparency and common environmental standards, which are required to compare the environmental footprint of the products and in GPP they are usually represented

in the form of eco-labels or EPD (Environmental Product Declarations) (Sapir et al., 2022; Hasanbeigi et al., 2019; OECD, n.d.). Moreover, while some countries like the Netherlands, Denmark, Norway, and France follow the MEAT principle with the inclusion of green criteria (the MEAT concept doesn't necessarily mean that green criteria have been applied), other countries like Romania, Lithuania, and Slovakia in 90 % of the contracts follow the lowest price criteria (European Commission, (n.d.-f). Finland follows the MEAT principle with the inclusion of recommended criteria for low carbon GPP in the construction sector, meaning applying of carbon footprint and LCC assessment, energy and emissions assessment, assessment of renewable and recycled materials, verification of innovative concepts, alignment with the EC's GP building criteria and compliance with environmental certification systems for buildings (GBC-Finland, 2015).

In the Netherlands, findings show that using conventional methods in the construction industry does not lead to meaningful sustainable innovations, as specifications in GPP contracts based on conventional materials prevent the reuse of construction products. Transition to a green industry requires the replacement of conventional construction products with bio-based materials which can be sourced locally and sequestrate carbon emissions during the whole lifetime resulting in CO2 reduction. Moreover, incorporating specific environmental criteria in construction contracts, for example, CO2e storage, can stimulate tenderers to use and reuse sustainable materials, for example, wood products (Bader, 2021; Pittau et al., 2018; Heidari et al., 2019; Arrigoni et al., 2017).

Amid barriers in the reuse of construction products usually there can be logistical and technical obstacles. The first one refers to guaranteed availability of supply, short demolition programs preventing proper deconstruction, and lack of sufficient storage space for recovered products. Technical obstacles imply the absence of standardization of components, limited understanding of the

product's properties, usage history, and need for quality assurance of reused products. (Li & Sierens, 2020).

Support for procurers in GPP is important and a good example is offered by the Dutch Ministry of Infrastructure and Environment where via special online software "DuboCalc", the latest GPP criteria can be inserted directly into tender documents based on a chosen level (basic-significant or ambitious) (Sapir et al., 2022; OECD, 2016). The "DuboCalc" helps to monetize the environmental influence of the construction projects in the award criteria, where bidders can access the life-cycle environmental impact of their offer and then via the "CO2 performance ladder" tool access reduction of carbon emissions. Such a mechanism enabling bidders to calculate expected discounts before the bid submission. Later, the results of "DuboCalc" and "CO2 performance ladder" become part of the contracts' requirements obligatory for performance (Sapir et al., 2022; OECD, 2016). In the Netherlands, there has been created a special center "PIANOo" which helps procurers to understand requirements and insert them into tender criteria based on their environmental impact (Dutch Public Procurement Expertise Center, n.d.; Sapir et al., 2022). A similar center "Procura" has been set on the European level enabling procurers to share knowledge and expertise in GPP (European Commission, 2016; ICLEI, n.d.).

In Finland, to support GPP practices in the construction sector multiple projects have been run. For example, CIRCuIT ("circular construction in regenerative Cities") which focused on circular construction, enabling reuse of components after dismantling and extending buildings' lifecycle through refurbishments and transformations (HSY, n.d.). The "Canemure" project, conducted over six years in Helsinki City, played a vital role in advancing calculation methods for evaluating CO2e reductions in the building and construction sector. The outcomes showed the effectiveness of integrating environmental criteria into GPP to mitigate environmental harm (Huomo et al., n.d.). In Tampere, environmental criteria have been utilized in the "Hiedanranta" district during the construction tendering where CO2 emissions have been considered across

different building stages, which helped to achieve resource efficiency and carbon neutrality by prioritizing the consideration of whether a building is designed for ease of repair or dismantling (Huuhka, 2019). In the "Rapurc" project (Finland), a unique "Demolishing Mapping Program" was developed to collect information about the reuse and recycling of materials/products that remain after demolition. These materials can be accepted without a CE mark if their primary purpose remains unaltered and suitability is confirmed through site-specific certificates or testing, as they fall outside the scope of the Construction Products Regulation (2011) that applies to new materials and does not cover the utilization of reusable materials (MikseiMikkeli, n.d.; Wahlström et al., 2019).

The findings from the "Ranta" project in Finland, which focused on the reuse of construction materials and products left after demolition activities, revealed that the reuse and recycling of materials/products often go overlooked in demolition contracts in which customers play an important role by dictating project requirements, with cost typically prioritized (Green Net Finland, n.d.). Purchasing of new materials is favoured over reused/recycled ones and usually, municipalities have a lack of capacity for material resale and storage (Green Net Finland, n.d.). The importance of CO2e emissions from demolition waste is frequently neglected in urban planning and to advance material usage, more ambitious targets are needed, for example, implementation of EU pre-demolition audits and uniform waste classification, extension of Circular Economy (CE) marking to demolition materials and standardized classification systems along with incentive measures for resource efficiency (Green Net Finland, n.d.). Circular initiatives should focus on the reuse of high-volume materials, for example, concrete, and bidders should not face restrictions by pre-defined materials so that they can maximize the reuse of demolition materials. Involving third-party providers can boost reuse rates and direct onsite work audits can provide a comprehensive picture of possible material reuse (Green Net Finland, n.d.).

Results from eight completed demolition pilot projects initiated in Helsinki in 2019 showed that a comprehensive demolition material survey is conducted only if there is a known application for reusable building components (Eriksson, 2023). In addition to Helsinki's internal capabilities, the engagement of private recycling operators is essential, especially in the fields of disassembly, refurbishment, storage of building components, and the capability to verify eligibility when necessary.

Challenges in the reuse of building components include such factors as vandalism, project timelines, associated costs, and lack of contractors' experience in meticulous deconstruction. Challenges also include determining whether minimum requirements or quality points are more effective, formulating transparent and achievable requirements, establishing the appropriate value of quality point requirements (e.g., assigning a specific value to one quality point), and identifying the efficient incentives to motivate contractors to adopt circular economy quality points. To ensure effective reuse, it is necessary to have a comprehensive understanding of all requirements related to the contractor's role before initiating the demolition contract tendering process. Quality-based tendering for demolition contracts needs a clear scoring system and a thorough description of quality criteria. (Eriksson, 2023).

7 Methodology

The choice of research methodology, as outlined by Rutberg & Bouikidis (2018), can be either qualitative or quantitative. Qualitative research emphasizes the subjective experiences and perspectives of individuals (Moore, 2015); whereas quantitative research focuses on numerical data and statistical analysis offering generalizable findings and providing the researcher with the ability to maintain objectivity when analyzing a large number of cases (MacDonald & Headlam, 2015). Cohen, Manion, and Morrison (2007) put forward the argument that there exists a third type of research method known as experimental research. This approach is characterized by its scientific nature and involves manipulating one or more independent variables to assess their impact on one or more dependent variables.

Creswell (2017) suggests that in situations where a comprehensive understanding of a problem is necessary, the utilization of a mixed qualitative-quantitative method is appropriate. Such an approach can provide a more complete understanding of the problem by combining both qualitative and quantitative perspectives and connecting the various aspects of the evaluation process.

7.1 Qualitative Method

The qualitative research method represents the subjective experiences and perspectives of individuals regarding real-life phenomena. It draws upon the expertise, experiences, and knowledge of participants and provides insights into their subjective perceptions of reality, shaped by their feelings and beliefs. The qualitative research process often requires a profound understanding of the topic and can be facilitated through the use of open-ended text responses (questionnaires), observations, or interviews. This research strategy is often favored in situations where the problem at hand is not well understood, and the underlying reasons need to be explored. (Rutberg & Bouikidis, 2018).

The collection of data is a critical component of any research study and requires careful consideration and planning. Ajayi (2017) differentiates between secondary data, which pertains to previously gathered information from past studies, and primary data, which is directly collected from the original source. The choice of data collection method should be guided by the research objectives and the type of data needed to address the research questions. While there are some case studies and pilot projects related to the reuse of construction materials from construction and demolition activities, the existing data is primarily represented in research and development formats, often lacking comprehensive explanations. The present study utilizes both primary and secondary data for data collection. Secondary data, obtained from online sources, will be utilized to complement the primary data collected directly from the original sources. This dual approach to data collection allows for the integration of existing information with new data, specifically collected for this thesis. The primary focus of this study is on a topic that has not been previously explored, thus, collecting data from primary sources is essential to achieve the research objectives.

This thesis employs a qualitative research approach that supports reach data collection and in-depth analysis; moreover, the choice of this method was partially influenced by the recommendation of the commissioner, who suggested that a qualitative and exploratory research design would be suitable to comprehend the underlying motivations and rationales and provide insight into the decision-making process in the context of the study. Exploratory research, as outlined by MacDonald and Headlam (2015), entails conducting interviews and gathering responses to open-ended questions from key stakeholders. This process aids in identifying priorities, testing hypotheses, and establishing connections among research subjects to advance the findings.

This thesis employs an open-ended questionnaire and semi-structured interviews as a method for data collection. An open-ended questionnaire and the semi-structured interview approach allow for flexibility in the process, as

they encourage more spontaneous, in-depth responses, enable the participant to share insights, and elaborate on their perspectives in-depth. The qualitative research approach is further reinforced through the utilization of a case study method. This combination of methods is expected to provide rich and detailed data that will aid in achieving the research objectives and enhancing our understanding of the topic under investigation.

7.2 Questionnaire and Semi-Structured Interview

The selection of an appropriate research methodology is based on several pivotal factors, which include the availability of potential participants, the nature of the research subject matter, the participants' degree of motivation, and the resources at hand for conducting the research. In the context of this thesis, a pragmatic approach was adopted, involving the utilization of both a questionnaire featuring open-ended questions and semi-structured interviews for data collection. The decision to combine two qualitative research methods is driven by the practical difficulty of scheduling online meetings with some of the participants due to their tight schedules, making a questionnaire with open-ended questions a more feasible option for collecting the required qualitative data.

The questionnaire serves as a versatile research method suitable for both quantitative and qualitative data collection purposes. In the context of this research, the questionnaire is employed as a qualitative tool, benefiting from the advantage of a relatively small sample size that facilitates comprehensive data analysis. The process of sampling necessitates a clear comprehension of the respondents, the establishment of a suitable sampling frame, and consideration of factors like language barriers and areas of expertise, as outlined by MacDonald and Headlam (2015). Distribution of questionnaires can be administered through various channels, including phone interviews, email surveys, or face-to-face interactions. For this thesis, open-ended questionnaires were distributed electronically to a predetermined list of participants, which

proved to be a cost-effective strategy for eliciting more comprehensive responses (MacDonald & Headlam, 2015).

Effective question design plays a pivotal role in the questionnaire, involving considerations related to question types, complexity, the inclusion of screening questions, and the sequencing of questions (MacDonald & Headlam, 2015). The utilization of open-ended questions, typically initiated with words such as "what," "why," or "how," enhances the ability to furnish extensive and comprehensive answers, thereby enabling the extraction of substantial volumes of data; whereas close-ended questions often result in more superficial and predicted answers. The interview questions in this thesis are categorized into thematic groups, simplifying data analysis and enhancing alignment with the theoretical framework and research inquiries.

As mentioned earlier, for the current thesis, questionnaires and semi-structured interviews were chosen as methods for data collection. The selection of the interview type depends on the objectives and goals of the research. According to Alsaawi (2014), there are three main types of interviews: structured, semi-structured, and unstructured. In a structured interview, the questions are pre-determined and asked in a pre-established order, which ensures a high level of focus on the topic but can limit the depth of information obtained due to the limited flexibility in the interview process. On the other hand, the semi-structured interview, which combines elements of both structured and unstructured, enables respondents to respond to predetermined questions in their own terms while also permitting the exploration of supplementary subjects through open-ended questions, making it suitable for researchers with a strong grasp of the subject who aim to delve deeper with follow-up questions (Alsaawi, 2014). Lastly, the unstructured interview, useful in situations where there is limited information about the interviewee, allows the interviewer to have a more spontaneous and open-ended conversation, with no restrictions or pre-arranged questions (Easwaramoorthy & Zarinpoush, 2021).

For this thesis, as an additional method for data collection, the semi-structured interview method was chosen because it guides participants while permitting in-depth exploration through open-ended questions which allows them to receive in-depth and extensive answers. Unstructured interviews were deemed unsuitable due to resource demands and potential complexity for data analysis.

According to Silverman (2013), in qualitative research the primary focus of the inquiry is on the experiences, processes, and perspectives, rather than the quantification of the amount, thus, the focus of questions is on “How”, rather than “How many”. For the current research, among the others, the following questions have been asked (full list see in Appendices 1-6):

- How does the voluntary nature of the GPP in Finland affect the promotion of the reuse of wood products left after demolition activities?
- What standards do you use to assess the possibility of the reuse of wood products left from demolition activities?

7.3 Data Collection

The data for the interviews were gathered from various departments of the City of Helsinki, Ministry of the Environment, University of Helsinki, SATO Oy, Rasek Consulting Oy, and AINS Group, as these organizations are involved in areas closely related to the implementation of circular economy, built environment, and management, making them valuable for the current research. Participants from the aforementioned organizations were selected with the help of the Commissioner based on the competencies of the experts in the research field. Notification about the research process was sent electronically, with a "Consent form for personal data processing" attached to ensure compliance with GDPR and relevant regulations. While some participants agreed to disclose their full names and job positions in the final research, others preferred that such information not be disclosed, thereby remaining generic based on the field of their expertise.

Data collection took place in August - December 2023, with some participants involved in both questionnaires and interviews to enrich the data. Questions in the questionnaire were categorized into groups based on the expertise of the participants, particularly, circular economy, public procurement, environmental services, consulting, and suppliers' experts (see Table 2). Conducting group interviews was unfeasible due to participants' limited availability. Questionnaires were distributed via Microsoft Outlook, while interviews were conducted through MS Teams, lasting 30-60 minutes per participant, followed by approximately 4 weeks for data analysis, resulting in data collection from a total of twelve experts. The selection of participants for data collection was based on their expertise in the research field, without considering gender or age, as they were not relevant to the research requirements.

Table 2. Data collection.

Circular Economy	Participant 1	City of Helsinki	Circular economy expert
	Participant 2	XAMK	Projektipäällikkö
Public Procurement	Participant 3 Natja Vuoristo	University of Helsinki	Property Manager
	Participant 4	City of Helsinki	Environmental and procurement expert
	Participant 5	City of Helsinki	Urban environment and procurement expert
Environmental Services	Participant 6 Harri Hakaste	Ministry of the Environment Finland	Senior Architect
	Participant 7	City of Helsinki	Environmental Specialist/ Urban Environment
	Participant 8	City of Helsinki	Environmental expert
Consulting	Participant 9 Antti Koponen	Rasek Consulting Oy Ltd	Consultant
	Participant 10 Erkki Luokkanen	City of Helsinki	Building control
Suppliers	Participant 11 Kirsi Ojala	SATO Oyj	Hankekehityspäällikkö
	Participant 12 Elli Kinnunen	AINS Group	Technology manager of Sustainable design

7.4 Data Analysis

Analysing the results of questionnaires and semi-structured interviews can pose difficulties due to the absence of standardized responses. An effective strategy can involve categorizing responses into groups based on identified keywords or phrases that correspond with the relevant research questions to conduct a further detailed examination of the data (Silverman, 2013). According to Perroni et al., (2021), content analysis can be performed using a set of techniques, including Categorical, Relations, Discourse, Evaluation, Enunciation, and Expression. In this study, a categorical approach was employed for content analysis focusing on categories established in alignment with the research questions, specifically examining participants' responses to questions designed to uncover similarities and disparities related to the research topic.

For a current thesis, questionnaires have been sent electronically via MS Outlook and interviews were conducted online via MS Teams. Data gathered through questionnaires were submitted in a written form, while semi-structured interviews were carried out informally without recordings to minimize additional data processing, ensuring GDPR compliance and participants' comfort. The interviews were manually transcribed using MS Word and subsequently verified by the participants. Text analysis and coding were performed using the Microsoft Word tool, which involved labelling, theme identification, relationship exploration, and data structuring as a part of the coding process (Linneberg & Korsgaard,2019). In the analysis of participants' responses, a thorough review of the answers and transcript was carried out. A coding process involved the labelling and categorization of relevant words, sentences, and phrases by grouping related codes and naming them in alignment with the underlying code themes. The categories were then ranked in order of relevance, and their interconnections were discerned by identifying patterns among them. Finally, information was simplified, and presented in a table format.

Microsoft Word was selected as the coding tool due to its feature to facilitate coding through the comment system, where codes could be added as comments to specific phrases, words, or sentences. With the help of macros “Doctool” (www.thedoctools.com) comments and codes have been extracted into a distinct Word file, which was subjected to analysis using MS Excel, where answers from participants were filtered based on predefined categories to discern variations and commonalities in their responses.

7.5 Reliability of the Research

Reliability is a critical criterion for evaluating research quality, particularly in qualitative studies. As Golafshani (2003) suggests, qualitative research can be deemed reliable when its outcomes consistently align, the sample is accurately represented, and subsequent similar research efforts yield comparable results. The assessment of qualitative research quality becomes paramount when the primary goal is to extract meaningful information. Stenbacka (2001) contends that the notion of reliability lacks relevance and can be misleading in the context of qualitative research, emphasizing that the primary objective of qualitative research is to foster understanding. However, Patton (2001) counters this argument by asserting that considering reliability in qualitative research is essential when evaluating research quality, study design, and result analysis; furthermore, he emphasizes the researcher's competence as a crucial component of research reliability. Healy and Perry (2000) propose that quality criteria for qualitative research encompass credibility, neutrality, consistency, and applicability. Seale (1999) reinforces the importance of scrutinizing trustworthiness to ensure the reliability of qualitative research.

In this study, professionals from various sectors encompassing public procurement, environmental services, the construction sector, and the circular economy cluster were engaged in research to enhance the reliability of the gathered data. A set of comparable inquiries focusing on six key categories related to the GPP criteria, monitoring, method, market, environmental, and

economic aspects, were posed to the experts. The primary aim of the investigation was to gain insights into the perspectives of experts representing diverse organizations concerning the challenges and opportunities within these aforementioned domains. The responses obtained from the participants were deemed reliable as they were provided by prominent experts within their respective fields. Nonetheless, it is worth noting that the research was carried out by a university student who possessed limited expertise and knowledge in areas such as specifics of public procurement, methods for assessment of the reuse of construction products left after demolition activities, standardization, market, and materials flow dynamics. This potential limitation may have influenced the relevance of the research questions. Consequently, there is a possibility that the credibility of the researcher could be questioned due to the relative inexperience, despite the credibility of the data source being maintained.

All tasks and data processing were conducted remotely due to the constraints posed by participants' busy schedules and the challenges associated with coordinating convenient times for online meetings with all the participants. However, online meetings were organized with some participants in addition to the use of open-ended questionnaires. Interviews and all forms of communication, including interaction with participants were carried out through MS Outlook and MS Teams.

8 Results of the research

So that to address the research questions outlined in subchapter 1.1, all responses obtained from interviews and questionnaires were categorized into twelve codes from the perspective of challenges and facilitations related to GPP, method, monitoring, market, as well as environmental and economic aspects. Ultimately, the analysis of each category helped answer the three main research questions.

The structure of chapter 8 is split into subchapters 8.1- 8.3. Subchapter 8.1 includes sections 8.1.1-8.1.6 covering interview results for the challenges associated with the reuse of wood products left from demolition activities (8.1.1-8.1.5), with section 8.1.6 addressing the first research question. Subchapter 8.2 includes sections 8.2.1-8.2.6, covering interview results on the facilitation of the reuse of wood products left from demolition activities (8.2.1-8.2.5), with section 8.2.6 addressing the second research question. Finally, subchapter 8.3 includes sections 8.3.1-8.3.3 covering interview results on challenges and perspective of GPP associated with the reuse of wood products left from demolition activities (8.3.1-8.3.2), with section 8.3.3 answering the third research question.

8.1 Challenges in the reuse of wood products

All the participants highlighted significant challenges regarding the reuse of wood products left from demolition activities. For a more comprehensive understanding, all challenges were categorized in association with monitoring, assessment method, market dynamics, environmental and economic factors.

8.1.1 Monitoring obstacles

Despite building control over the reuse of construction products, including the reuse of wood products left after demolition, the challenge remains in monitoring the quality of reusable products to ensure their compliance with

safety and health standards. Amid other challenges, participants highlighted a lack of digital tools, clear criteria, and legal guidelines. Moreover, existing practices in the supervision and sorting of wood products left after demolition have to be significantly changed to become more efficient.

> As stated by Participant 7: “Generally, monitoring is an issue that should be resourced better regarding procurement contracts and GPP and other criteria. Monitoring tools (excels, table sheets, dialogues with suppliers) are common, digital tools would be welcomed. Hopefully, the material account/statement of building act would provide a digital approach.”
>
> Participant 10: “Building control monitors the use of reusable construction products. The challenge is to ensure the quality of reusable construction products.”
>
> Participant 12: “There is still a lack of supervision, although separate collection of waste is required by law and regulation. Monitoring requires expertise and a change in attitude about the importance of sorting wood products.”

All the participants agreed that at the current stage reuse of wood products left after demolition is in the development stage, where most of the initiatives are run on an intuitive level via pilot projects to collect required expertise.

> Participants 4, 5, and 8: “There is not much to monitor. The reuse of construction projects is still very much done only in a few pilot projects. In a few pilot projects windows and doors were sold to private builders and there we did not monitor where they ended up.”

8.1.2 Assessment method hurdles

Amid top of the challenges in the reuse of wood products left after demolition activities participants highlighted the obscurity of the method for assessment. At the moment, there are no available environmental product declarations for the materials and the limited expertise of the operators prevents assessment for the reuse.

> Participant 11: “There is still quite limited expertise in calculations, and environmental product declarations (EPD) are not yet available for all materials (structures).”

> Participant 12: “I believe that there is still very little expertise in re-use assessment in Finland and instructions are expected. Experience is few. Methods can therefore vary.”

Difficulties in assessment depend on the characteristics of the products. While some wood products are easier to access, for example, windows and components; other wood products, like load-bearing components and glulam, require evaluation of different factors to meet safety standards and comply with existing regulations.

> Participant 11: “Windows and components are relatively simple products to access, whereas other wood products require an elaborate evaluation. In the case of load-bearing components, there may be differences, such as the kind of safety factors that should be applied to the used components or how to assess whether the components meet the regulations in force at the time of construction”.
>
> Participant 12: “There is insufficient expertise to determine the reuse potential of glulam.”
>
> Participant 9: “Designation of validity of glulam-products needs special expertise when reused as load-bearing structures.”

Obscure requirements and lack of Finnish national assessment method for construction works, including reuse of wood products left after demolition, lead to differences in assessment and fear for practical implementation due to unclarity and high cost.

> As stated by Participant 9 the challenge in method: “Missing experience on best demolition methods and their cost when construction products are demolished intact from old construction works. I have not assessed the possibility of the reuse of wood products in practical projects. I do not recommend using existing standards.”
>
> Participant 1: “We don't have a Finnish assessment method. We have our assessment method, but it is not a national level, not a Finnish method.”
>
> Participant 6: “The biggest obstacle besides the unbalance between supply and demand is the lack of qualification criteria of different product categories for new building purposes.”

Legal ambiguity and the absence of harmonized European rules for construction works restrain the potential for the reuse of wood products, thus leaving the issue to be regulated on national levels resulting in differentiation of requirements between European countries.

> Participant 9: “The European Commission has no intention to harmonize legal requirements for construction works. Harmonization would be impossible due to different climate conditions and construction practices. That is why the requirement levels in Finland will also in the future be different for reused construction products compared to other European countries.”

Unlike criteria for carbon footprint assessment, EN standards applicable for reused wood products do not yet exist which brings uncertainty in the assessment methods, different applications of EU Construction Product Regulation, and variations in the evaluation of reused components incorporated into new construction.

> Participant 8: “Carbon footprint is easier to have as criteria as there is a commonly used method to calculate it.”
>
> Participant 9: “Most assessment methods used in Finland for reused construction products are European ones (given in EN standards). However, part of the assessment methods are national ones and thus different from assessment methods in other European countries. The reason for this is that applicable EN-standard does not yet exist.”
>
> Participant 6: “There are differences between countries regarding the application of present EU-wide Construction Product Regulation and qualification of reused elements in new building. Finland has been, to my understanding, one of the most orthodox ones in procedures.”

8.1.3 Reuse market obstacles

Development and successful implementation in business models of reused wood products left after demolition require a functional demand-supply mechanism. Results of the research showed that the reuse market is in a state of stagnation without any dynamic in development; moreover, according to the views of some of the participants, the market does not even exist per se.

> Participant 12: “Now, I would estimate that there is no dynamic. Supply and demand do not meet. Currently wood ends up being burned because there is no market even for recycled wood in Finland.”
>
> Participant 2: “The problem now is that demand and supply do not meet. There is insufficient information available on reusable demolition products.”
>
> Participants 4,5, and 8: “From our point of view the biggest obstacle to reuse is the lack of a reuse market, and it is not affected by whether demolition projects require dismantling or not.”

Development of the reuse market requires integration of more operators into the process, more open-source APIs, new technology like standardized “data space” and multiple functional digital marketplaces similar to kiertoon.fi, where API integration was set to link the demolition survey application with the digital market space for data exchange.

> Participant 2: “More open-source APIs between applications needed. And new technology like standardized "data space" such as FIWARE. Regarding digital marketplaces, the connection was built between the demolition survey - application and the digital marketplace - kiertoon.fi., however, more connections are needed. “

Analysis of the interview answers revealed that there is a challenge regarding construction operators’ skills in operating with reused construction products and their willingness to invest money in processes. Particularly, this challenge was notable with wood products like doors and windows which might require refurbishment and could be in poor condition, thus not matching with high quality standards.

> Participant 9: “One of the challenges is missing reused construction product operators willing to invest in efficient and cost-effective processes of reused construction products.”
>
> Participants 4,5,8: “Doors and windows are often worn or otherwise in poor condition, which is based on our experience often the biggest barrier for reuse. In order for a reuse market to develop, there should be service providers who refurbish them and return them to the market in like-new or almost like-new condition and with all the necessary technical details.”
>
> Participant 6: “Reuse of wood in Finland (and elsewhere) on an industrial scale is very challenging because of before mentioned qualification criteria for new buildings and very varying quality of dismantled wooden products. Wooden structures are, however, to my understanding widely used in small-scale private projects where demands for high-quality standards are low.”

Despite the national strategy for an increased share of reused products in the construction sector, the volume of such products is still relatively low, irregular and it is challenging to find new construction sites where such reused construction products, especially reused wood products, could be utilized.

> Participant 9: “Volumes of demolished construction products which could be reused is low and availability irregular in the Finnish market. There is also difficulty to find new construction works where reused wood products could be used.”

8.1.4 Environmental issues

It is often considered by scholars and practitioners that the reuse of wood products left after demolition always contributes to the environment and positively affects the reduction of the carbon footprint. However, this is not always the case, since the reuse of wood products is not a one-action process and quite often includes additional operations such as transportation, the need for refurbishment, and additional energy consumption to support the activities, which ultimately lead to higher CO2e emissions.

> Participant 11: “The reuse of materials in urban development can actually cause more CO2e emissions in case of transporting reusable components over long distances for refurbishment or further processing.”

> Participants 4,5,8: “If the products need to be transported long distances or for example, the processing of reused products is energy intensive, then negative environmental consequences, i.e. more CO2 emissions can occur.”

> Participant 8: “A lot of carbon emissions might be possible if the carbon footprint of the new product is low and making the reused product reusable would take a lot of energy or something else causing a lot of carbon emissions.”

Collected data revealed, that so far, wood products left after demolition have limited possibilities to be recycled and even fewer chances to be reused. In scenarios where wood products left after demolition are considered waste, it is almost impossible to get end-of-waste status for their legal reuse in new construction. The aforementioned situation leads to wood products being treated through incineration or landfilling, thus causing more CO2 emissions.

> Participant 9: “Finnish environmental authorities have unpredictable interpretations on the waste status of demolished construction products intended to be reused. If products are considered waste, it is usually almost impossible to reuse them legally in new construction works.”

> Participants 4,5,8: “The wood's carbon store is only preserved when the wood remains in use and does not end up being burned. Wood is one of the few demolition materials for which, so far, it is not possible to find extensive

> possibilities even for recycling as a material. So, it would be really important to find new uses for wood products as well and to tighten up their reuse."

8.1.5 Economic challenges

According to the view of the participants, reuse of wood products left after demolition faces multiple economic challenges making it not the best feasible solution at the current stage. Among the most common obstacles highlighted by the participants were high costs associated with the reuse of wood products left after demolition, because most buildings were not designed in a way to be deconstructed thus, the reuse of wood cannot be paid enough to cover the costs of disassembly. Moreover, the market for reused products does not exist yet and it is cheaper to buy raw wood, which is relatively cheap, than to utilize reused ones.

> Participant 11: "It cannot be stated yet whether cost savings can be achieved through reuse."
>
> Participant 12: "We have a lack of demand, price of new products, and unclear eligibility procedures for reusable products now. Reuse is still more expensive than using new products...sorting of wood is not considered worth the money."
>
> Participant 4,5,8: "Removing products intact is more expensive than the traditional way of demolishing. The economic way still needs to be developed with the demolition contractors. Also, there is no market for reused construction parts yet, where the products would be paid even enough to cover the costs of disassembly."
>
> Participant 11: "Wood is a relatively inexpensive raw material, and its availability is good in Finland."

Most of the participants stated, that removing of wood products from a demolishing site requires expertise, it is time-consuming, can be dangerous, especially if a wooden construction has glass parts, for example. With a scarcity of techniques for dismantling, mainly such work is performed manually, and after all, removed parts usually cannot be used for the same purposes because they do not meet high energy and safety standards.

> Participant 1: "Removing and further reuse of doors and windows involves substantial manual work, which is pricy, as it requires removing not only the unit but also its frame. And if remove the window with glass, we have an energy

> demand which has been growing a lot, so you can't really use the glass window for the same purpose, instead, it should be repurposed for example for indoor use meaning you can't use it as the outdoor window again. So that's the problem. Residential doors often lack quality and might not find buyers if resold."
>
> Participants 4,5,8: "The dismantling of windows is also quite time-consuming and a little dangerous with the big glass surfaces, so if new techniques for dismantling were developed, the reuse would get more economical."
>
> Participant 9: "A lot of refurbishment work is needed for demolished windows and doors. Low U-value of demolished windows and doors making re-use of these products impossible on new energy-efficient buildings."

Difficulties in association with the reuse of wood products were seen by most of the participants in processes related to demolishing, refurbishing, storage, and transportation. To solve these problems, Helsinki City urgently trying to find the appropriate practical solutions via multiple pilot projects.

> Participants 4,5,8: "If we want to use doors and windows in our own new-build projects after dismantling, we need to store them appr. 1-2 years in warm storage. Also, transportation and refurbishment are needed. The city has no procedure or resources (persons, storage, etc.) for this at the moment, but we are piloting it."
>
> Participant 7: "Lots of issues are still open that may also raise costs, e.g. storing and resources used for materials."

There was a consensus among participants that at the moment, the reuse of wood products left after demolition seems to be financially unsustainable and mostly performed on a case-by-case basis through pilot projects. Bringing reuse initiatives on an industrial scale is challenging due to the lack of financial incentives for the participants, unclear requirements for reuse of wood products in Construction Product Regulation, and scarcity of real demand either from the client's side or from the contracting side.

> Participant 12: "There must be a need for re-use either from the client's side or from the contracting side. The GPP has no cost-effectiveness."
>
> Participant 6: "There are numerous ways of potential reuse of wood. The challenge is to bring it to an industrial scale. Recycling should also be on the agenda when we talk about circular uses of wood. There are no economic incentives at the moment."

> Participant 9: “There is an unclear impact of the new Construction Product Regulation (under revision) on the requirements of reused construction products.”

Among multiple challenges associated with the reuse of wood products left after demolition, one of the suppliers highlighted a noteworthy concern and solution, which might be not an immediate priority but is important to be addressed. The concern relates to a scenario, where the ubiquitous reuse of wood products can cause a threat to sales for the manufacturers of wood building components. The proposed solution was to suggest for manufacturers to repackage and sell wood products designated for reuse as a product offering.

> Participant 11: “Manufacturers of building components made from wood may perhaps see reuse as a threat to their product sales. However, the situation could also be viewed in a way that manufacturers of new products could package reconditioned reusable parts as a product offering.”

8.1.6 What are the key challenges in the reuse of wood products left from demolition activities

Analysis of the interview results and questionnaires regarding the first research question “Challenges associated with the reuse of wood products left after demolition” shows obstacles in monitoring the entire process due to challenges in ensuring the quality of reusable construction products. Moreover, supervision practices are constrained due to a lack of digital tools, clear criteria, and legal guidelines for all participants, including those involved in sorting practices on the demolishing sites. Such limitation prevents accountability and organizational oversight.

Currently, the reuse of wood products left after demolition is in the development stage and mostly executed via pilot projects to collect the required expertise, which is not sufficient for the industrial scale. The limited expertise of the operators in demolishing practices prevents fast progress. Moreover, it is time-consuming, mainly performed manually due to lack of technologies, can be dangerous and after all, the removed parts will mostly not be used for the same

purpose because they might require refurbishment or be in poor condition, thus do not meet high energy and safety standards. Results of the research showed that wood products left after demolition have limited possibilities to be recycled and even fewer chances to be reused. In scenarios where wood products left after demolition are considered as waste, it is almost impossible to get end-of-waste status for their legal reuse in a new construction. Since the reuse of wood products is not a one-action process sometimes it can lead to an increase in carbon footprint associated with additional operations such as transportation, the need for refurbishment, additional energy consumption to support the activities, or burning it if treated as waste.

Legal ambiguity, lack of harmonized European rules, and absence of Finnish assessment method for construction works restrain the potential for reuse of wood products left after demolition. Leaving the issue to be regulated at the national level results in the differentiation of requirements between European countries and variations in the assessment of reused components in new construction. Unlike criteria for CO2e assessment, EN standards applicable to reused construction products do not yet exist which results in uncertainty of assessment methods and different application of EU Construction Product Regulation. Difficulties in assessment vary between different wood products; while some wood products are easier to access, for example, windows and components, other wood products, like load-bearing components and glulam, require evaluation of different factors to meet safety standards and comply with existing regulations. Limited expertise of operators along with aforementioned factors leads to a situation where participants have a fear for practical implementation of such endeavors due to unclarity and high cost.

Conducted research revealed that at the moment, the reuse of wood products left after demolition seems to be financially unsustainable and mostly performed on a case-by-case basis through pilot projects. Bringing reuse initiatives on an industrial scale is challenging due to unclear requirements for the reuse of wood products in Construction Product Regulation, scarcity of real demand, high

costs linked to the reuse of wood products left after demolition, along with absence of financial incentives for the participants and willingness of operators to invest money in processes. One of the reasons for high costs is that most buildings are not designed in a way to be deconstructed, thus reuse of wood products like windows or doors cannot be paid enough to cover the costs of disassembly and it is cheaper to buy new materials than to utilize reused ones. Difficulties in the reuse of wood products also relate to demolishing, refurbishing, storage, and transportation which incur extra fees. Helsinki City is actively involved in finding appropriate practical solutions via multiple pilot projects.

Development and successful implementation in business models of reused wood products left after demolition require a functional demand-supply mechanism. Results of the research showed that the reuse market is in a state of stagnation without any dynamic in development. Moreover, according to the views of some of the participants, the market does not even exist per se. Development of the reuse market requires integration of more operators into the process, more open-source APIs, new technology like standardized “data space” and multiple functional digital marketplaces similar to kiertoon.fi, where API integration links the demolition survey application with the digital market space for data exchange. Despite Helsinki's strategy to increase the share of reused wood products in the construction sector the volume of such products is still relatively low and it is challenging to find new construction sites where such reused wood products could be utilized. Reuse market development should not be a “black swan” event that causes a threat to sales for the manufacturers of wood building components, thus, there has to be a mechanism that gradually creates opportunities for all of the participants.

8.2 Facilitation of the reuse of wood products left from demolition activities

Despite multiple challenges associated with the reuse of wood products left after demolition, there are effective ways how to facilitate the process and

overcome hurdles. For a more comprehensive understanding, all possible solutions were categorized in association with monitoring, assessment method, market dynamics, environmental and economic factors summing with the answer to the second research question “How to facilitate reuse of wood products left after demolition activities”.

8.2.1 Monitoring support

To facilitate the monitoring and reuse of wood products left after demolition participants highlighted the need for a pre-survey. Demolition-survey applications could assist in the creation of a list of products produced after demolition, for example, similar to the one developed by Miksei and XAMK. The monitoring could be intensified through reporting obligations to sales platforms regarding products that might be reused, for example, presenting the number of wood products for reuse in the form of a catalogue. For general estimation of the reused wood products, some existing old plans can be supportive in understanding the characteristics of the products.

> Participant 11: “For dismantled parts to be directed for reuse, they need to be pre-surveyed and perhaps even individually identified and catalogued. If parts are reused as materials, such as door frames made of wood, a somewhat more general estimate of quantities and characteristics may be enough, for example, based on old plans.”
>
> Participant 2: “In the future, the demolition survey -application increase the reuse of construction products. It offers its users the functionality to create demolition surveys that list products and/or wastes produced by the demolition. For example, the demolition survey -application is developed by Miksei and Xamk. It will be transferred to Motiva's maintenance in 10/2023.”
>
> Participant 12: It must be required to report reusable products to the sales platform and require the demolition contractor to present the number of construction products directed for re-use.”

The promotion of digital sales platforms similar to “Materiaalitori” or “Purkukartoitussovellus” can increase the flow of reused construction products, including the reuse of wood products left after demolition, by providing information about them directly to construction planners, architects, and other

parties starting from the design stage. At the moment, there is a gap in this flow since the aforementioned digital platforms are not commonly utilized and information does not pass.

> Participant 8: “Monitoring during the design stage is important...There is at least Materiaalitori (https://www.materiaalitori.fi/ for selling or buying materials, but I have never used those or am not familiar with how commonly used it is.”
>
> Participant 2: “Materiaalitori or Purkukartoitussovellus are intended for the professional exchange of waste and production side streams from companies and organizations.....however, the information needed for construction planners, architects, and other parties do not pass.”

Thorough sorting of the products for further reuse plays an important role in monitoring and can reduce efforts required for testing of reused construction products as part of the designation of validity. Moreover, precise sorting already on the construction site can help to catalogue the reused wood products left after demolition to show them to potential buyers, which is an alternative to their burning. For some basic parts, it might be so that even visual inspection is enough, whereas others require thorough testing. For example, glulam intended for structural reuse requires tests on the bond strength; or insulting glass units used in the windows require tests on the diffusion rate of insulating gas between glass panes.

> Participants 4,5,8: “Wood products should be separated as precisely as possible already on the construction site so that even in theory it is possible to show them a further use other than burning.”
>
> Participant 9: “Sorting of demolished construction products (including wood products) is often important if they are intended to be reused. Sorting should be performed in such a way that the condition in old buildings is the same and the performance characteristics of the population of sorted demolished construction products are closely the same. In this way the testing of reused construction products as part of designation of validity can be reduced. For demolished windows, doors, and glulam-products sorting can be performed quite easily. For sorting visual inspection is the main method for sorting.”

8.2.2 Facilitation of the assessment method

It is worth mentioning that at the moment there is no a harmonized European or Finnish national method for assessing the reuse of wood products left after

demolition. However, in the lack of clear guidelines and regulations facilitation of the reuse of wood products can be done via assessment methods which can take place at a construction site in the form of visual examination, demolition survey, usability survey, assessment based on old plans, reuse of wood products in a lower requirement class than the original purpose, for example, bearing logs reused as a non-bearing logs.

> Participant 11: “Tools are commonly used to access the possibility of the reuse of construction products: demolition survey, usability survey, developing planning tools to investigate the suitability/usability of demolition components in new construction, reuse in a lower requirement class than the original purpose (e.g., a load-bearing wall element reused as a non-load-bearing wall)... characteristics can be assessed based on old plans and visually. In my opinion, the condition and characteristics need to be examined more closely if the building component is designed as part of load-bearing structures.”
>
> Participant 12: “A visual examination of the condition of windows and doors can be utilized in defining the potential for reuse.”
>
> Participant 10 regarding assessment possibilities for reuse: “Act on the product approval of certain construction products: Demonstration of eligibility on a construction site basis.”

Facilitation of assessment methods can be achieved via collecting best demolition practices from construction projects, including circular economy experience from other countries.

> Participant 9: “More experience is needed from pilot projects so that best demolition methods with lower cost can be developed. More learning is needed from circular economy experiences in other countries.

Until an EU-standard method for assessing the reuse of wood products left after demolition is developed, in Finland, it is possible to utilize its own tools which can produce a reliable result and help participants to use the same method for designation of validity on a local level. A good example is the Helsinki Circular Economy Cluster, which offers an Excel file with the assessment criteria for the reuse of construction products, including wood products such as windows, doors, and glulam (Helsinki Circular Economy Cluster, 2023).

> Participant 9: “I promote the use of the Excel files which I have developed, and which were published last summer in the Helsinki Circular Economy Cluster web

> page. The Excel files are developed to reach the target that all actors will use the same methods for the designation of validity in Finland. The near future will show how well we have reached the target."
>
> Participant 10: "In principle, we use the same EU laws, but local interpretations may occur. I would assume that the interpretations will also be harmonized in this respect in the future."

8.2.3 Market facilitation for the reuse of wood products

Most of the participants stated that for market facilitation to happen, it has to be economically profitable to reuse wood products rather than recycling, burning, or buying new products. Moreover, the operational environment has to become more predictable to stimulate investments in the process of reusing construction products, including wood products. With changes in legislation such as new demand for low-carbon buildings and EU-taxonomy market facilitation can be achieved through financial incentives of the operators thus influencing on the reuse of construction products.

> Participant 9: "Change the operational environment more predictable so that circular economy operators are willing to invest in the process of reused construction products.
>
> Participants 4,5,8: "Hopefully, in the future, the market will develop in such a way that reuse will be more economically profitable than delivering demolition materials to recycling, burning, or end-use."
>
> Participant 6: "EU-taxonomy may become a strong incentive for reused content of new buildings. Also, the new demand for low carbon building in the new legislation will probably have a big influence."
>
> Participant 10: "Re-usable wood products (used ones) should basically be cheaper than new products."

Development of the market is directly connected with a need for learning and benchmarking, which can be achieved through analysis of the results of successful projects run in Finland and other countries, for example, the reuse of timber frame structures left after demolition in a new construction project or reuse of salvaged planks for design furniture.

> Participant 11: "A successful example of the reuse is design furniture which is manufactured from salvaged planks and other used wooden components."

> Participant 6 regarding examples of cases where the reuse of construction products left after demolition activities was successful: “Timber frame structures have for centuries been reused and are being reused also nowadays.”

Increased sharing of information and expertise via digital platforms and databases can support the market development for reused wood products left after demolition. Existing private and voluntary databases providing contacts for supply and demand are not sufficient. Obligatory demand for pre-demolition reports according to the new Construction Act will provide a digital pathway to the national material exchange database Materiaalitori along with open interfaces for other exchange databases.

> Participant 9: “More learning is needed from circular economy experiences in other countries. Better knowledge on the construction works in Finland (constructed partly on wood products) which will be demolished in the near future.”

> Participant 6: “There are and have been private and voluntary databases providing contacts for supply and demand, but their volumes of change have been small. Based on the new Construction Act demand for pre-demolition report/clearance will provide a digital pathway to the national material exchange database Materiaalitori but there will be open interfaces for other exchange databases. Proving the quality of the products is not yet included in the services.”

8.2.4 Environmental benefits of the reuse of wood products

Most of the participants highlighted the positive impact of the reuse of wood products left after demolition on the reduction of carbon footprint. Reused materials are considered to have zero carbon footprint since it has already been calculated in the previous building’s life cycle. The reuse of wood products has enormous potential from a climate perspective because it helps for carbon bonded to wood to be stored in the construction products as long as possible and wood products do not end up being incinerated.

> Participant 12: “Carbon bonded to wood should be stored in construction products for as long as possible. At present, however, this is not the case, as buildings are demolished around the age of 40 and the wood ends up incinerating, where the storage is released into the atmosphere. Therefore, the reuse of wood has enormous potential from a climate perspective.”

> Participant 8: “The carbon footprint would get lower using reused materials as these materials are considered to have zero carbon footprint. Embodied carbon

> is seen as 0 as it's already calculated in the previous building's life cycle. So, the reuse will be one way to lower the carbon footprint."

Reuse of wood products left after demolition also positively affects on reduced amount of consumption of raw materials, preservation of forests, and reviving of biodiversity which has direct and indirect environmental benefits.

> Participant 11: "We save natural resources that are consumed in growing the forest for timber, in harvesting, drying, and processing the wood, as well as in the manufacturing of the new product…. Forests are preserved."
>
> Participant 12: "In addition, the longer a tree circulates, the less virgin raw material is needed and there is an opportunity for reviving biodiversity. Trees are also important in adapting to climate change. The reuse of wood therefore has direct and indirect environmental benefits."
>
> Participant 6: "Climate benefits from carbon footprint (avoidance of producing new products) and carbon handprint (carbon sink), impacts on resource use and biodiversity, easy workability of wood."

In the circular economy of construction, reuse and repair have to be considered as the best options compared to demolition, in other words, "do not demolish unless you must". Reuse is the best way to reduce carbon footprint, since the carbon footprint of new production, for example, windows, is so high that even if a reuse of such windows requires some maintenance or transportation it is still far from a level before the emissions reach the carbon footprint corresponding to a new product.

> Participants 4,5,8: "The carbon footprint of new windows is so high that it is likely that a reused window can be handled and transported quite a lot before the emissions reach the carbon footprint of a new corresponding product."
>
> Participant 2: "In the circular economy of construction, you don't demolish unless you must. At first, you must check if the building can be repaired or changed without being demolished. That is the best way to reduce carbon footprint. The second best is the recycling of reusable demolition products."

8.2.5 Economic facilitation of the reuse of wood products

Economic and financial incentives along with clear regulations and guidelines ready for practical implementation can boost a healthy competitive situation on

the market for reused construction products. On a legislative level, through incentives, for example in a new Construction Act, feasible opportunities for the reuse of wood products left after demolition can be provided.

> Participant 11: “Various regulations and guidelines must be designed and implemented in a way that maintains a healthy competitive situation. There should always be practical applications readily available that align with new regulations.”
>
> Participant 6: “New legislation will provide good opportunities for reuse, and we will have to consider incentives based on the development after the new Construction Act.”
>
> Participant 9: “Financial incentives on the clever use of reused construction products will also encourage the reuse of construction products.”
>
> Participant 10 regarding incentivizing of the reuse: “By making laws and regulations easy to interpret.”

Participants from the supplier and procurer sides agreed that prices for raw materials have to become higher in the future along with the increased price for emissions trading, which will make reusable products more affordable. Reuse of wood products left after demolition has to become more economically profitable compared with recycling or burning.

> Participant 12: “The rise in the price of emissions trading is likely to affect the price of new products and reusable products will be made more affordable when the methods of reuse are clearer. Demand must be increased whenever possible.”
>
> Participant 2: “If raw materials become more expensive in the future, it is natural that the profitability of reuse will improve.”
>
> Participants 4,5,8: “Hopefully, in the future, the market will develop in such a way that reuse will be more economically profitable than delivering demolition materials to recycling, burning, or end-use.”

It was pointed out, that government and EU rules should create a predictable operational environment for the circular economy operators so that they can invest in efficient and cost-effective processes for the reuse of construction products, including, wood products left after demolition. Incentives and investments in the reuse of wood products in return will reduce the costs of reusable products making them more affordable for buyers compared with a new product.

> Participant 9: “Costs of reused construction products can be reduced when construction product operators are willing to invest in efficient and cost-effective processes of reused construction products. Government and EU should create a predictable operational environment for the circular economy operators so that they are willing to invest in efficient and cost-effective processes of reused construction products.”
>
> Participant 12: “The market must reduce the price of reusable products and improve availability, while at the same time making new products more expensive.”

Developments in the logistics and available storage places for construction products intended for further reuse within the same location can bring significant savings for the operators and Helsinki City, however, at the moment, this still remains an obstacle that needs to be overcome.

> Participant 7: “Generally, it would be most likely more cost-effective to use the materials inside the same project/location, but this is not always possible. For example, in infrastructure using excavated earth masses and development of logistics and storing has brought significant saving for the city.”

8.2.6 How to facilitate the reuse of wood products left from demolition activities

Analysis of the interview results and questionnaires regarding the second research question “How to facilitate the reuse of wood products left after demolition” showed, that to facilitate the reuse of wood products a series of actions has to be taken. It is recommended to have a thorough pre-survey and report obligations to sales platforms regarding wood products left after demolition. Demolition-survey applications could assist in the creation of a list of products produced after demolition and reporting obligations could include cataloguing the wood products intended for further reuse, which include characteristics of the wood products.

Conducted research demonstrated, that thorough sorting of the products for further reuse plays an important role and can reduce efforts required for testing of reused construction products as part of designation of validity. Precise sorting

already on the construction site can help to catalogue the reused wood products left after demolition to show them to potential buyers, which is the best alternative to their burning.

Research results showed that technical support via a digital sales platform similar to Materiaalitori or Purkukartoitussovellus can increase the flow of reused construction products, including the reuse of wood products left after demolition, by providing information about such products directly to construction planners, architects, and other parties starting from the earliest stages of the design process. It was highlighted, that the new Construction Act through the mandatory requirement for a pre-demolition report would establish a digital pathway to the material exchange databases, including the national material exchange database Materiaalitori.

The study results indicated that at the moment there is no yet a harmonized European method for assessment, neither Finnish national method for the reuse of wood products left after demolition. However, the lack of clear guidelines and legal regulations defining general characteristics of the wood products can be based on existing old plans of the building where quality characteristics of the product are provided. Moreover, results of the demolition survey and usability survey can also be utilized along with the reuse of wood products in a lower requirement class than their original purpose, for example, bearing logs reused for non-bearing structures. For certain categories of wood products, a demonstration of eligibility can be provided on a construction site basis, including a visual examination. Of course, more complex wood products, for example, window frames with glass, glulam intended for structural reuse, or load-bearing structures before the reuse require a thorough assessment to comply with safety and environmental standards.

Until the EU-standard methods for assessing the reuse of wood products left after demolition are developed, in Finland, on a local level it is possible to utilize their own tools which help participants to use the same method for designation

of validity. A good example is the Helsinki Circular Economy Cluster, which offers an Excel file with the assessment criteria for the reuse of wood products (Helsinki Circular Economy Cluster, 2023).

The facilitation of reuse of wood products left after demolition is directly connected with a need for learning and benchmarking, which can be achieved through analysis of the results of successful projects run in Finland and other countries. For example, in Finland, demolition practices from construction projects include the reuse of timber frame structures left after demolition in new construction projects or the reuse of salvaged planks for design furniture.

Conducted research revealed that successful market development is the key to the demand and supply for the reuse of wood products left after demolition. It has to become economically profitable to reuse wood products rather than recycle, burn, or purchase new ones. Moreover, the operational environment has to become more predictable to stimulate investments in efficient and cost-effective processes of reused construction products. Examining the data, it was evident that to make reusable wood products more affordable, prices for raw materials have to become higher in the future along with the increased price for emissions trading. Significant savings for the operators regarding the reuse of wood products left after demolition can be achieved through developments in the logistics and available storage places within the same location for construction products intended for further reuse.

The New Construction Act, EU-taxonomy, and latest requirements for low-carbon buildings promise to provide feasible incentives which in return could give a possibility to reduce the costs of reusable products making them more affordable for the buyers compared with a new product. Economic and financial incentives along with clear regulations and guidelines, that are consistent, easy to interpret, and ready for practical implementation could boost a healthy competitive situation on the market for the reuse of wood products left after demolition.

A factor that did not stay unnoticed is the positive environmental impact of the reuse of wood products for a carbon footprint reduction. Reused materials are considered to have zero carbon footprint since it has already been calculated in the previous building's life cycle. The reuse of wood products has potential from a climate perspective, meaning that carbon bonded to wood remains stored in the constriction products as long as possible and wood products do not end up being incinerated. Moreover, the reuse of wood products left after demolition also brings direct and indirect environmental benefits which can be traced through reduced consumption of raw materials, preservation of forests, and reviving of biodiversity.

8.3 GPP mechanism in the reuse of wood products left from demolition

One of the initiatives that can support the facilitation of the reuse of wood products left after demolition can be green public procurement, which can guide participants towards new sustainable practices via its own examples. To address the third research question, "How can GPP support the reuse of wood products left after demolition", this subchapter will examine the challenges associated with the reuse of wood products through the GPP mechanism and explore the opportunities it provides.

8.3.1 Challenges for the reuse of wood products through GPP

Participants from the suppliers' side revealed, that little practical experience and lack of feasible business potential hinder the reuse of wood products left from demolition through GPP. Additional costs associated with the reuse restrain public procurers from including criteria for the reuse of wood products left after demolition in the contracts.

> Participant 11: "The lack (or scarcity) of practical experiments hinders the proliferation of reuse; there is not yet seen any business potential in reuse, at least at this stage, as it is considered an additional cost to the project**."**

Some of the participants highlighted, that the voluntary nature of the “reuse of wood products left after demolition” as a GPP criterion, is not as efficient as those with legislative status. Voluntary nature restrains or reduces the reuse of wood products as only a few municipalities have targets in this regard and in case of having such criterion in the public contract not often comply with it. However, obligatory requirements for the reuse, are not reasonable as long as challenges associated with the demand and qualification criteria of reused elements are not solved. While big cities are involved in pilot projects with the reuse of wood products, for example, the City of Helsinki, for areas where the construction sector is not intensive the volume of reuse is minimal and more challenging, especially regarding verification, costs, shortages for market actors, storage, process development.

> Participant 2: “Voluntary reduces the reuse of construction products. It is often easier to build a new one than to use an old one.”
>
> Participant 12: “Voluntariness is not conducive to a circular economy at this stage. Few municipalities and public purchasers have targets for the re-use of construction products or are not complied with in projects. The further away from the growth centers, the lower the volume of construction and thus the reuses. Reuse Even if forced, this cannot be solved nationally, only in larger centers.”
>
> Participant 10: “Voluntary activity will probably not increase the reuse of construction products.”
>
> Participant 6: “It is clear that voluntary policy tools are not as efficient as those with legislative status. However compulsory demand for reusing construction products is not reasonable if challenges regarding demand and qualification criteria of reused elements are not solved.”
> Participant 7: “The City of Helsinki is aiming towards more circular building construction, but it is still complicated in many ways (verification, costs, shortage for market actors, storing, process development).”

It was stated by the participants that within a framework of GPP, verification of usability, distribution of responsibilities, and ownership relationships regarding the reuse of wood products have to be clearly defined in contract documents. Furthermore, there should be legal clarity on when and how wood products left after demolition can be reused, in what parts of the building, and what needs to be verified. Additionally, challenges associated with the reuse of wood products within the GPP framework arise when such products are considered as waste

which leads to a situation that it is almost impossible to reuse them legally in new construction works.

> Participant 11: “The distribution of responsibilities and ownership relationships is a clear challenge, requiring precise definition in the contract documents.”
>
> Participant 7: “Legal challenges for green criteria in a GPP is the verification of usability, maybe ownership sometimes.”
>
> Participant 8: “It still needs more clearing how and when reused building products can be used. It needs to be clear when and in what parts of buildings reusing is allowed and what needs to be verified for it.”
>
> Participant 9: “If products are considered waste, it is usually almost impossible to reuse them legally in new construction works.”

Implementation of green criteria “reuse of wood products left after demolition” into a GPP contract can face challenges associated with the contract performance. This implies that though characteristics of the dismantled parts are determined however it might be so that commitments need to be reshaped and adapted based on the new requirements which finally can dilute the goals. Moreover, possibilities for the reuse and the “recipient building” of the reused parts have to be assessed and known before the demolition process starts. In practice, it means, that the demolition company, should already have the possibility to calculate the number of materials they can resell.

> Participant 11: “The risk here is that, as the characteristics of the dismantled parts are determined, commitments may need to be reshaped, and goals may be diluted. Comparing bids would then involve assessing not only the proposed reuse rates but also the flexibility and adaptability of commitments to evolving information.”
>
> Participant 12: “The recipient building should also be known or there must be a market for the reuse of construction products.”
>
> Participant 1: “The challenge with contracts lies in the need to assess reuse possibilities before the demolition company starts its work. This involves issues of liability and material ownership on-site. When you negotiate a contract with the demolition company, they usually already calculate the number of materials they can resell.”

Currently, in GPP practices there is no requirement for all demolition projects to be reused since there is no much experience in this field, ways to verify the reused materials for their use in new buildings, possibilities to store large

amounts of such products. Challenges are also connected with finding both suitable demolition sites and demolition materials of sufficient quality. Some pilot projects had the requirement for the contractor to dismantle certain construction products, however, those products remained the property of the city and the city decided how to use or sell them.

> Participant 8: “We have not yet required reusing construction products in our contracts. It is quite new and therefore there is not that much experience about it. Problems are that how to verify the reused materials so that those can be used as part of new building, how to get these reused products as there are no warehouses to store large amounts of those at the time etc.”
>
> Participants 4,5,8: “It is not a requirement in all demolition projects. In a few pilot projects, it has been tested that the contractor has been required to dismantle certain construction products, but the construction products have remained the property of the city and the city has used or sold them.”
>
> Participant 10: “The challenge is finding both suitable demolition sites and demolition materials of sufficient quality.”

In GPP contracts with criteria “the reuse of wood products left after demolition,” all terms and conditions have to be clearly stated, however, at the current stage there is obscurity regarding cost distribution, supply and demand match, logistics, lack of storage places. Moreover, variations in the quality of materials and lack of warranty cause difficulties in including criteria in the contract and its further enforcement. Before formulating the terms and conditions of the contract with a criterion “the reuse of wood products left after demolition” it has to be provided information on what will be reused, where the reused materials are stored, who will pay for dismantling, refurbishment, and recycling. Besides, amid the challenges is the assessment of the quality of old products and the task of finding a buyer for used products, especially if the price is high.

> Participant 3: “Challenges include logistics (storage and supply/demand matching, cost to whom), determining quality (variations in materials, materials used), and warranty. Who will ultimately pay for recycling, the cost of manual dismantling, the cost of refurbishing the product, and how to make the price of the used product cheaper than the price of the new product. Will there be buyers for a used product if the price is close to new and how is the quality of an old product determined?”

Results of the interview regarding what is better “minimum requirements or quality points” in a GPP contract with the criteria “the reuse of wood products left after demolition” showed different positions of the participants. Some participants considered that both minimum requirements and scored “additional requirements” have to be set in a contract, however, to make it feasible the characteristics of the dismantled products have to be known beforehand to determine what is demanded. A suggested example from the participants of a “minimum requirement” was to prohibit the burning of demolition wood products for energy purposes; setting the minimum requirement more precisely was considered hard. Suggested examples of “additional requirements” included freedom for the suppliers to suggest their own views on reuse, while, staying committed to achieving the promised reuse rate. In practice, both the minimum requirements and especially the quality points require lots of effort from Helsinki City, *inter alia*, monitoring, clarity of the contract terms, verification practices, enforcement measures, harmonized rules, etc., which is challenging due to little experience in the field.

> Participant 11: “There should be minimum requirements and scored "additional requirements." The challenge is that the characteristics of the object and the parts to be dismantled must be known in advance to determine what can be demanded. The procurement process could, of course, be organized in a way that allows suppliers the freedom to present their own views on reuse, and in their offers, they commit to achieving the promised reuse rate.”
>
> Participants 4,5,8: “For now, the minimum level has been set that one should avoid taking demolition wood for energy burning. It is still difficult to set the requirement more precisely because there are only a few other uses available. Both the minimum requirements and especially the quality points always require quite a lot of additional effort from the city, when in addition to the requirements, the requirements monitoring, and verification practices and possible sanctions must be considered. Both minimum requirements and quality points need to be tested in various projects before having them in all projects.”
>
> Participant 3: “It is good to have quality points, through which the provider can introduce new insights into the use of recyclable products. The challenge is, how can a provider offer recyclable products, is a target given, or does the provider have to have its own stocks?”
>
> Participant 10: “A certain minimum level requirement could be included in public procurement.”

Minimum requirements and quality points regarding the reuse of wood products left after demolition are novelty within a GPP and there is little experience in this

regard even within pilot projects. Helsinki City has some ideas on how quality points might function in the procurement process, however, practical results are yet to come in the near future. Minimum requirements for the reuse of wood products left after demolition have not been developed yet to be used regularly within GPP contracts; currently, minimum requirements for reuse are tested only in pilot projects. However, when it comes to a new building, it is feasible to consider minimum or maximum requirements for reuse.

> Participant 1: “Procurement with the incorporation of the quality points hasn't been tested yet, so we don't know whether the quality points are better. We have some ideas of how they work in the procurement process, and the practical results should come out pretty soon. In a new building, you might consider minimum or maximum requirements for reuse, but regarding reuse of materials left after demolition, it is hard, it is something we should develop still.”
>
> Participant 7: “At the moment, I assume there are most likely none in general use minimum criteria for reuse. The situation is different with carbon footprint and low-carbon criteria.”

Integrating criteria for the reuse of wood products left after demolition into the GPP contract also faces challenges associated with a lack of reuse market, which is unaffected by whether demolition projects necessitate dismantling or not. For the reuse of wood products left after demolition to be functional as criteria within a GPP contract, it is essential to have a marketplace providing information about reusable construction products, including a schedule for upcoming reusable products in the market. Results of the test project where the contract required certain construction products for reuse, revealed the challenge to verify compliance when there is no planned direct use for the products and the contractor must find a buyer within a short timeframe of the demolition contract which might be incongruent with his normal operational activities. The challenge with the criteria for the reuse of wood products within a GPP lies in determining the responsibilities of the participants and ensuring the validity of products for reuse; additionally, lack of actors who can dismantle, renovate, store, and sell wood products for the reuse present the biggest bottleneck in the process.

> Participants 4,5,8: “There has also been a test project where the contractor has been required to deliver certain construction products for reuse. It turned out that it is difficult to verify this requirement during a demolition contract as it only lasts for a maximum of a couple of months. Especially if there is no direct use for the products but the contractor tries to sell the products. The contractor has only limited possibilities for reuse if there are no needs in the market. From our point of view, the biggest obstacle to reuse is the lack of a reuse market, and it is not affected by whether demolition projects require dismantling or not. The biggest bottleneck in the reuse process is at the receiving end. We lack actors who would dismantle, renovate, store, and sell the dismantled construction products. Also, everything related to re-use, for example in relation to responsibilities and validity of building products, still requires clarification through pilot projects before re-use can be carried out on a large scale.”

> Participant 3: “The challenge is quality, logistics. The client must find a way to use demolition products as part of normal operations.”

> Participant 10: “The biggest obstacles to the use of reusable construction products can be found in information and schedule management. There must be a marketplace with information about reusable construction products and, in addition, scheduled information about reusable products that are coming to the market.”

Setting requirements for GPP contracts to have criteria for the reuse of wood products left after demolition requires a functional market for reused construction products to avoid the risks that the products are dismantled and there is no any use of them. Development of such a market requires significant investments since demolition projects with reuse costs much more than traditional ones and the demolition contractor should be aware of what they can get from the reuse of construction products. Overall, most of the participants confirmed that at the current stage, the criteria for the reuse of wood products left after demolition via GPP brings additional costs to the project and there is no business potential in the reuse of wood products left after demolition until significant changes occur in the market and more expertise is obtained.

> Participants 4,5,8: “To set the requirement for all demolition projects, there should be a bigger market for reused building products than there is now. For now, there is a big risk that the products are dismantled, but no use can be found for them. The demolition project has, however, cost much more than a traditional project.”

> Participant 12: “Reuse is still expensive, and the demolition contractor must have the knowledge that they will benefit from the reuse of construction products.”

> Participant 11: “The lack (or scarcity) of practical experiments hinders the proliferation of reuse; there is not yet seen any business potential in reuse, at least at this stage, as it is considered an additional cost to the project. Determining the characteristics of dismantled parts is expensive and requires

> significant upfront investments. Finding more efficient ways to ascertain these characteristics could be helpful. There are few recycling operators, and product component suppliers have not extensively ventured into conceptualizing or productizing the industrial refurbishment of parts for reuse. Reuse is often still more expensive than acquiring a new building component."

8.3.2 Potential of GPP for the reuse of wood products

Considering the voluntary nature of GPP in Finland, there are different opinions regarding whether mandatory rules would boost development in the field or be a burden. Some of the participants suggest that having specific mandatory rules for the reuse of wood products can support existing GPP by providing a clear national or European view for the increase of reuse and recycling. Such a legislative approach can enable public organizations, cities, and private companies to act as pioneers making an impact until the desired reuse practice is established. Other participants see a voluntary model more preferable since it contributes to a more robust commercial model; moreover, if reusability becomes compulsory via mandatory rules prematurely than due to a lack of operators in the field, the costs would be excessively high.

> Participant 7: "In general, the legislative approach gives a clear national (or EU-level) view to direct actions – when thinking overall procurement categories and increasing the use of recycled materials and products. Although cities, public organizations, and private sector can (and should) act as pioneers, the legislative approach has the impact to make actions more established."
>
> Participant 9: "Helsinki City could develop more specific mandatory rules for wood products to support existing GPP."
>
> Participant 11: "When proceeding on a voluntary basis, the commercial model becomes more robust. If reusability were to become mandatory too early, it might initially add extra costs to assignments, as there are few operators and clients are in a forced situation."

Participants from the Helsinki City side and suppliers view financial incentives on the governmental or contract level as strong motivators that can encourage operators to participate in GPP with the criteria for the reuse of wood products left after demolition. Moreover, incentives and sanctions in the contract are effective if they are clear, and unambiguous and prevent the contractors' withdrawal from the project.

> Participant 7: “To facilitate the GPP bonuses and sanctions can be used e.g. in Asetelmakatu-case (by Canemure).”
>
> Participant 11: “Financial incentives or subsidies from the government for GPP promotion is good. SATO has been granted funding from the Ministry of the Environment for implementing a practical experiment. Increasing support for similar projects will turn words into action Sanctions in the contract can also be effective, but for them to encourage improvement, they need to be precise, unambiguous, and sensibly set so that contractors do not withdraw from the project."

To be successful, the reuse of wood products left after demolition through GPP should be supported by the company’s strategy across all stages of the project, including planning of demolition, receiving permits and approvals, handling product suitability. Additionally, participants stated that regarding GPP facilitation it is required to have common assessment methods for the reuse of wood products left after demolition, and common sales platforms with open collaboration between all participants involved in the process enabling the possibility to share best practices, new research, and benchmarks. Moreover, facilitation of the reuse via GPP requires the expertise of the participants, including operators who can refurbish reused wood products left after demolition and then insert them back into the market.

> Participant 3: “To facilitate the reuse via GPP it is possible to have “a common sales platform to receive all information on the products that have been dismantled. More research and support for pilots, creating quality criteria for the products used.”
>
> Participant 7: “Strategy and high-level support is very important for the promotion of sustainability goals. Digital tools and solutions can be very useful but should be planned resource-wise. External experts and cooperation with other big buyers allow sharing of best practices, new research, and benchmarks.”
>
> Participants 4,5,8: “To facilitate GPP we need support for: markets, common procedures for re-use (for example validity), operators who refurbish re-used building products and return them to the market.”
>
> Participant 11: “GPP must align with the company's strategy, requiring sufficient expertise and commitment within various business functions of the company. Additionally, it necessitates open collaboration among the various parties involved in the construction project. Practical experiments at different stages of the project have to be supported, starting from the planning of demolition, continuing through the permit process and approvals, reconsidering and simplifying building control processes (handling product suitability before building permit application).

It was suggested by one of the suppliers that the reuse of wood products left after demolition can be facilitated through direct provisions of such criteria in the contract documents for example, similar to the practices of SATO, which has a requirement for the recycling rate of 85% of construction waste. Setting requirements directly in the contract enables to demand of compensation in case they are not met by the contractors.

> Participant 8: “When the requirement is in the contract it is always a possibility to require compensation if the contractors are not meeting the requirements.”
>
> Participant 11: “So far, it has not been required to reuse the construction products, but the contract documents encourage the reduction of construction waste and increasing the utilization rate. SATO's requirement for the recycling rate is 85% of construction waste; there is no specific mention of the reuse of building components.”

Participants highlighted that when GPP criteria are taken into actual procurement besides complying with the Act on Public Procurement and Concession Contracts, these criteria have to provide very clear characteristics for the reuse of wood products before the bidding process to help suppliers in understanding what is demanded. To be successfully met by suppliers, GPP criteria for the reuse of wood products left after demolition should be based on market analysis and suppliers’ capabilities. Moreover, to boost innovations reuse should not be defined too strictly providing suppliers the possibility to suggest alternatives. A clear understanding of the responsibilities and validity of the products for reuse can be achieved via regular pilot projects enabling later reuse of wood products left after demolition on a larger scale.

> Participant 7: “When GPP criteria are taken into actual procurements, they have to be very clear and follow the principles of Act on Public Procurement and Concession Contracts. When setting criteria, the market situation and capability should also be known, since tenderers must meet the criteria for procurement to be successful.”
>
> Participant 11: “Requirements for the reuse of wood products should be well-documented before the bidding process so that it is known what can be demanded. On the other hand, room should be left for the supplier to innovate, so reuse should not be defined too rigidly.”

> Participants 4,5,8: “Everything related to re-use, for example in relation to responsibilities and validity of building products, still requires clarification through pilot projects before re-use can be carried out on a large scale.”

Regarding minimum requirements and quality points in the GPP contract participants from the suppliers’ side consider that minimum requirements for the reuse can be defined in the contract however should be accessed on a case-by-case basis depending on the condition of the components to be dismantled and the extent of any potential damage. Furthermore, during the tendering process, additional scores can be received in case of exceeding the minimum requirements. To make environmental quality points attractive for the contractor they should be sufficiently emphasized and be financially viable, where the added value should compensate for the price increase, however ensuring that procurement is not solely based on price.

> Participant 3: “So that it is attractive for the contractor to grab environmental points there should be an opportunity to showcase your skills and the value should cover any price increase. It must be financially viable.”

> Participant 11: “In the tendering process, minimum objectives should be defined, and exceeding them could be scored. The minimum requirements likely need to be defined on a case-by-case basis, based on condition assessments or studies. The same applies to the upper end of the scoring scale. I could imagine that environmental quality points should be emphasized to a sufficient extent so that the procurement is not determined solely based on price.”

When addressing the question of whether minimum requirements or quality points are preferable participants representing Helsinki City environmental services stated that procurers focus on minimum requirements, which include aspects that Helsinki City is unwilling to compromise on, whereas suppliers prefer quality points as a way to test something new. On the contrary, participants representing the Circular Economy cluster of Helsinki City revealed that based on the result of the pilot project it looks that for now, suppliers prefer minimum requirements to quality points, which can be explained by uncertainty in the scoring of such quality points, however, it is the outcome of just one project and more research is required.

> Participant 1: “We have tried to utilize both minimum requirements and quality points though quality points are not finished yet. However, minimum

> requirements have been tested in one project and suppliers say it is better to have them rather than quality points. But that is just one opinion, you don't know what the other contractors would say."
>
> Participants 4,5,8: "Minimum requirements are an easier way from the city's point of view. The minimum requirements should include those things that we don't want to compromise on. Contractors, however, like quality points, and they can be useful when you want to test something new or find out the contractors' readiness to meet new requirements."

The results of the pilot project revealed that clear minimum requirements should be set in the GPP contract before contracting a demolition, which requires prior information about what to dismantle and the price, thorough planning, and testing to ensure the reusability of the wood products. Additionally, due to the lack of storage places, it is beneficial to arrange selling from the demolition site before the actual demolition process.

> Participant 1: "Before contracting a demolition, you should already know what you are going to dismantle and the price. You have to plan it very carefully, do tests, and know are these windows or doors are reusable. Additionally, selling items from the demolition site should be arranged before the demolition due to storage issues, we don't have storage space."

Currently, due to a non-functional market and lack of demand for the reuse of wood products left after demolition, it is quite difficult to set any criteria in GPP contracts. One of the suppliers suggested that reporting and clarification can be held as minimum requirements in GPP contracts, whereas the number of reused products can be considered as quality points. From Helsinki City's side utilization of a certain amount of reused materials out of the total or having reused materials in a certain part of the building could be an example of criteria set in the GPP contract, however, guidelines for setting such criteria are needed. Meanwhile, with the market grows and upcoming changes in legislation, minimum requirements will also develop which in return facilitate the reuse of wood products within the GPP.

> Participant 8: "It is quite difficult to set criteria for reusing. Criteria could be to have a certain number of reused materials of all materials used or to have reused materials in certain parts of the building. There will be national limits coming soon. Guidelines for setting the criteria are needed."

> Participant 12: “Reporting and clarification may currently be required as a minimum requirement. The number of re-used construction products can be represented as quality points. The reason is still the lack of market and there is no demand for the products.”
>
> Participants 4,5,8: “The minimum requirements will certainly develop here as the market grows.”

Facilitation of the reuse of wood products via GPP can be supported by market regulation where the demand is increased, and large centers act as demand creators. The developed market in return will stimulate the contractors to implement new efficient ways of operations that are cost-effective and give a possibility to dismantle construction products intact for their further reuse. From Helsinki City’s side facilitation of the reuse market can be done by piloting the reuse of construction products in new-build projects and utilization of minimum requirements along with quality points in demolition projects.

> Participant 12: “Reuse of construction products requires a market and demand for it. Larger centers can act as demand creators now. By increasing demand and confronting it with supply, the reuse of construction products can be increased.”
>
> Participants 4,5,8: “Hopefully the market will be so large in the future that it would be worthwhile for the demolition contractor to dismantle the construction products as intact as possible and reuse them. Before that, we as a city can of course try to promote the creation of a reuse market by piloting the reuse of construction products in new-build projects, and on the other hand, in demolition projects, by using requirements and quality points, we can encourage contractors to develop their operations so that removing them intact becomes cost-effective.”

8.3.3 How can GPP support the reuse of wood products left from demolition

Analysis of the questionnaires and interview results indicated different positions of the participants on how GPP can support the reuse of wood products left after demolition. Many participants agreed that the voluntary nature of reuse criteria in GPP contracts may not be as effective as obligatory one, especially since only big municipalities like the City of Helsinki have specific targets for the reuse of wood products which are not followed regularly within GPP contracts, but mostly tested within pilot projects. The argument for mandating the reuse of wood products left after demolition is that it could enhance GPP by providing a clear national perspective and intensifying the reuse, empowering public

organizations, cities, and private companies to act as pioneers, influencing the establishment of desired reuse practices.

On the other side, participants who favoured a voluntary model emphasized its contribution to a more robust commercial framework. They expressed concerns that prematurely making the criteria for the reuse of wood products left after demolition compulsory through mandatory rules, could lead to excessively high costs, particularly due to challenges associated with qualification criteria for the reuse of wood products, verification methods, shortages for operators, storage related issues, lack of feasible business potential and market demand.

In light of diverging perspectives regarding the *mandatory or voluntary model* of the reuse within a framework of GPP, initial support can be voluntary until the establishment of a functional reuse market and clear guidelines, particularly regarding assessment methods, verification, and the reuse status. Subsequently, this support can become a mandatory framework.

The study showed, that currently in the GPP practices of Helsinki City, there is no requirement for all demolition projects to reuse wood products left after demolition since there are uncertainties in ways to verify the reused materials for their application in new buildings. Also, there is legal obscurity regarding when, how, and in what parts of the building wood products left after demolition can be reused and what needs to be verified. Moreover, there are challenges associated with the legal justification for the reuse of wood products if they are considered waste, as well as a lack of storage for such products. For example, in some pilot projects, there was a requirement for the contractor to dismantle certain construction products; however, the products that were dismantled later remained the property of the city and the city had to find a way how to utilize them. The research outcome signaled that to address the aforementioned challenges, it can be suggested to implement criteria for the reuse of wood products left after demolition in all pilot projects conducted by the City of Helsinki until a clear commercial framework is established. Such practice would

help to collect the required data and expertise, which later could be applied on a larger scale.

Conclusions drawn from the analysis of the research revealed, that GPP could support the reuse of wood products left after demolition through the direct provisions in the contract documents for example, similar to the practices of SATO, where the requirements are set for a recycling rate of 85% of construction waste. Setting requirements directly in the contract would help to demand compensation in case they were not met by the contractors, however, requirements should clearly define information on what would be reused, where the reused materials should be stored, who would pay for dismantling and refurbishment, and, in case of resale, define potential buyers for used products. The facilitation of reuse criteria through GPP should be supported by the company's strategy across all stages of the project, including the planning of demolition, receiving permits and approvals, handling product suitability.

Findings from the research revealed, that to support the reuse of wood products left after demolition through the GPP mechanism it is important to have common assessment methods and a common sales platform with an open collaboration between all participants involved in the process enabling the possibility to share best practices, new research and benchmarks. Moreover, facilitation of the reuse via GPP requires more expertise from the participants, including operators who can refurbish reused wood products left after demolition and then insert them back into the market.

The research outcomes indicated that while many of the concerns associated with the implementation of the criteria for the reuse of wood products left after demolition within a GPP need to be addressed on European or national levels, some of them could be solved locally. For example, to support GPP practices and provide a common assessment method a new tool was developed within a Helsinki circular economy cluster program which could be utilized by operators to verify eligibility for the reuse of construction products, including wood

products left after demolition, particularly windows, doors and glulam (Helsinki Circular Economy Cluster, 2023). The tool helps to assess the suitability of construction products for reuse based on eligibility criteria, for example, regarding windows, doors, and glulam the characteristics include resistance to wind, water, and heat. Moreover, such characteristics like breathability, density, moisture content, and emissions of hazardous substances are also considered.

Conclusions drawn from the research indicated the need for revision of the European norms for adaptability to reclaimed elements and the Waste Framework Directive regarding waste status for reused construction products. Until then, support of the reuse of wood products left after demolition within a GPP could include a compulsory pre-demolition audit to prevent reused wood products left after demolition from being unnecessarily classified as waste, as well as a clear distribution of responsibilities among the parties directly specified in the GPP contract.

The study outcomes indicated that possibilities for reuse have to be accessed before the start of the demolition process to ensure that commitments and goals for the reuse of wood products are not altered due to undetermined characteristics of the dismantled parts during the demolition process. In practice, it means that criteria for reuse in the GPP contract must provide clear characteristics for the reuse of wood products before the bidding process to help suppliers in understanding what is demanded. While being explicit, clear characteristics should not exclude the possibility for suppliers to suggest alternatives. Moreover, to be successfully met by suppliers, GPP criteria for the reuse of wood products left after demolition should be based on market analysis and suppliers' capabilities meaning that the demolition company should have the possibility to calculate the number of materials, they can resell beforehand.

Findings showed different opinions when addressing the question of whether minimum requirements or quality points are more preferable in a GPP contract to support the reuse of wood products left after demolition. While suppliers

preferred minimum requirements due to uncertainty in scoring for quality points, procurers focused on minimum requirements due to unwillingness to compromise on certain aspects. In practice, both the minimum requirements and especially the quality points require lots of effort from the City, including monitoring mechanisms, verification practices, enforcement measures, clarity of the contract terms, and characteristics of the dismantled product beforehand. Given that conducted research indicated that minimum requirements and quality points have not been regularly utilized, it might be a good idea to systematically test both within the pilot projects to collect relevant data and expertise.

Analysis of findings indicated that clear minimum requirements should be set in the GPP contract before contracting a demolition. The City of Helsinki, for example, suggested as a minimum requirement imposing a “ban on burning demolition wood for energy purposes”. Participants from the suppliers’ side suggested “reporting and clarification” as an example of minimum requirement in GPP contracts; moreover, from the suppliers’ point of view, the reuse should be accessed on a case-by-case basis depending on the condition of the components to be dismantled and the extent of any potential damage.

Findings demonstrated that support for the reuse of wood products left after demolition within a GPP can be intensified via the inclusion of quality points into the contract. Procurers and suppliers suggested similar quality points examples, such as “alternative reuse of wood products left after demolition” which suppliers promise to achieve, and “utilization of a certain amount of reused materials out of total”. Additionally, procurers considered having “reused materials in certain parts of the building” as an example of quality points, whereas suppliers considered additional scores can be received during the tendering process in case of “exceeding the minimum requirements”. Moreover, it was emphasized by suppliers that, for quality points to be attractive they should be sufficiently clear and financially viable, where the added value compensates for the increase in costs, however ensuring that procurement is not solely based on price.

Conducted research revealed that integrating criteria for the reuse of wood products left after demolition into a GPP contract has challenges associated with the non-functional market and lack of demand for reused wood products, which is unaffected by whether demolition projects necessitate dismantling or not. The development of the reuse market requires significant investments since demolition projects with the reuse cost much more than traditional ones and thus, there is little business potential in the reuse of wood products left after demolition until significant changes occur in the market and more expertise is obtained. Results of the test project where the contract required certain construction products for reuse, revealed the challenge to verify compliance when there is no planned direct use for the products and the contractor must find a buyer within a short timeframe of the demolition contract.

To foster the development of the market actions should be taken at both governmental and contract levels. On the governmental level changes in legislation and EU taxonomy could facilitate the reuse of wood products left after demolition and increase their demand, thereby encouraging contractors to implement new cost-effective operational methods that allow to dismantle construction products intact for their further reuse. On a contract level, financial incentives could encourage parties to participate in projects, whereas sanctions prevent their withdrawal. From Helsinki City’s side facilitation for the reuse of wood products within a GPP could be achieved by piloting the reuse of wood products in new-build projects and utilization of minimum requirements and quality points in demolition ones.

9 Discussion

This chapter presents findings based on the research questions along with recommendations for a further research. Additionally, own reflections on a learning process and development are presented, along with challenges faced during the thesis process.

For this study experts from three main groups were interviewed representing the City of Helsinki (procurers, environmental services, and circular economy cluster), suppliers in the construction sector, and independent consultants. The research aimed to understand the current challenges associated with the reuse of wood products left after demolition and ways of its facilitation. Moreover, given the innovative nature of the topic and the fact that projects with such criteria are only executed as pilot ones, the thesis also aimed to help Helsinki City in understanding how the reuse can be facilitated via the GPP mechanism. The findings of the thesis were based on the analysis of the responses provided by experts in relevant fields. Additionally, some insights were also presented in the literature review as previous findings that can be used for benchmarking (see in chapter 6). However, it has to be kept in mind that experiences from other countries in the field of reuse of wood products left after demolition can significantly vary from the Helsinki City experience due to variations in assessment methods, requirements for reuse, the nature of GPP and the general legal framework.

The main findings regarding the first research question, “Challenges associated with the reuse of wood products left after demolition” revealed that the lack of a functional reuse market and financial incentives are the primary obstacles in development. These challenges are followed by the absence of harmonized assessment methods and the legal obscurity of the entire mechanism (figure 11, in details, see section 8.1.6).

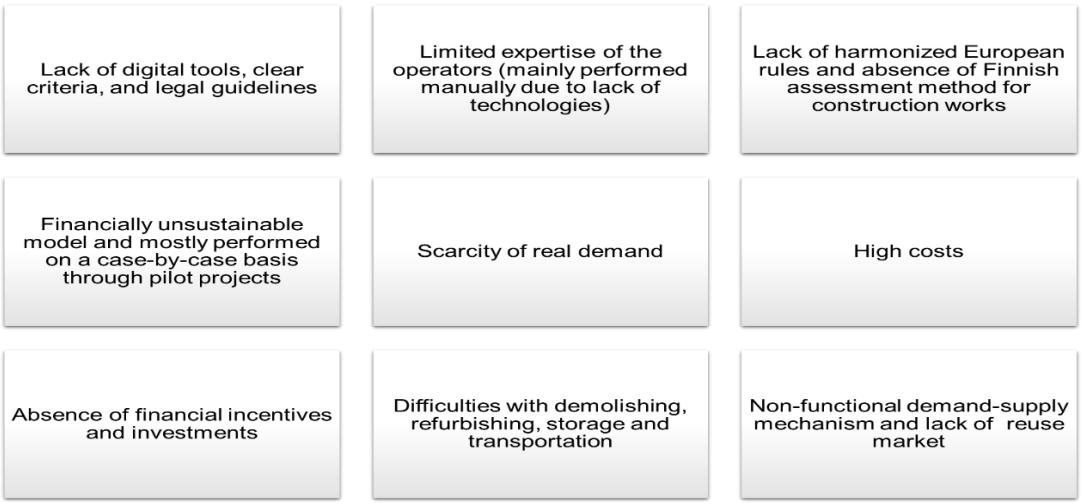

Figure 11. Challenges in the reuse of wood products left after demolition

The main findings regarding the second research question, “How to facilitate the reuse of wood products left from demolition activities” revealed that development can be intensified through functional national and European reuse markets, compulsory demolition audits, and report obligations to digital sales platforms, investments in cost-effective processes and national Finnish method for assessment. On the European level, facilitation of the reuse can be stimulated via high prices for raw materials and increased prices for emissions trading (figure 12, in details, see section 8.2.6).

Figure 12. Facilitation of the reuse of wood products left after demolition

The main findings related to the third research question, “How can GPP support the reuse of wood products left from demolition” demonstrated that at the moment support can be provided on a local level within the municipalities due to the lack of a functional reuse market, absence of clear guidelines and expected changes in legislation. Such measures can include the utilization of an assessment method that was developed by the Helsinki Circular Economy Cluster along with the incorporation of both “minimum requirements” and “quality points” in all pilot projects. Within a framework of GPP, initial support can be voluntary until the establishment of a functional reuse market and clear legal guidelines, particularly regarding assessment methods, verification, and reuse status. Subsequently, this support can become a mandatory framework (figure 13, in details see in section 8.3.3).

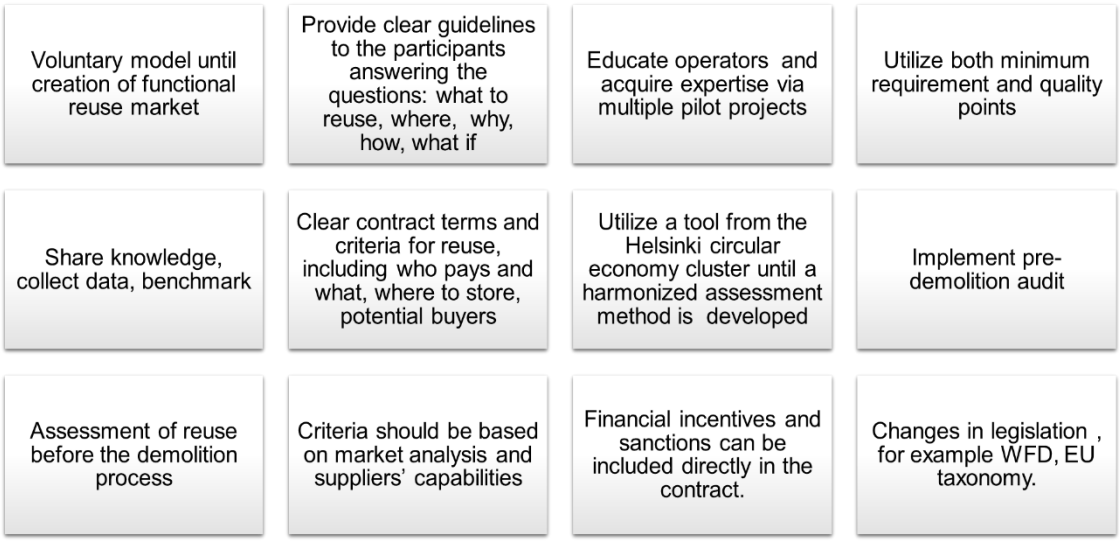

Figure 13. GPP support for the reuse of wood products left after demolition

9.1 Development ideas for further research

The European Union's Circular Economy Action Plan defines a robust strategy to encourage the reuse of construction products that can retain resource value and promote sustainability through incorporating circular economy principles into green public procurement, and EU funding allocation. Expected changes in legislation, including the Waste Framework Directive (WFD), the Energy

Performance of Buildings Directive, the Construction Products Regulation (CPR), and EU Taxonomy promise to boost the development in the field of reuse of construction products, including the reuse of wood products left after demolition, through the development of harmonized standards for assessment, reporting requirements of the reuse (in WFD) and incentive measures.

However, EU and national policies promoting the idea of reuse via changes in legislation are not sufficient unless a functional reuse market is developed, which seems to be a complex task. For a reuse market to be efficient it is required to connect all operators involved in the process via digital platforms, providing seamless data flow, reporting, assessment, and contracting possibilities. In this way, it is interesting to benchmark and compare the performance of different platforms assisting in sustainable public procurement and evaluating green criteria based on their environmental impact. For example, the special center “PIANO” in the Netherlands, the online software platform “DuboCalc” in Denmark, and the Competence Centre for Sustainable and Innovative Public Procurement “KEINO” in Finland.

Further research would be beneficial in understanding how upcoming changes in legislation impact the approach to the reuse of wood products left after demolition. Particular interest should be given to harmonized standards and assessment methods, examining how they could operate in practice, given the variety of approaches in construction practices and differences in climate conditions between European countries. Further research could cover topics related to the extension of CE marking to demolition materials, standardized classification systems, and the implementation of EU pre-demolition audits. Additionally, with the improvement of the Waste Framework Directive, which currently categorizes reusable items solely based on whether they retain their original purpose or not, further research can be conducted to investigate repurposing such products for less demanding functions. The study could also examine how a standardized waste classification system would affect the reuse of wood products.

Analysis of the results showed hesitation among suppliers in choosing quality points due to fear that they could not meet expectations and hesitation of procurers due to a lack of knowledge of how such quality points would perform in practice. In this regard, it might be interesting to leverage the experience from the French project “FCRBE” where reused materials were categorized and catalogued based on their reuse potential. Later, minimum targets were set for high-reuse materials and award criteria were established for exceeding the minimum targets or reclaiming materials from other categories. Since minimum criteria and quality points for reuse are still under development in Finland, it is possible to utilize the experience from France within pilot projects.

Findings showed that the engagement of private recycling operators, which can offer services in disassembly, refurbishment, storage of building components, and the capability to verify eligibility, when necessary, is essential for the reuse of wood products left after demolition. In this regard, further research is required to identify what companies can fill this niche, what skills are required, how they can operate, and what business model they should follow to be sustainable.

9.2 Reflection on own learning

Initially, the scope of the research was set to define the criteria that could already be utilized in the GPP contracts, along with exact metrics and mechanisms for monitoring and enforcement. However, while conducting the interview and questionnaire it became obvious that the topic is relatively new, with little or no specific results available to receive some clear guidelines for Helsinki City in their green public procurement practice, especially regarding criteria “the reuse of wood products left after demolition”.

Along with the thesis development, the decision was made to investigate the current challenges associated with the reuse of wood products left after

demolition and how these challenges can be overcome (first and second research questions). Based on the analysis of the two first research questions, a third research question aimed to provide suggestions of how the mechanism of GPP can support developments in the field.

The research topic is relatively new, with little information primarily derived from the results of pilot projects conducted in Finland and other Member States. Variations in results come from differences in assessment methods, legal requirements, and overall construction practices. However, my interest in this topic and great support from the Commissioner enabled me to conduct this research and get meaningful results that can be applied in practice.

During the time of writing this thesis, some changes in legislation are expected, particularly in the Construction Products Regulation (under revision), EU Taxonomy, and Waste Framework Directive. These changes can significantly alter the entire landscape and improve the reuse of construction products, including wood products left after demolition by stimulating operators to invest in efficient construction processes and contributing to the development of the reuse market.

The writing of this thesis took quite a long time, nearly 8 months, which can be explained by the novelty of the topic to the author and the need to obtain an adequate level of knowledge before delving into the details. Also, since the topic is new, it was challenging to find relevant sources and experts ready to participate in interviews and questionnaires. Grouping potential candidates for interviews faced multiple obstacles, as they represented different departments and companies associated with the topic. Moreover, their schedule was so tight that sometimes it took quite a while to arrange the interview part or receive answers on questionnaires. Data analysis took longer than initially planned, as some answers were received after the deadlines, which required restructuring of already written parts of the thesis. However, I must acknowledge that my

research would not have been possible without the huge support I received from my commissioner.

Throughout the thesis process, I obtained new skills in the field of reusing construction products with a focus on the reuse of wood products left after demolition. This includes gaining an understanding of assessment methods, European and national regulations, legal requirements, green public procurement practices, and challenges associated with the incorporation of green criteria.

In summary, this research can be considered as an R&D project aimed at understanding the current stage, challenges, and further development in the field of reusing wood products left after demolition, *inter alia*, through the prism of green public procurement practices in Helsinki City supporting the implementation of this green criteria.

10 Conclusion

Demolition waste constitutes a huge share of construction waste, contributing to the increase of CO2 emissions and generating a massive amount of products that still might be reused. Finland set a goal to achieve a 70% reuse and recycling rate by 2027, compared to the 40% set in 2019. One of the challenges in achieving this goal is a share of wood products left after demolition which should be reused or recycled rather than incinerated. In this research, the main challenges and facilitation methods for the reuse of wood products left after demolition, including the mechanism of public procurement practices incorporating such criteria, have been examined through a case study from Helsinki City.

The main obstacles to the reuse of wood products left after demolition have been defined as the lack of a functional reuse market and high costs; uncertainty for operators to invest in the processes due to a lack of financial and economic incentives, along with the absence of clear legal guidelines and harmonized assessment methods and standards. Additionally, shortage of storage places within easy reach and undeveloped technology are considered a barrier to reuse, coupled with insufficient practice of the operators primarily performing work manually. Since the prices for raw materials, especially wood, which is abundant in Finland, are much cheaper than the prices for reused products, there is no incentive for operators to prioritize reuse. The voluntary mechanism of GPP with green criteria can be a good start within pilot projects, however, it is not powerful enough to change the entire construction practices on a large industrial scale; regulatory changes are required.

Despite challenges, the facilitation of the reuse of wood products left after demolition can be achieved through a series of actions, including the revision of CPR for incorporating harmonized standards for different product categories, including harmonized technical specifications for reused wood products. CPR should clearly define what “the reuse of construction products” means, including

the extent to which alterations are possible and still qualify as reusable, along with the degree to which its usage can be modified. The revision of WFD could help to exclude construction products that are not waste and can be used for the same purpose, including wood products left after demolition, from the waste streams. This would allow operators to utilize such products later without legal uncertainty.

EU Taxonomy may become a strong incentive for reused content of new buildings. Moreover, facilitation of the reuse can be supported by pre-demolition audits, agreeing on assessment methods and on-site verification; inclusion of financial incentives directly into contracts, establishing digital platforms for benchmarking, and sharing information accessible to all operators starting from the design stage. The aforementioned measures could provide a robust basis for the establishment of reuse practices.

Since public procurement has a significant purchase power in the EU and dominates certain sectors of the market, including the construction sector, the decisions made within public procurement can have a significant impact on the promotion of goods and services with little environmental impact, development of environmentally friendly technologies, and overall reuse market. Even though GPP is a voluntary tool in Finland, the influence it can have is significant. In this regard, the incorporation of the criteria “reuse of wood products left after demolition” within all pilot projects run by Helsinki City, along with testing both minimum requirements and quality points in contracts can help to collect required data and obtain expertise for further expansion on a larger industrial scale.

Declaration of Competing Interest

I declare no conflict of interest.

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Appendices

Appendix 1. Questionnaire: Circular Economy Experts

GPP:	1. Do public contracts include provisions for reusing a certain share of construction products left after demolition activities? If yes, what are the reused products and why? If not, what are the reasons? 2. What challenges do you see in including requirements for the reuse of wood products, inter alia, doors, windows, and glulam, left after demolition activities in public contracts? Why and how to improve it? 3. What minimum and maximum requirements have to be in public contracts for the reuse of wood products left from demolition activities? If you cannot answer, what are the reasons, why is it difficult? 4. In your opinion is it better to include minimum requirements or quality points in public contracts? Why, what are the challenges, and how to overcome them? 5. What is attractive enough for the contractor to grab environmental quality points? Why? **6.** How does the voluntary nature of the GPP in Finland affect the promotion of the reuse of construction products left from demolition activities? Would the result vary if it is obligatory? **7.** What are the main obstacles in the reuse of construction products left after demolition activities? How to overcome them?
Economic aspects:	1. What do you think are the economic advantages and challenges of reusing wood products left from demolition activities, how can these challenges be addressed? 2. Do you see cost-effective alternatives to GPP to encourage the reuse of wood products left from demolition activities? 3. How can government and the EU incentivize the reuse of wood products left from demolition activities? What are the challenges?

Appendix 2. Questionnaire: Public Procurement

GPP:	1. Do public contracts include provisions for reusing a certain share of construction products left after demolition activities? If yes, what are the reused products and why? If not, what are the reasons? 2. What challenges do you see in including requirements for the reuse of wood products, inter alia, doors, windows, and glulam, left after demolition activities in public contracts? Why and how to improve it? 3. What minimum and maximum requirements have to be in public contracts for the reuse of wood products left from demolition activities? If you cannot answer, what are the reasons, why is it difficult? 4. In your opinion is it better to include minimum requirements or quality points in public contracts? Why, what are the challenges, and how to overcome them? 5. What is attractive enough for the contractor to grab environmental quality points? Why? 6. How does the voluntary nature of the GPP in Finland affect the promotion of the reuse of construction products left from demolition activities? Would the result vary if it is obligatory? **7.** What are the main obstacles in the reuse of construction products left after demolition activities? How to overcome them?
Monitoring	1. Do you monitor the reuse of construction products, inter alia, wood products (windows, doors, and glulam) left from demolition activities in new construction projects? If yes, what are the challenges, and how to overcome them? If not, why not? 2. How does sorting of construction products left from demolition activities, inter alia, wood products, affect their further reuse? What are the challenges and how to overcome them?
Environmental aspects	1. In your opinion, what are the environmental benefits of the reuse of wood products left from demolition activities? 2. In your opinion, in which scenarios can the reuse of wood products left from demolition activities cause negative environmental consequences, inter alia, more CO2e emissions? Why and how to eliminate these scenarios?
Economic aspects:	1. What do you think are the economic advantages and challenges of reusing wood products left from demolition activities, how can these challenges be addressed? 2. Do you see cost-effective alternatives to GPP to encourage the reuse of wood products left from demolition activities? 3. How can government and the EU incentivize the reuse of wood products left from demolition activities? What are the challenges?

Appendix 3. Questionnaire: Ministry of the Environment

GPP:	1. How does the voluntary nature of the GPP in Finland affect the promotion of the reuse of construction products left from demolition activities? Would the result vary if it is obligatory?
Method:	1. What are the main legal obstacles in the reuse of construction products left after demolition activities? How to overcome them? 2. How do Finnish legal requirements for the reuse of construction products left from demolition activities vary from other European countries? What future advancements can we expect? 3. How do assessment methods applied in Finland for the reuse of wood products left from demolition activities vary from other European countries? What future advancements can we expect?
Market:	1. How do you assess the supply and demand dynamics for the reuse of wood products left from demolition activities in Finland? What are the challenges and how to overcome them? 2. Do you have databases for construction products suitable for reuse, including wood products left from demolition activities? If yes, what are the challenges with them, and how they can be overcome? If not, why not? 3. Do you have examples of cases where the reuse of construction products left after demolition activities inter alia, wood products, was successfully utilized (Finland or abroad)? **4.** How do you think EU taxonomy will influence the reuse of construction products left from demolition activities, inter alia, wood products?
Environmental aspects	1. In your opinion, what are the environmental benefits of the reuse of wood products left from demolition activities? 2. In your opinion, in which scenarios can the reuse of wood products left from demolition activities cause negative environmental consequences, inter alia, more CO2e emissions? Why and how to eliminate these scenarios?
Economic aspects:	1. How can the government and the EU incentivize the reuse of wood products left from demolition activities? What are the challenges? 2. Do you see cost-effective alternatives to GPP to encourage the reuse of wood products left from demolition activities?

Appendix 4. Questionnaire: Environmental Services

GPP:	1. How does the voluntary nature of the GPP in Finland affect the promotion of the reuse of construction products left from demolition activities? Would the result vary if it is obligatory? 2. What are the main obstacles in the reuse of construction products left after demolition activities? How to overcome them?
Method	1. What standards (verification techniques) do you use to assess the possibility of the reuse of wood products left from demolition activities? What are the challenges and how to overcome them? 2. Do methods of assessment for the reuse of wood products vary depending on the actor (contracting authority, tenderer, supplier, external consultant…). Why? How can we ensure comparability of the results if different methods have been utilized?
Monitoring	1. How does sorting of construction products left from demolition activities, inter alia wood products, affect their further reuse? What are the challenges and how to overcome them?
Environmental aspects:	1. In your opinion, what are the environmental benefits of the reuse of wood products left from demolition activities? 2. In your opinion, in which scenarios can the reuse of wood products left from demolition activities cause negative environmental consequences, inter alia, more CO2e emissions? Why and how to eliminate these scenarios
Market	1. How do you assess the supply and demand dynamics for the reuse of wood products left from demolition activities in Finland? What are the challenges and how to overcome them? 2. Do you have databases for construction products suitable for reuse, including wood products left from demolition activities? If yes, what are the challenges with them, and how they can be overcome? If not, why not? 3. Do you have examples of cases where the reuse of construction products left after demolition activities, inter alia, wood products, was successfully utilized (Finland or abroad)?

Appendix 5. Questionnaire: Consulting & Inspection

GPP:	1. How does the voluntary nature of the GPP in Finland affect the promotion of the reuse of construction products left from demolition activities? Would the result vary if it is obligatory? 2. What are the main obstacles in the reuse of construction products left after demolition activities? How to overcome them? 3. In your opinion is it better to include minimum requirements or quality points in public contracts? Why, what are the challenges, and how to overcome them?
Monitoring	1. Do you monitor the reuse of construction products, inter alia, wood products (windows, doors, and glulam) left from demolition activities in new construction projects? If yes, what are the challenges, and how to overcome them? If not, why not? 2. How does sorting of construction products left from demolition activities, inter alia, wood products, affect their further reuse? What are the challenges and how to overcome them?
Method	1. What standards (verification techniques) do you use to assess the possibility of the reuse of wood products left from demolition activities? 2. Do methods of assessment for the reuse of wood products vary depending on the actor (contracting authority, tenderer, supplier, external consultant…). Why? How can we ensure comparability of the results if different methods have been utilized? 3. How do Finnish legal requirements for the reuse of construction products left from demolition activities vary from other European countries? What are the challenges and what future advancements can we expect? 4. How do assessment methods in Finland for the reuse of wood products left from demolition activities vary from other European countries? What are the challenges and what future advancements can we expect?
Economic aspects:	1. What do you think are the economic advantages and challenges of reusing wood products left from demolition activities, how can these challenges be addressed? 2. Do you see cost-effective alternatives to GPP to encourage the reuse of wood products left from demolition activities? 3. How can government and the EU incentivize the reuse of wood products left from demolition activities? What are the challenges?

Appendix 6. Questionnaire: Suppliers

GPP:	1. How does the voluntary nature of the GPP in Finland affect the reuse of construction products left from demolition activities? Would the result vary if it is obligatory? 2. What challenges do you see in including requirements for the reuse of wood products, inter alia, doors, windows, and glulam, left after demolition activities in public contracts? Why and how to improve it? 3. What minimum and maximum requirements have to be in public contracts for the reuse of wood products left from demolition activities? If you cannot answer, what are the reasons, why it is difficult? 4. In your opinion is it better to include minimum requirements or quality points in public contracts? Why, what are the challenges, and how to overcome them? 5. What is attractive enough for the contractor to grab environmental quality points? Why? 6. What do you consider the main obstacles in the reuse of construction products left after demolition activities? How to overcome them?
Monitoring	1. How does sorting of construction products left from demolition activities, inter alia, wood products, affect their further reuse? What are the challenges and how to overcome them?
Method	1. What standards (verification techniques) do you use to assess the possibility of the reuse of wood products left from demolition activities? 2. Do methods of assessment for the reuse of wood products vary depending on the actor (contracting authority, tenderer, supplier, external consultant…). Why? How can we ensure comparability of the results if different methods have been utilized? What are the challenges?
Environmental	1. In your opinion, what are the environmental benefits of the reuse of wood products left from demolition activities?
Economic aspects	1. What do you think are the economic advantages and challenges of reusing wood products left from demolition activities, how can these challenges be addressed? 2. Do you see cost-effective alternatives to GPP to encourage the reuse of wood products left from demolition activities? **3.** How can government and the EU incentivize the reuse of wood products left from demolition? What are the challenges?
Market	1. Do you assess the supply-demand dynamics for the reuse of wood products left from demolition activities? If yes, what are the challenges, and how to overcome them? If not, why not? 2. Do you have examples where the reuse of construction products left after demolition activities, inter alia, wood products, was successfully utilized (Finland or abroad)?