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# SUSTAINABILITY TRANSITIONS IN BUILDING RENOVATION SECTOR – DIFFUSION OF WOOD AS A SAFEGUARD MECHANISM AGAINST HIGH ENVIRONMENTAL IMPACT

Master's thesis

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# ABSTRACT

The Paris Climate Change Agreement adopted in 2015 sets out a long-term qualitative goal of reducing greenhouse gas emissions to support the global transition to a low-carbon and climate-resilient society. In regard, European Union (EU) objective is to reach climate neutrality by 2050. According to European Commission, the building stock is one of the largest energy consumers and 75% of the housing fund is wasting energy. European Commission Renovation Wave strategy sets out an ambitious target to double the annual energy renovation rate of buildings by 2030 to significantly reduce the harmful environmental impact through the reconstruction and deep renovation of the buildings. Estonia's objective is, in this regard, to completely renovate its building stock by 2050. The thesis aimed to analyze sustainable material usage in the renovation sector and the diffusion of wood (biomaterials). The method for the research was personal interviews and literature review. For the analysis, 18 interviews were conducted with various stakeholders from the EU level to local renovation contractors and procurers. Results showed that currently in the renovation sector sustainability of materials is not looked for. The main obstacles are related to the price as apartment building associations expect the best results with the least of investment and path dependency with no motivation to change without a driver from the strategic policy level. Estonia has a strong woodhouse production background and it plays as an advantage regarding wood diffusion and sustainability in the renovation sector. But the focus regarding wood usage in renovation is on the production and constructible (factory) side rather than on the sustainability aspects. To support wood diffusion, demonstrative projects must continue and knowledge diffusion. To support wood usage and sustainable materials, policy and grant schemes development should accept more of the sustainable aspects of renovation, not only energy efficiency. The author concludes that the current situation in the construction sector and lack of sustainable material approach mirror the situation in the renovation sector. The developments soon on the EU level will internalize the wider support to sustainable materials and life cycle approach in the Estonian renovation market.

Keywords: sustainable renovation, sustainability transition, sustainable construction material, timber, biomaterial, wood, innovation, socio-technical system.

# INTRODUCTION

*"Someone is sitting in the shade today because someone planted a tree long time ago."*

Warren Buffet

Europe plans to be climate neutral by 2050, and to achieve this, an agreement was reached in the form of a European Union (EU) "Green Deal" – a document that will guide the EU's progress to a sustainable economy. **"Green Deal" also expresses the importance of the improvement of the energy efficiency of buildings, that is, the reconstruction of buildings** (European Commission 2019). **The construction sector is emission-intensive**, responsible for around 40% of the total direct and indirect global CO2 emissions (International Energy Agency 2020; United Nations Environment Programme 2020). The sector is not only material-intensive but also energy-intensive (for example, the production of cement) (European Commission 2015).

**Around 80% of today's buildings in Europe will be still in use after 30 years** (European Commission 2020b). According to the theory of the life cycle of the building, the average life expectancy of the building is 50-70 years, so to keep the quality and sustainability of the living environment, **large-scale reconstruction of the built environment is a necessity** (European Commission 2020b). The European Commission has therefore prepared a plan of action for the energy efficiency of the buildings, "Renovation Wave" strategy aims on supporting energy and resource-efficient renovation. The strategy sets out an ambitious **target to double the annual energy renovation rate** of residential and non-residential buildings by 2030 (European Commission 2020c). Since the building stock is one of the largest energy consumers and 75% of the energy is wasted, it is possible to significantly reduce the harmful environmental impact through the reconstruction and deep renovation of the buildings (European Commission 2020d).

EU directive (2018/844/EU) on the energy performance of buildings recommends, based on the European Commission's impact assessment, the annual renovation rate of 3% of the existing building stock. Currently, the renovation rate in Estonia is less than 1% of the building stock, but **Estonia's objective is to completely renovate its building stock by 2050** in class C of energy efficiency. The reconstruction of apartment buildings to energy class C, based on the local

classification, will save approximately 65% of the heating energy, and the costs of heat energy and electricity costs will fall by up to 50%. (Kuusk et al 2014)

To keep the harmful environmental effects resulting from construction activities under control while the volume of reconstruction increases, the Estonian **solution may lie in strengthening the areas of bio-economy and circular bioeconomy**[1]. An economy that is based on biomass and does not use non-renewable materials (e.g. materials, chemicals, and energy derived from renewable biological sources such as plant and animal biomass) may allow a significant reduction in environmental impact (McCormick et al 2013). That means replacing heating and finishing materials in the reconstruction process with renewable materials (e.g. wool, assembly foam, plaster, frames, windows).

The need for **material diversity (including wood) can support environmental sustainability** and substantially **raise the value of the building sector**, but also the wood industry can have an important role in **the development of research-intensive and innovative solutions in the area of reconstruction**, based on the ambitious energy efficiency objectives of the EU and Estonian long-term renovation strategy (Aben 2020; Estonian Forest & Wood Industries Association 2021). However, sustainable reconstruction requires also large investments and it can take more than a decade until payoff according to Philp et al (2019, 46).

**In addition, sustainability transitions in the reconstruction sector need supportive policymaking.** Rogge et al (2016, 1632) described the context of policy mix development as a task that includes consistency, coherence, credibility, and comprehensiveness. Supportive policymaking means the policy mix has a wider set of elements (Rogge et al 2016, 1623) and the focus is not only on the market failures (Kirs et al 2018, 10). Therefore, designing a suitable policy mix for transitions is a demanding task for policymakers (Edler et al (2017, 17) that requires a deep understanding of the context and wider perspectives.

Based on the challenge of sustainable renovation, the thesis aims to analyze the possibilities of using wood, as a biomaterial, in the common soviet time apartment building renovation process by mapping the renovation market and later analyzing the role of wood and the challenges

[1] See also ”Report on Good Practice Business Models and Example Small and Medium Scale Pilot Business Projects for Sustainable Bioenergy and Side Bioproducts Production in the BSR”. Available: https://balticbiomass4value.eu/wp-content/uploads/2021/02/BB4V_A_2.3_REPORT_15.01.2021_FOR_WEB.pdf

biomaterials face in the diffusion process, and how to alleviate these problems through policy mix development. The following research questions will be answered:

- What is the potential of biomaterials, including wood, to support sustainability transition in the field of renovation of residential buildings?
- What are the key factors and challenges for using wood-based materials/technologies to support sustainability transition in the field of renovation of common soviet time **apartment buildings** in Estonia?
- What kind of change(s) in the policy mix is(are) needed to support sustainable renovation?

The paper is divided into two main parts – theoretical framework and empirical analysis. The theoretical framework will give an overview of the current theoretical discussions regarding sustainable transition, bioeconomy, and the challenges of biomaterial diffusion. A framework for the analysis is provided based on the realm of policy development. The second part, the empirical study, is a case study of the Estonian renovation sector and wood industry, mapping the current situation and key challenges. It will open the discussion of the sustainability transitions in the reconstruction sector and provide insights into the current developments regarding the usage of the wood. Based on the document analysis and semi-structured interviews, the challenges of the usage of wood will be examined and possible policy mix solutions are sought for which could alleviate the climate impact of renovation with embodied carbon approach.

# 1. THEORETICAL FOUNDATION FOR SUSTAINABILITY IN RENOVATION SECTOR

## 1.1. A brief overview of the key theoretical approaches to analyze sustainability transitions

Many authors of scientific articles, reports, and analysis have referred to the definition of sustainability in the Brundtland Report from the year 1987[2]: "*Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*" (Brundtland et al 1987; Jarvie 2016). Respectively, the debate of the sustainability transitions has been devoted on how to use research, technology and innovation policy for solving these societal challenges (Weber et al 2012, 1037), though the specific focus of different studies can be somewhat different depending on the theoretical frameworks applied. Figure 1 shows the key contributors and the main frameworks in the field of sustainability transition studies.

As the common nominators to frame the sustainability transition studies the following aspects are highlighted in this analysis:

- Sustainability transition is elaborated as a long-term and comprehensive fundamental transformation process resulting in a major socio-technical system shift to sustainable ways of production and consumption (Markard et al 2012, 957; Loorbach et al 2017, 603).
- A socio-technical system has different actors who interact with each other, are dependent on the network, and create the service layer for the society (Markard et al 2012, 956). Smith et al (2005, 1508) consider here also the two-sided effects of actor activities which can be desirable or undesirable towards the change.
- The transition of the socio-technical system includes changes in institutional structures and user practices and brings along wider technological and supportive innovations (Markard et al 2012, 956-957). Meaning that the path-dependent nature of the system has

[2] World Commission on Environment and Development published a report "Our common future" in 1987 which included the guiding principles for sustainable development generally understood today.

an exquisite battle of openness *versus* restriction of knowledge accessible to the niche actors (Edquist 2005, 79).

- The transition of a socio-technical system requires a directional change of the system in all its dimensions (including normative and cognitive collective rules) (Schot et al 2018, 1563).

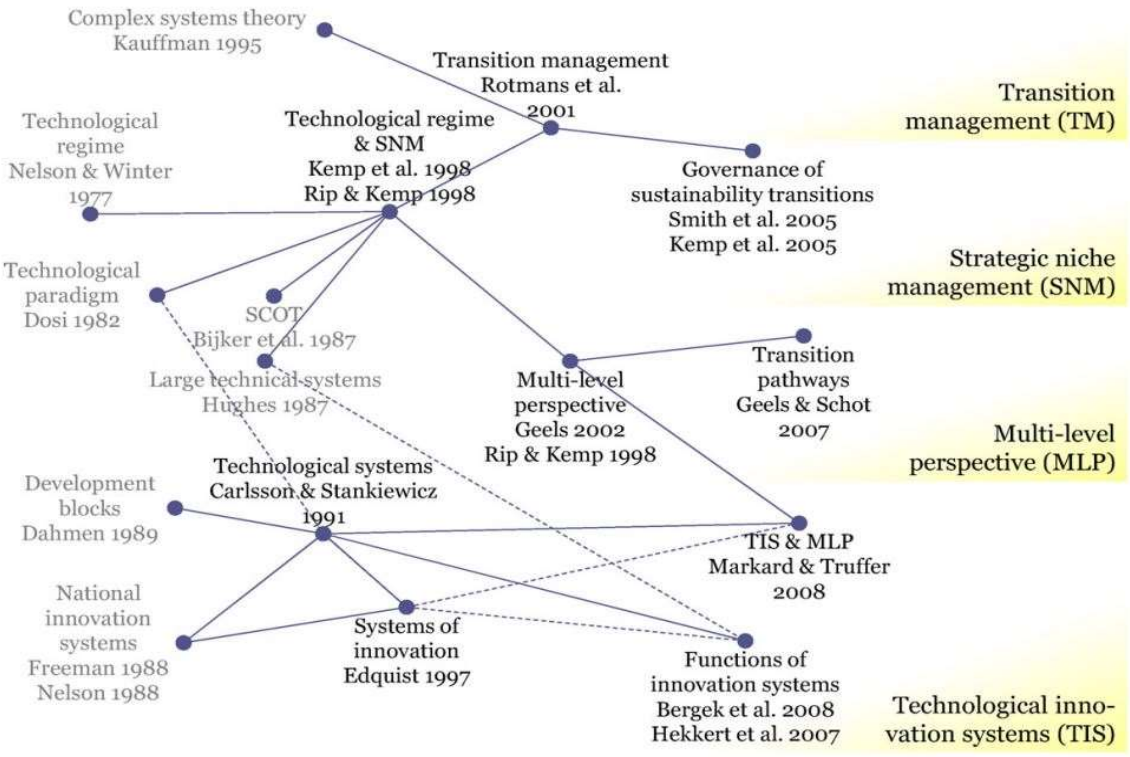


**Figure 1. Map of the evolving field of sustainability transition studies.**
Source: Markard et al 2012, 957.

The most suitable approach to study bioeconomy-related developments has been found in the multi-level perspective and technological innovation system (TIS) theory and their combinations (see literature review by Gottinger et al 2020; Markard et al 2008, 596; Weber et al 2012, 1038). TIS explores dynamic (Hekkert 2007, 417) and technology-specific developments in emerging industries (Bergek et al 2008a, 408) while revealing obstacles and systemic weaknesses blocking innovation processes. Multi-level perspective (MLP) has three analytical levels (niches, regimes, landscapes) that provide a holistic overview of multi-scalar developments (Schot et al 2018, 1562). Regimes comprise factors like knowledge, policies, investments, institutions, skills, cultural values that reflect the current set of know-how, rules, and coordination (including

potential path dependency and lock-in conditions) (Geels 2011, 28). Niche innovations demonstrate opportunities to lead to fundamental shifts in socio-technical regimes also caused by the landscape pressure (e.g. political ideologies, societal values, macro-economic patterns, climate change) (Gottinger et al 2020, 4). So TIS framework identifies barriers of the networks and policy mix while MLP elaborates lock-in effects and sectoral process routines (Gottinger et al 2020, 19; Schot et al 2018, 1563).

## 1.2. Sustainability transitions and the renovation of residential buildings

### 1.2.1. Rationale for renovation in the construction sector with biomaterials and wood

To frame the discussion of renovation in the construction sector the following aspects are highlighted in the context of the built environment:

- The built environment is a complex system where dynamics of transitions across different sectors can be led by actions of different actors, for example, architects, engineers, urban planners, etc. (Nielsen et al 2019, 232). But due to the capitalist market, actors with the most capital have the biggest influence and dictate the realm of the built environment. The capital and client's values are the driving force and the influence by the planners, designers, builders, and local municipalities become insignificant. (Nielsen et al 2019, 243)
- Nielsen et al (2019, 234, 241) describe a paradox where construction can be rather easily influenced by the local municipalities (urban planning) and the ones who control financing (grants and financial instruments), but when the building is built, it represents a socio-technical lock-in. Therefore, alternatives to renovation (demolition) or concepts of living in the city (community living, etc.) rely on political reality.
- The sustainability transitions of the built environment, especially urban areas, aim to serve the objective to create a higher standard of living (buildings quality, road system, etc.) without negative climate impact (Frantzeskaki et al 2017, 5).

The reconstruction for energy efficiency purposes (subsector of construction) of the static built environment becomes more relevant to explore as the changes in the built environment are long-term. Reconstruction or renovation in technical terms can be both considered synonym for

energy efficiency works to upgrade the façade, roof, and windows of the buildings. The renovation sector itself can be conceptualized as a socio-technical system because it involves a) networks of actors like individuals, businesses, various organizations; b) institutions as regulations, practices, societal and technical norms; c) **material artifacts (construction)** and d) knowledge. The above-mentioned elements together provide the renovation through interactions. (Markard et al 2012, 956)

Purkus et al (2018, 3955) mark that bioeconomy has a lot of political support from the EU, and expectations regarding climate change mitigation are high. That is the main argument for the construction sector to use wood as a building material and reduce greenhouse gas emissions. United Nations Environment Programme (2020, 10) report showed that 38% of total global energy-related CO2 emissions are from buildings and construction, construction constituting 10%. Considering the life cycle of buildings, the construction sector accounts for 42% of total energy consumption, 35% of total greenhouse gas emissions, 50% of extracted materials, and 30% of water consumption (Hurmekoski 2017, 3). American Forest Foundation (2021) says that compared to wood, steel consumes 12% and concrete 20% more energy, steel emits 15% and concrete 29% more greenhouse gases, steel releases 10% and concrete 12% more pollutants in the air, steel generates 300% and concrete 225% more pollutants into the water. Thus, the rationale for the renovation sector on a global level is bipartite: decrease the energy consumption of buildings and use materials that have a low impact on the environment (Kuittinen et al 2013, 14).

There are many ways for greenhouse gas reduction, either to improve the carbon capture and production processes, for example, concrete manufacture, or substitute the emission-intensive materials in construction (Ludwig 2019, 3). Latter means, wood with its capability of carbon storage (through photosynthesis) (Ministry of Agriculture and Forestry 2015, 18), has an advantage over modern materials with their resource-intense production. Wood from other mainstream building materials stands out with the capacity to store greenhouse gas emissions from the atmosphere in its' mass and therefore the environmental costs of the building are lower (Office of Government Commerce 2007, 5). As a material, it also needs less energy for processing and eventually can be used as a biofuel when at the end of its' life cycle (Kuittinen et al 2013, 14). So valuable energy could be extracted from the wood even after the service life as a part of the façade. And since during a life cycle of an apartment building, more than one renovation phase might be needed as the age of the materials, higher use of biomaterials brings

significantly down the cost of environmental impact and the overall greenhouse gas emissions related to the building (Kuittinen et al 2013, 14; Antikainen et al 2017, 20). Before discussed positive aspects of the wood can be most understandably conclude with the scheme (see Figure 2) of Kuittinen et al (2013, 27).

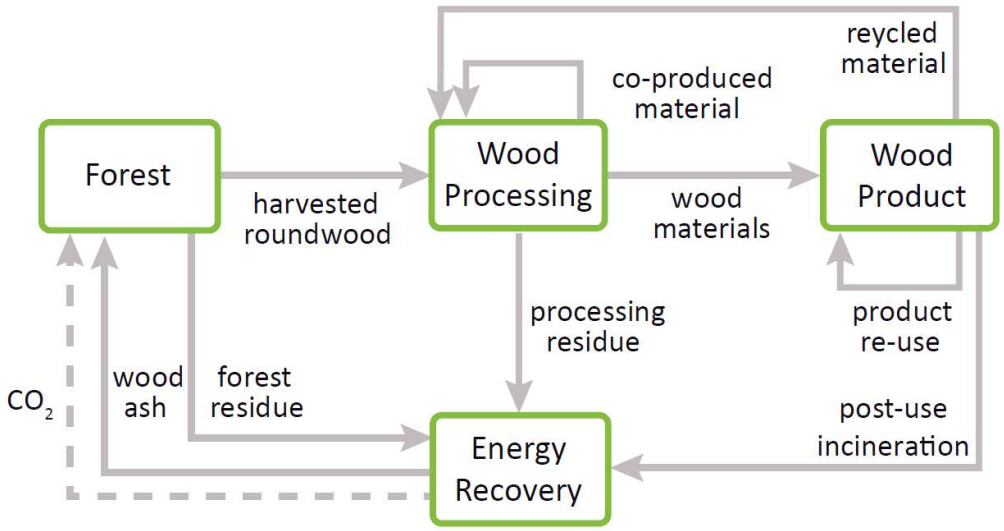


**Figure 2. Diagram of the wood material flows.**
Source: Kuittinen et al 2013, 27.

Ludwig (2019, 3) raised the question of possible negative aspects regarding wood usage increase since the demand for biomaterial puts pressure on environmental protection and forestry. According to Hurmekoski (2017, 3), if the construction market share dedicated to wood would be 100%, it would need in the EU annually a maximum of 400 million m3 of round wood, approximately 50% of the annual forest growth meaning the effects could be relatively small. Even so, wood as a biomaterial itself is still a somewhat limited resource taking into consideration of the different objectives (bioscience, construction, forestry, energy, etc.) and the pace of innovation thrive among the actors. But bigger demand can motivate forest owners and give a reason for active forest management (Hurmekoski 2017, 9).

Häkkinen et al (2012, 149) explain the material impact is closely related to the buildings' operational energy type and that energy type influences the carbon footprint of the building. If the energy comes from the wind, hydro, or other power solutions, materials used in reconstruction have more impact than the operational energy used during the life cycle of the building (Häkkinen et al 2012, 149). For example, the difference between using reinforced

concrete and wood can be more than 100kg CO2 per square meter (Link 2015, 82). Ruuska et al (2012, 80) therefore claim that the increase of wood in the renovation sector decreases greenhouse gas emissions and annual carbon uptake. Hurmekoski (2017, 7) estimates an average emissions reduction of approximately 2 tons CO2 for 1 ton CO2 of non-wood products substituted with wood products.

To conclude, wood diffusion in the reconstruction sector is considered a supportive solution towards a sustainability transition. And renovation with wood has also an impact on the living environment, the material is also known for its stress-related health benefits (Kotradyova et al 2019; Kuo et al 2001). Even wider exploration about positive wood aspects was led by Stora Enso (2020) who found more than 116 relevant articles supporting various positive effects of wood. So visioning sustainable renovation future and usage of wood not only with the benefits of decreased greenhouse gas emissions, but one can also consider possible complementarities of apartment buildings reconstruction with wood and the visual surfaces that arise in the urban environment.

### 1.2.2. Key factors and challenges for the sustainability transition in the renovation related socio-technical system

Geels (2004, 900) states that socio-technical systems are the outcome of human actor activities and these actors are part of a certain social group who share common characteristics (universities, customers, businesses, laborers, etc.). The aim of the transition should be the replacement of the prevailing socio-technical system to institutionalize new regulatory programs, regular practices, views, industry structures, professional levels, training programs (Geels 2020, 13; Nielsen et al 2019, 232). An important part of the change is continuing experimentation which is often considered as a seed that may lead to a fundamental transformation (Fuenfschillin et al 2019, 220). Figure 3 visualizes the complexity of the socio-technical system. The production side can be described as a renovation sector that includes all the counterparties who are involved in the design and market selling the “renovation package”. The application domain holds the view of the market on renovation and reflects technologies in use. Between the two sides is the regulative element, guided by the state to assure that the renovation is in line with the state objectives and other regulations in place.

Multi-level perspective (MLP) clarifies regime and niche level actors (stakeholders) who may have different ideas and visions about sustainability (Whitmarsh 2012, 484). So it will frame the

changes in the socio-technical systems (transition process) through the developments and interactions between three hierarchical levels: niches as radical renovation related innovations on the low level, regimes as practices and set of rules stabilizing existing renovation systems in the middle, landscape as EU level context (internalizing climate impact) which can't be influenced easily by the actors below (Geels 2011, 26).

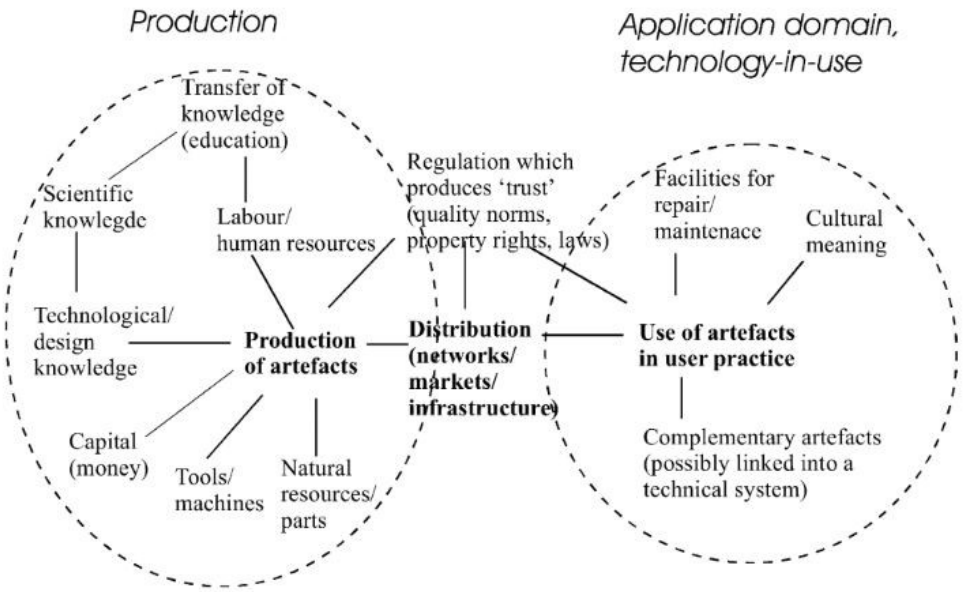


**Figure 3. Socio-technical system with basic elements and resources**.
Source: Geels 2004, 900.

The main challenge for the sustainability transitions is that consumers and businesses are locked into the already established solutions of consuming and producing (European Environment Agency 2016, 19). That means the path-dependant mechanism elicits incremental innovation (Geels 2011, 27). Thus, underlying processes like formulation of expectations, network building of the actors, and learning must be examined more thoroughly (Geels 2011, 28; Schot 2008; Bergek et al 2008a; Bergek et al 2008b; Hekkert et al 2007; Gottinger et al 2020).

Socio-technical system analysis will be done through the combined concept (national technological system) based on MLP and TIS showing the interactions of different levels of functions that are influencing the construction and renovation market overall (see Table 1).

**Table 1. Basis of analysis for technological innovation system**

| Concept for sustainable transition research | | | Key influencing factors | Example of specific factors |
|---|---|---|---|---|
| External environment | Landscape | | Climate change; economics (including shocks); broad cultural changes in values and ideologies | International agreements on climate change; European Unions' budgetary process and strategies; COVID-19 crisis |
| Internal environment | Regime | Policy creation – steering the processes | Creation of legitimacy and related policy-making processes (i.e. guidance of search processes) | Interest groups and their inclusion into policy-making; specific targets set by government regarding new technology; press articles (raising expectations); belief in growth potential; regulatory pressure; alignment with current legislation; expression of interest of leading businesses |
| | | Production – capacities emerging on supply side | Knowledge development and knowledge diffusion through networks | R&D projects; patents; R&D investments; workshops and conferences; networking; learning curves |
| | Niche | | Entrepreneurial activities and experimentation | Active businesses in the field; experiments conducted by the businesses; diversification of established businesses |
| | | | Resources mobilization | Availability of funding; availability of human resources; sufficiency of resources and raw materials |
| | | Production & Application – capacities emerging on supply side & demand | Market formation | Specific tax regimes; incentives from taxes; role of standards (including environmental); market size; actor strategies; lead customers (role models); subsidies for new businesses; supportive measures to customers |
| | | | Price-performance improvements | Subsidies for deployment and demonstration (learn-by-doing); pilot projects; public sector as a role model (procurement); R&D support |
| | | Application – affecting demand conditions | Awareness of the public | Information campaigns; the awareness of the consumers; breaking down prejudice about materials |

Source: Geels 2020; Geels 2004; Hekkert et al 2007; Bergek et al 2008a; Bergek et al 2008b; Markard et al 2008; Lihtmaa 2018; Gluch et al 2007; Esteban et al 2016; Gottinger et al 2020.

- **<u>Changes induced from the external environment</u>**

The external environment represents the political ideologies, societal values, macro-economic patterns, climate change, specific shocks like crises. All these factors influence actors on regime

and niche levels, the so-called vertical impact of the landscape. That kind of pressure can create opportunities for niches (Bilali 2019, 9), and the changes in regime created by niches can also influence landscape creating a stable environment (Geels 2011, 36-37). European policies, research, and innovation programs have progressively incorporated bioeconomy (circular economy) production and consumption models for sustainable and climate-neutral growth (Gatto et al 2021, 3). In the context of MLP, the EU climate neutrality goal can be considered as a landscape-level challenge that needs niche-innovation support and change of the current path-dependency (Geels 2020).

EU ratified in 2016 The Paris Climate Change Agreement, the first universal and legally binding global climate change agreement (United Nation 2021). To support the global goal, the EU set plans for climate neutrality by 2050[3] and created a document ("Green Deal") that guides the progress (European Commission 2019). The Commission proposed at the end of 2020 to raise the 2030 greenhouse gas emission reduction target even further than initially agreed 40% in the Paris Climate Change Agreement, to 55% compared to 1990 (European Commission 2020a).

European Commission argues in its Bioeconomy Strategy that sustainability is an opportunity for the EU who is already a global leader in the sustainable use of natural resources and strategic leader of the bioeconomy (European Commission 2018, 5-6; Gatto et al 2021, 3). Europe aims to shift the production system from a fossil-based economy to a biobased circular economy paradigm (Gatto et al 2021, 3) and the level of commitment is high (Markard et al 2012, 956). Ciurca (2020) also notes in the study of Germany's wood-based bioeconomy that the complexity of the topic needs a cross-sectoral and interlinked approach, especially if the assumption is that the bioeconomy is a political project involving stakeholders and actors with different objectives, interests, and strategies.

Climate change and environmental degradation are pressuring the energy, housing, and construction sector to create public policy changes, while also broad cultural changes in ideologies and values pressure the current renovation and construction sector (Geels 2004, 914; Antikainen 2017, 27). For example, United Nations (2020, 4) initiated a study that will explore

[3] Estonia set a target for greenhouse gas emission reduction at 80% decrease compared to 1990. Available: https://www.envir.ee/et/eesmargid-tegevused/kliima/kliimapoliitika-pohialused-aastani-2050-0

climate-neutral housing construction and renovation. Moreover, The New European Bauhaus[4] initiative by European Commission is searching for new solutions for sustainable and quality living spaces bringing together an EU-wide network involving bottom-up projects. The Commission is also analyzing different options how to measure carbon storage in the products (results by 2023) and recently started a research project to evaluate the climate benefits of the use of wood products in the construction sector (European Confederation of the Woodworking Industries 2020, 74).

- **Internal nation-state specific change mechanism**

Minimizing the footprint of buildings requires resource efficiency and circularity combined with construction sector alteration into a carbon sink (European Commission 2020b, 3). The struggle for biomaterial innovations in the renovation sector is to enter in that path-dependent and incremental locked-in mechanism maintained by the existing actors (Geels 2020, 9). The innovations that could submerge and support the changes are not easily accepted by the current system voluntarily, as the adoption can create "*winners*" and "*losers*", and the prevailing system needs more energy for absorption.

Though lock-in mechanisms and prevailing socio-technical systems tend to be seen negatively in the studies of sustainable transitions, Klitkou et al (2015, 35) concluded that they might also affect the technology positively. If an incremental innovation can provide sustainable results, radical paths might be less favorable. Still, path-dependency is a subject to barrier creation since the chosen path will eventually start blocking the more radical innovations (for example, element-based apartment building renovation) (Klitkou et al 2015, 35). Easily progressed cooperation discussions can be reduced rapidly due to the resistance of transitions. For that reason, Markard et al (2012, 956) considered transition as a process of considerable timespans, even more than 50 years due to the broad range of affecting actors. But the transition is not destructive, all the new knowledge during the progress (products, businesses, etc.) can partly complement and substitute the existing actors in the renovation sector. Thus, the structures of technology and institutions change, but the actors will change within (values of consumers, renovation businesses change their processes). (Markard et al 2012, 956)

[4] New European Bauhaus. Available: https://europa.eu/new-european-bauhaus/about/about-initiative_en

Internal nation-state-specific change mechanism for sustainability transitions in the renovation sector will be explored through three dimensions: (1) **policymaking-related aspects**; (2) **production-related aspects** and (3) **demand creation-related aspects**. These dimensions can be understood through the positive fulfillment of seven functions which are divided between the dimensions as follows. Policymaking aspects are the policy creation for steering the innovation processes including functions (Hekkert et al 2007) *creation of legitimacy* and *guidance of search*. Production-related aspects explore the capacities emerging on the supply-side and include the following functions (Hekkert et al 2007): *knowledge development and diffusion, entrepreneurial activities*, *resources mobilization*, *market,* and *price*. Demand creation-related aspects are mainly influenced by *market formation*, *price-performance* of the niche solution, and *awareness of the public*.

- **Creation of legitimacy and related policymaking processes**

That topic comprises two functions Hekkert et al (2007) brought out in their work – the *creation of legitimacy* and *guidance of the search.* New technologies have to become a part of the current regime and they can be opposed by the parties with vested interests (Hekkert et al 2007, 425). In the case of resistance, advocacy coalitions can support the transition and legitimize new technological trajectories (Hekkert et al 2007, 425; Smith et al 2012, 1026). Recognition of the niche technology and the ability to raise political support are considered important (Walz et al 2016, 4; Smith et al 2012). Research can be led by the renovation industry, the government, or by the renovation market which is a cumulative and interactive process where ideas are exchanged (Walz 2016, 4; Hekkert et al 2007, 423). To explore the function, interest groups and their lobby can be investigated while also mapping specific targets set by the renovation sector businesses and government regarding the use of a specific technology (Hekkert et a. 2007, 425).

- **Knowledge development and knowledge diffusion through networks**

That topic comprises two functions Hekkert et al (2007) brought out in their work – *knowledge development* and *knowledge diffusion through networks.* The purpose of the function is to exchange new information from the knowledge development emerging from learning through practice and research (including education and training) (Hekkert et al 2007, 422-423; Edquist 2005, 16; Walz et al 2016, 4; Bergek et al 2008a, 417). Klitkou et al (2015, 24) note that *learning by doing* has also a positive influence on the current system because it supports better quality and improvements with incremental innovation. Smith et al (2012, 1026) have brought out the same

aspects that knowledge itself is not necessarily supporting change. Thus, Hekkert et al (2007, 423) point out that policy decisions should be in line with the latest technological advancements and research agendas should change accordingly. To explore that function, Hekkert et al (2007, 423) suggest looking for R&D projects and investments, patents while also mapping the events (workshops, conferences) devoted to the specific technology topic (wood materials in renovation) and the networks regarding the knowledge diffusion.

- **Entrepreneurial activities and experimentation**

Hekkert et al (2007, 421) clarify that entrepreneurs are the backbone of the innovation process exploring the potential of the new knowledge, markets, and networks to grasp business opportunities (Bergek et al 2008a, 415). In the sustainability transition, the innovation process is not necessarily related to new companies, also companies already in the market can diversify the business to adapt to the new developments and gain from them. The main idea behind the function is that experimentation will allow evaluating the consumer reaction, competition, government standpoints, supply chains. Which gives great opportunities to *learn by doing*. Since there is no innovation system without entrepreneurs, the function can be analyzed by mapping new companies in the renovation field (Bergek et al 2008a, 416), activities of the incumbent actors with the aim for diversification (see also Walz et al 2016, 4) and the number of experiments (Hekkert et al 2007, 421).

- **Resources mobilization**

Financial and human resources are both necessary for an active innovation system and therefore investments are critical to support knowledge production (Hekkert et al 2007, 425). Gatto et al (2021, 6) also stress the importance of the availability of raw materials (biomass) supply for processing and transformation. Klitkou et al (2015, 24) explain that the economies of scale come into play when a niche is supported because the initial cost or earlier investments have been made for the incumbent technologies and their production capacity can already increase in volumes. So, the financial support for the new technologies, which are associated with a higher risk of failure, is a must (Walz et al 2016, 4). Otherwise, niches can be rejected because the low level of funding slows down knowledge development and research facilities might be discouraged due to lack of well-funded research groups, workshops, and conferences (Smith et al 2012, 1026). Since resource mobilization is closely tied with knowledge creation and diffusion,

Hekkert et al (2007, 425) suggest analyzing funding for niches and whether the main actors bring out the problem of underfunding.

- **Market formation**

Niche innovations face the "*Valley of Death*" according to Gatto et al (2021, 6), which is the cap between profitable commercialization and research studies because the market environment is stabilized by the institutions, user preferences, routines, supply, and demand, price mechanisms (Smith et al 2012, 1026; Klitkou et al 2015, 24). Niches have difficulties to compete with the incumbent technologies because the latter have also initial costs and investments made (Hekkert et al 2007, 424; Klitkou et al 2015, 24). Thus, Bergek et al (2008a, 416) explain that the new technology diffusion in the early-stage will evolve through the nursing market set-up as they also require an inconvenient change to the accustomed user practice (Smith et al 2012, 1026). The nursing market can also be replaced with tax incentives and other regulatory solutions (Hekkert et al 2007, 424). To analyze the market formation, market development, and drivers for market formation must be taken also into account (Bergek et al 2008a, 416). The function can be mapped by identifying niche markets (initiatives supporting new technology), tax regimes for the new renovation technologies, and (environmental) standards supporting the new environmental approach (Hekkert et al 2007, 424).

- **Price-performance improvements**

Kivimaa et al (2016, 209) bring out the price aspects because it supports the stabilization of the niche and enables it to become a non-costly alternative to incumbent technology. The main problem of the sustainable solutions is that external environmental costs are not represented in the user prices causing it to have no advantage under the normal market conditions (Smith et al 2012, 1026). As the renovation sector is a path-dependent and strongly price-driven market, it is very difficult for new sustainable solutions to become part of the current regime. That is also highlighted by Gatto et al (2021, 6) who brings out the aspects of high production costs and low investing confidence in high-risk models when compared biobased products over fossil-based. The function can be explored through interviews and discussions with the core actors in apartment building renovation and the wood-product market.

- **The awareness of the public**

Although biomaterials have been accepted as a versatile building material, socio-cultural perceptions often associate biomaterials and their design as outdated and old-fashioned. Thus, biomaterials are rather undesirable when compared to concrete, steel, and glass, which relate to modern and contemporary lifestyles (United Nations Environment Programme 2020, 53). Gottinger et al (2020, 18) also indicate that social acceptance of the bioeconomy niches is not mainly in focus of the current research dominated by engineering, chemistry, etc. But the preferences and opposition are created within the wider society, so the sustainability transition is according to Gottinger et al (2020, 18) driven by awareness-raising aspects, including consumer awareness of the related benefits (Gatto et al 2021, 6), which reinforces the new technology and materials while affecting customers' acceptance and perception. As Hekkert et al (2007, 423) explain, if societal preferences are visible and strong, it can support the diffusion of biobased solutions. That is also noticeable in the renovation market where neighboring apartment buildings usually renovate after the first renovation is ready in the neighborhood, suggesting that the first project encourages others to follow (Lihtmaa 2018, 4). Moreover, the awareness of the public can be hindered by asymmetrical communication where various sources and fragmentation of information can lead to a situation where different perceptions of the performance of renovation solutions develop in different communities (Lihtmaa 2018, 24). To investigate that function, information campaigns can be counted and conducted interviews can show some insights into prejudices of materials.

### 1.2.3. Key considerations for policy mix to support the sustainable renovation

For policy mix considerations, a comparative system was created to link sustainable renovation transition factors with systemic weaknesses of sustainability and implications of policy mixes. According to Gottinger et al (2020, 1), policy mix should build on a systemic understanding of the transition process. Based on the framework, policy mixes and their key aspects were weighted to find the key set of policies and bring out the positive and negative aspects (Table 2).

**Table 2. Systemic weaknesses to consider for policy mix development**

| Environment/ Technological innovation system | | | Systemic weaknesses | Implications for policy-mix |
|---|---|---|---|---|
| External environment | Landscape | | Lack of a credible and long-term transition policy-mix (underlying weakness of all TIS functions) | • Strengthen strategic commitment to a sustainability transition<br>• Support technology-push and demand-pull<br>• Strengthening of advocacy coalitions to improve political feasibility |
| Internal environment | Regime | Policy creation – steering the processes | Lack of a credible and long-term transition policy-mix<br><br>Lack of an effective selection environment<br><br>Lack of broad advocacy coalitions | • Support technology-push and demand-pull<br>• Goal setting and framing in strategies, regulations, voluntary agreements.<br>• Innovation platforms and foresight exercises, public procurement<br>• Creating structural reforms in legislation |
| | Niche | Production – capacities emerging on supply side | Lack of broad advocacy coalitions<br><br>Belief by stakeholders that the policies and legislations will solve the problems<br><br>Lack of new initiatives and innovations due to belief that there is no green market available for respective products and services<br><br>Slow learning characteristic of the renovation industry | • Support technology-push and demand-pull<br>• Strengthening of advocacy coalitions to improve political feasibility<br>• Educational policies, training, labour-market policies<br>• Financial instruments like R&D funding, subsidies, venture capital, low-interest loans<br>• Increase knowledge through networks<br>• Coordination of intellectual rights and reference guidelines for best available technology<br>• Involving niche actors in policy creation working groups<br>• Formation of new organisations or networks<br>• Withdrawing support from incumbent technologies<br>• Stimulating entrepreneurship and diversification of existing firms |
| | | Production & Application – capacities emerging on supply side & demand | Lack of collaboration between renovation process stakeholders<br><br>Lack of monitoring of ecological goals which disorientates the actors<br><br>Lack of understanding of influence by the banks and other financial entities (supportive measures) to support environmental actions<br><br>Uncertainty of returns and cheaper fossil-based competition | • Support technology-push and demand-pull<br>• Strengthening of advocacy coalitions to improve political feasibility<br>• Deployment and demonstration subsidies and R&D<br>• Market-based policy instruments, regulations, tax exemptions |
| | | Application – affecting demand | Lack of knowledge and low consumer awareness of the related benefits | • Consistent reliable and simplified information provision |

Source: Purkus et al 2018; Kivimaa et al 2016; Gluch et al 2007; Esteban et al 2016; Lihtmaa 2018; Gottinger et al 2020; Weber et al 2012.

Systemic weaknesses of the sustainability transitions in the renovation sector will be explored through three dimensions: (1) **policymaking-related aspects**; (2) **production-related aspects** and (3) **demand creation-related aspects**.

1) **Policymaking related aspects**

Steering the processes of policy creation contains a multitude of systemic weaknesses. **Lack of credible policy mix** from the EU level creates external pressure to the renovation sector to change or not to change accordingly, but also the internal lack of ambitious long-term transition policy mix can cause a standstill or rather support the incumbent change of the current regime. So internal changes regarding policy creation are somewhat led by the landscape pressure on the current practice (Purkus et al 2018, 3962). For example, the EU's "Green Deal" initiative and "Renovation Wave" strategy set far-reaching goals, but are taking more of a neutral standpoint on how to internalize the goals nationally since the union's responsibility is mainly concerned with equal competition and free flow of goods. Purkus et al (2018, 3962) argue that visions and strategies have to be internalized with adequate policies which should also have pressure on the traditional approach of renovation to support a regime change, meaning a preference for the wood over the fossil-based materials. If political priorities are uncertain and wider sustainability transitions are not seen, the market for biobased options will not substitute fossil-based materials. The only option would be a long-term and consistent orientation for policies to support sustainability transitions (Purkus et al 2018, 3962).

**Lack of an effective selection environment** means that the innovations are led by technology and not the material, thus innovations focus is on renovation speed and technological solutions, not on the sustainability transition (Purkus et al 2018, 3963). Purkus et al (2018, 3963) also mention the lack of importance from the bioeconomy side that the materials extracted from nature (forest) would be used sustainably. From the renovation perspective, increased usage of wood should result in more sustainable wood material usage (carbon capture) and increased demand for higher-value chain production, thus positively affecting the overall forestry and wood industry as higher valued materials can have less of an environmental impact. But that would also raise the question of the raw resource mobilization and its distortion towards incumbent actors in the field (Purkus et al 2018, 3963). **Lack of broad advocacy coalitions** inhibits the promotion of policies supporting the wood-based bioeconomy. If there is uncertainty about the biobased technologies and no coherent advocacy groups, policy creators have no interest in supporting policies for a renovation regime transition (Purkus et al 2018, 3963).

Therefore, Kivimaa et al (2016, 209) suggested balancing the involvement of regime actors in the policy advisory processes with niche actors and support the formation of organizations and networks that can lead the sustainability transition in the field of renovation.

To overcome the weaknesses from steering the policy processes, it is important to establish strong commitment in external (EU) and internal (state) strategic levels which are interlinked with other affecting strategic goals (Purkus et al 2018, 3964). Moosmann et al (2020, 18) suggest that sustainability governance by a monitoring mechanism with policy targets should be created at the higher international level to support sustainability transition. Wesseling et al (2017, 114) specify that policies should be well coordinated to avoid revert to original regime logic. Overall, there is a wide mix of policy instruments that can support the creation of legitimacy and guidance of search: goal setting in strategies; targeted R&D funding schemes; regulations and tax incentives; foresight exercises; voluntary agreements among stakeholders; innovation platforms and networks; public procurement; labeling systems for legitimacy; structural reforms in legislation or new overarching laws; cross-national agreements on specific sustainability criteria; information and moral persuasion instruments (Purkus et al 2018; Moosmann et al 2020; Bahn-Walkowiak et al 2017; Kivimaa et al 2016; Weber et al 2012).

2) **Production related aspects**

Capacities emerging on the supply side can be hindered by various obstacles. Firstly, the **lack of a long-term transition view** and **absence of the broad advocacy coalitions** come into play (Purkus et al 2018, 3963). That means there are no direct and indirect demand-pull policy instruments, causing uncertainty and lack of momentum from the entrepreneurial activities. Coalitions in support of the sustainability transition should involve firms, academia, financing institutions, and environmental organizations. In the case of construction, for example, Estonia's long-term construction sector vision 2035[5] brought together different stakeholders in the field. If thorough support is not seen from a higher strategic level with coherent actions, the social acceptance of the bioeconomy technologies and materials will fall into uncertainty to be accounted for a change in the incumbent regime (Purkus et al 2018, 3963). Gluch et al (2007 iii-iv) bring out that in the construction sector there can be a **belief that only the policies and legislations will solve the problems**. More complex regulations can create a more complex bureaucratization that can backfire and inhibit innovation. Moreover, Purkus et al (2018, 3963)

[5] Ehituse pikk vaade 2035. Available: https://www.mkm.ee/et/uudised/avalik-ja-erasektor-panevad-paika-ehituse-tulevikuplaani

also mention the environmental interest groups who might be differently positioned towards entrepreneurs focusing on bioeconomy-based solutions. The case of limited raw material resources dilemma where scientific calculations and expertise are not the only factors contributing to the solution of the obstacles. When there is no strong commitment to change, there is also a **lack of innovations due to the belief that there is no green market available** for respective products and services (Gluch et al 2007 iii-iv). That means newcomers do not see the potential of the market and biobased material diffusion in the incumbent renovation regime will not pick up speed.

Gluch (2005, 11) describes (re) the construction market with a strong focus on results where a successful project means the highest quality achieved with the lowest input of financial resources. Especially, in the case of the renovation market, price sensitivity comes into play (Lihtmaa 2018, 24). **Slow learning characteristic of the (re)construction industry** means that the changes in the sector are time-consuming due to the complexity of it and therefore knowledge development and knowledge diffusion through networks have very important input (learning effects) for sustainability transitions in that field (Gluch et al 2007, iii-iv). Lack of collaboration in knowledge creation between R&D departments and institutions, environmental organizations, entrepreneurs can contribute to a deficient basis for the development and creation of ground-breaking green ideas, innovative green technology, and new green business opportunities (Gluch et al 2007, iii-iv).

To overcome the production capacity weaknesses for sustainability transition, Lovric et al (2020, 9) brought out the usefulness of EU projects for innovation development and knowledge creation. Moreover, Lovric et al (2020, 10) bring out the need for the European Commission's research and innovation call for project proposals to be modified to increase the number of innovations reaching later stages of development. Purkus et al (2018, 3964) also stress the importance of the technology-neutral indirect demand-pull instruments like decarbonization or resource efficiency policies and direct demand-pull technology-specific instruments for niche support. Other policies that will support the sustainability transition regarding the production, can be the following: support for R&D (incubators, reference guidelines for best sustainable solutions, advisory) and demonstration; R&D funding schemes and subsidies, low-interest loans, venture capital; educational and labor-market policies including training and knowledge diffusion through networks; regulative measures that will coordinate intellectual rights and support experimenting; withdrawal of support from incumbent technological solutions which are

not sustainable (changing financing schemes, etc.); policies diversifying existing businesses and bringing new ones into the market (Purkus et al 2018; Bahn-Walkowiak et al 2017; Kivimaa et al 2016; Weber et al 2012; Lovric 2020).

### 3) Demand creation related aspects and production

Demand creation is closely related to production and some of the functions (*market formation, price-performance improvements*) are overlapping between the two topics. In the current discussion, weaknesses that are connected to production and demand creation are elaborated under here. Gluch et al (2007, iii-iv) identified in the research that there is a **lack of collaboration between (re)construction process stakeholders** and that is a drawback in the case of sustainable innovations uptake. Gluch (2005, 11) also describes the situation of the (re)construction sector as a decentralized network where business relations are done with familiar counterparties to avoid any unnecessary surprises during the project. Since the reconstruction of an apartment building is a complex process involving, not only the construction activities, but also social aspects like interactions with the various apartment owners and stakeholders, the knowledge and experience to avoid mistakes is highly valued, and testing something "new" will most likely be avoided. If there is no monitoring system for the sustainability and ecological goals (**lack of follow-up of goals and plans**), there is also no feedback to motivate the stakeholders to choose sustainable materials and approach to renovation (Gluch et al 2007, iii-iv).

**Lack of understanding of influence by the banks and other financial entities** is another weakness needed to be addressed. That means there is a perception that the banks and other financial institutions, like government entities that provide supportive measures for energy efficiency, have little or no impact on the renovation process done by the companies, and thus, sustainability and environmental impact is falling outside the business agenda (Gluch et al 2007, iii-iv). That is also driven by the **uncertainty of returns and cheaper fossil-based competition** where technological unconventionality and uncertain policy support drive the market towards cheaper fossil-based materials and products (Gottinger et al 2020, 13). Overly important is also the **lack of knowledge and low consumer awareness of the related benefits** and Purkus et al (2018, 3963) mentions that the societal attitude towards technologies with higher uncertainties can also be a problem besides sustainability. Society plays an important role in the attitudes (preferences) towards sustainability and therefore also affects the apartment building renovation market (Gatto et al 2021, 13). Here also, earlier mentioned political commitment and strategic

leading is necessary to create support from the society. Purkus et al (2018, 393) explain it as to strengthen consumer trust and build critical mass. Even more, the following policy instruments can be brought out: support for R&D and demonstration projects; promotion and creation of the networks; information and moral persuasion instruments; strengthen advocacy coalitions for political feasibility; market-based policy instruments like regulations, tax exemptions, subsidies; consistent reliable and simplified information provision about sustainable renovation; technical consultancy service provision for renovation (Purkus et al 2018; Gatto et al 2021; Kivimaa et al 2016; Lihtmaa 2018).

# 2. THE CASE OF SUSTAINABLE RENOVATION SECTOR AND WOOD IN ESTONIA

## 2.1. Renovation sector in Estonia

Around 80% of today's buildings in both Estonia and Europe will still be in use after 30 years (European Commission 2020b). The average life expectancy of the building is 50-70 years if the theory of the life cycle of the building is taken into consideration, so to keep the quality and sustainability of our living environment, large-scale reconstruction of the built environment is a necessity (European Commission 2020b).

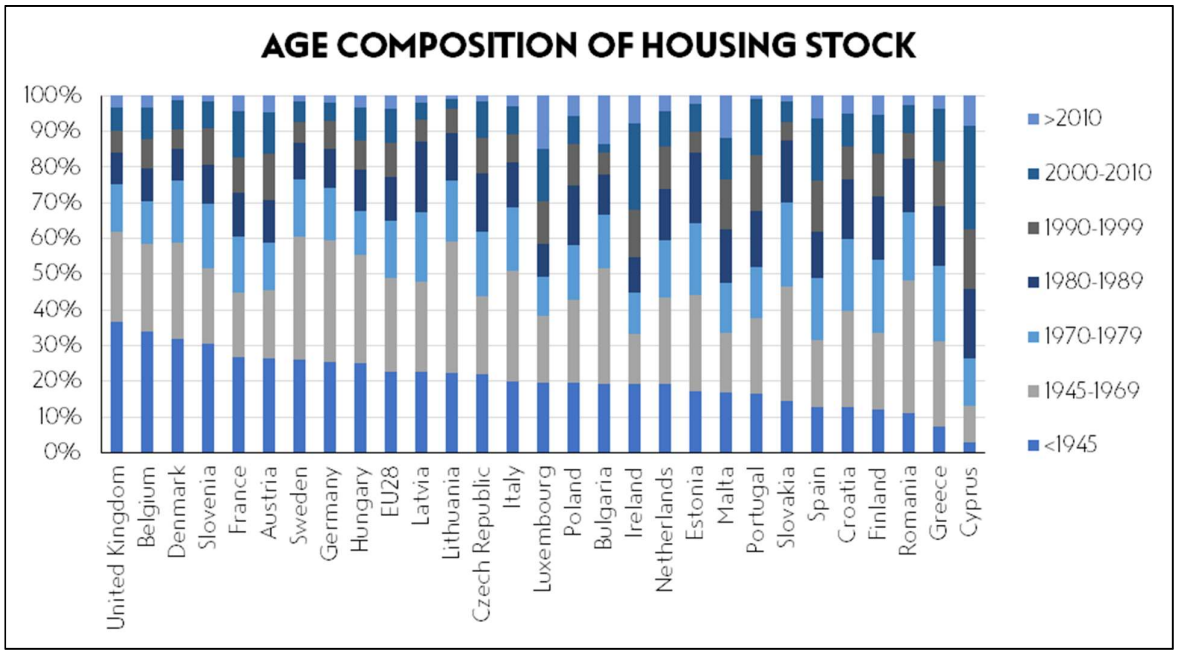


**Figure 4. Age composition of housing stock in European Union**

Source: European Commission (2020a)

By 2050, Estonia's goal is to decrease greenhouse gas emissions to almost 80% percent compared to 1990 levels[6] (EU 80-95%[7]). Estonia's objective is to completely renovate building

[6] Climate policy of Estonia. Available: https://www.envir.ee/et/eesmargid-tegevused/kliima/kliimapoliitika-pohialused-aastani-2050-0

[7] Climate goals of EU. Available: https://www.envir.ee/et/EL-eesmargid

stock by 2050 in class C of energy efficiency saving approximately 65% of the heating energy (Kuusk et al 2014; Arumägi 2017). Apartment building deep renovation has been ongoing in Estonia for 10 years and it has had good results as the energy consumption of dwellings has remained the same within the last 15 years despite the increasing housing stock (Ministry of Economic Affairs and Communications 2020a, 4). The ambition of Estonia is to improve energy efficiency[89] in 14 000 apartment buildings with a total of 18 million square meters (Ministry of Economic Affairs and Communications 2020a). To meet the goals set by the Estonian long-term strategy for building renovation, the volume of renovation must be increased around five times compared to today, so the number of buildings to be reconstructed every year will increase significantly compared to today. Currently, the renovation rate in Estonia is less than 1% of the building stock while the EU directive on the energy performance of buildings recommends the annual renovation rate of 3% of the existing building stock (2018/844/EU).

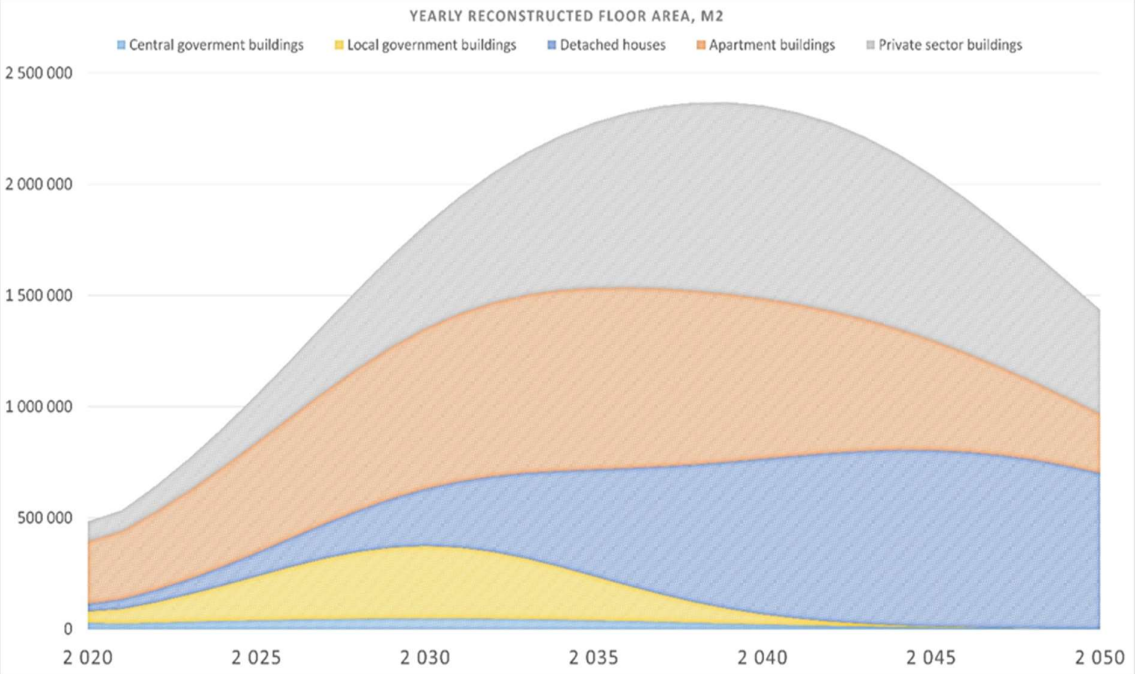


**Figure 5. Cumulative annual renovation need in Estonia**
Source: Ministry of Economic Affairs and Communications (2020c, 5), cumulative annual renovation needs for Estonia to meet the 2050 renovation target.

[8] See also: National Development Plan for the Energy Sector Until 2030. Available: https://www.mkm.ee/sites/default/files/ndpes_2030_eng.pdf
[9] See also: National Energy and Climate Plan Until 2030. Available: https://ec.europa.eu/energy/sites/ener/files/documents/ee_final_necp_main_en.pdf

The largest share of the Estonian housing stock consists of apartment buildings built between 1970 and 1990 (industrialization period of residential construction in the Soviet Union in 1960-1990) when the requirements for quality and energy efficiency were sensitively lower. Around 70% of the Estonian population lives in the old apartment buildings and most probably up to 90% of these buildings stand in 2050. However, the situation of most apartment buildings is not so bad in terms of construction and real estate value that they need to be demolished. The important role of the revival of the apartament building is on KredEx Foundation – a government organization that offers renovation loans, loan guarantees, and renovation support measures for energy efficiency works and indoor climate improvement. (Kalamees et al 2015, 5; Kalamees et al 2009)

Urbanization (including suburbanization), as a global trend (Riigikantselei et al 2020), also affects the (re)construction market in Estonia. Between 2001 and 2018, the number of people living around Tallinn increased by 64%, Tartu by 27%, and Pärnu by 28% (SA Eesti Koostöö Kogu 2020). As most of the regions of Estonia are becoming exodus areas and the demand for real estate is low in these regions, the prices are declining (€200/m2 or less) (Ministry of Economic Affairs and Communications 2020a; Lihtmaa 2018, 4-5). Low real estate value hinders the reconstruction, renewal, or construction of residential buildings because the volume of loans and investments are generally higher than the value of the building itself after completion of the works (Lihtmaa 2018, 4-5). Private banks consider the granting of a loan to be risky and, if a loan is granted, for example, a higher deductible, loan guarantee, or additional guarantee is necessary. As there are significant obstacles to the renovation of existing real estate and there is very little construction activity, the built environment outside the large urban areas has the main strategic focus ( Ministry of Economic Affairs and Communications 2013; Lihtmaa 2018, 4-5; Ministry of Economic Affairs and Communications 2020a, 3).

The construction sector is emission and energy-intensive, responsible for around 40% of the total direct and indirect global CO2 emissions (International Energy Agency 2020; United Nations Environment Programme 2020; European Commission 2015). Therefore, European Commission is pushing towards sustainable renovation by emphasizing circular and nature-based solutions (European Commission 2020b)[10][11]. European Commission (2019b) suggested in 2019 to

[10] See also: EU taxonomy for sustainable activities. Available: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en

calculate embodied energy of the materials used during the life cycle of the buildings[12] and around that time European Forest-Based Industries brought out the topic of substitution of carbon-intensive raw materials and fossil energy with forest-based alternatives (European Forest-Based Industries 2019, 4). European Commissions also updated the Circular Economy Action Plan that explored the possibilities of wood as a carbon sink and sustainable material, but it has to be noted that the woodworking sector is heavily affected by the legislation, access to raw materials, and performance of the construction sector (Good Wood Project 2020, 6). European Commission study showed that around 245 policy items affect the forest-based sector at the EU level, directly or indirectly. (Leon et al 2016, 31)

There have been created various studies lately observing wood usage in the Estonian construction sector (Pukk 2016; Kallas 2018; Riistop et al 2016; Zimmer 2018). For example, Pukk (2016, 60) brought out from his research that one main obstacle for wood usage was the cost of wood and no knowledge of the price estimates and that came from the lack of experienced specialists. Zimmer (2018, 62) found that in the current construction market, the one who already uses wood as a building material also considers environmental aspects more. The conclusion of the current low level of diffusion of wood and lack of environmental aspects taken into account in the construction sector could be summed up by the following: lack of a state-level vision, low awareness of environmental friendliness in the construction sector; limited financial resources (preferring only cheap price); path-dependency and minimum risk approach. (Zimmer 2018, 63).

Wood usage is not common in the renovation sector and the public debate has been focusing more on the general awareness of the wood as a reconstruction material. Regarding sustainability transitions in the built environment, according to Nielsen et al (2019, 241), active urban professionals influence the development of the built environment across different sectors (waterworks, heating, transport, etc.). Estonian local municipalities who give out permits and permissions for construction and reconstruction vested by law[13] also have the power to lead the transitions in the built environment i.e. establish terms and conditions for the projects. In practice, still, the capital holder and client have the main influence on the results of the

[11] See also: European Commission technical guidance on the application of "do no significant harm" under the Recovery and Resilience Facility Regulation. Available: https://ec.europa.eu/info/sites/info/files/c2021_1054_en.pdf
[12] See also: The Level(s) framework for sustainable buildings. Available: https://ec.europa.eu/environment/topics/circular-economy/levels_en#ecl-inpage-266
[13] Estonian Building Code. Available: https://www.riigiteataja.ee/en/eli/ee/526022021001/consolide/current

renovation project. Moreover, in the case of construction, the life cycle approach of the building is not taken into account, meaning that the production and transport of materials, construction site, and disposal of excess materials are not calculated in the carbon reduction calculations. Regarding materials used in the construction processes, it is hard to find any other material in Estonia with similar carbon capture and low impact on the environment[14] (Ministry of Economic Affairs and Communications 2021).

The most promising niche to support the increasing renovation rate is Estonians' wooden house production entrepreneurial activities. The industrial production of wooden houses is a significant industry with more than 140 companies that mainly focus on export, Estonia is the largest exporter of wooden houses in Europe. Considering that soon buildings life cycle becomes more important and more attention should be paid to the construction materials and local forestry. The potential of wood has been hindered largely due to the traditionally conservative nature of construction and market preferences, which can also be explained by socio-psychological rather than rational arguments. (Ministry of Economic Affairs and Communications 2021)

In Estonia, the wood came more into play when Tallinn University of Technology participated in a MORE-CONNECT project[15], funded from EU's Horizon 2020 framework program for research and innovation, to find solutions for deep renovation toward nearly Zero Energy Building. A Prefabricated concrete large panel apartment building underwent a deep energy efficiency renovation with prefabricated timber frame insulation elements. The building was located at the campus of Tallinn University of Technology at Akadeemia tee 5A and served as a dormitory. The building represented the dominating apartment building type from the 1960-1990 Soviet Union period (Pihelo, 32). The prefabricated timber frame insulation elements were produced by a producer of timber-based elements and modules, thus first more thorough experience with wood material usage in apartment building reconstruction was gained (Pihelo, 64). Another project currently in progress (started in 2020), is the Horizon 2020 funded DRIVE0 concept, where the circular deep renovation solutions[16] are developed by Tallinn University of Technology and Timbeco Woodhouse (woodhouse producer). The project also entails woodhouse producers and timber-based elements for façade renovation. The aim is to also

[14] See also: Puuinfo. Available: https://www.puuinfo.ee/keskkond/mets-puit-ja-kliimamuutused/
[15] MORE-CONNECT project. Available: https://www.more-connect.eu/more-connect/
[16] Drive0 project. Available: https://www.youtube.com/watch?v=XdEph6ZmPgs&feature=youtu.be

evaluate the material circular flow considering the life cycle of the apartment building and its façade.

From the positive experience of prefabricated timber frame element reconstruction, the KredEx Foundation, The Estonian Woodhouse Association, and the Ministry of Economic Affairs and Communication prepared a factory reconstruction grant for apartment buildings[17] to emphasize more of the factory-based solutions and also support new innovative practice for renovation. So, the positive externalities from the prefabricated element experience paved a way for a larger project that would support the diffusion of niche solutions in the renovation market. Since the technical solution uses wood and involves the woodhouse market, it gives a great advancement for the Estonian renovation market itself to turn more sustainable (carbon capture) in the matter of used materials.

## 2.2. Overview of methodology

The methodology for the research subject was chosen based on the complexity of the structure of networks and interactions. The information was gathered via semi-structured interviews, as well as from relevant documents and other readily available materials (including research articles). The interviews were conducted with various stakeholders in the renovation field and government entities to grasp the insights of different key players in the wider network influencing the sustainability transitions in the apartment building reconstruction sector.

Since the empirical analysis focuses on the national-level policy implications and influences from EU, the theoretical framework was constructed with the help of various researchers (Purkus et al 2018; Kivimaa et al 2016; Hekkert et al 2007; Bergek et al 2008ab) to list relevant policies dealing with TIS functions weaknesses. To explore the topic, qualitative research (including literature analysis) for knowledge acquirement to better understand socio-technological systems regarding the topic of the thesis was chosen as a suitable methodology for sustainability transition research (Õunapuu 2014, 52). Although Read and Marsh (2002, 237) stress the importance of the combination of qualitative and quantitative analysis to increase the validity of results, regarding the subject at hand, a quantitative approach would be too early and resource costly (availability of data) at the current stage of the research. So, a quantitative approach would

[17] Factory reconstruction grant for apartment buildings. Available: https://kredex.ee/en/node/2072

gain better grounds in the next steps. Regarding the qualitative approach, the main aspects of the qualitative research align with the purpose of the current research: examined under natural conditions; interested in subjective meanings; research is inductive; working with non-numerical data; the result is a detailed description of the phenomenon under study. To include, interviews besides document analysis are necessary because they allow the research to reach more hidden areas to explore sensitive and delicate topics that are not available through observation. (Õunapuu 2014, 54)

For the research, the best practice was to use semi-structured interviews on the field, to firstly, identify the valuable data given by the interviewee, and secondly, adapt accordingly to the new information and possible conclusions that could be drawn from the conversation. (Õunapuu 2014, 170-171) The selection of the interviewees (Appendix 1) was based mainly on the TIS framework and several categories were identified (Table 3).

As the TIS framework considers actors and networks an integral part of the functioning of socio-technical systems, actors chosen for the interviews were accordingly classified. The target was on mapping the main counterparties who are involved in the reconstruction processes and who are leading the innovative projects with a concentration on wood materials. Relying on Mahoney and Goertz (2006, 243), that kind of selective approach allows to identify special factors that might not be a part of the theoretical framework and assumptions, but are essential and thus, can be more thoroughly discussed.

**Table 3. The logic for the selection of key experts to be interviewed**

| Classification of the interviews | Interviewee |
|---|---|
| (1) European Union and its influence on sustainability | EU Energy Commission's representative, Estonian Ministry of Environment, EU spatial design expert group representative |
| (2) Businesses in the renovation field (traditional and newcomers), umbrella organisations | Company with traditional renovation practices, company with innovation solutions (wood), Estonian Woodhouse Association |
| (3) Universities and government bodies as drivers of innovation | TalTech university, Estonian Ministry of Economic Affairs and Communication, SA KredEx (provider of grant and financial instruments) |
| (4) User community | The Estonian Union of Co-operative Housing Associations, technical consultant, owner supervision, financial institution, wood products reseller |

Source: Author.

The interviews themselves were conducted as a discussion about Estonia and in the preparation phase of the questions, the following topics were acknowledged:

- the potential of biomaterials, including wood, to support sustainability transition in the field of renovation of residential buildings;
- mapping of the main actors, institutions, and networks - key counterparties and their roles and activities regarding wood diffusion;
- key factors and challenges for using wood-based materials and technologies to support sustainability transition in the field of renovation of soviet time apartment buildings;
- systemic weaknesses of the sustainable renovation solutions and biomaterials diffusion;
- proposals for policy mix to support sustainable renovation solutions in apartment building renovations.

Since the interviews were semi-structured, no strict line was drawn to the topics, but the interpretation of different interviews enabled us to find the patterns and identify possible obstacles and opportunities. The results regarding socio-technical functioning and key challenges are presented in a summarised form mirroring the content of the interviews, relevant quotes are highlighted.

## 2.3. Results

### 2.3.1. Description of the respective socio-technical system and its functioning

#### 1. Policymaking related aspects/creation of legitimacy, the guidance of search

Estonia's long-term goal is to move to a low-carbon economy, which means transforming the economic and energy system into more resource-efficient, productive, and environmentally friendly. Considering the conducted interviews, the perception that climate change and climate goals will become more important was well acknowledged. "*Sustainability and energy efficiency topics are very important and hot, and these topics have come to stay*." (Interview 6). The EU's role is seen in a positive perspective by the interviewees. Estonia is considered to have good access to Director-General departments. "*One of the functions of the EU is to remove market barriers, thus the European Commission will help to solve these barriers"* (Interview 3). One of the interviews brought also out that European directives are saving resources and Estonia will then specify the regulations according to local circumstances. "*If we had to come up with big solutions ourselves, it would significantly increase the state apparatus."* (Interview 1). So, market gains from common standards also enable successful export.

EU does not have one approach to the whole union in terms of reconstruction and it provides an open window until 2050 for the member states to reach the climate objectives. *"For the climate neutrality goal, European Commission has gathered many different topics – circular economy, decarbonization and use of biomaterials which all have a positive connotation."* (Interview 3). Estonia's focus in renovation is to support the deep renovation, but the EU level accepts also medium-depth renovation of the building and supports renovation passports for partial renovations. Europe is also supporting the diffusion of different renovation solutions like the BAUHAUS[18] program. That program is considered to have a positive impact on Estonia because it allows sharing renovation ideas and gaining knowledge about other built environment-related solutions. Also, it was mentioned that BAUHAUS involves architecture which could help to create better spatial ideas and solutions for the renovation. Estonia is also represented in the EU-

[18] New European Bauhaus. Available: https://europa.eu/new-european-bauhaus/about/about-initiative_en

level expert group which aims to internalize the Davos Declaration[19] that highlighted the need to design and create a quality living environment. The expert group will develop the idea further as quality assurance and evaluation system consisting of eight quality criteria. The report is in the final stages and is soon to be launched. The European Commission expert group will operationalize these findings from the report through case studies performed in the Member States (Interview 17).

Since Estonia has strong economic relations with Scandinavia regarding woodhouse sector export, it was brought out that soon the markets will regulate the material usage and there will be carbon footprint limits regarding construction projects. As for wood, it is considered as a lowering factor in the carbon footprint calculations since it is referred to as a "*carbon sink*". If the carbon analysis will not consider the transportation of the materials in its calculations, wood has an advantage in the construction sector regardless of its origin. In Estonia, it is the question of ambition whether to regulate the carbon footprint of the construction sector – Finland firstly created instructions (a handbook[20] in 2018) and plans to place regulations. Estonia does not have methods for measuring construction footprint, but it was brought out that the method exists as a standard (EN 15978[21]) and the EU uses that also for its purposes. Estonia in that sense can uptake already existing knowledge and procurement for the calculation methods has been recently announced[22] (Interview 12). A similar case is with the renovation materials carbon footprint, materials could be regulated with a standard and if carbon footprint becomes measurable, it can be controlled and regulated.

Today, renovation financing schemes can be considered to support new technologies in the renovation regime. "*What we have always done is that, through funding, we have led apartment building associations to implement new solutions. For example, when ventilation system for good inner climate by the researchers was found important. Ventilation was added as mandatory to the grant scheme so that the one who reconstructed apartment building with the ventilation system got higher grant than the one who didn't add it*." (Interview 14). But it is also brought out

[19] Davos Declaration. Available: https://davosdeclaration2018.ch/
[20] Carbon Handprint Guide. Available: https://cris.vtt.fi/ws/portalfiles/portal/22508565/Carbon_Handprint_Guide.pdf
[21] European Committee for Standardization. Available: https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:31325&cs=16BA443169318FC086C4652D797E50C47
[22] A study on the application of construction carbon footprint assessment principles in the Estonian construction sector. Available: https://riigihanked.riik.ee/rhr-web/#/procurement/3112892/general-info

that the market is fragile and changes in regulations (for example, material usage) should have a long-term focus, otherwise it can hinder the implementation of the grant and financing schemes.

2. **Production related aspects/knowledge development and diffusion, entrepreneurial activities, resource mobilization**

**Knowledge development and knowledge diffusion through networks**

Most of the interviews concluded that TalTech is the main actor and driver of innovation in the field of renovation. Some active scientists are searching for new projects and look for businesses to participate in the programs. But today there are no initiatives from the businesses. *"The state does not have a lot of resources and entrepreneurs should be able to innovate by themselves. However, the scope of the ideas from businesses is short. They work on a project basis and there is no long-term view."* (Interview 1). Reasons are mainly related to the limited human resources and another reason is directly related to the woodhouse sector and the fact that the sector is not very old (25 years), and business models so far have not required more knowledge. *„It is important for us, as a small country, that our companies who operate across borders can cross borders and thus our technology must be appropriate*" (Interview 13). Recently Estonian Woodhouse Association has been more involved with the element-based pilot project that brought together woodhouse manufacturers to find solutions to a common project of element-based solutions.

"*In some ways, there are two very different approaches. TalTech has the scientific touch and wants to experiment and try things that may not work in the first round but learn from that and do research. Collaboration between manufacturers and builders is focused on how to do things better and more confidently. Innovation should come from both sides – only by doing science we will not achieve results and only by optimizing we will not find good solutions."* (Interview 4). There were also other actors named in the interviews who are considered important in the wood solutions development regarding construction – Estonian University of Life Sciences, University of Tartu, Võrumaa Vocational Education Centre, Estonian Academy of Arts, and The Estonian Wooden House Association. The existence of the Estonian Wooden House Cluster[23] or its role was not mentioned at all. Also, there is no active and wide cooperation regarding wood diffusion aspects in the renovation sector. But that is not the case of wood-based construction, there are

[23] Estonian Wooden House Cluster. Available: https://www.puitmajaliit.ee/meie-projektid/puitmajaklaster

several competitions for wood promotion – "The most remarkable buildings of wood"[24] competition by Estonian Forest and Wood Industries Association; "Factory House of the Year"[25] competition by The Estonian Wooden House Association; "The best thesis in the field of prefabricated wooden houses"[26] competition by The Estonian Wooden House Association.

Both, the development of renovation and the development of the life cycle analysis are considered gradual development processes as the changes cannot be too fast since technological capabilities and other connected aspects must follow up. Regarding the wood, the importance of teaching is brought out and the need for more programs meant for wood construction and skills development. *"... engineers who have graduated from concrete and steel schools, who have asked stupid questions about wood, including finishing and design, we have seen more than once."* (Interview 9). Overall, knowledge-related programs were considered important to have more specialists in the companies and more experts to diffuse knowledge. Thus, different projects and pilot projects got also positive feedback and support.

**Entrepreneurial activities and experimentation**

The goal of the apartment building association is to get the best work with the best price that meets the conditions of the KredEx Foundation grant scheme. Based on the price criteria, materials and work technologies are selected by the renovation companies. The bigger the apartment building, the better are the options to choose from because bigger buildings have more inhabitants meaning also a bigger budget. Technical consultants help to choose the materials and renovation solutions for the apartment building association. Today, not all active technical consultants are qualified enough and the same goes for the renovation companies. Since the company tries to maximize profits, they look for budget cuts and inexpensive materials. Regarding the KredEx Foundation grant scheme, there have been also problems that materials used were below standards, but this is not controlled by the Foundation. "*There is no direct control over the materials until they are on the wall"* (Interview 14).

The quality of woodworking companies is considered much higher than in the renovation market today. The element-based renovation is considered as a positive turnover in the market. At the

[24] The most remarkable buildings of wood. Available: https://empl.ee/aasta-puitehitis-2020-on-saue-vallamaja/
[25] Factory House of the Year. Available: https://puitmajaliit.ee/aasta-tehasemaja
[26] The best thesis in the field of prefabricated wooden houses. Available: https://www.puitmajaliit.ee/teadustoo-konkurss

same time, the renovation market is considered closed and small-scaled, needing fresh companies to meet the demand and raise the overall quality of the market. Moreover, great potential for outreach is considered because standard buildings were built all over Europe for 50 years similar to Estonia. There is a lot of doubt whether the woodhouse companies will continue after the pilot project. Another active pilot project is in the Saue, Kuuma 4 apartment building, where a woodhouse company with the help of an active renovation company is exploring the renovation aspects in practice. They test new ideas for the element-based renovation and included recycling aspects to reuse old insulating elements. That project is considered to be successful because there was an element-based project successfully done yeas before with TalTech[27].

Overall, wood usage is seen as an increasing area of focus, and wood is used more often, companies gain more experience and the competencies are growing. The main reasons why wood has been unpopular, are drawn from the history that during Soviet time the focus was fast mass production and urbanization, thus concrete technologies were more in the focus and wood was in the background for a long time in Estonia. "*I recently got a letter that Silikaat[28] ends silicate bricks manufacturing, most of the Soviet time buildings used these bricks. There was no fault with the quality of silicate bricks, but presumably, today's production with a higher carbon footprint is not in competition anymore."* (Interview 9).

**Resources mobilization**

Regarding raw resources of wood, it was seen that the wood has to be high quality and the concerns are related to bioeconomy size itself – there is not enough material for all sectors, or at least good forestation and forest management solutions are needed. The question of the forest and the view of the people was also raised as a topic that whether the public would support the renovation sector if there is a need for a large amount of wood. Today, also a lot of wood is imported to Estonia because our timber companies have high capabilities. When other materials are considered, Estonia is considered as a small player for suppliers, thus we are not the first ones in the line to receive new materials, etc.

[27] MORE-CONNECT project. Available: https://www.more-connect.eu/more-connect/
[28] Silikaat. Available: https://silikaat.ee/en/

Also, from the circularity approach "*urban mining*" was mentioned where the question is how to recover the materials from demolished buildings in a way that the value is not downgraded (Koutamanis et al 2018, 33). Wood in that sense has good capabilities to be reused again in construction: "*element-based approach is one step further than gluing and plastering the wall of expanded polystyrene. Expanded polystyrene is a purely and completely non-recyclable oil-based material after 50 years. If you look at the façades that have broken down so far, they will go to the landfill, and I do not know how it can be used or recycled today*." (Interview 1). One business also tried to use recycled wood materials, but there was a lack of it when they procured it. Moreover, the Estonian Association of Circular Companies has received a quality class for the recycled materials, but usually, entrepreneurs do not deal with these materials because it needs more work and effort, thus more time and planning. *"When it comes to time, time is money and long waiting time doesn't support the use of recycled materials as sustainable solutions in the construction process"* (Interview 12). Thus, recycled material, as a sustainable competitor for wood solutions, in the short term when volumes are low, is not a threat to incumbent material flows.

Regarding financial and human resources, the renovation sector is not using development investments and it is similar in the woodhouse factories sector. The main reason tends to be that it needs more attention and resources than companies have available.

3. **Demand creation related aspects and production/market formation, price-performance improvements, awareness of the public**

**Market formation**

The renovation market is considered a price-driven market where a set of operations and solutions are constantly repeated. There are standard projects in use and as the renovation sector is driven by the market demand, renovation prices are important, and building materials are not overviewed every time. The renovation sector works like a conveyor method in that sense. Since the renovation market is small and has many counterparties, trustworthy networks are sought for and formed by actors in the field.

Due to the lock-in process, materials used are the same and there is a strong drive from material suppliers to keep their products in. One of the key persons in the renovation process who is affected by the lobby is a technical consultant who is mandatory when a renovation grant is used.

Technical consultants have an important role to lead the planning of the renovation. The technical consultant should be a neutral consultant for the apartment association to consult, file applications, and support procurement for construction works. But the consultant's impartiality is not clear since they are well lobbied by the construction companies and material suppliers to emphasize materials not based on the carbon footprint. That means wood or any other sustainable material have no role in the renovation – important is the quality, not the origin of the materials. "*In practice, we see that the requirements and recommendations of one material manufacturer come through one technical consultant. Also, technical consultants' procurements tend to end with the same company winning, perhaps inevitably raising questions from apartment associations that how independent technical consultants are*" (Interview 10). Similar cases are brought out regarding building designers (Interview 10), but that is also explained by the small market size and tendency to continue to cooperate with trustworthy partners.

The other side of the technical consultants and their neutrality is that they are looking for the best solution for the apartment building associations, but the main procurement logic is set only on the price (90%) by the KredEx Foundation grant scheme. "*…but we have to look for a cheaper price"* (Interview 2). That means pre-procurement interrelations are sought to guarantee that renovation will be effective and of good quality, usually with a constructor company with whom longer cooperation has already been established. "*There is no public procurement in renovation sector in that sense, a suitable company could be still secretly selected beforehand with whom the materials and practices are agreed upon"* (Interview 2).

Regarding material selection and apartment building associations availability to suggest other solutions for renovation, are limited. The designer puts the solution in place and occasionally associations argue to have different insulation material or other aspects, but they lose the arguments because they have no information or knowledge. Regarding the insulation than a better version could be used, but that would also need a re-change of the projects. And since the logical processes of renovation are well thought through and time-efficient, it falls out of the question fast.

The carbon footprint has become more important in the banking and in the Autumn of 2020, Swedbank came out with a renovation loan that would give out a longer loan than usual for renovations – instead of C class renovation, if B class is met, the loan is 25 years instead of 20 years. The bank will therefore gain from the fact that they can consider their investments green

and borrow money cheaper from other markets. At the same time, the banks will not go further without the lead from the policy creators. Related to carbon footprint, also was brought out that the materials used are constant that won't change after the building is ready, but the energy cost is scenario-based, thus if renovation materials would also be measured, it would be easily calculated in the buildings life cycle analysis and thus more benefits could be given.

Regarding the carbon advantage from wood, wood material itself was not considered by the interviewees as the only factor regarding the building life cycle and renovation. The approach should focus also on the process of the renovation itself, whether it is factory efficient or onsite with well-managed recycling solutions.

**Price-performance improvements**

One question that arises regarding price and renovation is also whether to build a new apartment building with sustainable solutions i.e. wood or would the renovation be cheaper instead. One of the interviews demonstrated that the renovation is two times cheaper than building the new apartment building on the same site: *"If today the average price per square meter is 1,200 euros for the construction of a new building, then the construction price for a 1,400 square meter apartment building with 24 apartments would be about 2 million euros. The price for renovation today is over two times cheaper. Today's owners certainly cannot afford the new apartment building"* (Interview 4). The main factor that influences the cost of building, is the price of the land. If the cost of the land is high, i.e. in a densely populated area, demolition of the old and building the new apartment building could become profitable, since it is financially viable to add more floors and fund the construction from sales of additional apartments.

Regarding the apartment building associations, everything must come with the calculations of investment and budget. If there are unneeded aspects, they will be eliminated from the project. But it is also considered to be changing, as the ventilation requirement for the deep renovation grant was added a few years back because the inner climate without it is poor to inhabitants. If the ventilation is built, the grant percentage is higher. So, the wood and sustainability requirements could also work in the same way.

Regarding the wood usage and the cost of materials, it is brought out that the price is competitive because there are more and more public procurement examples where the new buildings are wood-based. And the more there are new constructions, the more price-friendly can the wood

solutions be also for renovation because there will be more skilled specialists and experience in the market. From the interviews, it was also interesting that wood was not considered expensive itself, but rather the ineffectiveness of the processes was mentioned. For example, woodhouse factories who are part of the element-based factory pilot, have the biggest costs regarding the payroll and other costs related to manufacturing processes (wood materials 30% and other costs 70%). It was claimed that wood-based elements also bring down the costs of the renovation. *"The volume and system enhancements with factory renovation bring down the costs of the renovation considerably."* (Interview 16).

**The awareness of the public**

Most of the interviews brought out a lack of information about wood and sustainable material usage among the apartment building associations. Wood and sustainable materials do not play a role because the apartment building associations follow KredEx Foundation funding and loan schemes, the construction companies have the same logic. With wood and sustainable materials, the same process can happen like was the starting point of the deep renovations around 2007 when the awareness of the associations started to grow slowly. Demonstrative projects help to grow awareness a lot. *"I was at the beginning of the renovation when it started more widely. In 2007, the first deep renovation was done. Then the next house was in Elva, Tartu mnt 27c and then the next two apartment buildings renovated were right next to the Tartu mnt 27c*" (Interview 11). Regarding other technologies it was felt that the same will happen, it just takes time. But today, there are no discussions regarding the materials carbon footprints used in the renovation.

Prejudice about the wood was also brought out. Most people like nature and biophilic effect, and many other positive aspects about wood, but there is still a wide range of rumors around. The main drawback is brought out as a fire safety question and the fact that wood might not last as well as other conventional solutions. In reality, there is better quality wood available, but the opinion is that to have a well-maintained wood façade, it has to be processed in a way that it would not have any positive aspects left. There is also the question of maintenance period as one of the interviews pointed out "*The manufacturer says, it's tested for 15 years but also says that it still doesn't need maintenance, thus to the customer is told that up to 15 years is the maintenance interval, but it's not known exactly*" (Interview 4). Regarding fire safety, there has not much been done regarding the awareness, but there are no obstacles for wood to be used. The main concern from the EU level that there will be no risks regarding fire safety and no fire-related death-toll rising.

### 2.3.2. Key challenges for change

1. **Policymaking related aspects/creation of legitimacy, the guidance of search**

In 2015, one of the Estonian Governments added in its Action Program 2015-2019[29] an analysis of the possibilities of building wooden public sector buildings. But the analysis was never finished and publicly announced. It could be considered as one of the early indicators in the society that the progress of wood as a material, has become more acceptable as a building material. *„At the policymaking level, it is difficult to promote one material over another, because then you will receive complaints as to why we support one material more than others"* (Interview 17). There is also no leader for the topic currently, so it's divided between many stakeholders.

*"The ball needs to get rolling the same way as the Energy Directive[30] and the requirement for the near-zero energy public buildings"* (Interview 1). The public sector could set an example by ordering only buildings with a small environmental footprint, and this is equipped with biomaterial circular economy solutions and are very durable. And if the construction sector would have regulations in place allowing only the ones to reconstruct sites that comply with the professional standards, fewer mistakes would be made in the renovation, and buildings would last longer.

EU Construction Product Regulation brings out the sustainable use of natural sources and the reuse of materials, endurance. But this is not being designed in the construction projects. "*That 50 years of life written in construction projects, it is never actually designed. It's only declarative*" (Interview 1). Regarding the life cycle view and carbon footprint, the topic was at first in Estonia's renovation strategy draft, but it was discarded because, on the one hand, there was no intention to introduce new tax and, on the other hand, there was no analysis of the wider economic dimension. It was also mentioned that Estonia should use its geographical location and forest richness to add more value to wood. "*If we see that companies exist, why not set conditions or create opportunities to expand in the market"* (Interview 10). The same logic is seen behind life cycle analysis, that there must be a driver which is currently missing, and then there would be a change in the renovation sector. *"Today, the environment and green thinking*

[29] Vabariigi Valitsuse tegevusprogramm 2015-2019. Available: https://www.riigiteataja.ee/akt/317052016013
[30] Hoone energiatõhususe miinimumnõuded. Available: https://www.riigiteataja.ee/akt/107072020011?leiaKehtiv

*are out of the renovation market. The idea carries it, but the activities that encourage it do not overlap with the idea"* (Interview 7).

Fire regulations were considered overall very good, but the supervision was considered low quality. "*It is unique in Estonia that wood can be considered a non-combustible material in certain conditions when fully encapsulated"* (Interview 5). There are many ways to prove fire safety, but the rescue services officers are not always considered cooperative and that can also turn into an issue when apartment buildings are renovated with wood-based elements. The reasoning behind that is brought out as a lack of knowledge and lack of professionals available.

2. **Production related aspects/knowledge development and diffusion, entrepreneurial activities, resource mobilization**

One challenge is that the renovation market is small and with a very specific niche, so only a limited number of companies are working in the sector. "*Average builders do not want to come because they have tried and got burned, and then want no more"* (Interview 6). If the renovation wave puts strong pressure on the market, the prices will rise and there seems to be an issue. Currently, the need for new businesses is seen. As a solution, element-based solution providers and bigger construction companies who so far have been focusing on bigger projects are considered as solutions.

"*Today renovation company does not generate enough revenue to create significant development activities for the reconstruction itself"* (Interview 7). All these solutions need collaboration and in the end, everything comes down to funding, this research has not been in the focus of current renovation providers and there has been rather an incremental development by incumbent actors in the renovation field. "*Renovation has reached such a level that the natural development between builders and cooperatives is starting to go beyond the minds of the countrymen, that these technologies should be re-studied*" (Interview 7). The problem was also seen that if there is a funding program, there are still not enough human resources to deal with development also from the woodhouse sector side. And the network is thin in the wood construction and not all actors dealing with wood, are involved with wood-based development networks.

Today, diffusion of wood in the renovation sector is minimum. It is used in more expensive façade solutions as a constructive part, but in simpler solutions, it can be used for window framing, but mainly the use of wood is rather limited. And the solution of the façade is decided

by the apartment association who focuses on the strict budget so that instead of a more expensive façade, they can choose renovated halls or parking lot. Moreover, the lack of professionals who could manage and understand wood-based construction was also mentioned, so training was acknowledged. Besides that, it was said that the solutions used in the renovation sector are more than 10 years old and therefore the assemblies and other solutions should be overlooked again also. The subcontractor does not have the perspective to train and does what the main contractor asks. Thus, skilled workers do not have competence, and subcontractors do not have funding or time and the main contractor does not have anyone on payroll. The biggest weakness of Estonian knowledge-based construction is the lack of an educated workforce (Ministry of Economic Affairs and Communications 2021). The contracting authority does not dare to write in the professional certificate requirement in the procurement, because perhaps the procurement is not successful.

### 3. Demand creation related aspects and production/market formation, price-performance improvements, awareness of the public

"*Short-term perspectives outweigh long-term, i.e. the charm of short-term cheap investment is so great that no long-lasting building with less environmental impact will be made. But if pollution is taxed, then a cheap solution is not an advantage"* (Interview 1). Apartment building associations are very price sensitive and that must be accounted for. Lack of experience is an important problem related to wood construction and renovation because it also makes it more expensive. If wood usage becomes more common, the price can come also down.

There is a social obstacle rather than regulations regarding the usage of sustainable materials because there is a lack of experience. Uncertainty is high and people tend to choose more confident solutions in these situations. *"The apartment association is very price-sensitive client and environmental awareness is low or still developing"* (Interview 10). Thus, if an environmental dimension is written in euros, it will be much easier for people to understand. What was also mentioned in the interviews was that greenwashing can be a new challenge, but at the same time it can be solved.

Regarding the carbon footprint and life cycle analysis of the building, there is no change unless regulations are set, and the system is developed. The customers could be more aware also through banks who offer green loans with better interest if their carbon footprint is lower. *"The energy efficiency requirement on this scale came into force in early 2008. That does not mean*

*that energy-efficient buildings were not made before, they were just made from enthusiasm. Once the criteria and standards were set, it went to the masses. You need to come up with a framework and calculation rules, and simple tools"* (Interview 1). And when the carbon footprint is measured, also non-specialist apartment building associations can have information of impact from different materials and can better understand what to choose and how to choose. And the support measures could then be changed or not changed from a regulative level: *"All the possibilities are in the hands of the policymakers. They can set the conditions and allocate funds accordingly"* (Interview 14).

Today the role of wood in construction is growing because it is a renewable resource. Estonians do not have so much faith in building wood because there is an established principle that wood does not last as long as other materials. There is also the lobby of the entire concrete and steel industry who do not want to give up their market share, protectionist approach. So, there are many obstacles ahead – people's awareness and the construction market lock-in situation. Regarding the renovation market, lock-in harms wood diffusion in renovation projects in the apartment building renovation market also concerning as woodhouse producers in the element-based renovation project. That means another aim should also be to raise awareness about element-based renovation.

Since the capitalist market powers the ones who are investing in the built environment beforehand, in reality, the struggle of the wood usage (and other sustainable solutions) is also the question of governance and the usage of powers local municipalities have when leading the changes in the built environment. So, the empowerment of the local authorities is one question to be solved to coordinate sustainability transitions across different sectors.

## 4. Sustainability transitions and the importance of different factors

The following section will give an overview of the key challenges by the ranking of their importance regarding the sustainability transitions in the renovation sector. Gottinger et al (2020, 14) also analyzed how the sustainability transitions are studied by scholars and brought out three main categories, in order of importance: knowledge development and diffusion, creation of legitimacy, market formation, and price-performance improvements. The main difference with the current analysis is that in the renovation sector demand related aspects are considered the most important and production-related aspects least important factors.

**Table 4. Ranking of the factors regarding the sustainability transitions**

| Topics | Factors | Importance by ranking | |
|---|---|---|---|
| | | According to the interviews | According to Gottinger et al 2020 |
| Policymaking related aspects | Creation of legitimacy, the guidance of search | 2. | 2. |
| Production related aspects | Knowledge development and diffusion, entrepreneurial activities, resource mobilization | 3. | 1. |
| Demand creation related aspects and production | The market formation, price-performance improvements, awareness of the public | 1. | 3. |

Source: Author.

That is due to the sector-specific focus where the main concerns are related to the price-performance and demand from the clients. Since there are no specific regulations regarding the sustainability of renovation, the renovation market of the apartment buildings focuses on price-based procurements. Production-related aspects as entrepreneurial activities and knowledge development are considered effective but are influenced by the demand side. Thus, the importance of policymaking is seen as the second most important factor (as Gottinger et al 2020) that provides a clear direction of change in the sector and technology push via policies. Gottinger et al (2020, 14) also brought out that sector-based researches (as the current analysis) had the highest ranking for the barrier related to demand creation and path-dependency (lock-in effect) which is in correlation with the current analysis where the demand creation was considered the most important topic to work with to support the transitions.

## 2.4. Discussion

Estonian construction sector productivity rate is two times lower than the EU average. Low productivity is the outcome of multiple factors leading to lack of innovation – companies are smaller and oriented to the home market (low ambition) and cooperation between universities and companies is limited (Ministry of Economic Affairs and Communications 2020b). Moreover, laboratory networks that link the building sector with new knowledge are still an important subject and should be at the center of attention (Kask et al 2018). In the Estonian context, bigger universities focus on the usage of wood as an alternative material excluding steel, plastic, concrete, and have wood laboratories. For example, the University of Tartu wood laboratory focuses on molecular biology (biochemicals) to search for new characteristics of wood as a material, which can also redesign the usage of wood processing residue (circular economy) (Looglab 2021). Bröchner et al (2016) have also pointed out that although the capacity of research in universities can be high, the source of innovative technical ideas is often within construction firms. Hence the need for cooperation to achieve higher productivity and value proposition through innovation. "*Good enthusiasm is maintained by the cooperation between the academy, the private and the public sector"* (Interview 3).

Interviews confirmed that there were seen activities between woodhouse production companies and TalTech University. There was no insight that any type of collaboration with current renovation companies and universities is ongoing, but there was a collaboration with a woodhouse production company as niche and renovation company as incumbent regime actor. There were no other activities regarding wood diffusion identified in the renovation sector and therefore interviews suggested to have stronger leadership regarding wood diffusion and renovation development was adequate. *"An architectural competition could be held for sustainable and wood-based renovation projects. For example, similar activities were done in Rakvere. Today, renovation is based on conveyor method and standard projects – there could be more architects in the process who would also combine these materials"* (Interview 10).

Although, since the incumbent renovation regime does not have a strong relation with wood bases, the role model has to be the construction sector who drives the renovation sector's material progress also. Pukk (2016, 61) summed up in his research that the lack of large-scale wooden buildings comes from the fact that there is not yet enough experience with wood in the construction sector and specialists who know how to support wooden building construction.

Thus, there is a need for wood-specific training throughout the construction sector and supervising officials (Pukk 2016, 61). Moreover, there is a need for a renovation sector network to generate more sustainable and technical solutions and drive them. *"Introduce a national debate on the use of wood and sustainable materials and involve universities, designers, architects, technical consultants, builders and the wood industry"* (Interview 10).

Emphasis on the renovation sector is needed and not related to the wood diffusion only, but to address the challenge of the EU Renovation Wave initiative to accelerate renovation rates multiple times. Estonia has one of the strongest wood industries in Europe and is the number one exporter of wooden houses in Europe (Ministry of Economic Affairs and Communications 2020b). 3500 companies are operating in the Estonian forest and timber sector, 50% of which are forestry companies. There are only two companies involved in the chemical processing of timber, which, at the same time, provide 4,8% of the sector's added value. In 2018, there were 28 178 people employed in the sector, which accounted for 6% of all workers in companies. The estimated total added value of the forest and timber sector is 2,2 billion euros, which represents approximately 14.7% of the added value created in Estonia. To conclude, based on the current structure of the sector, the mechanical processing of timber provides added value (Aben 2020).

Strength of the woodhouse sector and recently started a pilot project where element-based renovation solution is tested, also highlights positive aspects of wood and its usage, even if it's not widely used in the incumbent renovation market today. The research showed that there is a collaboration between niche players and incumbent businesses since the niche players do not know the market so well nor have experience. The collaboration logic is explained by Hekkert et al (2007, 421) as a way for the companies already in the market to diversify their business and gain from the new technological advancements. Niches may also have difficulties competing with the incumbent technologies (Hekkert et al 2007, 424; Klitkou et al 2015, 24), but that is not considered the case because factory based niche will be cost-effective and faster with higher quality: *"I don't see the need for separate support from the government if the current pilot starts alright. Because the volume and system enhancements with factory renovation could bring down the costs of the renovation even by 50%."* (Interview 16).

And the basis for the factory efficiency is provided by wood material which can be easily processed. It can also help to identify the real costs and support the myth bust of the high price issue or as Pukk (2016, 60) put it, there is a lack of knowledge of the wood usage and thus it is

also avoided. So, element-based solutions, even if the wood is only a construction part, will help to identify and solve the price issue, i.e. lack of it.

For the success of the niche, the market must accept the new niche and housing associations must be ready to procure new niche solutions. Moreover, it must compete by price if KredEx Foundation grant schemes after the pilot project will not change. Since the price is the main driver for the associations and element-based renovations should target a low price range, it should be accepted more easily by the market. That means the focus is not on the wood material itself anymore, but on the value, it helps to create. So, the question also arises that what is the point of the wood other than in the element? The solution can be a bibliophilic effect – wood is used as a design material and on a facade, to make a positive impact on health, stress, and other aspects (Stora Enso 2020).

Renovation practices in the market today also showed that the focus on one material usage is too narrow. If the selection of materials used in the renovation process, would be wider, also recycled materials could be used as sustainable, for example. Besides that, produced elements can be opened after utilization, and materials from elements are easily extracted for recycling purposes. Thus overall, there was similar cognition among the interviewees that the discussion of sustainability transition is wider than only wood related. *"That it is possible to go beyond biobased materials, for this biobased solution it is still necessary to produce material, grow wood, and process and harvest it. But if we could make use of the resource of this material that already exists in the buildings, so that we do not have to throw it away, it is already like a higher level."* (Interview 1).

The wood has a positive background, but since the incumbent renovation sector has no developments regarding sustainability, material usage, and recycling, there are many obstacles to overcome besides the diffusion of wood. To support the diffusion of wood with life cycle analysis, there should first be a tool or manual to calculate or search materials based on carbon footprint. That is like solutions suggested for the construction sector regarding the carbon footprint and life cycle analysis. But it was also noted that probably the change in the construction sector would come rather from the regulations, not from the guidance alone. The people perceive problem areas with which they have personal contact, while problems that are not tangible, are often too far away and abstract to perceive their importance (Keskkonnaministeerium 2020, 11). Although they are usually aware of their role in

environmental problems, the responsibility for dealing with problems is often seen by the state (and large companies) rather than by themselves (Keskkonnaministeerium 2020, 11). But regarding the renovation sector, there can be risks regarding how it would be implemented. *"The state can address its preferences through funding, for example, if the goal of a circular economy comes, it is easiest to regulate with a funding scheme. Only regulations create defiance and unacceptability. However, the logic of the "cookie" would work better."* (Interview 14).

Estonian people care about environmental issues, as evidenced by the relatively high interest in environmental information and the fact that most residents have been concerned about some environmental problems. But people's environmentally friendly behavior is manifested in dealing with the consequences rather than preventing environmental damage (e.g. reducing consumption, which would break the environmentally unfriendly production and consumption chain) (Keskkonnaministeerium 2020, 11). That confirms the information from the interviews that today apartment associations don't think about the ways how to be more sustainable and there are limited options to even find more sustainable renovation options because the renovation sector is path-dependent and organized in a way that associations don't decide on material choices, which again is also related to price sensitivity. As Keskkonnaministeerium (2020, 11) study explained, changes are moderate in the level of beliefs and opinions.

State role in the renovation process was considered important at the regulative level and as a leader in the innovative process. Hekkert (2007,426) also has said that usually the change is called for by the government and its goals. The state must be an example for procurements for new buildings and the renovation of the old buildings. In that case, demonstrative projects can be elaborated and used as a learning basis for all the stakeholders in the renovation sector. Thus, the state's role is considered important to create a renovation policy that is supportive for sustainability transitions, but not counteractive. *"Each time you push, there is a backpressure. The more you push, the more you push against"* (Interview 15). More emphasis regarding the demonstrative projects must be put also on awareness, as the interviews explained the importance of demonstrative projects and the positive effect from the past. Also, information sharing has key importance in the market and it was brought out that good availability of information that is easily graspable to apartment building associations, should be prepared and available regarding materials and their carbon footprint. "*Every market is available to consumers so that there are choices and high-quality information about which materials and how they work*

*together. For example, in the case of energy efficiency appliances, there are different energy classes and some information."* (Interview 3).

As an outcome of the discussion, the authors own elaboration on the propositions for the policy mix regarding sustainable renovation are the following:

- Demand creation for sustainable renovation solutions from apartment building associations is the most important aspect and it can be supported with: a) reliable and simplified information provided to all relevant actors; b) market-based instruments (grants and financial instruments) that will support sustainable renovation; c) regulative measures framing sustainable renovation to push towards sustainable material usage.
- Second aspect is policymaking and strategic view of the state: a) strengthen advocacy coalitions; b) strengthen the strategic commitment to a sustainability transition; c) support technology-push and demand-pull.
- Third aspect is production-related and hereon the focus should be: a) on the diversification of the existing firms which will support the openness of the path-dependent renovation sector; b) on the knowledge diffusion and networks creation to diversify experience; c) on educational policies and training; d) withdrawal of support and focus from incumbent technologies.

Regarding the current status of the renovation market and the usage of materials, the demand side of the renovation regime can be considered as the one main area to focus on because new niches can diffuse in the regime if there is enough market demand. Thus, element-based renovation can use the factory aspects to diffuse also wood, but in reality, to also reach design and thoroughly thought material selection, more regulative pressure and information should come hand in hand with the market change to more sustainable materials including wood.

# CONCLUSION

Estonia's objective is to completely renovate building stock by 2050 and there is an ambition to improve energy efficiency in 14 000 apartment buildings with a total of 18 million square meters. (Ministry of Economic Affairs and Communications 2020a) To meet the goals set by the Estonian long-term strategy for building renovation, the volume of renovation must be increased around five times compared to today, so the number of buildings to be reconstructed every year will increase significantly compared to today. To keep the harmful environmental effects resulting from construction activities under control while the volume of reconstruction increases, the Estonian solution may lie in strengthening the areas of bio-economy and circular bio-economy with a special focus on wood diffusion.

The master thesis presented the following research questions:

- What is the potential of biomaterials, including wood, to support sustainability transition in the field of renovation of residential buildings?
- What are the key factors and challenges for using wood-based materials/technologies to support sustainability transition in the field of renovation of common soviet time apartment buildings in Estonia?
- What kind of change(s) in the policy mix is(are) needed to support sustainable renovation?

Answers to these questions were found with a literature review and thorough interviews conducted with different stakeholders in the renovation market or affecting fields.

The first part of the thesis draws the theoretical framework for the renovation sector market to map the current regime by its functioning and stakeholders' activities. A technological innovation system was used for mapping the national system of renovation and a multi-level guidance framework was used to show the interactions on the EU level.

As part of the second part of the master's thesis, a study was conducted with 17 interviews of the relevant stakeholders on the EU and Estonian level, incumbent and niche businesses, government officials, etc. The results of the personal interviews gave an insight into the current renovation system, the views of niche development, and wood diffusion as such.

Results showed that currently in the renovation sector sustainability of materials is not looked for. The main obstacles are related to the price as apartment building associations expect the best results with the least investment and there is path dependency with no motivation to change without a driver from the strategic policy level. Estonia has a strong woodhouse production background and it plays as an advantage regarding wood diffusion and sustainability in the renovation sector. But the focus regarding wood usage in renovation is on the production and constructive (factory) side rather than on the sustainability aspects. To support wood diffusion, demonstrative projects must continue and knowledge diffusion in the sector should be supported. To support wood usage and sustainable materials, policy and grant schemes development should accept more of the sustainable aspects of renovation, not only energy efficiency. The state must take a stronger role in leading the sustainability vision and accordingly support the change of the market with various tools like information, regulation, emphasize and lead development, a source for funding, etc. Most important is the leader position and showing guidance.

Based on the research, can be concluded that the current situation in the construction sector and lack of sustainable material approach mirrors the situation in the renovation sector. The developments soon on the EU level will internalize the wider support to sustainable materials and life cycle approach in the Estonian renovation market.

# SUMMARY IN ESTONIAN

## JÄTKUSUUTLIKKUSELE ÜLEMINEK HOONETE REKONSTRUEERIMISES – PUIDU KASUTAMINE KESKKONNAMÕJUDE VÄHENDAMISEKS

Raiko Puustusmaa

Eesti eesmärk on 2050. aastaks täielikult renoveerida kogu hoonefond ja parandada 14 000 korterelamu (18 mln $m^2$) energiatõhusust. (Majandus- ja kommunikatsiooniministeerium 2020a) Eesti hoonete rekonstrueerimise pikaajalises strateegias seatud eesmärkide saavutamiseks tuleb renoveerimismahte tänasega võrreldes viis korda tõsta. Renoveerimismahtude kasvamisest tulenevate kahjulike keskkonnamõjude vähendamisele võib oluliselt kaasa aidata puidu laiem kasutus ning biomajanduse ja ringbiomajanduse osakaalude suurenemine.

Magistritöös esitati järgmised uurimisküsimused:

- Milline on biomaterjalide sh puidu potentsiaal toetada jätkusuutlikkusele üleminekut eluasemete renoveerimise valdkonnas?
- Millised on põhitegurid ning väljakutsed puidumaterjalide ja -tehnoloogiate kasutamisel Eestis asuvate nõukogudeaegsete korterelamute renoveerimise jätkusuutlikkusele üleminekul?
- Millised muudatused poliitikates on vajalikud jätkusuutliku renoveerimise toetamiseks?

Küsimustele leiti vastused läbi valdkondlike kirjalike materjalide läbitöötamise ja põhjalike intervjuude, mis viidi läbi erinevate valdkonnas tegutsevate või seda oluliselt mõjutavate osapooltega.

Töö esimeses osas kirjeldatakse teoreetilist raamistikku, mille põhjal renoveerimissektorit analüüsitakse, et kaardistada olemasoleva režiimi funktsioonid ja peamiste osapoolte tegevused. Kasutati mitmetasandilise juhtimise ja tehnilise innovatsioonisüsteemi kombineeritud raamistikku, mille abil analüüsiti ka Euroopa Liidu tasandi mõjusid.

Töö teises osas viidi läbi 18 intervjuud Eesti ja Euroopa Liidu erinevate osapooltega – ettevõtjad, ametnikud, spetsialistid. Intervjuud andsid detailse ülevaate, kuidas renoveerimise turg toimib ja millised on selle lähiaja arengud ning kuidas need seonduvad puidu kasutamisega.

Tulemused näitasid, et praegu renoveerimissektoris materjalide jätkusuutlikkust ei jälgita. Peamised takistused on seotud ehitushindadega, sest korterelamute ühistute peamine soov on saada energiatõhustamisel parimad tulemused vähimate kuludega. Sektorit kirjeldab seetõttu ka rajasõltuvus ja muudatusi saab esile kutsuda läbi poliitikakujundamise. Eestis on tugevad puitmajatootjad ja see on eeliseks puidu levikule renoveerimise sektoris. Samas ei peeta niivõrd oluliseks puidu rolli süsiniku hoiustajana, vaid tema lihtsat töödeldavust ja sobivust korterelamute rekonstrueerimise tehase abil läbiviimiseks. Puidu kasutamise toetamiseks tuleb jätkuvalt toetada uusi pilootprojekte ja toetada teadmiste loomist ning levikut sektoris. Selleks, et toetada jätkusuutlike materjalide kasutust rekonstrueerimisel, tuleb enam arvestada poliitikakujundamisel ja toetusmeetmete loomisel keskkonnamõjude leevendamisega. Riigil on oluline roll juhtida jätkusuutlikkusele üleminekut sektoris läbi informatsiooni jagamise, reguleerimise, arenduste toetamise ja rahastuse pakkumise. Seejuures kõige olulisem on riigi juhtiv roll suunanäitajana.

Töö põhjal võib järeldada, et praegune olukord ehitussektoris ja jätkusuutlikkuse printsiipide vähene jälgimine peegeldavad olukorda renoveerimissektoris. Samas Euroopa Liit oma kliimaneutraalsuse eesmärgiga survestab üha tugevamini renoveerimispraktikaid ja Eesti oludes on peatselt näha jätkusuutlike materjalide osakaalu kasvu korterelamute rekonstrueerimises.

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# APPENDICES

## Appendix 1. List of interviews

All interviews were conducted by the author and carried out via video and audio calls on a computer. In the analysis, references to interviews are mixed and do not respond to the interview catalog.

**Interview A** – professor, Department of Civil Engineering and Architecture, TalTech. Audio recording. 27 March 2021.

**Interview B** – technical consultant for renovation, Majaabi OÜ. Audio recording. 29 March 2021.

**Interview C** – cabinet member, EU Energy Commissioner Cabinet. Audio recording. 29 March 2021.

**Interview D** – sales manager, Timbeco Ehitus OÜ. Audio recording. 29 March 2021.

**Interview E** – manager and development adviser, Eesti Puitmajaliit. Audio recording. 29 March 2021.

**Interview F** – area manager of apartment associations, Swedbank. Audio recording. 29 March 2021.

**Interview G** – business manager and sales manager, Balti Vara Ehitus OÜ. Audio recording. 30 March 2021.

**Interview H** – advisor, Estonian Ministry of Environment. Audio recording. 30 March 2021.

**Interview I** – sales director, Puumarket AS. Audio recording. 30 March 2021.

**Interview J** – chairman of the board, The Estonian Union of Co-operative Housing Associations. Audio recording. 31 March 2021.

**Interview K** – owner supervisor and engineer, Tartu Regional Energy Agency. Audio recording. 31 March 2021.

**Interview L** – expert, Academy of Architecture and Urban Studies, TalTech. Audio recording. 31 March 2021.

**Interview M** – manager, Department of Construction and Housing, Estonian Ministry of Economic Affairs and Communication. Audio recording. 31 March 2021.

**Interview N** – manager, Housing and Energy Efficiency Department, KredEx Foundation. Audio recording. 31 March 2021.

**Interview O** – head of housing, Department of Construction and Housing, Estonian Ministry of Economic Affairs and Communication. Audio recording. 31 March 2021.

**Interview P** – managing director, AS Matek. Audio recording. 31 March 2021.

**Interview Q** – member, European Commission spatial design expert group. Audio recording. 6 April 2021

**Interview R** – expert, Department of Civil Engineering and Architecture, TalTech. Audio recording. 6 April 2021.

## Appendix 2. Interview topics and questions

**1. Potential of biomaterials, including wood, to support sustainability transition in the field of renovation of residential buildings**

1. Ehitustööd ja rekonstrueerimine on suure CO2 jalajäljega. Kas korterelamute rekonstrueerimine energiatõhusaks selles kontekstis omab vastuolusid Euroopa Liidu kliimaneutraalsuse ja keskkonnasäästlikkuse eesmärke silmas pidades?
2. Kui oluline on puidu ja biomaterjalide roll Euroopa Liidu poliitika kujundamise tasandil? Kas ja kuidas biomaterjalide kasutamist soodustatakse Euroopa Liidu ja laiemalt rahvusvahelisel tasandil? / *How important is the role of timber and biomaterials at the level of policymaking in the European Union? How is the use of biomaterial promoted at international level?*
3. Kas ja miks peaks rekonstrueerimine arvestama biomaterjalide kasutamisega kui suur võit keskkonnale tuleneb kütteenergia kokkuhoiust?
4. Milliste materjalidega on kõige lihtsam või tavapärasem korterelamu rekonstrueerimist läbi viia? / *What materials are the most customary for apartment buildings reconstruction?*
5. Millised on puidu negatiivsed omadused?
6. Kuidas materjalide hind korterelamute rekonstrueerimist mõjutab, kas puidu kasutamine võib olla soodsam alternatiiv? / *How does the cost of materials affect the reconstruction of apartment buildings, whether the use of wood can be a more favourable alternative?*
7. Millised on võimalused puidutehnoloogiast tulenevate uute materjalide kasutamisel korterelamute rekonstrueerimisel? Kuidas viimased suuremad puidupõhised innovatsioonid jätkusuutlikku rekonstrueerimist mõjutama võivad hakata? / *What are the possibilities for using new materials derived from timber technology to reconstruct apartment buildings? How can the latest major wood-based innovations affect sustainable reconstruction?*
8. Kui suures ulatuses oleks täna võimalik korterelamu rekonstrueerimine läbi viia ainult biomaterjale kasutades? Kuidas puidu kasutamine rekonstrueerimise protsessi võib mõjutada? Kui suur on jätkusuutliku rekonstrueerimise ehk biomaterjalide kasutamise potentsiaal rekonstrueerimisel (CO2 mahukate materjalide asendamine?
9. Kui me räägime rekonstrueerimisel võimalikult väikesest jalajäljest, siis kui palju tekib täna rekonstrueerimisel materjali ülejääki ja mida sellega tehakse? / *When we talk about the small footprint in reconstruction, how much is the material surplus in the reconstruction today and what is done with it?*
10. Kas jätkusuutliku rekonstrueerimise läbiviimise saavutamiseks on puidule olemas ka alternatiive? / *Are there alternatives to wood to achieve sustainable reconstruction?*
11. Palju kasutatakse korterelamute rekonstrueerimisel arhitekte ja/või disainereid, et saavutada parim lahendus?

**2. Mapping of the main actors, institutions, and networks - key counterparties and their roles and activities regarding wood diffusion**

1. Millised ettevõtted, avalikud asutused ja erinevad organisatsioonid täna töötavad jätkusuutliku ehk biomaterjalide põhise rekonstrueerimise ja selle edendamisega Eestis?
2. Kas keegi on (isik, ametlik ühendus või organisatsiooni) täna puidupõhise rekonstrueerimise eestkõneleja? Kui, siis miks? / *Is anyone (person, official association or organization) today a spokesperson for wood-based reconstruction?*

3. Millised on täna aktiivselt tegutsevad ametlikud ühendused või organisatsioonid, mis on puidu kui ehitusmaterjali kasutamise eeskõnelejad?
4. Kas ja kuidas toimub täna biomaterjalidel põhinevate ehitusmaterjalide ja toodete arendustegevus? Kui laialdaselt tehakse koostööd ettevõtete ja teadusasutuste poolt? / *How is the development of construction materials and products based on biomaterials taking place today? How widely companies and research institutions cooperate?*
5. Kuidas toimub täna korterelamute rekonstrueerimisega soenduv arendustegevus (uued materjalid, töövõtted, jne)? Kas suheldakse teadusasutustega, osaletakse projektides?
6. Kuidas korterelamute rekonstrueerimisega seotud ettevõtted hangivad ehitusmaterjalid?
7. Kui palju mõjutab korterelamute rekonstrueerimise tehnoloogiate ja materjalide valikut tellija ehk korteriühistu või kohalik omavalitsus? / *How much the choice of technologies and materials for reconstructing apartment buildings is influenced by the client (apartment association or local government)?*
8. Millisel määral osaletakse rahvusvahelistes võrgustikes ja organisatsioonides, kus fookuses on korterelamute rekonstrueerimine või puidu kasutamine? Palju on Eesti tasandil rahvusvahelist koostööd biomaterjalide kui ehitusmaterjalide vallas? / *What role do international networks and organisations play in Estonia regarding biomaterials and apartment building renovation?*
9. Kas on korterelamute rekonstrueerimise valdkonnas on olnud möödarääkimisi või väärarusaami erinevate osapoolte vahel?
10. Kas ja kui suur võib olla puidupõhise ehituse toetuskond Eestis? / H*ow big is the wood-based construction support in Estonia?*
11. Kuivõrd oluline on avaliku sektori tegevus korterelamute rekonstrueerimise valdkonnas? / *How important is public sector activity in the area of reconstruction of apartment buildings?*
12. Millised regulatsioonid täna mõjutavad puidu ja biomaterjalide kasutamist korterelamute rekonstrueerimisel? Kehtivad regulatsioonid ja nõuded? / *What regulations today affect the use of timber and biomaterials in the reconstruction of apartment buildings?*

**3. Key factors and challenges for using wood-based materials/technologies to support sustainability transition in the field of renovation of common soviet time apartment buildings in Estonia**

1. Kui palju mõjutavad ELi sh rahvusvahelised standardid, nõuded ja tegevused korterelamute rekonstrueerimist ning puidu kasutust? / *How much impact does the EU regulations have on the reconstruction of apartment buildings and the use of timber?*
2. Kuidas täna on võimalik biomaterjalide põhist ehitamist ja rekonstrueerimist või nende materjalide kasutust õppida?
3. Millised on riiklikut teadusarenduse prioriteedid ja kui oluline on selles biomaterjalide fookus ehitust silmas pidades? / *What are the priorities for the state regarding research development and how important is the focus of biomaterials usage in construction sector?*
4. Kui palju teadusasutusi tegeleb puidu kui (ehitus)materjali arendustegevusega ja kui suur on Eestis nende mõju? Milliseid arendusprojekte on algatatud või plaanitud biomaterjalidega seonduvalt?
5. Kui palju rahastatakse pilootprojekte ja tegevusi, mis on suunatud korterelamute rekonstrueerimisele ja/või biomaterjalide kasutusele? Millised need projektid on?
6. Kui palju mängivad rolli korterelamute rekonstrueerimise arendustegevuses ettevõtted ja milline on nende tellimus ülikoolidele? Kui suur on ettevõtete huvi?

7. Kas puidu kasutamisele on nõudlust tellijate poolt ehk korterelamu rekonstrueerimist sooviva korteriühistu või kohaliku omavalitsuse üksuse poolt? / *Is there a demand for the use of timber by the apartment association or local governments wishing to reconstruct apartment buildings?*
8. Kui suur on ettevõtete huvi korterelamute rekonstrueerimist jätkusuutlikult läbi viia ehk kasutada biomaterjale?
9. Kas rekonstrueerimise turg on mitmekülge ehk kuidas iseloomustada täna tegutsevaid ettevõtteid? Palju on uusi tulijaid? / *How to characterize companies operating in reconstruction market today? How many newcomers?*
10. Kui palju täna juba kasutatakse biomaterjale ja puitu korterelamute rekonstrueerimisel? Kui oluline puit korterelamu rekonstrueerimisel on?
11. Kuidas materjalide hind korterelamute rekonstrueerimist mõjutab? Millised fassaadi komponendid kõige suuremat mõju omavad? / *How does the price of materials affect the reconstruction of apartment buildings?*
12. Kas ja kuidas muutuvad regulatsioonid, mis on seotud korterelamute rekonstrueerimisega? Kuidas ja kas see mõjutab puidu kasutust? / *How the regulations related to the reconstruction of apartment buildings are changing? How does it affect the use of timber?*
13. Kas puidu kui ehitusmaterjali arendusteks on võimalik taotleda rahastust Eestis? Millisel viisil puidu kasutust Eestis täna toetatakse?
14. Kas Eestis on piisavalt spetsialiste, teadureid ja valdkondlikke eksperte, kes puitmaterjali arendusega tegelevad? / *Are there enough specialists, scientists and sectoral experts in Estonia who are involved in the development of timber?*
15. Millal on korterelamu rekonstrueerimine jätkusuutlik ehk milline saab või võiks olla biomaterjalide osakaal?
16. Millised riiklikud strateegiad täna kõige olulisemalt puidu kasutamist mõjutavad või toetavad? Kuidas täna nende elluviimine toimub? / *What national strategies today most importantly affect or support the use of timber?*
17. Kuidas täna arvestatakse puidu rolli poliitilise debati tasandil, kui oluline on seal fookus puidul kui ehitusmaterjalil?

**4. Systemic weaknesses of the sustainable renovation solutions and biomaterials diffusion**

1. Puidul on palju positiivseid omadusi, miks seda täna ei kasutada laialdaselt ehituse ja rekonstrueerimise puhul?
2. Kas keskkonna jalajälge rekonstrueerimisel kui tegevusel (materjalide kasutus) mõõdetakse ja kas seda peetakse oluliseks? / *Is carbon footprint in reconstruction activity (use of materials) measured and is the topic considered important?*
3. Milline on mõju korterelamute jätkusuutlikule rekonstrueerimisele tänastel regulatsioonidel - piirangud, nt tuleohtuse nõuded? Kuidas tänased regulatsioonid korterelamute rekonstrueerimisel puidu kasutamist reguleerivad?
4. Kas ja kuidas riik toetab täna biomaterjalide põhist rekonstrueerimist? Kas kõik osapooled on toetavad? / *How does the state support the reconstruction with biomaterials? Are all actors and stakeholders supportive?*
5. Kas keegi veab eest jätkusuutliku rekonstrueerimise teemat tervikuna ja kas see on oluline? Miks?
6. Kuidas täna hinnatakse rekonstrueerimise jätkusuutlikkust? / *How is the sustainability of reconstruction assessed today?*
7. Kas puidu ja biomaterjalide laialdane kasutamine korterelamute rekonstrueerimisel vajab tuge või on see tänastes tingimustes juba rakendatav?

8. Mis on puidu ja biomaterjalide kasutamise kõige suuremad väljakutsed korterelamute rekonstrueerimisel? / *What are the biggest challenges for the use of wood and biomaterials in the reconstruction of apartment buildings?*
9. Milline on inimeste teadlikkus puidu kasutamise võimalustest korterelamute rekonstrueerimisel? / *What is the awareness of people about the possibilities of using wood in the reconstruction of apartment buildings?*
10. Kas on olemas nõudlus keskkonnasäästlikele rekonstrueerimise projektidele?
11. Kuidas ja kas kohaliku tooraine kättesaadavus puidu kasutamist rekonstrueerimisel võib mõjutada? Kas tänased puidu tootmismahud suudavad teenindada korterelamute rekonstrueerimist? / *How can the availability of local raw materials influence the use of timber in reconstruction of apartment buildings?*
12. Kas ja millised on võimalikud mõjud puidu laiale kasutusele huvikaitseorganisatsioonide tegevusel?
13. Palju on meetmeid, projekte või avaliku sektori tellimusi, mis toetavad puidu kasutamist ehituses sh pidades silmas ka rekonstrueerimist?
14. Kuidas laenuasutused, eelkõige pangad suhtuvad korteriühistu jätkusuutliku rekonstrueerimise soovile? / *How do lending institutions, especially banks, view the sustainable reconstruction of the apartment building?*

**5. Proposals for policy mix to support sustainable renovation solutions in apartment building renovations**

1. Kuidas suurendada korteriühistute nõudlust ja teadlikkust keskkonnasäästliku rekonstrueerimise läbiviimiseks (biomaterjalide kasutamine)? / *How to increase the demand and awareness of apartment associations for environmentally friendly reconstruction?*
2. Millised regulatiivsed muudatused on vajalikud puidupõhise ehituse ja rekonstrueerimise mahtude kasvamiseks - piirangud ja eelistused? / *What regulatory changes are necessary to increase the volumes of wood-based construction and reconstruction?*
3. Kuidas riik saab toetada keskkonda säästvate rekonstrueerimise lahenduste väljatöötamist ja levimist? / *How can the state support the development and diffusion of environmentally sustainable reconstruction solutions?*
4. Kas jätkusuutlik rekonstrueerimine vajab eraldi organisatsioonilist keha, eestvedajat või näiteks konsortsiumi? / *Does sustainable reconstruction require a separate organisational body, leader or, for example, a consortium?*
5. Milline koostöö on täna puudu või pole piisav puidu kasutust silmas pidades? / *What cooperation is lacking today or is not sufficient in view of the use of timber?*
6. Kas biomaterjalide ja puidupõhine rekonstrueerimine vajab eraldi toetus- ja finantsskeeme või on ta võimeline asendama tänaseid praktikaid?
7. Mida tuleb veel teha selleks, et rekonstrueerimisel puidu ja biomaterjalide osakaal suureneks? Miks? / *What else should be done to increase the proportion of timber and biomaterials in the reconstruction process?*
8. Kas strateegilisel tasandil tuleb rohkem rõhku seada biomaterjalide kasutusele korterelamute rekonstrueerimisel või ei? Miks?
9. Kuidas rahvusvahelisel tasandil koostöö saab kaasa aidata jätkusuutliku rekonstrueerimise osas? Milline mõju on Bauhausil?
10. Kuidas tagada biomaterjalide sh puidu kui tooraine kättesaadavus rekonstrueerimise mahtude kasvamisel?
11. Millistele arendustegevustele tuleb puidu ja biomaterjalide osas rõhku panna, et tagada rekonstrueerimise kvaliteet? / *What developments should be emphasised in terms of*

*timber and biomaterials in order to ensure the quality of reconstruction of the apartment building?*

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