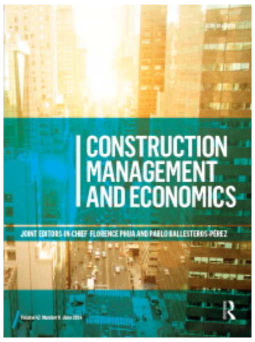

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To renovate or build with wood? Results from Finnish citizen survey data

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ABSTRACT

Finland shows strong support for reducing its climate footprint originating from the built environment as part of the national carbon neutrality goal by 2035. Two prime examples are increasing wood use in construction and favoring building renovation to alleviate emissions from the use of virgin construction materials. However, the open question remains whether citizens also support these decarbonization pathways. By using national-level data from a randomly sampled citizen survey in Finland ($n = 1448$), we model citizen preferences to these two decarbonization pathways. The results suggest that a preference to renovate rather than to build anew is shown by respondents of the female gender; over 55 years of age; with a lower household equivalent income; and possessing housing property investment. Wood material is positively favored by respondents with higher age; a lower household equivalent income; living in smaller population centers in the countryside; and owning forestland. Interestingly, the effect of climate agency was negative in both models. This can be interpreted in the wood material case as reflecting conflicting views of negative environmental effects from forest harvesting to produce renewable building materials. In the renovation model case, we argue that the climatic impact of renovations remain weakly understood by citizens in Finland, given that the media and national regulations emphasize operational emissions. These results benefit both policy makers and municipal-level decision making in understanding of acceptability of wood material use and building retrofits among the general public.

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Housing characteristics; climate agency; renovation; survey data

Introduction

The building sector constitutes one of the largest global users of virgin resources and produces over one third of global carbon dioxide (CO_2) emissions (United Nations Environment Programme UNEP 2022). These emissions can be parsed into two categories: operational emissions, and embodied emissions. Operational emissions constitute emissions generated during a buildings occupational phase, for instance heating, cooling, or lighting. In 2021, the operational emissions of buildings reached an all-time high of 10 $GtCO_2$ (UNEP 2022, p. xvi). Embodied emissions are generated through the production of buildings materials used either to construct new buildings or to renovate existing buildings. The embodied emissions associated with the building sector were estimated to account for 3.6 $GtCO_2$ in 2021 (UNEP 2022, p. xvi). Various strategies for reducing embodied emissions are available (e.g., see the meta-analysis by Pomponi and Moncaster 2016).

The European Union (EU) is striving to become the 'first climate-neutral continent' by 2050 (EU 2019), with the EU's Green Deal roadmap proposing various key policies and measures towards achieving inclusive carbon neutrality objectives. Altogether, eight areas for transformation are highlighted, one of which addresses the energy and resource intensiveness of the building sector through the construction and renovation of buildings (UNEP 2022, Section 2.1.4). While both operational and embodied emissions constitute major sources of global emissions, researchers argue that operational emissions have historically received greater attention in the literature (Pomponi and Moncaster 2016, Seo *et al.* 2018). This disparity is evident when examining building codes across the globe – few national building codes are found to account for embodied carbon (UNEP 2022, p. 27). To

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progress towards more environmentally sustainable construction, Salmi *et al.* (2022) highlight the importance of local conditions and the municipal context, which calls for understanding decision-making rationale at the local market level (see also Franzini *et al.* 2023).

One approach is substituting energy-intensive construction materials with low-carbon construction materials. Cradle-to-gate analysis of construction materials find that the emissions generated during the production of construction materials vary widely (e.g., Hertwich *et al.* 2019, table 1), some of which estimate that the emissions associated with concrete production to be more than twice that of wood products. To this end, various researchers have examined and promoted the substitution of wooden construction materials in lieu of concrete as a means of reducing embodied carbon emissions (e.g., Churkina *et al.* 2020). This relates especially to multistory residential buildings, which from the early twentieth century have been built dominantly with non-renewable materials (i.e., concrete, steel, and bricks) (Urban 2012). As a result of global population increase and urbanization, multistorey residential construction will contribute the highest growth in the global use of building materials (Marinova *et al.* 2020). In all, building with wood to substitute nonrenewable materials has strong potential to enhance environmental benefits both in construction (e.g., decarbonization and energy efficiency) and at the occupational phase of buildings (e.g., carbon storage and energy efficiency when combined with well-controlled building service technologies) (Dangel 2016, Nore *et al.* 2017, Amiri *et al.* 2020). However, the extent of the substitution impact offered by wooden construction materials remain open (Hurmekoski *et al.* 2023).

One strategy highlighted by the European Commission under its Renovation Wave (EU 2020), aiming to reduce embodied emissions, is to decrease the overall volume of construction materials. This can be achieved by lessening material consumption via building renovations that increase the lifespan of the built environment, thereby reducing undue building demolition (e.g., Pomponi and Moncaster 2016). Hence, renovation is an equally important driver of building material consumption as new construction, and the importance of renovation is expected to grow in the future due to the increasing share of middle-aged population in Europe (e.g., Hurmekoski *et al.* 2015). According to Power (2008), compared to demolition, home refurbishment may bring both environmental (e.g., greater reuse of materials, reduced landfill disposal) and socioeconomic (e.g., local economic development, neighborhood renewal) benefits. While little research exists quantifying the extent to which increasing building renovation and building life cycles lead to decreased virgin material extraction and reduced embodied emissions (Schwartz *et al.* 2022, Ruokamo *et al.* 2023), the role of material reuse and recycling is growing in the era of a circular economy and tightening international regulation (Ogunmakinde *et al.* 2022). The final amount of 're-use versus waste generated' depends on the locally available waste management system and regulation. For example, a review by Menegaki and Damigos (2018) on construction and demolition waste practices finds that, among EU member states, some member countries recycle up to 90% of their construction and demolition waste while other countries achieve recycling rates of only 15%.

Overall, extending the lifetime of buildings through deep renovation rather than demolishing and building anew can be associated with lower embodied emissions (Schwartz *et al.* 2018, Ramboll 2020), but the emissions impacts are typically case-specific and depend on many aspects such as construction and renovation methods, logistics, building characteristics and used materials (Schwartz *et al.* 2018). According to Marinova *et al.* (2020), residential buildings are primarily constructed using virgin materials and, due to a global population increase, the need for housing is to increase during forthcoming decades. This is a result of various barriers, including a lack of coordinated actions and policies that encourage the circularity of materials and components in the building sector (e.g., local building practices and formal building code regulations impede the use of such materials in construction) (Giorgi *et al.* 2022). Furthermore, building demolition practices are complex, in that demolished materials can either follow a circular pathway of reuse or a linear pathway of waste and landfilling.

While strategies focused on lower-carbon material substitution and reducing building demolitions provide approaches towards decarbonizing the built environment, the implementation of these pathways have proven challenging, especially in the context of residential multistory buildings. To illustrate this example, we turn to the case of Finland, which has set ambitious goals to reach national level carbon neutrality by year 2035. Aiming to reduce carbon emission within the building sector, the Finnish Ministry of the Environment (YM) supports the implementation of wooden construction, especially in the public sector (Toivonen *et al.* 2021). This has culminated in key agenda voluntary targets to increase the number of public wooden multistory buildings[1] across the country), but despite this, the market share of wooden multistory apartments has according to YM (2020) remained below 10%, representing an untapped opportunity in the residential housing market.

In a similar fashion, Huuhka and Lahdensivu (2016) show that Finland's demolition rate (0.25% of the existing stock if measured as the number of buildings, and 0.15% if measured as floor area) is among the highest when compared with other Western European countries with demolition rates varying between 0.025% and 0.20% (Thomsen and van der Flier 2011). The typical cause for demolition is to give way for new construction; meanwhile, destruction or abandonment account for only a minority of demolition decisions (Huuhka and Lahdensivu 2016). This suggests untapped possibilities for renovations rather than the standard operation to demolish and build a new construction project. Compared to current or future residents, construction value chain actors (e.g., developers, architects, engineers) have a larger possibility to influence housing material choice (Jussila *et al.* 2020), but they often associate wood with low attractiveness as a structural frame material in housing projects (Toppinen *et al.* 2019).

As citizens are a critical societal group who can both provide acceptance towards novel innovation and create demand-pull in the housing market through their views on materials (e.g., Harju and Lähtinen 2022), scoping consumer preferences towards various strategies in the build environment is important. In addition, due to the large proportion of owner-occupied housing both in the detached and multistorey residential housing sectors in Finland (appr. 60% of the housing stock) (Andersson *et al.* 2007), Finnish citizens have influence on the choices of building materials. In case of new residential building, future homeowners of single-family house are key decision-makers at all phases of building processes (Jussila and Lähtinen 2022), while for multistorey construction the decisions on the load-bearing materials and facades are typically made by construction companies (Lähtinen *et al.* 2023). At the time of renovations, also in the residential owner-occupied multistorey buildings, the power of homeowners as decision-makers increases due to their role as shareholders in these limited liability companies (in Finland called as "housing companies") (Lujanen 2010). Thus, especially in case of the Finnish owner-occupied housing sector, consumers bear financial responsibility for the overall maintenance of their homes also in the multistorey building sector (e.g., Puustinen *et al.* 2017).

To this end, the overall aim of this study is to examine citizen preferences towards two environmentally oriented sustainability pathways, that is, (1) adopting wooden materials as the primary material in residential housing construction, and (2) preferring building renovations rather than demolishing and rebuilding. Our study sample is made up of Finnish nationals, who we refer to as citizens. Consequently, we formulate a research question as: Do citizen sociodemographic characteristics, housing attributes or citizen climate agency influence their preferences on the two decarbonization pathways connected to the wooden material usage and building renovations?

Background literature

In the consumer literature, various factors are found to impact citizen preferences towards using wood in construction. Regarding the potential of wood to decarbonize the built environment, it is of a key importance to identify how citizens' climate perceptions impact their preferences towards wooden materials. For example, several studies indicate that citizens perceive wooden construction materials as *environmentally friendly* (e.g., Gold and Rubik 2009, Høibø *et al.* 2015, Larasatie *et al.* 2018, Lähtinen *et al.* 2019, Viholainen *et al.* 2020, Lähtinen *et al.* 2021, Harju and Lähtinen 2022).

However, the literature occasionally operationalizes 'environmental friendliness' as an umbrella term, thereby creating uncertainty over which dimensions are viewed as environmentally (un)friendly. Viholainen *et al.* (2020) find that citizens hold various positive and negative views about the environmental outcomes of using wood in construction, citing topics such as forest management, circularity, biodiversity, climate change, and energy consumption. The study also finds that a citizen may hold ambivalent views, meaning the same citizen might associate using wood in construction as a means towards mitigating climate change that concomitantly leads to biodiversity loss (see also Larasatie *et al.* 2018).

While the relationship between citizens' *climate change awareness* and their preferences towards wooden construction materials is cited across various studies (e.g., Roos *et al.* 2022; Vehola *et al.* 2022), climate awareness and environmental friendliness remain distinct elements. Aguilar *et al.* (2023) show that the positive relationship between citizen desires to reduce their carbon footprint and preferences for wooden construction are diminished among citizens who also believe that harvesting wood leads to habitat destruction. Importantly, citizens also evaluate other properties of a wooden construction material when forming preferences. The literature has cited that citizen preferences are impacted by aspects such as technical durability (Nore *et al.* 2017) and whether the material leads to a high-quality lifestyle (see e.g., Lähtinen *et al.* 2021, Harju and Lähtinen 2022, Roos *et al.* 2022). However, the impact of climate awareness and other so-called 'climate perceptions' on material preferences is especially relevant when considering whether citizens will prefer wooden materials as a decarbonization strategy. For example, in the context of Japan, wooden construction may represent a renaissance for using traditional building techniques and increasing the use of renewable materials to meet new citizen preferences for building quality, which are lacking in the existing housing stock (Wuyts *et al.* 2019).

Apart from the views on how construction materials impact environmental outcomes, researchers have also studied the relationship between various sociodemographic factors against citizen preferences for wood. For example, the role of *age, education, gender, income,* and *locality* are all previously explored sociodemographic factors (e.g., Hoibo *et al.* 2015, Harju and Lähtinen 2021, Roos *et al.* 2022; Vehola *et al.* 2022, Aguilar *et al.* 2023). Observing sociodemographic characteristics helps in identifying different beliefs among consumer segments. For example, while Hoibo *et al.* (2015) failed to find an outright relationship between sociodemographic and citizens' stated preferences for wood, the study did observe weak signals that younger citizens tended to prefer wood. They argued that this reflected the younger generation's larger preferences towards the use of environmentally friendly materials. Vehola *et al.* (2022) also noted that age is related to citizen beliefs towards wooden construction; specifically, older age groups held larger negative beliefs concerning the outlook of wooden buildings. However, unlike Hoibo *et al.* (2015), the findings from Vehola *et al.* (2022), related to identified positive effect of citizens' climatic beliefs, focused on the technical properties of wooden material use, especially related to extreme weather events.

Another noteworthy sociodemographic factor is whether a citizen inhabits an urban or rural locality (Høibø *et al.* 2018, Lähtinen *et al.* 2021, Roos *et al.* 2022, Vehola *et al.* 2022). These studies consistently find that citizens residing in urban settings tend to regard wooden construction more skeptically. In other words, urban residents have more negative beliefs towards wooden construction materials. It appears that both groups share similar environmental beliefs but their beliefs concerning the technical qualities of wooden construction materials differ (e.g., Lähtinen *et al.* 2021, Roos *et al.* 2022). Finally, following Harju and Lähtinen (2021) or Vehola *et al.* (2022), we may add *forest land ownership* as potential determinant of propensity to favor wood construction, considering the high importance of private land ownership in the Finnish context.

There is very limited research providing insights concerning citizens' views of renovations to increase building lifespans and promote decarbonization. Hence, we turn to the literature on consumer choices to undertake energy-related retrofits to provide information on possible factors underpinning their preferences towards building renovation. In addition, compared to the construction of new buildings, supply-related factors in the renovation markets are characterized by handicraft-based individual solutions combined with a lack of energy standards, audit reports, or certificates (Mahapatra *et al.* 2013). Due to the multiple economic, environmental, and social impacts of renovations on residential building owners and residents, decisions concerning such factors would frequently require case-by-case evaluations (Wuyts *et al.* 2019). In addition, from the perspective of demand-related factors, practices of the citizens as residents at the occupational phase of buildings are in a more important role compared to the production of new dwellings.[2]

Conceptually, Zavadskas *et al.* (2004) have categorized the factors affecting resident renovation decisions as macro-level (e.g., environmental, social, and economic factors) and micro-level factors (e.g., indoor environmental quality, health benefits). In all, propensity to renovate residential buildings has been found to be connected to the physical attributes of the dwellings (e.g., quality of foundations, technical solutions and materials) affected by national building traditions combined with economic aspects (e.g., mortgages, taxation, subsidies) that, abreast with individual preferences (e.g., lifestyle, living standards), reflect in citizen views concerning renovations (Wuyts *et al.* 2019). Likewise, according to Organ *et al.* (2013), several economic and market motivation factors for refurbishment exist that, if absent, may also act as hindrances. On the *economic* side, factors include high energy bills, household income, and other *sociodemographic* variables. Of the non-economic factors, *comfort, social norms,* or a lowering *carbon footprint* and environmental impact are listed.

Empirical studies provide a scattered picture of the energy renovations phenomenon: Baumhof (2018) and Jowkar *et al.* (2022) are among the few recent examples applying survey methods to study residents' motivation toward energy renovations. Clearly, *housing ownership* plays a large role in decision-making, and Astmarsson *et al.* (2013) found residents renting their property on the Danish housing market to be reluctant or even unable to undertake sustainability retrofits without full-package solutions consisting of legislative changes, financial incentives, and solid dissemination of information. Hence, in empirical analysis, the ownership and *length of tenancy,* along with the *type of housing* (single, multi-family) need to be acknowledged.

According to a structural equations analysis with data from Germany, Baumhof (2018) found altogether 17 indicators as significant explanators regarding motivation, opportunity, and ability to affect the extent of energy-related refurbishment efforts made by owner-occupiers of single and two-family houses, including factors such as economic aspects or a need for building maintenance, or having related *knowledge*. Zundel and Stieß (2011) found that, in their survey from Germany, non-economic factors connected to issues of *building aesthetics, everyday life,* or *support of low-carbon lifestyle* and perceived resilience against climate change may also play a role in addition to operating costs and securing house value.

As barriers limiting interest in home renovation, Jowkar *et al.* (2022) found economic issues and perceived high cost to be the most common reasons among citizens in a case of one Norwegian city. Capital may be scarcely available, and instead of lowering emissions from housing, homeowners may be more interested in interior investments, such as renovating kitchens or bathrooms, or they may suffer from the knowledge of lower energy bills via energy efficiency measures (Jowkar *et al.* 2022). Based on experimenting with various interactive tools with homeowners, Temeljotov-Salaj *et al.* (2020) found the motivation for upgrading dwellings to vary: some are interested in the *social aspects* and development of their *community* in connection with their *living environment* rather than just their own residence, while others only consider the private benefit of renovating their own dwellings. Drawing from an analysis of six European countries, Ferreira *et al.* (2013) also emphasize the *expectation of future reduced costs* as an elementary aspect. Hence, suppliers and installers of energy improvement investments may have a significant influencer role on homeowner decisions. To recap, we have a myriad of potential factors motivating citizens towards low-carbon housing renovation investments, including economic and sociological factors, comfort, and esthetics, along with pro-environmental perceptions like a low-carbon lifestyle and perceived housing resilience against climate change. However, it is a task for forthcoming empirical analysis to reveal which are the key determinants in the case of the renovation market in Finland and to contrast these with factors arising in a case where wood, a low-carbon building material, is preferred.

Data and methods

Survey material collection

The data described in this research study are part of a larger questionnaire targeting the preferences of Finnish citizens towards climate-wise housing and low-carbon construction policies. The questionnaire was designed iteratively through researcher workshops. The target group of the survey consisted of people permanently residing in Finland. Thus, the survey was conducted in two official languages in Finland (i.e., Finnish and Swedish) and English by first designing the questions and variables in Finnish and subsequently translating the contents into Swedish and English. Prior to data collection, the survey design was tested in two phases: First, we conducted 16 interviews to recieve preliminary feedback on the survey content in October 2021. Second, the formulation of the survey items and appropriate understanding of the questions among the target groups was tested in the three data collection languages (i.e., Finnish, Swedish, and English) using a pilot survey ($n = 55$) conducted between January and February of 2022. However, these pilot responses were not merged with the responses of the final survey due to differences in the questionnaire and sampling method.

A simple random sample of 10,000 individuals was collected from the official population records managed by the Digital and Population Data Services Agency of Finland. A third-party service was used to deliver an invitation by post with instructions for participating in the survey. Each participant had their own identification number to access the online survey. The online survey platform used a third-party web-based program (*Webropol*). The postal letters were delivered on the second week of March 2022. A reminder was distributed 3.5 weeks later and the survey remained open until 24 April 2022. Respondents who completed the survey were eligible to participate in a random lottery draw.

A total of 1448 survey responses were collected, reflecting a 14.5% response rate. The respondents were representative of the average household size (see Table 1). Moreover, the division of respondents between rural and urban areas and house type similar to the national average. However, the respondents were somewhat older and included slightly more women than the original random sample. The collected sample was also more educated than the average Finnish population of over 15-year-olds. This difference is, however, mitigated if we account for the fact that the collected sample only included individuals aged between 18 and 80. Unfortunately, national-level income distribution is not publicly available with the presented division.

Abreast with the general measures, such as sample characteristics in relation to population or response rate, the representativeness of the survey data is also affected by potential bias sources (Cook *et al.* 2000). Incorrect answer bias (e.g., Nederhof 1985) and social desirability bias (Sjöström *et al.* 1999) were reduced in this study by piloting the survey in a test group (i.e., enhancing question validity) and by securing respondent anonymity (i.e., avoiding any impacts of responses given to please the interviewers or other respondents). As a result of both statistical considerations in relation to population in Finland and the process of material gathering, the representativeness of the data of this study can be considered fairly good.

Dependent and explanatory variables

The survey included two statements to measure preferences toward wood construction and building renovation. These statements were (i) 'I think it is important to use wood as the main material in new residential buildings', that is, *Wood*, and (ii) 'I think that renovating and repairing buildings should be favored instead of tearing them down and building new ones', that is, *Renovate* (see Figure 1). Responses were anchored to a bipolar scale from −2 to 2, measured with a Likert scale ('Strongly disagree', 'Somewhat disagree', 'Neither agree not disagree', 'Somewhat agree', 'Strongly agree') and supplemented with the escape option 'I cannot say'. The responses to the two statements were transformed into binary categorical measures, where responses from −2 to 0 were recoded as 0, and responses from 1 to 2 were recoded as 1. In addition, 'I cannot say' responses were recoded as 0. Approximately 71% of the respondents either 'Somewhat agreed' or 'Strongly agreed' with the renovate statement, whereas the corresponding share for the wood statement was 61% (Figure 1).

Table 1. Descriptive statistics of the survey respondents and the corresponding population in Finland.

	Respondents ($n = 1448$)	Population in Finland
Age in years (average)	52.7	49.4[a]
Household size (average)	2.4	2.4[a]
Gender (%)		
Female	53.3	51.1[a]
Male	46.7	48.9[a]
Household gross income in euros/month (%)		
<2,000	13.5	–
2000–3999	28.2	–
4000–5999	24.8	–
6000–7999	15.4	–
8000–9999	8.7	–
>10,000	6.1	–
No response	3.3	–
Education (%)		
Primary, secondary (e.g., vocational degree), or other education	55.6	–
Higher education (university or applied sciences degree)	44.4	33.0[b]
Community type (urban – rural division) (%)		
Town or city	69.5	72.3[c]
Sparsely populated area or small population center	29.9	27.7[c]
Other or no response	0.6	–
House type		
Detached or semidetached house	51.2	47.8[d]
Row house	12.4	13.2[d]
Apartment building	34.9	37.7[d]
Other or no response	1.5	1.3[d]

[a]Random sample ($n = 10{,}000$) obtained from the civil registry.
[b]Finnish population of those over 15 years old in 2021 (Official Statistics of Finland 2023a).
[c]GIS-based urban–rural classification for Finland and the Finnish population from Helminen *et al.* (2020).
[d]Finnish dwellings and housing conditions in 2021 (Official Statistics of Finland 2023b).
– Non-available national level information.

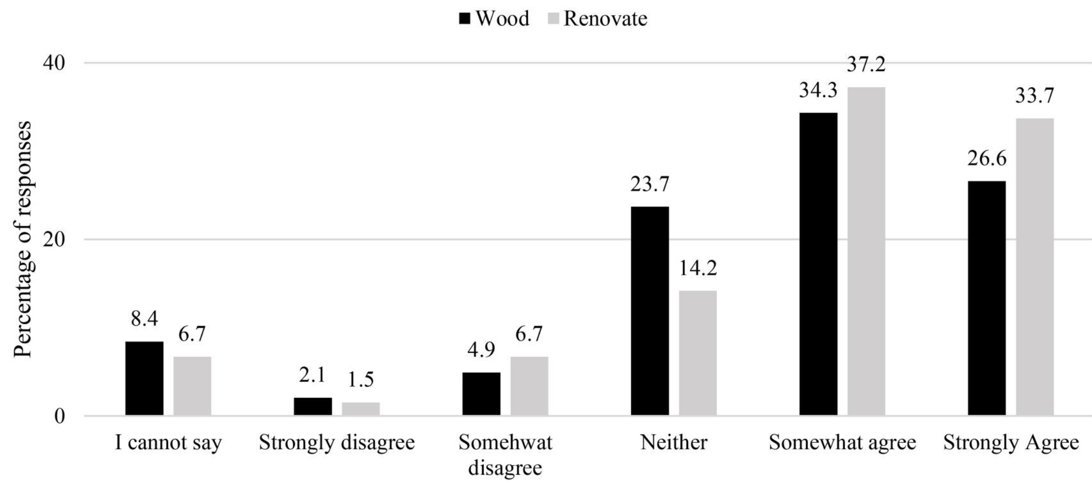

Figure 1. Respondent beliefs concerning the importance of using wood as the main material in residential construction (Wood), and the beliefs whether renovating buildings is preferred to demolishing and reconstruction (Renovate).

To explore preferences toward *Wood* and *Renovate,* we used background factors measuring respondents' sociodemographic characteristics, housing characteristics, and climate change agency I (see also Section 2 for the motivation of explanatory variables). Note that 206 respondents were excluded from the analysis due to missing or 'I cannot say' responses to some of the explanatory variables. In particular, missing responses to the income question ($N = 108$) and 'I cannot say' responses about forest ownership and housing property investment decreased the number of observations.

The descriptions and full set of response frequencies of the background questions are available in Table 2. The background information was collected using both categorical and continuous measures. The continuous measures (i.e., age and home size) were transformed from continuous into categorical measures with four levels by using the quartile distribution of the continuous range as the cutoff points for the categories. Household equivalent income (HEI) variable was created by using the original household monthly gross income and dividing it by the number of consumption units in the household (see details about *equivalent income* in Official Statistics of Finland 2022). Note that the highest income group was omitted from the analysis due to implausibility to calculate the HEI similarly to other income groups.

Furthermore, the survey covered 14 items measuring citizens' climate perceptions (Appendix), which were utilized to create a latent variable with factor analysis. Climate change perception is a complex multidimensional element that according to previous literature includes various psychological characteristics such as perceived risk and worry about climate change (incorporating knowledge, attitude, beliefs, and effects) (e.g., Bouman *et al.* 2020). In our measurement scale it also captures climate action among decision-makers and the aspect of global responsibility, so we name the variable as citizen climate agency.

Methods of exploratory factor analysis and binary logistic regression analysis

Exploratory factor analysis (EFA) and binary logistic regression (BLR) were used as the analysis methods. EFA allows investigating a particular phenomenon by identifying factors (i.e., latent variables) that are less in number compared with the original variables and that are based on the covariation between them (Kim and Mueller 1978, Henson and Roberts 2006). In this study, EFA with maximum likelihood estimation was employed to build a latent variable for climate agency for variables in Appendix addressing the question 'Do you agree or disagree with the following statements related to climate change?'.

After EFA execution, BLR was used to assesses interrelationships between a dichotomous dependent choice variable and independent variables (Pampel 2000). BLR modeling provides information on the underlying factors driving the outcome of the dependent variable and the occurrence probability of the phenomenon (Woolridge 2010). One advantage of this approach is that it can estimate the effect of both continuous and categorical independent variables on a binary dependent variable (Hair *et al.* 2019: Chapter 8). In this study, the two binary categorical preference items (respondent preferences towards *Wood* and *Renovate*) were employed in two separate BLR models as dependent variables, which were tested

Table 2. Overview of dependent and explanatory variables.

Variables and descriptions	Category	Frequency
Dependent variables:		
Wood (Prefer to use wood as the main material in new buildings)	Nominal	
Yes		756
No		486
Renovate (Prefer to renovating rather than demolish and build a new)	Nominal	
Yes		881
No		361
Explanatory variables:		
Sociodemographic		
Gender	Nominal	
Male		567
Female		675
Age	Ordinal	
18–36		284
37–54		309
55–67		331
68–81		318
Education	Ordinal	
Elementary school		104
Vocational/HS Diploma		379
College level degree		213
Lower university degree		248
Higher university degree		298
Occupation	Nominal	
Employed		656
Pension		456
Student		82
Unemployed		48
Household Equivalent Income (HEI)	Ordinal	
<1000€		87
1000–1999 €		384
2000–2999 €		362
3000–3999 €		225
4000–4999 €		111
5000–5999 €		73
Forest Ownership (Household member(s) own(s) forest)	Nominal	
No		913
Yes		329
Housing Property Investment (Household member(s) hold(s) housing property investment(s))	Nominal	
No		1035
Yes		207
Second Home (Household Member(s) own(s) a second home)	Nominal	
No		861
Yes		381
Housing characteristics		
Home Type	Nominal	
Apartment		417
Detached house		602
Other		223
Living Environment around the home	Ordinal	
City center		172
Urban residential, majority apartments		248
Urban residential, majority of single-family houses		440
Local centre in the countryside		150
Sparsely populated area in the countryside		232
Home Size (m^2)	Ordinal	
17–49		134
50–70		217
71–97		249
98–853		642
Home Tenancy	Nominal	
Owner		958
Rental		249
Other		35
Home Time (Time inhabiting the current home in years)	Ordinal	
0–1		201
2–5		241
6–18		368
18+		432
Climate agency (Variable built based on exploratory factor analysis)	Continuous	1242

Table 3. Final factor solution for perceptions relating to climate change.

Statements	Factor 1 loadings	Communalities extracted
g) I think that the decision-makers should do more to mitigate climate change.	0.840	0.70
j) I think that the severity of climate change is exaggerated in the media.	−0.796	0.63
f) I think we are too worried about climate change at the expense of the well-being of the present.	−0.742	0.55
h) In my opinion, countries with a high standard of living should do more to curb climate change.	0.700	0.49
b) The actions of an individual matter in controlling climate change.	0.616	0.38
e) I have noticed the effects of climate change in Finland.	0.614	0.38
% variance explained 52%		

Maximum likelihood was the extraction method. No rotation method was necessary because the solution is unidimensional.

against the 12 background variables and the 'climate agency' scale variable.

Limitations

There are some limitations in the empirical survey data and analysis to consider. First, representativeness of the survey population is based on a single random sample, which is an improvement in comparison to the field of research where qualitative inquiries or smaller convenience samples have only been used (e.g., Jowkar *et al.* 2022, Wuyts *et al.* 2019). We reached a 14.5% response rate, which is a fairly typical level these days, but, based on the survey language, the sample underrepresented immigrants and individuals whose first language was not Finnish or Swedish. Second, those interested in the topic of low-carbon housing were more likely to have responded to the lengthy survey. However, we feel this does not significantly influence composition of our sample, as also indicated by comparison of our respondents to the general population data shown in Table 1. Third, while exploratory factor analysis was used to compose a latent variable for climate agency (i.e., to predict stated preferences for wooden material and renovation over building demolition), we can identify issues in building such as construct. Clearly, climate change concerns can be a major motivator of climate change action. Therefore, the latent variable did not solely focus on household or respondent's individual responsibility but also included (see Appendix) a broader bundle of aspects associated with the media exposure or decision-makers, for example. Hence, further fine-tuning could be recommended to allow the survey questions to make a distinction between aspects of agency related to individuals (i.e., respondents) themselves and their views on the agency of other societal actors.

Results

Exploratory factor analysis

Running an EFA of the attitude questions (see Appendix) resulted in a one-dimensional solution. The factor solution held an explanatory variance of 52% and all items held communalities of at least 0.30. The outputs of the factor analysis are summarized in Table 3. Note that the items associated with a positive factor loading are concerned with respondents' climate awareness and climate action, while the items associated with a negative loading are related to climate cynicism (e.g., 'overexaggerated' and 'too worried'). Based on the set of questions used in the final factor solution, we concluded that the latent factor is largely a measure of the respondents' *Climate Agency*.

Binary logistic regression

Table 4 presents the results of the BLR models for preferring wood as the main material in new buildings (*Wood*) and preferring renovations over demolishing and constructing new buildings (*Renovate*). Overall, both models capture several statistically significant and insignificant variables explaining respondents' preferences for the two options. Nagelkerke R^2 measure for the *Wood* model is 0.27 and the overall significance (i.e., Hosmer-Lemeshow) of the model is $p = 0.41$. This model is able to predict 72.8% of cases for the dependent variable correctly. The *Renovate* model has a Nagelkerke R^2 measure of 0.12 and the overall significance of the model according to Hosmer-Lemeshow is $p = 0.73$. This model can predict 73.1% of cases for the dependent variable correctly. Thus, both models have a reasonably good fit.

The BLR model for *Wood* finds seven variables that significantly predict respondents' preferences towards using wood in construction projects. Specifically, respondent *Age, Education, Household Equivalent Income (HEI)*, *Living Environment*, home occupation time *(Home Time)*, *Forest Ownership*, and *Climate Agency* are found to be significant variables. The likelihood to prefer wood increases if the respondent is over 55 years old. A *HEI* of over 2000€/month and higher university degree are associated with a lower likelihood of preferring wood. *Gender* and *Profession* do not statistically significantly explain respondent preferences.

Table 4. Results of the binary linear regression (BLR) models to prefer wood as main material in new buildings (Wood) and prefer renovations over demolishing and constructing new buildings (Renovate), with */**/*** marking the level of significance at 10, 5 and 1% level, respectively,

	Wood				Renovate			
	B	S.E.	Sig.		B	S.E.	Sig.	
Gender								
Male	a	–	–	–	a	–	–	–
Female	−0.061	0.133	0.648		0.261	0.134	0.051	*
Age (years)								
18–36	a	–	–	–	a	–	–	–
37–54	0.142	0.200	0.479		0.208	0.191	0.275	
55–67	0.502	0.233	0.031	**	0.629	0.230	0.006	***
68–81	0.529	0.315	0.093	*	1.479	0.323	0.000	***
Education								
Elementary school	a	–	–	–	a	–	–	–
Vocational/HS Diploma	−0.316	0.280	0.259		0.363	0.279	0.193	
College level degree	−0.400	0.297	0.178		0.146	0.297	0.623	
Lower university degree	−0.172	0.299	0.565		0.190	0.295	0.519	
Higher university degree	−0.585	0.289	0.043	**	0.303	0.288	0.292	
Profession								
Employed	a	–	–	–	a	–	–	–
Pension	0.084	0.242	0.730		−0.177	0.242	0.464	
Student	−0.420	0.285	0.141		0.031	0.272	0.910	
Unemployed	−0.251	0.334	0.452		0.556	0.368	0.131	
Household Equivalent Income HEI								
<1000€	a	–	–	–	a	–	–	–
1000–1999 €	−0.351	0.306	0.251		−0.492	0.321	0.126	
2000–2999 €	−0.880	0.313	0.005	***	−0.793	0.326	0.015	**
3000–3999 €	−0.694	0.329	0.035	**	−0.756	0.341	0.027	**
4000–4999 €	−1.174	0.365	0.001	***	−1.010	0.372	0.007	***
5000–5999 €	−1.506	0.401	0.000	***	−0.737	0.409	0.071	*
Housing Property Investment								
No	a	–	–	–	a	–	–	–
Yes	−0.164	0.186	0.379		0.381	0.197	0.053	*
Forest Ownership								
No	a	–	–	–	a	–	–	–
Yes	0.768	0.162	0.000	***	0.171	0.159	0.284	
Second Home								
Yes	a	–	–	–	a	–	–	–
No	0.005	0.155	0.975		0.144	0.157	0.360	
Home Type								
Apartment	a	–	–	–	a	–	–	–
Detached house	0.694	0.318	0.029	**	0.473	0.324	0.144	
Other	−0.073	0.274	0.790		0.219	0.279	0.434	
Living Environment								
City center	a	–	–	–	a	–	–	–
Urban residential, mainly apartments	−0.883	0.223	0.000	***	−0.214	0.222	0.335	
Urban residential, mainly single-family houses	−0.049	0.270	0.857		0.119	0.276	0.666	
Local centre in the countryside	0.613	0.337	0.069	*	0.066	0.328	0.839	
Sparsely populated area in the countryside	0.336	0.327	0.304		0.388	0.332	0.243	
Home Size (m^2)								
17–49	a	–	–	–	a	–	–	–
50–70	0.075	0.257	0.769		0.051	0.258	0.843	
71–97	−0.149	0.283	0.598		−0.206	0.282	0.465	
98–853	−0.195	0.319	0.541		−0.337	0.320	0.293	
Home Tenancy								
Owner	a	–	–	–	a	–	–	–
Rental	−0.217	0.230	0.344		−0.164	0.228	0.472	
Other	0.003	0.399	0.995		0.368	0.436	0.400	
Home Time (years)								
0–1	a	–	–	–	a	–	–	–
2–5	−0.635	0.222	0.004	***	−0.087	0.222	0.693	
6–18	−0.287	0.219	0.190		−0.038	0.221	0.863	
18+	−0.301	0.235	0.200		−0.084	0.237	0.724	
Climate Agency	−0.285	0.076	0.000	***	−0.159	0.076	0.035	**

As expected, *Forest Ownership* is a strong predictor for preferring wood as a construction material. In addition, living in a detached house increases the likelihood of preferring wood. These findings are in line with previous literature (Vehola *et al.* 2022) for Sweden.

Living Environment is associated with preferences towards wood construction. Respondents living in urban areas with apartment buildings making up the majority of the housing stock are less likely to have positive preferences towards wood construction.

However, respondents living in local population centers in the countryside are more likely to state the opposite. Similar results have been obtained for Finland, Sweden, Norway, and Denmark in Lähtinen *et al.* (2021), indicating that people with preferences for living in urban neighborhoods have the highest likelihood for prejudices against building with wood, while those interested in living close to nature, in suburban areas for example, hold more positive attitudes towards wood use in construction. Surprisingly, living in more sparsely populated areas in the countryside does not have statistical power in explaining wood preference.

The duration of living in the current home (*Home Time*) is not a strong predictor for wood preferences. However, living in the current home for two to five years decreases the likelihood of preferring wood as a construction material. The latent *Climate Agency* variable is negatively associated with wood preferences. *Home Size*, type of *Home Tenancy, Housing Property Investment,* or *Second Home* ownership do not statistically significantly explain wood preferences.

The BLR model for *Renovate* shows five variables that significantly predict the respondents' preferences for renovating over demolishing and new construction. In this model, the respondent's *Gender, Age,* income *(HEI), Housing Property Investment,* and *Climate Agency* are found to be significant variables. Similar with wood preferences, the likelihood to prefer renovation increases if the respondent is over 55 years old and decreases if the respondent has a HEI of over 2000€/month. If the respondent identifies herself as a female, the likelihood to prefer renovation increases. *Education* and *Profession* are not statistically significant predictors of respondents' preferences.

Housing Property Investment is linked with a higher likelihood to prefer renovation. Also in the renovation model, the latent *Climate Agency* variable is negatively associated with renovation preferences. *Living environment, Home Size, Home Time*, type of *Home Tenancy, Forest ownership* or *Second Home* ownership do not statistically significantly explain preferences for renovation.

Discussion

With increasing urbanization, urban residential construction is particularly in turmoil to match the demand for residential housing. The objective of the European Commission (2020) Renovation Wave strategy is to double the annual energy renovation rate of residential and non-residential buildings by 2030 and to foster deep energy renovations. The substitution of energy-intensive construction materials with low-carbon construction materials is another avenue towards decarbonization, as the emissions associated with the dominant building material, that is, concrete, may be twice that of wooden building products (e.g., Hertwich *et al.* 2019, Churkina *et al.* 2020). Indeed, wooden multistory construction is described as a sociotechnical innovation, challenging the incumbent practice to construct concrete multistory buildings (e.g., Mahapatra *et al.* 2013, Toppinen *et al.* 2019, Lazarevic *et al.* 2020). This perspective evokes questions over the extent to which the general public supports such novel strategies that promote decarbonization in the built environment.

Citizens are a critical societal group who can create demand-pull in the housing market through their views on material choice or acceptance of renovation over demolition. Hence, large-scale national-level surveys can be useful in understanding citizen perceptions on the preferred decarbonization strategies. They can also provide valuable information for the decision-making of construction sector professionals, and for policymakers advocating a transition to a lower carbon economy at national and regional levels. Therefore, we addressed the following question: 'Do citizen socio-demographic characteristics, housing characteristics and climate agency influencing their preferences towards decarbonization pathways?' by using a national level random sample of 1448 Finnish citizens. Due to the large proportion of owner-occupied housing both in the detached and multistorey residential housing sectors in Finland with approximately 60% of the housing stock (Andersson *et al.* 2007), Finnish citizens make an interesting case by their involvement in the choice of building materials.

Based on our data, citizen acceptance in Finland for these two strategies is found to be high, with 71% of respondents either somewhat or strongly agreeing with the renovation statement, whereas the corresponding share for preferring wood material was 61% (see Figure 1). While there is no comparative study at national level data on the preference toward renovation, the high level of acceptance for wood is in line with a survey from the US by Larasatie *et al.* (2018) which found a large majority of respondents to believe that wooden buildings are more environmentally friendly than buildings made from other materials.

Drawing from the binary logistic regression models from Table 4, our results suggest that a propensity to renovate rather than demolish is shown by respondents of female gender; over 55 years of age; a low income (HEI); and possessing housing property investment. Our results differ from Jowkar *et al.* (2022), who found economic issues and the high cost of renovation to be the first and most common reason for the limited interest in building renovation among residents of Trondheim in Norway.

Interestingly, the effect of climate agency was found to be negative. As one explanation for the adverse effect, we argue that the concept of renovations in the context of a low-carbon housing survey may still be rather weakly understood by citizens. Hence, the respondents may interpret the question to either include interior renovation or to resemble structural or façade-related renovations that have the potential to increase energy efficiency. Another explanation could be that the emphasis in the media and regulation has been for a long time on the operational emissions, and thus, people might perceive renovations to be less climate friendly than demolishing and new construction. Alternatively, the adverse effect from climate agency could be associated with the fact that renovation-related information was not framed when building the climate agency variable (see Appendix), and it therefore had very limited emphasis in the survey.

For favoring wood material, significant effects relate to respondents with higher age, with lower household equivalent income (HEI), living in smaller population centers in the countryside, and owning forestland. Regarding wood material, our findings contrast with a recent study by Hoibo *et al.* (2015) from Norway, in which younger people with strong environmental values were found to be the most receptive toward increasing wood-based urban housing. The negative effect of climate agency in the wood material case can be interpreted as reflecting criticism on the negative environmental effect caused by forest harvesting for producing sustainably procured material. The finding contrasts with Vehola *et al.* (2022), who, using large-scale citizen panel from Sweden and Finland, indicated that the respondents perceived building with wood as an efficient climate change adaptation measure. However, our result is in line with a review by Ranacher *et al.* (2020), who found conflicting perceptions from Europe concerning wood in construction: there is a segment in the public with a wish to protect forests from logging activities, but in parallel, positive views of wood as an environmentally friendly building material are also abound. Hence, it may also be the case that people in our survey who placed more weight on biodiversity aspects may find wood use in construction to be a threat for safeguarding forest habitats. The similar adverse environmental association with wooden building was found in Roos *et al.* (2023) for a survey in Finland and Sweden, which found beliefs that wood buildings drive global warming and harm biodiversity to be associated with nonrural residence, female gender, young age, children in the household, and lower income level. Aguilar *et al.* (2023) also showed that the positive relationship between citizen desires to reduce their carbon footprint and preferences for wooden construction are diminished among citizens who also believe that harvesting wood leads to habitat destruction.

To use or not to use more wood in urban residential construction is an example of conflicting societal needs, which are arising with growing material recognition, for example with the New European Bauhaus initiative. However, path dependences of construction culture and practices are also influencing citizen preferences regarding wood materials in European countries (Hurmekoski *et al.* 2015). Despite wood material use having climate-positive benefits through the substitution of emission-intensive materials, like concrete, and by acting as long-term carbon storage, the public has concurrent concerns with diminishing carbon sinks in forests and logging-related biodiversity concerns (Ranacher *et al.* 2020, Roos *et al.* 2023), as also demonstrated by our data and analysis.

Overall, citizen climate agency measure was captured in our study using a limited set of seven statements drawing on a large-scale housing survey dataset. The data collection in spring 2022 was carried out during the aftermath of COVID-19. Other contemporary surveys have revealed that, for European Union citizens, the degree of climate change perception during this period significantly decreased throughout the EU when comparing data from 2019 and 2021, and responsibility placed on the government to solve the climate change problem increased significantly (Matiiuk *et al.* 2023). Hence, despite our respondent group being highly aware on the climate change and the related threats,[3] the motivation and action toward household level climate mitigation and adaptation may still have been constrained by repercussions of global health concerns during the time of data collection. This needs to be kept in mind when interpreting the findings.

Despite the observed high acceptability of these two solutions among citizens, judged by the massive cumulative renovation debt or low market share of multistory wood construction in Finland, there is untapped potential in both of these decarbonization pathways. Hence, there are barriers that stop from more effectively challenging incumbent practices within the residential building sector. For example, choosing renovations over demolition is not only a technological or regulatory issue, but is strongly also affected by behavioral attitudes among citizens towards refurbishment practices aiming to extend the life-cycle of residential buildings (for results from Japan, see also Wuyts *et al.* 2019). As pointed out by Larasatie *et al.* (2018), there is still limited familiarity on the use of wood at population level, which means that people may not possess strong a priori beliefs. Thus, they may be open to communication and information from sources they perceive to be credible, and which seldom touch upon the detailed level of material solutions of structural frames, or the nature and complexity of deep renovations.

Conclusions

Citizens as current or future residents (or as voters, landowners, employees, or advocates for environmental agendas), can, via their preferences, create strong demand–pull in the housing market concerning low-carbon material choices or whether building renovation should be preferred over demolition. Challenging the current modes of production and consumption within the residential building sector evokes questions over whether citizens will also support these policy pathways. The large proportion of owner-occupied housing both in the detached and multistorey residential housing sectors in Finland constituted an interesting context for a national level random sample survey. The results indicate high level general acceptability, which benefits both construction industry and policy makers and municipal-level in their future decision making.

While the findings of our study contribute to understanding the role of citizen background sociodemographic factors, housing attributes, and to some preliminary extent the effect of climate agency, there is still ample room for further elaboration of these aspects. Regarding future research needs, especially the multifaceted nature of what constitutes deep renovation as an activity in the built environment poses challenges for eliciting preferences on related building practices. Empirical research should also add understanding of the preferred mitigation and adaptation measures among citizens with lower sociodemographic status because these groups are often underrepresented in large-scale surveys or consumer panels. Analysing these concerns continues to be an area of further research, as well as building better understanding of what kind of information and communication strategies would be needed toward the general public for accelerating development toward lower carbon housing sector. To complement our single-country analysis, focusing on the determinants of decarbonization pathways at the cross-country level definitely has some merit. The identified high acceptance for wood as environmentally friendly building material in the urban context merits getting further insights also on potential regional differences, even across different cities in a single country.

Our findings also have implications, for example, on industry and policymakers developing more efficient climate information and communication campaigns. With the stronger emphasis in the media and regulation being on the operational emissions, the climatic impact of renovations appears to be weakly understood by citizens in Finland. Hence, there is merit in focusing more on the role of renovations in targeting decarbonization of the built environment. Tailoring the information requirements of different socio-demographic segments among the general public is also needed for targeting development toward the lower-carbon housing sector, and this applies to even countries with high awareness concerning climatic change.

Finally, our study also offers practical implications for construction management. Even though integrating residents in industrialized building design processes may increase in customer value creation, in reality this rarely is focused on in building projects. The literature further suggests citizens to be limited in their ability to influence material selection beyond that of the interior materials of the homes they purchase (e.g., Kylkilahti *et al.* 2024). Therefore, the questions of whether and how, future or current residents may more effectively influence construction design or material choices remains to be explored.

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Data availability statement

Data protection statement provided to respondents prohibits publicly disclosing data.

Notes

1. Wooden multistory buildings constitute apartment buildings, in which load-bearing structures are made with various timber-based technologies to substitute more traditional materials such as concrete, steel or bricks (e.g., Urban 2012, Ramage et al. 2017).
2. It has also been suggested that policies to reduce the environmental impact of housing should more strongly be reframed to address the mundane practices of everyday life, now and into the future (e.g., Judson and Maller 2014, Vlasova and Gram-Hansen 2014). However, methodologically this would call for a more qualitative approach.
3. Around 70% of our respondents had observed the effects of climate change in Finland.

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Appendix: Survey questions related to climate agency. Respondents were presented with the option to answer, "strongly disagree", "somewhat disagree", "neither agree nor disagree", "somewhat agree", "strongly agree", or "I cannot say"

Do you agree or disagree with the following statements related to climate change?
a) It is difficult to find reliable information about climate change.
b) The actions of an individual matter in mitigating climate change.
c) I believe that my lifestyle is environmentally sustainable.
d) I have experienced anxiety over climate change.
e) I have noticed the impact of climate change in Finland.
f) I think we are too concerned about climate change at the expense of our contemporary well-being.
g) I think that decision-makers need to do more to mitigate climate change.
h) I think that countries with high living standards ought do more to mitigate climate change.
i) The costs of mitigating or adapting to climate change must not rise too high for individual households.
j) I think that the severity of climate change is exaggerated in the media.
k) I believe that the ecological carrying capacity of the earth is enough for a good life for all.
l) I feel that others in my neighborhood think the same way about climate change as I do.
m) The discussions in my circle of friends have an impact on what I think about climate change.
n) Our family talks about the effects of climate change often.