BUILDINGS & CITIES

Extending building longevity: wood-based product–service systems

RESEARCH

ANNE VILJANEN
ANGELINA KORSUNOVA-TSARUK
JANINA HARMANEN
ELINA SOFIA OIJALA
ANNE TOPPINEN

*Author affiliations can be found in the back matter of this article

]u[ubiquity press

ABSTRACT

Wood has been considered renewable, low-carbon and flexible for use in buildings. Product–service system (PSS) configurations related to building longevity are identified by using PSS archetypes as analytical lenses. These PSS configurations of buildings containing wood are assessed against resource efficiency (RE) and circular economy (CE) hierarchies. Qualitative interviews (n = 31) from Finland provide insights into opportunities for timber products in the building sector. The use of timber in construction and retrofit innovations is examined for flexibility and extending building lifespans. Lower-level practices from CE hierarchies (*e.g.* material recycling) appeared more institutionalised while higher-level practices from RE hierarchy (*e.g.* use of vacant spaces) seemed to be more in their early stages. As a response to the expected market growth, innovation bundles were found to centre around new construction, lacking a needed emphasis shift to sharing spaces and building retrofits.

PRACTICE RELEVANCE

This study makes a case for stronger integration of PSS thinking into timber construction and retrofits. Developing such solutions requires greater co-creation with multiple stakeholders involved during the building life-cycle, including the integration of end-user and living phase aspects into building planning. Future legislation and policy could support this development at the national and city policy levels by encouraging renovation, adaptability and incorporation of services that extend building longevity.

CORRESPONDING AUTHOR:
Anne Viljanen
Faculty of Agriculture and Forestry, University of Helsinki, Latokartanonkaari 7, 00014 Helsingin yliopisto, FI
anne.viljanen@helsinki.fi

KEYWORDS:
wood products; product–service systems; innovation; longevity; service life; resource efficiency; timber buildings; circular economy; Finland

TO CITE THIS ARTICLE:
Viljanen, A., Korsunova-Tsaruk, A., Harmanen, J., Oijala, E. S., & Toppinen, A. (2026). Extending building longevity: wood-based product–service systems. *Buildings and Cities*, 7(1), pp. 1298–1313. DOI: https://doi.org/10.5334/bc.882

DOI: 10.5334/bc.882

1. INTRODUCTION

Product–service systems (PSS) have been pinpointed as promising business models in the scopes of wood, building cyclical closed loops and longevity (Ghafoor *et al.* 2023; Pelli & Lähtinen 2020). A PSS business model allows firms to deliver and capture value by selling the function or use of physical products and building unique relationships with clients (Tukker 2004). Global environmental risks and uncertainty are inherent to the present time (Neise *et al.* 2024) and influence existing and planned buildings. To prepare against uncertainty and changing conditions while concurrently preserving precious natural resources, rethinking and reusing embedded materials in buildings through new urban building experiments and pilots can promote the longevity and flexibility of multistorey buildings and their surroundings (Kuittinen 2023; Pelsmakers & Warwick 2022). Using carbon-storing solutions, including wood materials and nature-based solutions (NBS), can create multiple benefits around urban dwellings (Kinnunen *et al.* 2022). Buildings are usually considered as 'finished products' rather than 'ongoing processes' of PSS, which often leads to short-sightedness when considering the operation and end-of-life phases. However, further PSS development could lead to longer building life and innovative solutions for sustainability and improved quality of life for residents (Azcarate-Aguerre *et al.* 2018). The circular economy (CE) focuses on extending building lifespans by decelerating, narrowing or closing resource loops throughout the entire building life-cycle (including design, construction, operation, maintenance and deconstruction), while preserving the value of buildings, components and materials for as long as possible (Pomponi & Moncaster 2017).

Buildings are a special type of 'product' for at least three reasons (Benachio *et al.* 2020). First, they are usually planned as 'one-off' projects, without much consideration regarding material reusability or recyclability. Second, they comprise many materials and manufactured products, each with its own life-cycle, interacting in space and time. Some of these are highly complex, such as elevators or heating systems, and often represent a PSS of their own. Third, buildings have very long lifespans compared with many other products. For instance, the average lifespan of a building in the European Union is approximately 87 years, while cars average 21-year lifespans (Circle Economy 2025).

The long lifespan of buildings increases the uncertainty regarding their future use, regulatory changes and other external factors that may affect their operation. Residential multistorey buildings in Finland are often owned collectively by apartment owners, *i.e.* decisions to renovate and refurbish are made through housing committees and depend on their capacity for strategic and sustainability-oriented decision-making. Buildings are therefore complex entities. Assessing their overall sustainability is challenging, as the sustainability of the whole does not necessarily equal the sum of its individual components.

Despite the urgency in transitioning the urban building stock to be low carbon and resilient (Binz *et al.* 2025; Lukkarinen *et al.* 2025), limited research exists regarding PSS related to building materials, such as wood (Pelli 2021). Existing PSS typologies are mostly material neutral, although PSS feasibility and configuration are likely influenced by the physical properties and value-retention possibilities of the products around which the system is organised. Mont (2002) describes PSS as a system of products, services, and supporting networks and infrastructure designed to be competitive, satisfying customer needs, but also lowering the environmental impact when compared with conventional business models. In this sense, wood warrants specific attention in PSS because of its renewable nature, ability to store carbon and multiple cascading possibilities. In a building's life-cycle, the full sustainability potential of wood often remains underutilised because of downgrading through energy recovery (Niu *et al.* 2021). Investigating wood-related PSS provides an opportunity to examine higher value retention possibilities for wood throughout a building's life stages. Additionally, research is lacking in relation to NBS in buildings, *e.g.* green roofs, green walls, biodiversity-enhancing yards and rain gardens (Dorst *et al.* 2019), and in services with social dimensions (Windrum *et al.* 2016) with wood material use.

Prior research has investigated wood material longevity and decay from a structural engineering and building physics viewpoint. For instance, more natural methods for enhancing wood material longevity have been studied to acquire non-decaying and more durable properties from the wood

material (Evans *et al.* 2022). Despite some existing PSS and wood product manufacturing studies (Lähtinen & Häyrinen 2022; Pelli & Lähtinen 2020), this logic has seldom related to buildings, which is the topic investigated in this study. Ghafoor *et al.* (2023) have investigated circular buildings from a PSS perspective. However, the perspective of circularity and PSS achieved through biobased materials, and versatile wood uses throughout a building's life-cycle and extended life-cycle, is, to the authors' knowledge, missing from the literature.

This explorative study focuses on identifying PSS solutions relating to wood in the local context of Finnish urban building initiatives. Its research questions of this study are as follows:

- RQ1: What kinds of product–service configurations can be identified in practitioners' descriptions of buildings containing wood?
- RQ2: How do the identified configurations relate to the resource efficiency (RE) hierarchy?

2. BACKGROUND

Conceptually, this study draws from PSS and circular buildings and then integrates wood materials into the equation. PSS have been depicted as a promising new approach to develop new business models (Ghafoor *et al.* 2023; Pelli & Lähtinen 2020), with the ability to trigger greater levels of circularity (Yang *et al.* 2018). Despite the conceptual opportunities of PSS, they have rarely focused on buildings or housing, except for Ghafoor *et al.* (2023). This conceptual approach is also used in this study.

Six main PSS archetypes exist in the literature: product , use, result, service, performance and integration oriented (Clayton *et al.* 2012; Ghafoor *et al.* 2023; Tukker 2004; Yang & Evans 2019). PSS archetypes have been tied to the manufacturing sector (Clayton *et al.* 2012; Neely 2009) and specifically to the sector providing prefabricated wooden elements (Pelli & Lähtinen 2020), with less focus on buildings. However, as this study uses the refined PSS typology as part of the product–service configuration to examine circular buildings, the closest conceptual approach is by Ghafoor *et al.* (2023). The approach is to use the PSS archetypes to examine cases of urban buildings built, extended, retrofitted or made versatile with wood materials and to study empirically which areas of PSS typology the wood-related innovations are centred around.

This study focuses on product-, use- and result-oriented PSS (Figure 1). The literature reveals that product- and service-oriented PSS overlap largely (Yang & Evans 2019). Separating them analytically would be rather meaningless, and they were therefore merged in this study. Similarly, performance-oriented PSS, used by Ghafoor *et al.* (2023), and result-oriented PSS, used by other sources (Neely 2009; Pelli & Lähtinen 2020; Tukker 2004; Yang & Evans 2019), have been merged into a PSS type named 'result-oriented PSS'. Integration-oriented PSS appeared interesting from the CE viewpoint, *e.g.* turnkey solutions or integrating services vertically up- or downstream along supply chains (Yang & Evans 2019). Nonetheless, after careful consideration it was not used as a separate analytical lens because it was considered not to be as relevant a distinction in relation to the phenomenon of building longevity.

The main PSS types are defined as follows. Product-oriented PSS offer tangible products directly linked with a service, such as maintenance (Ghafoor *et al.* 2023; Neely 2009; Pelli & Lähtinen 2020). Use-oriented PSS offer product performance through systems of product sharing, pooling and leasing (Neely 2009; Pelli & Lähtinen 2020; Tukker 2004) (Figure 1). Result-oriented PSS, in this case, offer an agreed result without specifying tangible products. It is aligned with the definition of performance-oriented PSS in Ghafoor *et al.* (2023), but also with other result-oriented PSS literature, *e.g.* Tukker (2004) on result-oriented PSS offering 'functioning results' more flexibly than by merely providing a technology or product. Also, according to Ghafoor *et al.* (2023), result-oriented PSS, which they call 'performance-oriented PSS', mostly relates to more intangible qualities and capabilities of PSS. These offer, for example, comfort, quality and affordability (Figure 1), enabling long-term responsibility of the building for their suppliers, which is pivotal from the building longevity perspective. In this way, product-, use- and result-oriented PSS became fundamental in the present study's typology of PSS when examining building longevity and wood.

DOI: 10.5334/bc.882

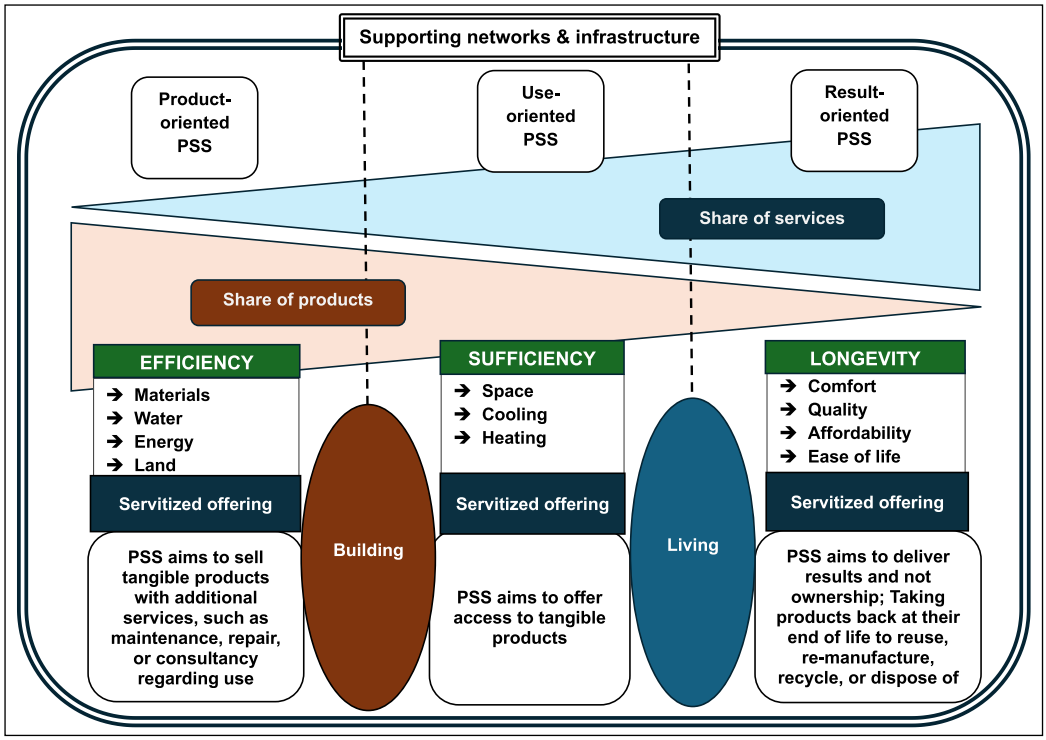


Figure 1: Types of product–service systems (PSS) in the built environment.

Sources: Adapted from Ghafoor *et al.* (2023) and Tukker (2004).

The building retrofit PSS literature has typically related to energy retrofits. For instance, one-stop shops for energy renovations (Pardalis & Sula 2026; Boza-Kiss *et al.* 2021) offer integrated services through a single point of contact, including assessment, technical advice, coordination and financing support, and can improve renovation governance and increase renovation uptake. Pardalis & Sula (2026) further suggest embedding sufficiency principles in early-stage assessment, system sizing and evaluation criteria to reorient energy renovation pathways toward proportional and context-sensitive strategies. In comparison with energy renovations, material aspects in renovation have gained less focus. Recent directions for PSS in the digital era include smart PSS in which networks of people, virtual spaces and services are connected with enormous amounts of data (Wu *et al.* 2025). Moreover, system dynamics modelling has been used in both circularity assessments and the conceptual approach of PSS (Werrel *et al.* 2024).

The hierarchy for resource-efficient construction, developed by Kuittinen (2023), is an important contribution to the balanced resource use of buildings. In this study, it is combined with insights from Reike *et al.* (2018) concerning the evolution of hierarchies in the CE. According to Kuittinen (2023), vacant and shared spaces should always be used first, emphasising that 16% of European houses are underoccupied or empty. If this is not possible, then existing buildings should be renovated, old buildings extended and only as a last resort should new buildings be built (Kuittinen 2023). Reike *et al.* (2018) conceptualise that the CE prolongs resource productivity. According to them, the hierarchically highest form of the CE is 're-servitization', which places 'functionality' at the core by emphasising rethinking and adapting services, notably developing PSS as part of CE business models. Extending building longevity becomes focal when combining these approaches.

The wider context of service design is experiencing a broader shift from traditional and linear approaches toward embracing systemic, relational and regenerative orientations, with implications for long-term value creation (Heinonen 2025; Konietzko *et al.* 2023). The focus on system solutions is important in a CE, where the outcome ensures decelerating or closing the loops. Reim *et al.* (2015) observe that it is crucial to understand how value creation, delivery and capture take place. Following a hierarchy for resource-efficient construction (Kuittinen 2023), existing buildings should be used as a priority and renovated as much as possible to ensure longevity and efficient use. This study is interested in systemic value propositions, which can be defined as more complex solutions to customer problems, according to Teece (2009).

Wood provides an attractive option for both building longevity (Attia *et al.* 2025) and durability, but also for creating temporal and flexible structures (Ding *et al.* 2023). Wood offers flexibility in the form of lightweight movable walls, creating modular structures and even whole small buildings. These enable modifications to living space functions as life situations and needs change (Lavikka & Laiho 2023; Öberg *et al.* 2024). However, a more profound shift towards timber buildings being designed for disassembly faces obstacles, *e.g.* immediate costs versus long-term benefits, wood product traceability systems and lack of practical applications (Öberg *et al.* 2024).

Wood products typically have lower embedded carbon. This also applies to multistorey constructions in the scope of the CE. First, reclaiming wood for the original function (as a construction material) at the end-of-life phase would quantify the benefits typically attributed to wood materials, including contributing to carbon storage and diminishing carbon emissions by replacing high embodied carbon materials (Patrizi *et al.* 2026). Second, existing multistorey buildings constructed with other materials, including concrete, can be retrofitted with wood by building rooftop extensions or facade replacements or via deep renovations (Julistiono *et al.* 2024; Pihelo *et al.* 2020). Third, existing wood materials, including those found in old buildings and furniture, along with industrial by-products, packaging materials and temporary support structures, could be reclaimed and repurposed for new applications (Bergsagel & Heisel 2023; Pitti *et al.* 2020). Fourth, timber construction has been connected with NBS as contributing to urban carbon sinks (Kinnunen *et al.* 2022). Thus, wood materials offer many alternative and complementary functionalities for building construction and retrofitting.

3. MATERIALS AND METHODS

3.1 FINNISH CONTEXT

Finland progressed into a service economy over four decades from the 1970s to the 2010s (Honkatukia *et al.* 2014). It is therefore worthwhile investigating whether Finnish construction businesses are shifting from selling products to selling PSS (Lähtinen & Häyrinen 2022). Finland has strong traditions in timber construction in the single-house sector. However, the construction of multistorey buildings in Finland has a clear path dependency on concrete practices and products with associated high environmental impacts (Jussila *et al.* 2022). The geographically major Finnish southern cities of Helsinki, Tampere and Turku form an area with increasing population growth and housing demand. The buildings and business development in these localities and their immediate vicinity were therefore chosen as the focus of this study.

3.2 QUALITATIVE DATA ANALYSIS

Qualitative interview data were collected from 31 participants based in Finnish companies. The data were collected in the period 2021–25 over three phases: the first phase included 12 interviews and 14 interviewees in 2021–22 (codes 1-A1–1-K14, one group interview with three people and the rest as single-person interviews); the second phase consisted of eight interviews in 2023 (codes 2-D15–2-K22); and the third phase included nine interviews in 2024–25 (3-W23–3-R31) (see Appendices 1 and 2 in the supplemental data online). Interview length varied between 18 and 120 minutes. The interviewees represented architectural companies, design engineering companies, construction companies, building developers, material suppliers and an energy-efficiency solutions provider (see Appendix 1 online). Interviews were originally conducted in Finnish, anonymised, transcribed by an external service provider and translated to English in the data coding and categorising phase (see Appendices 2 and 3 online).

The following sampling strategy was used at each stage. Informants were selected based on rigorous internet searches of topical news articles and reports available online, ensuring that the informants were active in the field (see Appendix 4 in the supplemental data online). All selected informants were confirmed through this internet search to having been part of planning or conducting a construction or retrofit project that incorporated significant wood use, thus ensuring that the data produced were timely and relevant. The data were collected at various stages of one research project, therefore forming differing interview foci (see Appendices 1 and 2 online).

While the interview guide for the third dataset (2024–25) included explicit questions regarding PSS, secondary qualitative analyses (Heaton 2008) were applied to the first two datasets to identify practices, service arrangement and value-creation mechanisms. These can be interpreted through the PSS lens and connected with significant wood use in buildings. While the data from all three datasets are not equivalent, they are complementary and serve the aim of understanding what product–service configurations can be identified from the practitioner descriptions (see Appendix 1 online).

Although the data were collected in three stages, all datasets were analysed simultaneously using ATLAS.ti 26. Coding followed an abductive and iterative approach, guided by PSS and wooden building literature. First, all transcripts were read and coded to identify PSS examples related to projects, plans and construction or retrofit activities described as innovative by the informants. Second, the identified wood-related PSS examples were categorised into PSS types based on the literature. These categories evolved during the analysis, with the initial four PSS types reduced to three where categories overlapped or provided no additional insight into building longevity. Third, the codes and categories were refined and validated through iterative analysis rounds and discussions among the co-authors (see Appendix 3 in the supplemental data online). Finally, code co-occurrence analysis was conducted in ATLAS.ti, and the results were visualised using Sankey diagrams (Figures 2–4).

This study used an exploratory qualitative research design (Given 2016; Stebbins 2001). It was built on an existing meta-study by Ghafoor *et al.* (2023) on circular housing PSS and on Pelli & Lähtinen (2020) regarding wood material manufacturing PSS, combining these in a novel way. The ways in which wooden construction supports buildings' longevity was an unexplored research stream. This led to the explorative approach (Given 2016; Stebbins 2001) and to the detailed qualitative research data regarding wood use in buildings being used in this study.

The sample size of 31 participants drew on their practical construction experience and retrofit projects and plans. Similar themes recurred during the analysis as ambitious sustainability projects were discussed through all the data-gathering phases. This indicated the construction field's interest to adopt wood material innovations (Jussila *et al.* 2022) and justifying the data collection through three phases.

Data reliability and validity were ensured throughout the research. First, analysis objectivity was created with researcher triangulation. The research design was planned collaboratively, and two study authors were involved in each planning and data-collection phase from 2021 to 2025. Three researchers interviewed the participants in three phases. Later, a team of researchers combined and analysed the data. Data coding and categorisation were conducted by the first author, but these were openly accessible and discussed among the co-authors to modify and validate. Second, initial and updated internet searches for relevant participant selection enabled data triangulation, *i.e.* cross-checking information sources against each other.

4. RESULTS

4.1 PRODUCT–SERVICE CONFIGURATIONS

Several initiatives, innovations and building development projects incorporating wood PSS were found from the study data. These practical plans and built projects with their varying mixes of projects and services were plotted against the chosen PSS typology (Figure 1). A fairly balanced and interlinked categorisation—product-, use- and result-oriented PSS—was evident in the informant discussions regarding 'solutions' or 'innovations' that they had developed related to wooden materials and buildings (Figure 2). Figure 2 shows the themes were intertwined, and no exact interpretations should be made of the numerical values. Nonetheless, the themes 'improved design', 'conversion to new spaces' and 'building longevity' prevailed as key discussion points.

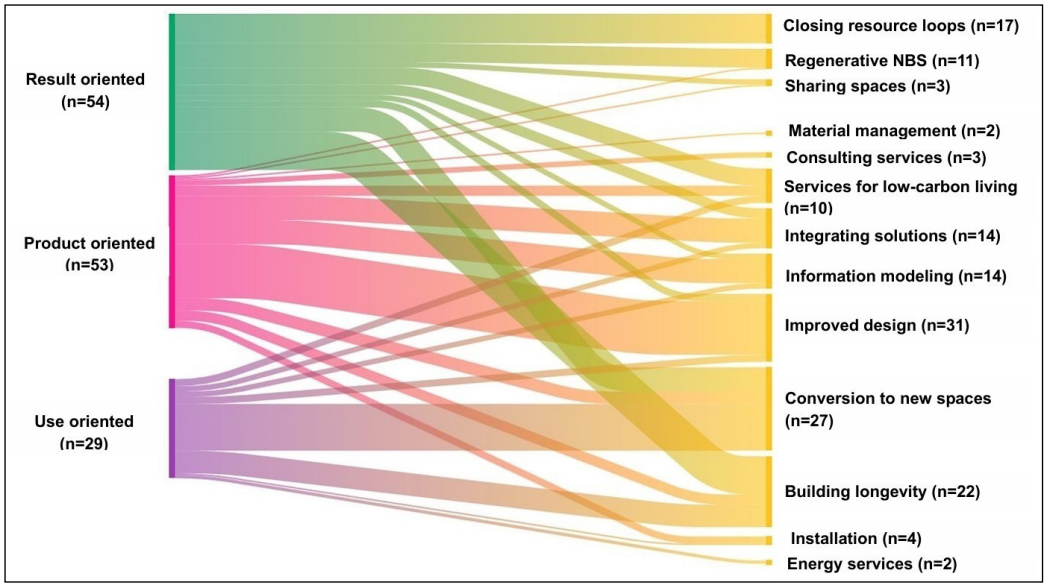


Figure 2: Overall coded themes (right-hand side) shown in relation to three product–service system (PSS) types (left-hand side).

Note: Shown are the intertwined qualitative themes, and no exact interpretations should be made of the numerical values. *n* = Code occurrence in the data.

4.1.1 Product-oriented configurations

The first investigation was a product-oriented PSS pertaining to a provider selling wood construction products supplemented with additional services. With product-oriented PSS, the participant discussion was on the following themes: improved design, services for low-carbon living, information modelling and integrating solutions. Other traditional services provided with the wooden products were occasionally also mentioned, including installation, material management and consulting services (Figure 2).

Multistorey timber construction entailed many types of improved design services, including architectural, structural, acoustics, wood element, retrofit and conceptual design. Also, when hybrid materials are used in new construction or existing buildings are extended with timber, the joints between the timber structures and industrial elements require improved design:

> Timber structural joints and interphases in relation to this industrial element production demand [...] the re-creation of these current sites especially, and the objective of the re-creation is [...] to increase efficiency and ease and through these to also lower the costs of the project.
>
> (design engineering, 1-D2)

Timber element prefabrication was a recognised product-oriented PSS in the interview data, as it includes design and installation services. Prefabricated timber decreases the required on-site work. Moreover, one participant illustrated how the prefabricated wood design diminishes costs by reducing waste:

> a lot less waste is produced when [prefabricated timber] is designed and measured precisely at the production facility.
>
> (building material supplier 3-B26)

Improved design using prefabricated wood elements is therefore a good example of a modern PSS, with the wood products saving both materials and money.

Creating services for low-carbon living in a product-oriented PSS related more to the timber product itself, and participants stated having conducted carbon footprint or carbon handprint calculations. In the *n* multistorey timber buildings, the calculations favoured buildings with significant timber use over buildings with other materials. Calculations for timber retrofits in a regular multistorey building favoured retrofits over new construction, enabling part of the existing materials to be saved compared with new construction.

> Based on the carbon calculations, [...] wood binds carbon as long as it is [stored] in that building. And [...] it functions as a carbon handprint, a carbon storage.
>
> (design engineering, 1-D9)

Information modelling, especially complex and verifiable calculations regarding carbon handprint and carbon footprint in the pursuit of providing low-carbon living, was typically mentioned, as legal requirements for these are expected to tighten in future.

Participants mentioned services based on information modelling to verify aspects of sustainability, including carbon footprints, energy efficiency class calculations or investing in geothermal heat. Based on the interview data, information modelling and calculations were seen to be increasingly important with expectations expressed for new directions in calculations and modelling.

Use- and result-oriented PSS were also connected to measurement systems, but focused on building convertibility or preservability. For instance, carbon handprint calculations are considered an opportunity to highlight deep renovation using timber. More complex calculations will be needed when building circularity is aimed for:

> A measurement system exists for being low carbon [...] but then [...] for the circular economy [...] we can calculate the whole material mass used for construction and [...] the amount of circular raw materials, [...] or the amount of renewable building parts, but it is immediately more challenging work. And then, if we still think [...] that we utilize convertibility, flexibility, or reusability or preservability, then these qualities only emerge during the construction phase where they are used.
>
> (consulting, 2-D15)

This suggests an opportunity to establish data system measurements for the CE.

4.1.2 Use-oriented configurations

Use-oriented PSS (Figure 2) were investigated, where the main characteristic was 'conversion to new spaces'. This related to existing retrofit cases in larger Finnish cities. The participants discussed the rooftop additions, in which new timber structures are built over existing roofs of multistorey buildings, originally built with other materials, *e.g.* concrete. In some cases, the timber addition also involved a conversion project during which office buildings or factory buildings were altered for residential use. Timber retrofits were often executed simultaneously with other retrofits and energy renovations, as a construction company representative states regarding retrofits commissioned by a city-owned rental housing company of two residential multistorey buildings:

> Everything was remade in [the renovations], the whole building services engineering was redone and the outer walls were further insulated and re-rendered, energy efficiency was enhanced, and the windows replaced, so it was a full-scale, comprehensive renovation [...] nothing but the building's skeleton was left, the whole building was redone and one more floor was added at the same time.
>
> (builder, 1-C3)

In other words, simultaneous improvements to energy services were also applied, including cooling, heating, ventilation systems and measures to optimise electricity use.

The theme 'conversion to new space' was connected in the interviews with both other PSS types (Figure 2). This would suggest that conversion to new spaces entails both material and immaterial aspects and combining new products and new services. Timber products were more often emphasised in product-oriented PSS, with discussion regarding prefabricated, flexible and lightweight timber elements. Conversions to new spaces were discussed in connection with shared spaces (such as saunas, laundry rooms and club houses). These shared spaces are offered as a service in densely built city areas:

> For instance, the shared sauna is a typical element [in such a renovation]. You consider the social and the use side [...], we serve exactly their needs and the place where [the renovation] is carried out.
>
> (architect, 3-A25)

The topic 'building longevity' relates to 'conversion to new spaces', as both aim to preserve and extend the life-cycle of existing buildings or to preserve materials embedded within by incorporating new elements (including new living spaces and apartments) or bringing new functionalities to the existing apartment via new or movable wooden walls.

4.1.3 Result-oriented configurations

'Building longevity' is the most prominent element when investigating the result-oriented PSS (Figure 2). In this category, the longevity of built structures was extended by using flexible solutions. Participants discussed the new layers that timber materials and structures could bring to the buildings. Some noted that relocating wooden buildings to other places has been a historical tradition in Finland, and this type of wooden material and structural reuse, even of whole buildings, could be something worth designing for in the future building stock as well. An architectural participant (3-A29) was considering planning a building in which the end-of-life use of the building materials would be considered already during the planning phase.

Prefabrication and wooden modular elements were also mentioned to create more flexibility for building residents and construction companies. Options include tailored solutions for various interior design plans, creating conversion projects, or as a means for transportation. In one case, the new residents who engaged in the group building format of a rooftop addition had the opportunity to influence their future apartments' layouts. Various conversion models for existing built environments were discussed, such as building attics converted into residential use, old concrete facades being replaced by timber ones or creating deep renovations with timber. These would have transformed the building structure altogether by retrofitting most of the building while using significant wood materials in the process. Timber component modularity was mentioned for its export potential, as this eases the transport and construction. The enhanced modularity could provide flexible and modifiable building solutions that overlap between the three PSS types shown in Figure 2.

4.2 BUILDING LONGEVITY AND RE

Enhancing building longevity is highly linked with the notion of time in both extending the life-cycles of old buildings and ensuring the longevity of current buildings in future. Figure 3 shows that product-oriented PSS are most prominent as existing solutions, while result-oriented PSS break down into existing and more future-oriented solutions, as discussed. Nonetheless, future-oriented product and service development are also ongoing among product- and use-oriented PSS.

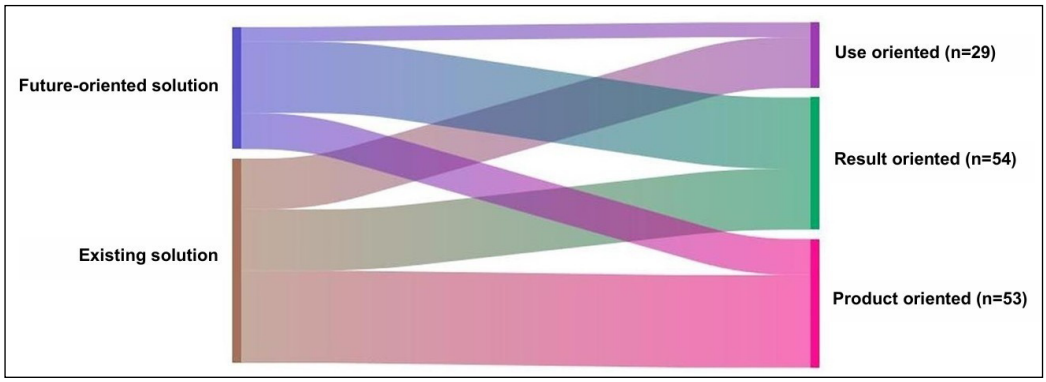


Figure 3: Product–service system (PSS) types coded and categorised between existing solutions and future-oriented solutions.

Note: Shown are the intertwined qualitative themes, and no exact interpretations should be made of the numerical values. *n* = Code occurrence in the data.

These future-oriented solutions include calculations on how low carbon in buildings could be studied in the next 50–100 years. This quotation discusses reuse being a part of a cross-laminated timber (CLT) product:

> We produce CLT, which [can even have a] negative carbon footprint [...] another point may be that these products are also reusable to a large extent [...] we produce a large CLT element, [which can be] dismantled [later] and used elsewhere [...] by adjusting its size.
>
> (material supplier, 3-W23)

Future-oriented solutions were also discussed in the case of planning a deep retrofit or when integrating building solutions of various materials (including wood) and alternatives (such as wood and NBS). A business manager from a building and material supplier company elaborates that the company has the capability to offer various PSS mixes, depending on market demand:

> We are developing the entirety, we are strongly participating with our wide scale of offerings, providing these new nature-based and sustainable solutions. [...] we [...] listen to the market regarding what solutions they are willing to receive [...] as a product and service producer and provider, we are not only actively developing our own products but also looking into [solutions] elsewhere [in Europe].
>
> (business manager, 3-B26)

In product-oriented PSS, the services centred on improved design, enabling material combinations (new and/or old), relying on complex material flow calculations and availabilities for impact assessments.

In the data, the 'conversion to new spaces' and 'building longevity' categories emerged as strongly rooted in existing solutions, *i.e.* actual building and retrofit projects that had been carried out. However, highly ambitious experiments and projects enhancing building longevity were future oriented by sentiment and were discussed in the context of architectural plans, competitions or development projects rather than as implemented projects. Based on the results, these solutions are rooted in the present by certain existing pilots, experiments, projects and historical building practices. These existing solutions prove that building longevity can be technically achieved with certain timber-related solutions. The mainstreaming of these solutions remains a challenge yet an aspiration among certain actors that could drive this field.

Figure 4 shows that the hierarchy for resource efficient construction proposed by Kuittinen (2023) is least visible in the discussions. Thus, a 'new building', which should be considered the least preferable option according to Kuittinen, is considered most frequently by the informants, while 'use vacant and shared spaces', which should be prioritised, is considered least by the informants. Even the future-oriented solutions category is most centred on 'new building' instead of alternative, more resource-efficient ways to solve spatial needs, as proposed by Kuittinen.

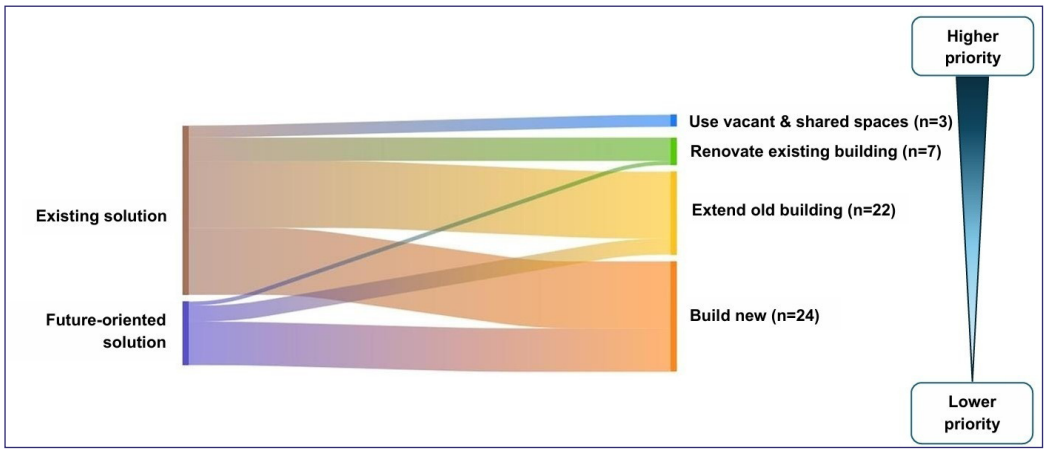


Figure 4: Hierarchy for resource-efficient construction developed by Kuittinen (2023) combined with insights from Reike *et al.* (2018) on balanced resource use for buildings plotted against the data.

Note: Shown are the intertwined qualitative themes, and no exact interpretations should be made of the numerical values. *n* = Code occurrence in the data.

The categories of 'closing resource loops' and 'regenerative NBS' were almost exclusively coded as result-oriented PSS (Figure 2). However, this association should be interpreted in light of the predefined characteristics of result-oriented PSS within the conceptual framework (Figure 1), which includes the CE value delivery of 'taking products back at their end of life to reuse, remanufacture, recycle, or dispose of'. Beyond this framework-based association, the interview findings suggest

DOI: 10.5334/bc.882

that result-oriented PSS reflects a desirable direction of building development expressed by the informants. This was exemplified by coded categories namely 'services for low-carbon living', 'sharing spaces', 'integrating solutions' and 'conversion to new spaces', alongside 'information modelling' and 'improved design' which could contribute to resource-efficient circular construction (Figures 2–4).

5. DISCUSSION

The need for systemic value propositions for building longevity is growing simultaneously with worsening environmental problems (Neise *et al.* 2024). Following theoretical underpinnings from PSS and the RE hierarchy and applying these to various wood-related PSS brings new insights to both research and practice. The framing by Ghafoor *et al.* (2023) does not yet dive deeper into catalysts or levers that would create a mindset shift to wooden PSS or to enhancing building longevity via PSS archetypes. Therefore, more empirical research is needed and, as Tukker (2004) points out, no single PSS archetype would cover all elementary aspects.

The results from interview that address RQ1, 'improved design', 'conversion to new spaces' and 'building longevity', were key solutions identified for circular buildings in the PSS configurations. These configurations highlight the limited practical applicability of conceptual framings and PSS typologies in the literature, responding to the need for empirical evidence identified by Ghafoor *et al.* (2023). They further entail high complexities that cannot be easily reached through single archetype. The present study reveals new insights that PSS types are indeed highly interlinked, yet the emphasis could be shifted more strongly from an emphasis on RE toward a broader aim of enhancing buildings' longevity. While existing PSS typologies are largely material-neutral, this study shows that the feasibility of a PSS can also be shaped by the physical properties and value-retention potential of the core material used, in this case, wood.

RQ2 addressed how identified configurations relate to the RE hierarchy. In line with the hierarchy for resource efficient construction by Kuittinen (2023), the higher levels of 'R' hierarchies (R0, 'refuse'; R1, 'resell/reuse' from Reike *et al.* 2018) in CE solutions were less discussed by participants (Figure 4). Moreover, the new 'potential R0' proposed by Reike *et al.* (2018), 're-servitization', seemed to be in its early stages when related to timber-based and circular building PSS in Finland, whereas the lower 'R' hierarchies, such as 'recycling', appeared already more institutionalised practices, as also observed by Reike *et al*. (2018).

There is a need for a shift toward regenerative and re-servitised approaches of PSS that place functionality and societal wellbeing at their core (Konietzko *et al.* 2023; Reike *et al.* 2018). A practical implication for companies and policymakers is the need to create and foster flexible and time-enduring building structures with added capabilities for reusing, rethinking and re-servitising the buildings' embedded materials. For local policymakers, the findings highlight the need for regulatory conditions that enable PSS to operate across the extensive life-cycles of buildings (Ghafoor *et al.* 2023), in line with national requirements (*e.g.* in Finland; Hakaste *et al.* 2024). Policy measures can support their uptake by promoting circular service models through public procurement, incentives, standards and requirements for durability, adaptability, repair and reuse, as European Union legislation also increasingly requires for the buildings of member states (Corsini 2025; López-Mesa *et al.* 2024).

Due to its material properties, wood was seen as a unique enabler in favourable conditions for various flexible building longevity-enhancing PSS and a component in low-carbon and convertible buildings (Niu *et al.* 2021; Pelli & Lähtinen 2020). However, at present, no construction standards exist in Finland to promote the reuse of reclaimed timber. This is a barrier against mainstreaming its use (Niu *et al.* 2021).

As buildings are complex systems, they are compatible with PSS approach (Azcarate-Aguerre *et al.* 2018). Longevity-enhancing aspirations add to the complexity. PSS are aligned with increased RE hierarchy levels and adaptability of buildings over time, enabling further extensions of their life-cycles (Ghafoor *et al.* 2023; Kuittinen 2023; Pelsmakers & Warwick 2022; Reike *et al.* 2018). The participants understand this to be a business opportunity.

Re-servitisation development is more evident through modern building practices with prefabrication. Information streams are multiplying, so mainstreaming solutions requires addressing even higher levels of complexity and sophisticated information modelling. This implies that the complex digital information systems should be developed and offered as an advanced service business model for timber PSS. The verified resilient and long-lasting materials, elements and even entire buildings would optimally circulate in the built environment, also in line with developments including smart PSS (Wu *et al.* 2025).

Creating new spaces for building longevity appears to be connected throughout all the PSS types (Figure 2). However, balancing resource use in PSS may depend on the extent that incorporated intangibles can replace tangible products enabling the reuse of resources. Linking Figures 1 and 4 reveals the potential of result-oriented PSS to support the ambitions of the RE hierarchy through its stronger emphasis on services. However, more substantiative work, preferably in other contexts, is needed to confirm this.

In buildings, PSS complexity is high due to the range of services across business-to-business networks (in the planning phase of buildings), including intermediate actors such as building managers and building end-users (in the living phase). Thus, building a functional PSS requires exploring and interacting with multiple stakeholders. Yet, the shift from fragmented project-focused thinking to holistic networks in construction required for enabling PSS can be challenging and slow, as also explained by Ghafoor *et al.* (2023). This is analogous to energy renovation one-stop shops (Pardalis & Sula 2026), where integrated services through a single contact point are needed, including assessment, technical advice, coordination and financing support. In this way, energy renovation uptake can be increased effectively.

The practical implications of the study suggest that municipalities and construction or maintenance companies must begin thinking beyond mere products or services and must nurture a more systemic way of connecting these in their value propositions, with untapped potential in enhancing building longevity. Moreover, interactions between service providers and residents could be used to inform the further development of wooden housing solutions, innovation co-creation and supporting a more consumer-inclusive approach to sustainability (Kylkilahti *et al.* 2024; Windrum *et al.* 2016). For example, little is currently known about end-user acceptance of reclaimed wood, so introducing it to shared facilities (such as common rooms) could be an opportunity to explore various solutions for it in residential buildings.

Overall, more sophisticated PSS connected with timber buildings, including pilots, experiments and architectural plans, remain largely under-investigated, despite their potential to shape future cities. Examining buildings as 'material banks' from a service business development viewpoint would contribute to the circular regeneration of the urban building stock.

This study has limitations. The interview data were collected in three phases over five years, with economic conditions influencing the interview tones. Thus, the analysis is tied to specific time periods and developments in the Finnish national economy. However, collecting data during three phases is also a strength because it provides multiple perspectives on the broader economic context. The general themes may be affected by the thematic focusing of the interview guides in various data-collection phases and should be interpreted cautiously, as timber retrofit codes, NBS codes and PSS-related codes have been more frequent in phases 1, 2 and 3, respectively. However, all the interviewee organisations have engaged in planning or executing wood use-related building projects. This shared trait of participants enabled an exploratory examination of PSS throughout the dataset.

The authors addressed these limitations through researcher and data triangulation, with secondary data on projects and active organisations widely gathered via internet searches for cross-checking the results. However, as a limitation, the inverted hierarchy presented in Figure 4 may partly reflect from the individuals interviewed and may not be representative of the sector. The data coding developed over time. In addition to the core PSS types (product-, use- and result-oriented PSS) chosen as the analytical lens, a fourth PSS type was considered: integration-oriented PSS. Certain aspects of integration-oriented PSS may have been lost from this study from the CE viewpoint. However, after careful consideration, integration-oriented PSS was not used as a relevant distinction in relation to the researched phenomenon of building longevity.

6. CONCLUSIONS

This study aimed to identify novel, sustainability-enhancing product–service system (PSS) configurations based on industry professionals' practical and timely experience in planning or conducting timber-based building and retrofit projects. This study shows that all three PSS types are highly interlinked and contribute to building longevity when aiming for circularity-related improvements.

Greater academic and practical attention should be directed towards exploring the potential of result-oriented PSS to support building longevity, particularly through closing resource loops and re-servitisation. Increasing the variety of services in the PSS mix is necessary for aligning with the resource efficiency (RE) hierarchy, shifting from efficiency finally to building longevity, and by acknowledging embedded materials and building practices of retrofits and new buildings.

Increasing knowledge and awareness of building longevity-related PSS among practitioners could create an input for new solutions during various phases of the building life-cycle, thus optimising circular material use.

Future research could build on this study in several ways. The economic rationale behind the building longevity-enhancing activities was unclear and requires further investigation. Specific circular building-related PSS types or themes could also be examined as separate cases, *e.g.* investigating integration-oriented PSS, which was left out of the study scope. Moreover, the role of resident-driven services and social dimensions of the identified PSS could be explored further. Comparative studies across international contexts could help to reveal how geographical, cultural or political differences influence the emphasis placed on various themes within circular building-related PSS.

AI DECLARATION

No artificial intelligence (AI) tools or assisted technologies were used in the preparation of this manuscript.

AUTHOR AFFILIATIONS

Anne Viljanen orcid.org/0000-0001-7166-8022
Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, FI

Angelina Korsunova-Tsaruk orcid.org/0000-0001-8424-2426
Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, FI

Janina Harmanen orcid.org/0009-0009-9340-9975
Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, FI

Elina Sofia Oijala orcid.org/0009-0004-0771-1187
Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, FI

Anne Toppinen orcid.org/0000-0003-0910-1505
Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, FI

AUTHOR CONTRIBUTIONS

A.V.: conceptualisation; data curation; formal analysis; funding acquisition; investigation; methodology; validation; visualisation; writing—original draft; writing—review and editing; A.K.-T.: conceptualisation; methodology; validation; writing—original draft; writing—review and editing; J.H.: data curation; writing—review and editing; E.S.O.: data curation; A.T.: conceptualisation; funding acquisition; methodology; validation; project administration; writing—original draft; writing—review and editing.

COMPETING INTERESTS

The authors have no competing interests to declare.

DATA ACCESSIBILITY

Due to confidentiality reasons promised upon receiving consent from interviewees, the qualitative data are not freely open at this time. However, the data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICAL APPROVAL

All interview data collected for this study were handled in accordance with general ethical standards and requirements of the University of Helsinki, and in line with applicable rules and regulations on privacy and data protection (General Data Protection Regulation (GDPR) and the Finnish Data Protection Act (1050/2018)). The processing of personal data is based on legal grounds about which the research subject is informed in the privacy notice and was not subject to ethical board review. The privacy notice includes detailed descriptions of the processing of personal data and the general processing activities. Informants were asked to give consent to participate in the study as representatives of affiliated organisations with personal details being highly limited (name, job description and professional contact information only). The highly limited personal data ensured ethical soundness of data handling. Thus, informed consent was obtained from all participants before the interviews took place, including for audio recording, third-party transcription and the publication of anonymised quotations, and the participants were promised anonymity. Anonymised datasets are protected by means of access control and only the identified project researchers had access via password protected institutional data storage.

FUNDING

This research was conducted with the funding of Business Finland (grant number 8348/31/2022) for the project 'Resilient Urban Building and Housing Solutions from Finnish Frontrunner Firms—Pathways for Global Exports' (FoREfront) ongoing in the period 2023–25; and by the funding of Strategic Research Council (SRC) established within the Research Council of Finland (grant number 358343) for the project 'Citizens as Agents of Change in Decarbonizing Suburban and Rural Housing' (DECARBON-HOME) ongoing in the period 2020–26.

SUPPLEMENTAL DATA

Supplemental data for this article can be found at: https://doi.org/10.5334/bc.882.s1

REFERENCES

Attia, S., Verdier, T., & **Van Acker, J.** (2025). How long can timber buildings last? Strategies for service life and sustainability. In Fink, G., Jockwer, R., & Cabrero, J. M. (Eds.), *Holistic design of taller timber buildings* (pp. 205–212). Springer Nature Switzerland. https://doi.org/10.1007/978-3-032-02098-7_16

Azcarate-Aguerre, J. F., den Heijer, A. C., & **Klein, T.** (2018). Integrated facades as a product–service system: Business process innovation to accelerate integral product implementation. *Journal of Facade Design and Engineering*, 6(1), 41–56. https://doi.org/10.7480/jfde.2018.1.1840

Benachio, G. L. F., Freitas, M. do C. D., & **Tavares, S. F.** (2020). Circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production*, 260, 121046. https://doi.org/10.1016/j.jclepro.2020.121046

Bergsagel, D., & **Heisel, F.** (2023). Structural design using reclaimed wood—A case study and proposed design procedure. *Journal of Cleaner Production*, 420, 138316. https://doi.org/10.1016/j.jclepro.2023.138316

Binz, C., Coenen, L., Frenken, K., Murphy, J. T., Strambach, S., Trippl, M., & **Truffer, B.** (2025). Exploring the economic geographies of sustainability transitions: Commentary and agenda. *Economic Geography*, 101(1), 1–27. https://doi.org/10.1080/00130095.2024.2445530

Boza-Kiss, B., Bertoldi, P., Della Valle, N., & **Economidou, M.** (2021). *One-stop shops for residential building energy renovation in the EU. Luxemburg*, https://doi.org/10.2760/245015

Circle Economy. (2025). *The circularity gap report 2025*. https://circularity-gap.world/report/2025/cgr-2025-overview

Clayton, R. J., Backhouse, C. J., & **Dani, S.** (2012). Evaluating existing approaches to product-service system design: A comparison with industrial practice. *Journal of Manufacturing Technology Management*, 23(3), 272–298. https://doi.org/10.1108/17410381211217371

Corsini, L. (2025). A systems approach the circular economy: Policy recommendations to increase building components reuse. *Sustainable Production and Consumption*, 57, 292–305. https://doi.org/10.1016/j.spc.2025.05.019

Ding, Y., Pang, Z., Lan, K., Yao, Y., Panzarasa, G., Xu, L., Lo Ricco, M., Rammer, D. R., Zhu, J. Y., Hu, M., Pan, X., Li, T., Burgert, I., & **Hu, L.** (2023). Emerging engineered wood for building applications. *Chemical Reviews*, 123(5), 1843–1888. https://doi.org/10.1021/acs.chemrev.2c00450

Dorst, H., van der Jagt, A., Raven, R., & **Runhaar, H.** (2019). Urban greening through nature-based solutions—Key characteristics of an emerging concept. *Sustainable Cities and Society*, 49, 101620. https://doi.org/10.1016/j.scs.2019.101620

Evans, P. D., Matsunaga, H., Preston, A. F., & **Kewish, C. M.** (2022). Wood protection for carbon sequestration—A review of existing approaches and future directions. *Current Forestry Reports*, 8(2), 181–198. https://doi.org/10.1007/s40725-022-00166-x

Ghafoor, S., Hosseini, M. R., Kocaturk, T., Weiss, M., & **Barnett, M.** (2023). The product-service system approach for housing in a circular economy: An integrative literature review. *Journal of Cleaner Production*, 403, 136845. https://doi.org/10.1016/j.jclepro.2023.136845

Given, L. M. (2016). *100 Questions (and answers) about qualitative research*. SAGE. https://doi.org/10.4135/9781483398655.n30

Hakaste, H., Häkkinen, T., Lahdensivu, J., & **Saarimaa, S.** (2024). *Lifecycle performance in promoting the longevity of buildings durability, adaptability and reusability as tools for a circular economy*. Ministry of the Environment. https://urn.fi/URN:ISBN:978-952-361-187-0

Heaton, J. (2008). Secondary analysis of qualitative data: An overview. *Historical Social Research/Historische Sozialforschung*, 33(3), 33–45. https://doi.org/10.12759/hsr.33.2008.3.33-45

Heinonen, K. (2025). Editorial: Designing for complexity and regeneration: new perspectives in service design. *Journal of Services Marketing*, 39(7), 725–727. https://doi.org/10.1108/JSM-06-2025-0432

Honkatukia, J., Tamminen, S., & **Ahokas, J.** (2014). *Suomi on jo palvelutalous*. https://urn.fi/URN:NBN:fi-fe20260709110443

Julistiono, E. K., Oldfield, P., & **Cardellicchio, L.** (2024). Up on the roof: A review of design, construction, and technology trends in vertical extensions. *Architectural Science Review*, 67(1), 63–77. https://doi.org/10.1080/00038628.2023.2240289

Jussila, J., Nagy, E., Lähtinen, K., Hurmekoski, E., Häyrinen, L., Mark-Herbert, C., Roos, A., Toivonen, R., & **Toppinen, A.** (2022). Wooden multi-storey construction market development—Systematic literature review within a global scope with insights on the Nordic region. *Silva Fennica*, 56(1), 1–24. https://doi.org/10.14214/sf.10609

Kinnunen, A., Talvitie, I., Ottelin, J., Heinonen, J., & **Junnila, S.** (2022). Carbon sequestration and storage potential of urban residential environment—A review. *Sustainable Cities and Society*, 84, 104027. https://doi.org/10.1016/j.scs.2022.104027

Konietzko, J., Das, A., & **Bocken, N.** (2023). Towards regenerative business models: A necessary shift? *Sustainable Production and Consumption*, 38, 372–388. https://doi.org/10.1016/j.spc.2023.04.014

Kuittinen, M. (2023). Building within planetary boundaries: Moving construction to stewardship. *Buildings & Cities*, 4(1), 565–574. https://doi.org/10.5334/bc.351

Kylkilahti, E., Autio, M., Harvio, V., Holmberg, U., & **Toppinen, A.** (2024). Co-developing sustainability—A consumer-inclusive approach to wooden housing business in Finland. *Housing Studies*, 39(5), 1219–1238. https://doi.org/10.1080/02673037.2022.2114592

Lähtinen, K., & **Häyrinen, L.** (2022). Servitisation and the future of business development—Insights from the forest industry. In D'Amato, D., Toppinen, A., & Kozak, R. (Eds.), *The role of business in global sustainability transformations* (pp. 96–115). Routledge. https://doi.org/10.4324/9781003003588-9

Lavikka, R., & **Laiho, S.** (2023). Motivations and market solutions for flexible housing in Finland. *Journal of Housing and the Built Environment*, 38(3), 1789–1818. https://doi.org/10.1007/s10901-023-10013-5

López-Mesa, B., Hernández-Minguillón, R. J., Gómez-Gil, M., & **Arbulu, M.** (2024). Assessing the effectiveness of building renovation policies and decarbonization progress: A review of European legislation. In López-Mesa, B., & Oregi, X. (Eds.), *Assessing progress in decarbonizing Spain's building stock: Indicators and data availability* (pp. 1–16). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-51829-4_1

Lukkarinen, J. P., Lähteenoja, S., Hyysalo, S., Marttila, T., Faehnle, M., & **Korhonen-Kurki, K.** (2025). Trade-offs in expanding citizen participation in low-carbon transitions: Seven transition arena experiments. *Environmental Science & Policy*, 172, 104198. https://doi.org/10.1016/j.envsci.2025.104198

Mont, O. K. (2002). Clarifying the concept of product–service system. *Journal of Cleaner Production*, 10(3), 237–245. https://doi.org/10.1016/S0959-6526(01)00039-7

Neely, A. (2009). Exploring the financial consequences of the servitization of manufacturing. *Operations Management Research*, 1(2), 103–118. https://doi.org/10.1007/s12063-009-0015-5

Neise, T., Verfürth, P., & **Franz, M.** (Eds.). (2024). *The changing economic geography of companies and regions in times of risk, uncertainty, and crisis*. Routledge. https://doi.org/10.4324/9781003457626

Niu, Y., Rasi, K., Hughes, M., Halme, M., & **Fink, G.** (2021). Prolonging life cycles of construction materials and combating climate change by cascading: The case of reusing timber in Finland. *Resources, Conservation and Recycling*, 170, 105555. https://doi.org/10.1016/j.resconrec.2021.105555

Öberg, V., Jockwer, R., & **Goto, Y.** (2024). Design for structural adaptation in timber buildings: Industry perspectives and implementation roadmap for Sweden and Australia. *Journal of Building Engineering*, 98, 111413. https://doi.org/10.1016/j.jobe.2024.111413

Pardalis, G., & **Sula, M.** (2026). One-stop shops as leverage points for renovation sufficiency. *Buildings & Cities*, 7(1), 614–632. https://doi.org/10.5334/bc.811

Patrizi, N., Sporchia, F., Ruini, A., Neri, E., Bruno, M., Zarroli, G., Bastianoni, S., & **Marchettini, N.** (2026). Designing for reuse in timber buildings: The environmental benefits of aligning the time of nature and time of use. *Resources, Conservation and Recycling*, 225, 108638. https://doi.org/10.1016/j.resconrec.2025.108638

Pelli, P. (2021). Service innovation and sustainable construction: Analyses of wood vis-à-vis other construction projects. *Cleaner Engineering and Technology*, *2*, 100061. https://doi.org/10.1016/j.clet.2021.100061

Pelli, P., & **Lähtinen, K.** (2020). Servitization and bioeconomy transitions: Insights on prefabricated wooden elements supply networks. *Journal of Cleaner Production*, 244, 118711. https://doi.org/10.1016/j.jclepro.2019.118711

Pelsmakers, S., & **Warwick, E.** (2022). Housing adaptability: New research, emerging practices and challenges. *Buildings & Cities*, 3(1), 605–618. https://doi.org/10.5334/bc.266

Pihelo, P., Kuusk, K., & **Kalamees, T.** (2020). Development and performance assessment of prefabricated insulation elements for deep energy renovation of apartment buildings. *Energies*, 13(7), 1–20. https://doi.org/10.3390/en13071709

Pitti, A. R., Espinoza, O., & **Smith, R.** (2020). The case for urban and reclaimed wood in the circular economy. *BioResources*, 15(3), 5226–5245. https://doi.org/10.15376/biores.15.3.5226-5245

Pomponi, F., & **Moncaster, A.** (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production*, 143, 710–718. https://doi.org/10.1016/j.jclepro.2016.12.055

Reike, D., Vermeulen, W. J. V., & **Witjes, S.** (2018). The circular economy: New or Refurbished as CE 3.0?—Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation and Recycling, Sustainable Resource Management and the Circular Economy*, 135, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027

Reim, W., Parida, V., & **Örtqvist, D.** (2015). Product-service systems (PSS) business models and tactics—A systematic literature review. *Journal of Cleaner Production*, 97, 61–75. https://doi.org/10.1016/j.jclepro.2014.07.003

Stebbins, R. A. (2001). *Exploratory research in the social sciences*. SAGE. https://doi.org/10.4135/9781412984249

Teece, D. J. (2009). *Dynamic capabilities & strategic management: Organizing for innovation and growth*. Oxford University Press.

Tukker, A. (2004). Eight types of product–service system: Eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment*, 13(4), 246–260. https://doi.org/10.1002/bse.414

Werrel, M., Klar, M., & **Aurich, J. C.** (2024). Circularity assessment of product–service systems using system dynamics modeling. *Sustainable Production and Consumption*, 52, 124–135. https://doi.org/10.1016/j.spc.2024.10.021

Windrum, P., Schartinger, D., Rubalcaba, L., Gallouj, F., & **Toivonen, M.** (2016). The co-creation of multi-agent social innovations: A bridge between service and social innovation research. *European Journal of Innovation Management*, 19(2), 150–166. https://doi.org/10.1108/EJIM-05-2015-0033

Wu, C., Wang, X., Chen, T., Li, H., & **Wang, H. qi.** (2025). Conceptual design of smart product–service system based on function-oriented search. *Journal of Engineering Design*, 36(5–6), 976–1010. https://doi.org/10.1080/09544828.2024.2432837

Yang, M., & **Evans, S.** (2019). Product–service system business model archetypes and sustainability. *Journal of Cleaner Production*, 220, 1156–1166. https://doi.org/10.1016/j.jclepro.2019.02.067

Yang, M., Smart, P., Kumar, M., Jolly, M., & **Evans, S.** (2018). Product–service systems business models for circular supply chains. *Production Planning & Control*, 29(6), 498–508. https://doi.org/10.1080/09537287.2018.1449247

TO CITE THIS ARTICLE:
Viljanen, A., Korsunova-Tsaruk, A., Harmanen, J., Oijala, E. S., & Toppinen, A. (2026). Extending building longevity: wood-based product–service systems. *Buildings and Cities*, 7(1), pp. 1298–1313. DOI: https://doi.org/10.5334/bc.882

Submitted: 10 June 2026
Accepted: 26 October 2026
Published: 16 November 2026

COPYRIGHT:
© 2026 The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. See https://creativecommons.org/licenses/by/4.0/.

Buildings and Cities is a peer-reviewed open access journal published by Ubiquity Press.