Canadian Journal of Forest Research

OPEN ACCESS | Article

Citizen beliefs concerning wood as a construction material under extreme weather events

Anni Vehola[a], **Elias Hurmekoski**[a,b], **Katja Lähtinen**[c], **Enni Ruokamo**[d], **Anders Roos**[e], **Ritva Toivonen**[a,b], and **Anne Toppinen**[a,b]

[a]Department of Forest Sciences, University of Helsinki, Helsinki 00100, Finland; [b]Helsinki Institute of Sustainability Science (HELSUS), University of Helsinki,Yliopistonkatu 3, Helsinki 00100, Finland; [c]Natural Resources Institute Finland (Luke), Latokartanonkaari 9, Helsinki 00790, Finland; [d]Finnish Environment Institute (SYKE), Latokartanonkaari 11, Helsinki 00790, Finland; [e]Department of Forest Economics, Swedish University of Agricultural Sciences (SLU), Almas Allé 8, Uppsala 75007, Sweden

Corresponding author: **Anne Toppinen** (email: anne.toppinen@helsinki.fi)

Abstract

Climate change places great pressure on the construction sector to decrease its greenhouse gas emissions and to create solutions that perform well in changing weather conditions. Our study explores citizen perceptions on wood usage as a building material under expected mitigation and adaptation measures aimed at a changing climate and extreme weather events. The data are founded on an internet-based survey material collected from a consumer panel from Finland and Sweden during May–June 2021, with a total of 2015 responses. By employing exploratory factor analysis, we identified similar belief structures for the two countries, consisting of both positive and negative views on wood construction. In linear regression models for predicting these beliefs, the perceived seriousness of climate change was found to increase positive views on wood construction but was insignificant for negative views. Both in Finland and Sweden, higher familiarity with wooden multistory construction was found to connect with more positive views on the potential of wood in building, e.g., due to carbon storage and material properties. Our findings underline the potential of wood material use as one avenue of climate change adaptation in the built environment. Future research should study how citizens' concerns for extreme weather events affect their future material preferences in their everyday living environments, also beyond the Nordic region.

Key words: climate change adaptation, wood, residential building, extreme weather, citizen data

Résumé

Les changements climatiques exercent une forte pression sur le secteur de la construction pour l'inciter à réduire ses émissions de gaz à effet de serre et créer des solutions performantes dans des conditions météorologiques changeantes. Notre étude se penche sur les perceptions des citoyens en ce qui a trait à l'utilisation du bois comme matériau de construction dans le cadre des mesures d'atténuation et d'adaptation prévues pour faire face aux changements climatiques et aux événements météorologiques extrêmes. Les données sont fondées sur une enquête en ligne menée auprès d'un panel de consommateurs finlandais et suédois en mai et juin 2021. Nous avons reçu un total de 2015 réponses. En utilisant une analyse factorielle exploratoire, nous avons identifié des structures de perceptions similaires pour les deux pays, consistant en des opinions positives et négatives sur la construction en bois. Dans les modèles de régression linéaire permettant de prédire ces perceptions, on a constaté que la gravité perçue des changements climatiques augmentait les opinions positives sur la construction en bois, mais n'était pas significative pour les opinions négatives. En Finlande et en Suède, on a constaté qu'une plus grande familiarité avec la construction en bois à plusieurs étages était liée à des opinions plus positives sur le potentiel du bois dans la construction, par exemple, en raison du stockage du carbone et des propriétés du matériau. Nos résultats soulignent le potentiel de l'utilisation du bois en tant que moyen d'adaptation aux changements climatiques dans l'environnement bâti. Les recherches à venir devraient étudier comment les préoccupations des citoyens concernant les événements climatiques extrêmes influencent leurs préférences futures en matière de matériaux dans leur environnement de vie quotidien, et aussi au-delà de la région nordique. [Traduit par la Rédaction]

Mots-clés : adaptation aux changements climatiques, bois, bâtiment résidentiel, conditions météorologiques extrêmes, données citoyennes

1. Introduction

Increasing awareness of climate change since the launch of the IPCC (2018) Global Warming of 1.5 °C special report has set great pressure to the aim of rapidly decreasing global greenhouse gas (GHG) emissions. With the increasing recognition that climate change is a serious matter causing a real crisis, public perceptions on mitigation and adaptation measures need to be studied. According to a recent study by Moran et al. (2020), changes in consumer practices and consumption patterns may reduce carbon footprints beyond business-as-usual by roughly one-fourth in Europe, with primary actions targeting transport and food systems, and the building sector. In the urbanizing world, wood construction has been identified as one of the opportunities for mitigating these emissions.

The built environment is responsible for 40% of the final energy consumption, 35% of total GHG emissions, 50% of the utilization of extracted materials, and 30% of the water consumption in the European Union (EU), including not only construction processes, but also the use phase of buildings (European Commission 2011). Toward 2050, the EU carbon neutrality target will require significant measures for decarbonizing the housing stock, particularly through improving the energy efficiency of buildings. With new residential buildings already being built with strict energy efficiency requirements, lower embodied carbon building materials should be increasingly adopted in the future.

Substituting more energy-intensive and fossil-based materials, such as concrete and steel, with wood in construction offers ways to reduce the embodied (fossil) carbon in buildings (e.g., Upton et al. 2008; Gustavsson et al. 2010; Cabeza et al. 2014). Building with wood has strong traditions in the forest-rich countries of Finland, Norway, and Sweden, with approximately 90% of detached houses constructed with wood as the load-bearing material (Schauerte 2010). Despite this, the annual market share of wood in new apartments remains at approximately 5% in Finland and 20% in Sweden (Sipiläinen 2018; Swedish Federation of Wood and Furniture Industry 2021). Due to this, efforts to promote building with wood have been targeted at wooden multistory construction in residential and public buildings in both Finland and Sweden have, especially since the 1990s (Gustafsson et al. 2006). Compared with international discourse on wood construction, these aims have been similar to other countries, where the possibilities of building with wood are seen to connect particularly with the need to provide solutions for urban building (Wiegand and Ramage 2021). The construction of multistory residential and public service buildings (such as schools and kindergartens) with wood has also been spurred by innovation in industrial prefabrication (Hildebrandt et al. 2017), referring to the off-site manufacturing of elements and components. This allows combining several work phases in a single off-site location, potentially resulting in productivity and quality gains (Malmgren 2014).

Besides climate change mitigation, buildings must be constructed to adapt to the changing climate-induced extreme weather events, such as higher rainfall during winter months, extended heat waves, storms, or flooding. These phenomena are by nature unexpected, unusual, and severe. They can constitute unseasonal weather which is out of the range that has been seen in the past, and may result in heat-related human stress, danger of severe forest fires, or diminishing ground water levels.[1]

Extreme weather events are currently widely discussed by the public and in the media globally, with awareness of climate change and the related crisis building a momentum to change the existing building material regimes. This publicity can create a higher level of awareness concerning climate change-induced risks and the need to adapt infrastructure for coping with extraordinary weather events. The need of finding lower carbon building materials, techniques, and solutions that would perform well in changing weather conditions while supporting climate change mitigation is a real challenge.

Švajlenka and Kozlovská (2021) point out that key aspects that determine the sustainability of housing from the perspective of users are the standard of construction workmanship, construction time, cost-efficiency, material composition, and floor plan design. In addition, climate events are likely to affect operational costs, insurance requirements, and the capital cost of building assets, and thus increase the perceived risks of rising operating and maintenance costs (Alzahrani et al. 2016). According to Lucas et al. (2021), a personal experience of extreme weather events may affect an individual's likelihood of purchasing home insurance.

As an outcome of the extreme weather events, there could be both positive or negative impacts on wood industry production chains, and how different building materials are in the public preferred as a means of climate change adaptation.[2] Construction professionals perceive wooden structures to be more expensive to maintain (Ijäs 2013), but the cost differences between alternative materials may be decreasing due to the negative impact of extreme weather on all facade materials.

In the Nordic region, long and mild winter seasons with wet conditions could have adverse effects on wooden structures, especially on the facades, and citizen views could become averse to wood despite carbon storage benefits. Hence, from a sustainability perspective, this is a potentially "two-sided coin" situation that complicates the opinion-making of citizens: extreme weather may be a risk factor for using wood in the exterior applications of buildings and comes with increasing maintenance costs, while concurrently the increase in the embodied carbon stock in the building sector is principally motivated by the urgency of climate change adaptation measures. We can conclude that there is very limited understanding in the scientific literature on how the general public perceives building materials under extreme weather events. Furthermore, it is not clear whether citizens regard

[1] In this paper, we understand extreme weather events to also include a more gradual change in average weather that may have drastic impacts to infrastructure, such as radically increasing rainfall during the winter months.

[2] We thank an anonymous reviewer for pointing out this aspect.

wood construction as beneficial or risky from the perspective of climate change mitigation and adaptation, and how these beliefs may be affected with increased occurrence of extreme weather events.

Citizen perceptions 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. However, research on public views concerning the benefits of wood construction is limited in the high-rise context (Larasatie et al. 2018; Lähtinen et al. 2019), possibly also connected with prejudices, which relate to both building with wood in urban milieus and its technological properties as a building material (Lähtinen et al. 2021).

Connected to wood material use in construction, awareness of the need for climate change mitigation does not only concern public perceptions of timber as a building material, but also the public's requests for sustainable forest management practices in raw material procurement (Petruch and Walcher 2021). According to Viholainen et al. (2021), citizens from seven countries held multifaceted views regarding the technical, environmental, social, and economic aspects of using wood as a construction material. Citizens from forest-rich countries (especially Finland and Norway) emphasized different aspects compared to citizens from less-forested countries (UK, Germany, and Denmark), which were more skeptical concerning the environmental ramifications of harvesting timber needed for wood materials. As a result, citizen views of wood construction may be sensitive to their engagement, either via employment or forestland ownership (Ranacher et al. 2017).

Our study sets out to fill the research gap through the following research questions: (1) How do citizens in the two forest rich countries of Finland and Sweden perceive climate change (its origin, level of concern, and treatment in the media) and wood as a construction material under the effects of extreme weather events? (2) What socio-demographic characteristics explain citizens' beliefs of wood as a construction material in these countries?

Finland and Sweden are chosen as target countries, where global warming is expected to increase the risk of heavy and slanting rains, which are especially damaging in urban areas with limited capacity for the soil to absorb excess water (see, e.g., Gregow et al. 2021). Indeed, for Finland, national climate change expert panel scenarios indicate that a combination of increased rainfall and rising average temperatures will be a likely outcome (Gregow et al. 2021). Essentially, there is a commonly expressed belief that a combination of increased rainfall and rising average temperatures during the dark winter months could create a new season that the public mockingly calls "endless November". Furthermore, Stagrum et al. (2020) reviewed literature on the effects of, and adaptation measures for climate change relating to buildings and found that evidence concerning relevant adaptation measures is in particular limited in cold climates such as the Nordic area. Most residential buildings in the Nordic countries are not typically equipped with mechanical cooling systems, and experiences from the recent 2018 heatwaves have shown the need for installing active cooling systems to avoid overheating, which is forecasted to increase energy demands toward 2050 (Farahani et al. 2021). Forest fire frequency has also increased following summer heat waves, with several out-of-control fires in Sweden in the summer of 2018. With private family ownership being predominant in both countries, these events have been widely publicized and have caused widespread concerns, which presents a good opportunity to empirically explore the two research questions.

2. Materials and methods

2.1. Data

Data were collected from the general public in May–June 2021. An internet-based survey was deployed to a consumer panel from Finland and Sweden, with approximately 1000 responses targeted from both countries. The respondents are fairly in line with population data from the two countries regarding certain key socio-demographic variables such as gender, age, and education level (Statistics Finland 2021; Statistics Sweden 2021). Due to the sampling techniques and reliance on a consumer panel, we will not attempt to make a full generalization of our results.[3] The survey was offered in the native languages of each country, and panelists responded in their native language. Nine-point Likert scales (1 = strongly disagree … 9 = strongly agree) were used to understand respondents' views on the statements.

We used a part of 12-page questionnaire to elicit information, focusing on three sets of questions regarding citizen perceptions of climate change and construction materials, with emphasis on wood as a construction material (see Appendix A). The survey measured respondents' views toward (1) climate change (five statements), (2) wood construction, climate effects, and the trade-offs with the natural environment (six statements), and (3) using wood in construction, especially under extreme weather conditions (nine statements). The survey did not specify between residential or public buildings, nor between new or renovation construction. Thus, the focus of the survey was to gain general information on citizen perceptions of wood as a construction material.

The questionnaire did not provide a ready-made description of what constitutes extreme weather events, because the phenomenon had been recently discussed in the public in the Nordic context extensively, especially due to severe forest fires, extended heat waves, drought, and floods due to heavy rainfalls. At this exploratory stage of research, it was also felt to be a preferred option to avoid distorting respondents' narrative on the phenomenon. Instead, four different statements were applied from the extreme weather perspective, namely suitability of wood as load-bearing material, wood in exterior use (e.g., in facades), technical durability of wood material under extreme weather, and the possible influence of extreme weather on building maintenance costs.

[3] Our survey data can be made available in anonymized form upon request.

Table 1. Summary of Finnish (FIN) and Swedish (SWE) respondents' socio-demographic characteristics and response distributions regarding wooden building-related factors.

	FIN respondents ($n = 1007$)	SWE respondents ($n = 1008$)
Gender		
Male	49%	50%
Female	51%	50%
Age groups	Mean age 46 years	Mean age 46 years
18–35	30%	31%
36–55	35%	36%
56–99	35%	33%
Residential location		
Large city	47%	46%
Small/medium-sized city	37%	36%
Countryside	16%	19%
Education level		
Primary education	9%	9%
Secondary education	46%	51%
University degree, bachelor	28%	29%
University degree, master	15%	10%
University degree, doctoral	1%	2%
Association with forest sector (Yes)	33%	19%
Familiarity with multistory wooden buildings (Yes)	76%	63%
Preference for load-bearing material in own home		
Primarily wood	26%	20%
Wood with other materials	34%	32%
Other than wood (e.g., brick, concrete, steel)	29%	28%
Do not know	11%	20%

Table 1 shows a summary of respondents' socio-demographic characteristics and response distributions related to forest sector association, their familiarity with wooden multistory buildings (in the survey, defined as "any building of a wooden structure with a minimum of three stories/floors"), and their views of wood as the preferred load-bearing construction material for the respondents' own homes.

In the survey, association with the forest sector was examined with two binary (yes/no) questions: whether a respondent works/has worked in the forest sector and whether the family owns any forestland. For the analysis, these two variables were combined to examine any association with the forest sector. Moreover, the current residential location was originally a five-choice categorical response option, but for the analysis, it was transformed into a three-choice categorical, where "metropolitan" and "large city" were combined into "large city"; "countryside" and "village" into "countryside"; and "small/medium-sized city" remained its own category. The education groups were divided into two, where "lower education" consisted of primary and secondary education and "higher education" consisted of a bachelor's, a master's, and a doctoral degree. Fifty-five percent of the Finnish respondents and 60% of the Swedish respondents had completed a "lower education."

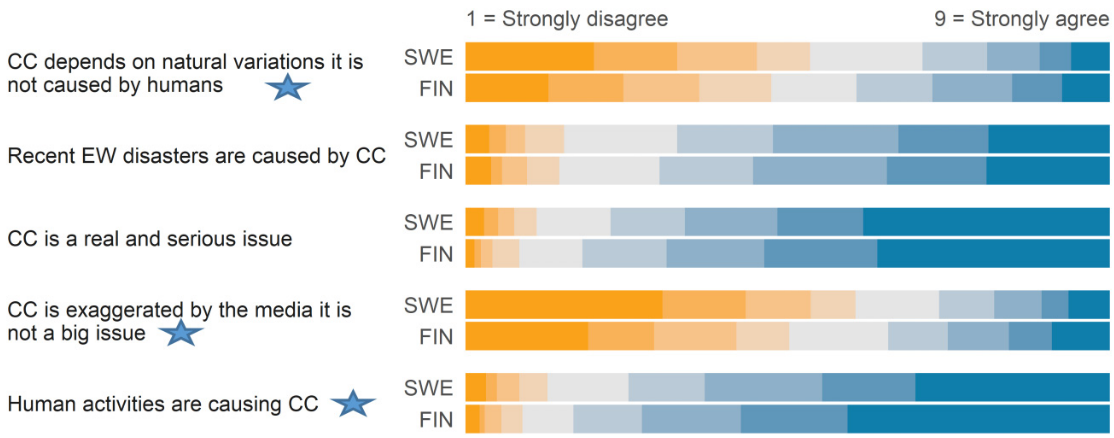
2.2. Analysis

2.2.1. Exploratory factor analysis

Exploratory factor analysis (EFA) was conducted for the set of statements regarding wood construction under climate change and extreme weather events, to study whether responses to these statements represent any analogous group (Fabrigar and Wegener 2011). To begin with, we applied the Kaiser–Meyer–Olkin (KMO) test for sampling adequacy (a minimum value of 0.60 for sampling adequacy) and Bartlett's test of sphericity (Kim and Mueller 1978; Henson and Roberts 2006; Beavers et al. 2013).

Kaiser criterion and parallel analysis were utilized to determine the number of factors to be extracted. According to the Kaiser criterion, the number of eigenvalues greater than one defines the number of factors to be extracted (originally proposed by Kaiser 1960). On the other hand, the idea of parallel analysis lies in the comparison of eigenvalues from real data, with the corresponding eigenvalues obtained from random data (originally proposed by Horn 1965). EFA was constructed with maximum likelihood estimation and Varimax rotation using the R program. Factors that had only one loaded item, along with items that had a loading below 0.4 or above 0.4 for multiple factors, were removed from the final analyses.

Fig. 1. Level of agreement on statements concerning origin of climate change (CC) and extreme weather (EW). The statements with significant cross-country differences marked with a star.



Moreover, the Cronbach's alpha of each formed factor was studied to measure the internal consistency of the analysis.

2.2.2. Linear regression analysis

The second step of the analysis included a linear regression modelling to study how different respondent sociodemographic background characteristics (age, gender, education, and residential location) affected the identified beliefs concerning wood construction under climatic and extreme weather events. EFA scores were used as the dependent variables of citizen beliefs, and separate regressions were executed for both countries. The effect of forest sector association, preferred home load-bearing material, familiarity with wooden multistory buildings, and awareness of the seriousness of climate change were additionally included as moderating variables in the models.

The resulting linear regression models were further analyzed with regression diagnostics to study the linear regression assumptions of linearity, the residual normality, the homoscedasticity of variance, and the independence of residual error terms (Yan and Su 2009). Multicollinearity between predictors was studied through generalized variance inflation factors (GVIF), and Bonferroni was used to reveal whether significant outliers exist. Beta coefficients, error terms, and statistical significances are presented for each model in the presentation of the regression models. Diagnostic tests and graphs are available in Appendices A–C, and the R code used is available in Supplementary material. The significance level of all statistical tests and analyses was set at $p < 0.05$.

3. Results

3.1. Views on climate change, extreme weather events, and wood material in construction

The response frequency distributions in Finland and Sweden for the set of questions regarding climate change (Question 13; for full wording, see Appendix A) are shown in Fig. 1. In general, respondents strongly agreed that human activities are causing climate change, climate change is a real and serious matter, and recent extreme weather disasters are caused by climate change. Statistically significant differences were not found between the Finnish and Swedish respondents for the latter two statements (Wilcoxon rank test with prob. exceeding 0.05 for these).

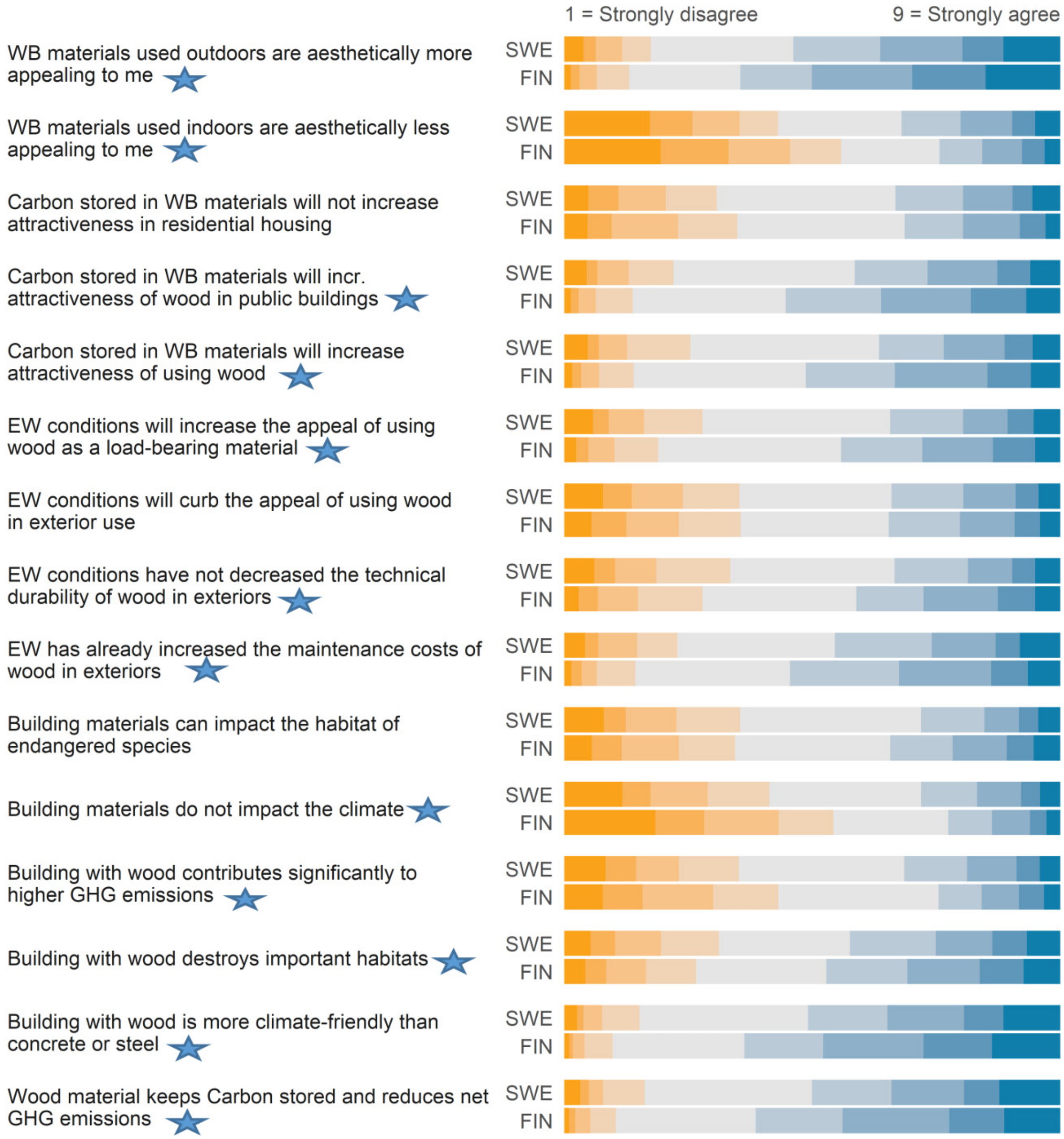
Based on these responses, the proportion of respondents denying the seriousness of climate change (i.e., so-called climate denialists) is just few percentages in Sweden and Finland. In contrast, respondents were less homogenous on statements regarding whether climate change depends on natural variations or whether climate change is exaggerated by the media: Swedish respondents were more convinced than Finnish respondents that the media does not exaggerate climate change. On the other hand, Finnish respondents were, on average, more likely to perceive that human activities predominantly cause climate change.

Regarding the question of wood as a construction material in relation to climate change and the effects that wood harvesting has on biological diversity (Question 14), the neutral alternatives (4 or 5 on the scales in Fig. 2) were the most frequently chosen responses. Citizens in Finland were more strongly in favor that carbon stored in wooden building materials will increase the attractiveness of using wood in construction, but at the same time they voiced that the use of building material — whether wood, steel, or concrete — does impact climate. Respondents from both countries also agreed in their views about the statement that building materials used negatively affect important habitats for endangered species.

Regarding the perceptions about construction materials and extreme weather (Question 15, see Appendix A), neutral views were again clearly in the majority. The statement concerning the appeal of wooden materials was the only exception, as responses consistently indicated that the majority of respondents either consider wooden materials appealing, or do not have a strong opinion about the appeal of wooden

Can. J. For. Res. 52: 1266–1279 (2022) | dx.doi.org/10.1139/cjfr-2022-0108

Fig. 2. Level of agreement on statements concerning extreme weather (EW) and the association with building with wood (WB). Statements with significant cross-country differences marked with a star.



materials. When comparing respondents from the two countries, statistical differences were found for "the use of wood in exterior buildings" or "carbon stored in buildings to increase the attractiveness of using wood". Citizens in Sweden were more strongly in favor that extreme weather conditions have not decreased the technical durability of wood in exterior use, such as in facades. Regarding Fig. 2, based on a large proportion of neutral choices, one may conclude that evaluating the effects of extreme weather events on buildings is not an easy task. Furthermore, respondents from the two countries were found to somewhat differ in their perceptions regarding several questions (marked with a star in Fig. 2), which provides a rationale for analyzing and modelling extreme weather-induced beliefs separately for Finland and Sweden.

3.2. Step 1: exploratory factor analysis of citizen beliefs concerning wood material in construction

In the first modelling step, EFA was used to analyze citizen beliefs about extreme weather events and construction under Question 15. According to the results, both sampling adequacy (KMO = 0.76 for Sweden and KMO = 0.72 for Finland) and Bartlett's test of sphericity ($p < 0.001$) showed that the samples are suitable for factor analysis in both countries. Based on Kaiser criteria, we examined the eigenvalues exceeding one and the two- and three-factor solutions from the parallel analysis. The three-factor solution did not yield sensible results, with insufficiently loaded items above 0.4. Thus, the two-factor solutions were extracted from the two country data sets to enable logical interpretation. The items

Table 2. Final factor solution for citizen views concerning construction and extreme weather events in Finland (FIN) and Sweden (SWE).

Variable	FIN positive beliefs Factor 1	FIN negative beliefs Factor 2	SWE positive beliefs Factor 1	SWE negative beliefs Factor 2
15D. Extreme weather conditions will increase the use of wood as a load-bearing material in construction	**0.607**	0.101	**0.651**	0.275
15E. Carbon stored in wood will increase wood use in construction	**0.873**	– 0.018	**0.887**	0.120
15F. Carbon stored in wooden buildings will increase wood use in public service buildings	**0.851**	0.006	**0.868**	0.110
15I. In outdoor use, wooden materials are more appealing	**0.499**	– 0.168	**0.507**	– 0.022
15C. Extreme weather will curb wood use in building exteriors	– 0.046	**0.644**	0.155	**0.576**
15G. Carbon stored in wooden buildings will not increase wood use in residential housing construction	0.002	**0.658**	– 0.068	**0.772**
15H. In indoor use, wooden materials are less appealing	0.004	**0.661**	0.160	**0.635**
Eigenvalue	2.11	1.32	2.28	1.43
Explained variance	0.30	0.19	0.33	0.20
Cronbach's alpha	0.790	0.685	0.821	0.693

Note: Bold values are the items selected into a respective factor.

that loaded onto the factors were the same for both models, leading to the interpretation of one factor indicating positive beliefs concerning wood construction (named "positive beliefs") and the other factor indicating negative beliefs (named "negative beliefs", Table 2).[4]

Altogether, the two-factor solution for Finland accounted for 49% of the variance explained by the model, while the solution for Sweden accounted for 53% of the explained variance. Cronbach's alphas ranged from 0.685 to 0.821, indicating an acceptable level of internal reliability. The resulting factor scores formed variables for explaining respondent beliefs about wood use as a construction material, and they were used as dependent variables in the regression analyses during the second-stage modelling.

3.3. Step 2: Linear regression models of beliefs concerning wood construction and the effect of respondent characteristics

In the next step, the results of the linear regression analyses examining the effect of respondent characteristics on positive and negative beliefs for wood construction (as measured by factor solutions) by country can be seen in Table 3.[5] Accordingly, a positive beta coefficient indicates a positive relationship, i.e., an increase in the independent variable is associated with an increase in positive or negative beliefs, whereas a negative beta coefficient indicates a negative relationship. Based on GVIF, no multicollinearity was found between the predictors (see Appendix B). Looking at the regression diagnostics (see Appendix C), the assumptions for linear regression analysis were fulfilled for all models. Bonferroni outlier test further indicated that no extreme outliers statistically differing from the other observations exist for any of the models.

Perceived higher awareness of the seriousness of climate change (Question 13C) was significant for the extracted positive beliefs in both countries, which suggests that respondents connect increasing embodied carbon stock in the wooden building sector to be motivated by the urgency of climate change mitigation. A binary variable measuring familiarity with wooden multistory buildings was also found to significantly reflect positive beliefs for both countries. Association with the forest sector was only weakly significant in the Swedish model, and it was linked with positive beliefs. This result is somewhat counterintuitive, as a lower proportion of respondents in Sweden (19%) were associated with the forest sector compared to Finland (33%). However, the result may be indirectly influenced by the higher adoption rate of wooden multistory construction solutions in Sweden than in Finland and hence the higher legitimization.

Compared to the reference level, i.e., "primarily wood" as the preferred home load-bearing material, all other preference categories were found to effect on negative beliefs toward wood construction. This was especially noticeable when the preferred material was "other than wood," as this variable was negatively significant in the positive belief models for Finland and Sweden while showing positive signs for the negative belief models, respectively. Residents in large cities tended to have more negative beliefs of wood construction compared to respondents living in rural areas or smaller cities. Moreover, the two older age groups (respondents above 35 years of age) were associated with negative beliefs concerning building and living with wood. The age group variable did not have a significant impact on positive beliefs.

[4] For both countries, two items, i.e., "Extreme weather has increased wood maintenance costs" and "Extreme weather has not decreased the technical durability of wood" were excluded from the final analysis due to factor loadings below 0.4 or fairly even cross-loadings between the two factors, which disabled interpretation.

[5] Reduced models with backwards elimination were also tested, but for better comparison between the models, only full models are reported.

Table 3. Linear regression modelling results for factor solutions of citizen beliefs regarding construction and extreme weather events in models for Finland (FIN) and Sweden (SWE).

	FIN positive beliefs	FIN negative beliefs	SWE positive beliefs	SWE negative beliefs
	Factor 1	Factor 2	Factor 1	Factor 2
Intercept	**− 0.75 (0.17)*** **	**− 0.04 (0.15)**	**− 0.60 (0.16)*** **	**− 0.21 (0.14)**
Age group				
36–55	0.00 (0.07)	**− 0.18 (0.06)** **	**− 0.11 (0.07)**	**− 0.21 (0.06)*** **
56–99	0.12 (0.07)	**− 0.34 (0.06)*** **	**− 0.15 (0.07)* **	**− 0.51 (0.07)*** **
Gender				
Male	**− 0.03 (0.06)**	**− 0.00 (0.05)**	0.11 (0.06)	**− 0.08 (0.05)**
Education level				
Primary or secondary education (lower)	**− 0.04 (0.06)**	0.08 (0.05)	**− 0.08 (0.06)**	0.05 (0.05)
Residential location				
Large city	**− 0.04 (0.08)**	**0.19 (0.08)* **	0.08 (0.08)	**0.15 (0.07)* **
Small/medium-sized city	**− 0.07 (0.08)**	0.12 (0.08)	0.04 (0.08)	0.11 (0.07)
Opinion on Question 13C				
Climate change is real and serious	**0.11 (0.02)*** **	− 0.02 (0.01)	**0.10 (0.01)*** **	0.02 (0.01)
Preference for load-bearing material in own home				
Other than wood (e.g., brick, concrete, steel)	**− 0.49 (0.08)*** **	**0.42 (0.07)*** **	**− 0.37 (0.08)*** **	**0.34 (0.08)*** **
Wood with other materials	**− 0.19 (0.07)* **	**0.16 (0.07)* **	**− 0.17 (0.08)* **	0.11 (0.07)
Do not know	**− 0.55 (0.10)*** **	0.17 (0.09)	**− 0.37 (0.09)*** **	**0.18 (0.09)* **
Forest sector association				
Yes = 1	0.11 (0.06)	0.08 (0.06)	**0.15 (0.07)* **	0.12 (0.07)
Familiarity with wooden multistory buildings				
Yes = 1	**0.30 (0.07)*** **	**− 0.07 (0.06)**	**0.22 (0.06)*** **	**− 0.00 (0.06)**
R^2	0.14	0.09	0.12	0.11
Adjusted R^2	0.13	0.07	0.11	0.10
No. of observations	1007	1007	1008	1008

Note: Indications of statistical significances of beta coefficients are denoted with ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$. The error terms of the coefficients are given in parentheses.

Respondent's education level and gender had no statistically significant effect on any of the identified beliefs.

4. Discussion

Large-scale cross-country surveys on citizens' material-related beliefs provide valuable information for construction sector professionals in their decision-making and for policy-makers in advocating for measures related to carbon neutral economy at national and regional levels. Citizen views affect market development in the construction sector through their home choices in the owner-occupied and rental housing markets. In addition, citizens have power as voters to affect the democratic processes influencing, for example, initiatives pertaining to building material choices used in multistory residential and public buildings. Despite existing research on the public perceptions of building with wood (such as Hoibo et al. 2015; Larasatie et al. 2018; Viholainen et al. 2021), the effect of extreme weather events has not been covered previously.

Hence, the aim of our study was to shed light on citizen views regarding wooden building under the imperative of climate change mitigation and adaptation to extreme weather events. Urbanizing, boreal forest-rich countries, with cold climates that require high-quality housing insulation to protect against the highly variable temperatures, are attractive targets for analyzing public perceptions toward living with wood and detecting potential trade-offs in terms of climate change mitigation and adaptation in the construction sector. To achieve this, we used survey data from Finland and Sweden, where the prospects for increasing wood use in urban areas have been considered positive (e.g., Toppinen et al. 2018) due to environmental regulation extending to include the embodied emissions of construction products. Our choice of two Nordic countries is further motivated by their ambitious climate policies and because local-level effects and threats associated with climatic change and extreme weather are greatly discussed in the media. Further, the idea was to understand how different socio-demographic characteristics may affect these perceptions.

According to our EFA and linear regression modelling results, respondents from Finland and Sweden were found to have similar views on perceived climate change and extreme weather events, but they also showed differences based on

Figs. 1–3. According to the EFA results, the loaded items were concerned with the effect of extreme weather on future wood use in construction and the aesthetic properties of wood use in buildings, both indoors and outdoors. However, not all items loaded onto the factor solutions, for example, items regarding the technical durability of wood or increased maintenance costs due to extreme weather events were removed from the factor solution. We interpreted this to mean that these questions fall into the area of expertise of real estate management and are probably difficult to evaluate without a professional background in or familiarity with real estate management. In the analyses, the two factor solutions (positive and negative beliefs) from both countries explained approximately 50% of the variance in the variables, with no significant cross-loadings between the variables, and there was clear interpretability of the factor solutions. Furthermore, the results of our linear regression analysis for Finland and Sweden indicate similarities between the two countries regarding how the different respondent characteristics relate to the expressed beliefs. Based on the linear regression results, positive public beliefs regarding the effects of extreme weather events on wooden building are associated with the perceived seriousness of climate change in both countries, which in turn implies that respondents perceived building with wood as an efficient adaptation measure.

The similarity of our findings between Sweden and Finland in terms of the EFA solution and linear regression analysis results is not surprising, as both countries have strong wood building traditions (Schauerte 2010). Previous literature has found perceptions of local temperature increases to also play a role in people's beliefs concerning climate change. According to Ottelin et al. (2021), the Finnish residents of wooden housing tend to have more sustainable consumption habits than their counterparts, perhaps because of their higher environmental awareness. Sisco et al. (2017) found relative abnormalities in local temperatures to generate increased awareness of climate change, while Osaka and Bellamy (2020) identified an association between climate change beliefs, personal experiences with extreme weather, and pro-environmental attitudes in respondent backgrounds. Furthermore, according to Taylor et al. (2014), perceived changes in wet weather-related events may be an even stronger predictor for climate change-related beliefs compared to changes in hot weather-related events, and expected vulnerabilities may also connect to the building stock (Alzahrani et al. 2016), which would potentially resemble our Nordic case.

Based on socio-demographic background characteristics, gender and education level were insignificant in regression models, while residential location was found to have some effect on respondent beliefs concerning wood construction. In both countries, respondents residing in large cities tended to have negative beliefs more often than those residing in the countryside. This could be associated with wood construction in detached housing being more common in rural areas in both countries, and hence leading to greater familiarity with the material. For example, in a recent study by Hoibo et al. (2015) from Norway, younger people with strong environmental values were found to be the most receptive toward increasing wood-based urban housing, while higher respondent age did not appear significant in any of our models for positive beliefs. Regarding Swedish and Norwegian building material markets, Roos and Nyrud (2008) have previously found that environmentally conscious consumers are often women, have a higher education level, and prefer items with product warranties. Moreover, respondents preferring load-bearing materials other than wood or wood combined with other materials were more likely to have negative beliefs about wood construction. Similarly, those who did not know which home load-bearing material to choose, i.e., one fifth of the Swedish respondents and ca. one tenth of the Finnish respondents, tended to often have negative beliefs regarding wood construction.

From the building maintenance cost perspective, using wood exterior applications has been considered more expensive than plastered surfaces because wood requires more regular maintenance and repainting. Approximately half of our respondents believed that extreme weather has already increased the maintenance costs of buildings. This material-based difference in maintenance costs may even out in the future, as concrete and other mineral facades may also experience increased weather stress, but the issue is likely too vague a topic for the general public to evaluate, at least currently. While among construction sector professionals, compatibility with construction codes, impacts on costs and fulfillment of building performance requirements are seen as the primary criteria to choose structural materials for buildings (Knowles et al. 2011), the practical meaning of building performance, or environmental attributes of wooden construction materials may still be a somewhat technical issue for most citizens. For example, providing more explicit information on the volume of wooden elements used in the structural and non-structural components of the building would have made the topic more clear for the respondents. Now, it is likely that the identified dichotomy in beliefs is related to more general level attitudes toward building with wood under change weather patterns.

The effect of forest sector association on beliefs concerning wood construction was weakly significant for Swedish respondents, indicating positive beliefs among those associated with the forest sector. This is in line with a previous study conducted in four European countries by Ranacher et al. (2017). On the other hand, Peterson St. Laurent et al. (2018) found that while the Canadian public is generally accepting of enhanced forest carbon management strategies, including increased production of long-lived wood products, respondents employed by the forest sector can be less likely to support any of the proposed mitigation strategies. This result was interpreted to reflect the recent uncertain economic climate in the region and reluctance to alter various environmentally driven forest management strategies. The observed differences between models regarding forest sector association also in our study could be partly explained by the unequal distribution of respondents associated with the forest sector in each country: every third respondent in Finland had a connection with the forest sector, as opposed to only one fifth of the Swedish respondents.

Overall, a higher familiarity with wooden multistory buildings associated with positive beliefs in both countries. Prejudices against wood have also been detected in previous literature: citizens in the Nordic region showing appreciation for an urban lifestyle and for living in attractive and reputable neighborhoods expressed increased prejudices against wooden buildings, while higher appreciation of aesthetics and natural milieus decreased the prejudices expressed towards wood (Lähtinen et al. 2021). This could partly reflect in familiarity being highly significant in models explaining positive beliefs toward wood, regardless of the country. It is still good to bear in mind that the explanatory power of the linear regression models was quite modest. Since the resulting model interpretations and effects of the explanatory variables were mostly reasonable in relation to their signs, and were consistently similar across the two countries, which can be seen to illustrate validity of our results.

Citizen beliefs on climate change and the effects of extreme weather on construction materials were captured in our study using a limited set of statements drawing on a large-scale survey data. The use of consumer panel is a limitation of our study, as the data set is not fully representable of randomly selected respondents across each country. Nevertheless, the respondent background information (in terms of gender, age, or education level) was in solid alignment with general population in both Finland and Sweden. This suggests that the respondent recruitment had followed adequate professional conduct. However, future citizen surveys should focus on collecting randomly sampled data sets, also beyond the Nordic region to increase generalizability of these findings.

As a final thought, the building material-based opinion-making of citizens remains a complex topic. While extreme weather may be seen as a risk factor for using wood material in especially the exposed exterior applications of buildings, possibly with increasing maintenance costs, investing in measures to increase embodied carbon stock in the building sector is positively associated with renewable wood material (see, e.g., Ottelin et al. 2021). Ultimately, which one of these views—rising maintenance costs or carbon storage benefits of wood — becomes more overarching appears to be dependent on individual citizen background characteristics, at least based on this study. Citizens are sensitized in the Nordic region to the urgency of climate change adaptation measures, and interest in using novel engineered wood building materials from domestic sources is growing.

5. Conclusions

At the local level, growing concern and awareness for extreme weather-induced events in the future may trigger growing awareness of climate change, impacting residential building and renovation material choices. Our findings of the identified positive beliefs underline the potential power of citizen choice in adopting lower carbon building materials as one avenue of climate change mitigation- and adaptation-related policies. Our findings indicate that the development and marketing of wooden multistory buildings must also consider heterogeneity of preferences and views coming from various citizen groups. More specifically, there seems to be some potential to maintain a positive image among the younger age groups and to gradually increase the acceptability of wooden construction among the older segments. Moreover, while increased climate concerns may increase the future demand for wood from the perspective of embodied carbon and renewability of wood materials, concerns for increasing maintenance costs due to extreme weather are also eminent. Public concerns also exist on the effects of loggings on the endangered habitats.

Our study opened many avenues for further research. Examining citizen preferences for low-carbon housing and construction solutions while accounting for climate change adaptation provided interesting results, but this direction clearly also requires new data and analyses. To avoid conceptual confusion, citizen surveys to begin with a more explicit definition of the concept of extreme weather events. To also address whether the respondents had previously experienced severe climate events in their daily lives is needed, since citizens' greater personal vulnerability and increase in risk perceptions can associate with their prior direct experiences of extreme weather events. Hence, longitudinal approaches focus on analyzing perceptions of the more exposed groups, for example. This on technical aspects regarding building materials after flooding, heat stress or other calamities could be recommended. Among Swedish respondents association with the forest sector predicted positive beliefs toward wood materials, while this was not the case for Finnish respondents. This would seem to call also for further cross-country analysis.

Finally, studying, how citizens' climate attitudes, sociodemographic characteristics, and their current living practices are reflected in their future housing preferences would be important. Empirical research should also add understanding of the preferred mitigation and adaptation measures among citizens with lower socio-economic statuses because these groups are often underrepresented in large-scale surveys or panels.

Author contributions

Anni Vehola: Data curation, Formal analysis, Software, Writing — original draft

Elias Hurmekoski: Conceptualization, Formal analysis, Methodology, Supervision, Writing — original draft

Katja Lähtinen: Funding acquisition, Investigation, Methodology, Writing — original draft

Enni Ruokamo: Methodology, Writing — original draft

Anders Roos: Methodology, Writing — original draft

Ritva Toivonen: Funding acquisition, Writing — original draft

Anne Toppinen: Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Supervision, Visualization, Writing — original draft

Acknowledgements

We thank two reviewers and Associate Editor for their helpful comments on our manuscript. Financial support acknowledged from DECARBON-HOME funded by Strategic Research Council affiliated with Academy of Finland (grant Nos. 335241, 335245, and 335252) and Tandem Forest Values II (KnockOnWood).

Article information

History dates

Received: 14 April 2022
Accepted: 20 June 2022
Accepted manuscript online: 27 June 2022
Version of record online: 7 September 2022

Copyright

Data availability

Data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Author information

Author ORCIDs

Anne Toppinen https://orcid.org/0000-0003-0910-1505

Competing interests

The authors declare there are no competing interests.

Supplementary material

Supplementary data are available with the article at https://doi.org/10.1139/cjfr-2022-0108.

References

Alzahrani, A., Boussabaine, H., and Alzaed, A. 2016. Emerging climate changes and the risks to the operation of building assets in the UK. J. Fac. Manag. **14**: 21–35. doi: 10.1108/JFM-11-2014-0038.

Beavers, A, Lounsbury, JW, Richards, JK, Huck, SW, Skolits, GJ, and Esquivel, SL. 2013. Practical considerations for using exploratory factor analysis in educational research. Pract. Assess. Res. Eval. **18**: 1–13. doi: 10.7275/qv2q-rk76.

Cabeza, L., Rincon, L., Vilarino, V., Perez, G., and Castell, A. 2014. Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. Renew. Sustain. Energy Rev. **29**: 394–416. doi: 10.1016/j.rser.2013.08.037.

European Commission. 2011. Communication from the commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions. Roadmap to a resource efficient Europe, COM/2011/571. Available from http://www.europarl.europa.eu/meetdocs/2009_2014/documents/com/ [accessed June 2021].

Fabrigar, L., and Wegener, D. 2011. Exploratory factor analysis. Oxford University Press, Oxford.

Farahani, V., Jokisalo, J., Korhonen, N., Jylhä, K., Ruosteenoja, K., and Kosonen, R. 2021. Overheating risk and energy demand of Nordic old and new apartment buildings during average and extreme weather conditions under a changing climate. Appl. Sci. **11**: 3972. doi: 10.3390/app11093972.

Gregow, H., Mäkelä, A., Tuomenvirta, H., Juhola, S., Käyhkö, J. Perrels, A., et al. 2021. Ilmastonmuutokseen sopeutumisen ohjauskeinot, kustannukset ja alueelliset ulottuvuudet. Suomen ilmastopaneelin raportti 2/2021. Instruments, costs and regional dimensions of climate change adaptation. Available from https://www.ilmastopaneeli.fi/wp-content/uploads/2021/09/SUOMI-raportti_final.pdf [full report only in Finnish]. [accessed 1 November, 2021].

Gustavsson, L., Madlener, R., Hoen, H.F., Jungmeier, G., Karjalainen, T. Klöhn, S., et al. 2006. The role of wood material for greenhouse gas emissions. Mitig. Adapt Strateg Glob Chang. **11**: 1097–1127. doi: 10.1007/s11027-006-9035-8.

Gustavsson, L., Joelsson, A., and Sathre, R. 2010. Life cycle primary energy use and carbon emission of an eight-storey wood-framed apartment building. Energy Build. **42**(2): 230–242. doi: 10.1016/j.enbuild.2009.08.018.

Hildebrandt, J., Hagemann, N., and Thrän, D. 2017. The contribution of wood-based construction materials for leveraging a low carbon building sector in Europe. Sustain. Cities Soc. **34**: 405–418. doi: 10.1016/j.scs.2017.06.013.

Horn, J. 1965. A rationale and test for the number of factors in factor analysis. Psychometrika, **30**(2): 179–185. doi: 10.1007/BF02289447. PMID: 14306381.

Henson, RK, and Roberts, JK. 2006. Use of exploratory factor analysis in published research: common errors and some comment on improved practice. Educ. Psychol. Meas. **66**: 393–416. doi: 10.1177/0013164405282485.

Hoibo, O., Hansen, E., and Nybakk, E. 2015. Building material preferences with a focus on wood in urban housing: durability and environmental impacts. Can. J. For. Res. **45**(11): 1617–1627. doi: 10.1139/cjfr-2015-0123.

Ijäs, V. 2013. The obstacles and potential pertaining to the construction of wooden multi-story buildings. A comparative attitude survey of interest groups in the Finnish construction industry and real estate sector. Dissertation, Publication 1142. Tampere University of Technology, Tampere, Finland.

IPCC. 2018. Summary for policymakers. *In* Global warming of 1.5° C. An IPCC Special Report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. *Edited by* V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield. World Meteorological Organization, Geneva, Switzerland. p. 32.

Kaiser, H.E. 1960. The application of electronic computers to factor analysis. Educ. Psychol. Meas. **20**: 14l–151. doi: 10.1177/001316446002000116.

Kim, J.-O., and Mueller, C.W. 1978. Introduction to factor analysis. What it is and how to do it? Sage University Paper. Series: Quantitative Applications in the Social Sciences. SAGE Publications, California. p. 78.

Knowles, C., Theodoropoulos, C., Griffin, C., and Allen, J. 2011. Oregon design professionals views on structural building products in green buildings: Implications for wood. Can. J. For. Res. **41**: 390–400. doi: 10.1139/X10-209.

Larasatie, P., Guerrero, J.E., Conroy, K., Hall, T.E., Hansen, E., and Needham, M.D. 2018. What does the public believe about tall wood buildings? An exploratory study in the US Pacific Northwest. J. For. **116**(5): 429–436. doi: 10.1093/jofore/fvy025.

Lucas, C.H., Booth, K.I., and Garcia, C. 2021. Insuring homes against extreme weather events: A systematic review of the research. Clim. Change. **165**: 61. doi: 10.1007/s10584-021-03093-1.

Lateen, K., Haji, C., and Toppinen, A. 2019. Consumers' perceptions on the properties of wood affecting their willingness to live in and prejudices against houses made of timber. Wood Mater. Sci. Eng. **14**(5): 325–331.

Lähtinen, K., Häyrinen, L., Roos, A., Toppinen, A., Aguilar, F. Thorsen, B., et al. 2021. Consumer housing values and prejudices against living

in wooden homes in the Nordic region. Silva Fenn. **55**(2): 10503. doi: 10.14214/sf.10503.
Malmgren, L. 2014. Industrialized construction: Explorations of current practice and opportunities. Doctoral thesis, Lund University.
Moran, D., Wood, R., Hertwitch, E., Mattson, K., Rodriguez, J., Schannes, K., and Barrett, J. 2020. Quantifying the potential for consumer-oriented policy to reduce European and foreign carbon emissions. Clim. Policy. **20**: S28–S38. doi: 10.1080/14693062.2018.1551186.
Ottelin, J., Amiri, A., Steubing, B., and Junnila, S. 2021. Comparative carbon footprint analysis of residents of wooden and non-wooden houses in Finland. Environ. Res. Lett. **16**(7): 074006. doi: 10.1088/1748-9326/ac06f9.
Osaka, S., and Bellamy, R. 2020. Natural variability or climate change? Stakeholder and citizen perceptions of extreme event attribution. Glob. Environ. Chang. **62**: 102070. doi: 10.1016/j.gloenvcha.2020.102070.
Peterson St-Laurent, G., Hagerman, S., Kozak, R., and Hoberg, G. 2018. Public perceptions about climate change mitigation in British Columbia's forest sector. PLoS ONE, **13**(4): e0195999–e0195999. doi: 10.1371/journal.pone.0195999. PMID: 29684041.
Petruch, M., and Walcher, D. 2021. Timber for future? Attitudes towards timber construction by young millennials in Austria — marketing implications from a representative study. J. Cleaner Prod. **294**: 126324. doi: 10.1016/j.jclepro.2021.126324.
Ranacher, L., Lähtinen, K., Järvinen, E., and Toppinen, A. 2017. Perceptions of the general public on forest sector responsibility: A survey related to ecosystem services and forest sector business impacts in four European countries. For. Policy Econ. **78**: 180–189. doi: 10.1016/j.forpol.2017.01.016.
Roos, A., and Nyrud, A. 2008. Description of green versus environmentally indifferent consumers of wood products in Scandinavia: Flooring and decking. J. Wood Sci. **54**: 402–407. doi: 10.1007/s10086-008-0957-5.
Schauerte, T. 2010. Wooden house construction in Scandinavia—a model for Europe. *In* Internationales Holzbau-Forum (IHF 2010) : Aus der Praxis–Für die Praxis [Internet]. Eberl Print GmbH., CH-Biel. pp. 1–10. Available from http://urn.kb.se/resolve?urn=urn:nbn:se:lnu:diva-10157 [accessed 1 November, 2021].
Sisco, M., Bosetti, V., and Weber, E. 2017. When do extreme weather events generate attention to climate change? Clim. Change. **143**: 227–241. doi: 10.1007/s10584-017-1984-2.
Sipiläinen, I., 2018. Toimialaraportit: Puutuoteteollisuus. Työ-ja ElinkeinoministeriönIulkaisuja 37/2018. Available from https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161135/Toimialaraportit%20-%20Puutuoteteollisuus.pdf?sequence=1&isAllowed=y [accessed 25 September 2019] [in Finnish].
Stagrum, A.E., Andenæs, E., Kvande, T., and Lohne, J. 2020. Climate change adaptation measures for buildings — a scoping review. Sustainability, **12**(5): 1721. doi: 10.3390/su12051721
Statistics Finland. 2021. Available from https://www.stat.fi/til/vrm.html.
Statistics Sweden. 2021. Available from https://www.scb.se/ [accessed 20 October 2021].
Švajlenka, J, and Kozlovská, M. 2021. Factors influencing the sustainability of wood-based constructions' use from the perspective of users. Sustainability, **13**(23): 12950. doi: 10.3390/su132312950.
Swedish Federation of Wood and Furniture Industry. 2021. Available from https://www.tmf.se/statistik/branschstatistik/trahusstatistik/ [accessed 5 July 2021].
Taylor, A., de Bruin, W.B., and Dessai, S. 2014. Climate change beliefs and perceptions of weather-related changes in the United Kingdom. Risk Anal. **34**: 1995–2004. doi: 10.1111/risa.12234. PMID: 24919520.
Toppinen, A., Röhr, A., Pätäri, S., Lähtinen, K., and Toivonen, R. 2018. The future of wooden multistory construction in the forest bioeconomy—a Delphi study from Finland and Sweden. J. For. Econ. **31**: 3–10. doi: 10.1016/j.jfe.2017.05.001.
Upton, B., Miner, R., Spinney, M., and Heath, L. 2008. The greenhouse gas and energy impacts of using wood instead of alternatives in residential construction in the United States. Biomass Bioenerg, **32**: 1–10. doi: 10.1016/j.biombioe.2007.07.001.
Viholainen, N., Franzini, F., Lähtinen, K., Nyrud, A., Widmark, C., Hoen, H., and Toppinen, A. 2021. Citizen views of wood as a construction material: results from seven European countries. Can. J. For. Res. **51**: 647–659. doi: 10.1139/cjfr-2020-0274.
Wiegand, E., and Ramage, M. 2021. The impact of policy instruments on the first generation of tall wood buildings. Build. Res. Inf. **50**: 255–275. doi: 10.1080/09613218.2021.1905501.
Yan, X., and Su, X. 2009. Linear regression analysis: theory and computing. World Scientific, Singapore. doi:10.1142/6986.

Appendix A

Overview of climate and construction-related measurement scales.

13. Perceptions concerning climate change

"In my opinion…

A. …human activities are causing climate change."

B. …climate change is exaggerated by the media, and it is not a big issue."

C. …climate change is a real and serious issue."

D. …recent extreme weather disasters are caused by climate change."

E. …climate change depends on natural variations, and it is not caused by humans."

14. Perceptions about construction, climate, and the environment*

"In my opinion…

A. …wood as a construction material stores carbon and thus can help reduce net emissions of global warming gases."

C. …building with wood is more climate friendly than concrete or steel."

D. …building with wood destroys important habitats for rare and endangered species."

E. …building with wood contributes significantly to higher greenhouse gas emissions."

F. …building materials — whether steel, wood, or concrete — do not impact the climate."

G. …building materials — whether wood, steel, or concrete — can impact the habitat of endangered species."

15. Perceptions concerning construction and extreme weather events

"In my opinion…

A. …extreme weather has already increased the maintenance costs of wood in exteriors (e.g., facades)."

B. …extreme weather conditions have not decreased the technical durability of wood in exteriors (e.g., facades)."

C. …extreme weather conditions will curb the appeal of using wood in building exteriors."

D. …extreme weather conditions will increase the appeal of using wood as a load-bearing material in construction."

E. …carbon stored in wooden building materials will significantly increase the attractiveness of using wood in construction."

F. …carbon stored in wooden building materials will significantly increase the attractiveness of using wood in the construction of public service buildings (e.g., schools)."

G. …carbon stored in wooden building materials will not significantly increase the attractiveness of using wood in the construction of residential housing."

H. …wooden building materials used indoors are aesthetically less appealing to me than other materials."

I. …wooden building materials used outdoors are aesthetically more appealing to me than other materials."

*Variable 14B excluded from the analysis due to differences in questions setting between countries.

Appendix B

Multicollinearity results (GVIF)

Table B1. GVIF table for Finnish data.

	GVIF	df	GVIF^(1/(2*Df))
Age groups	1.087501	2	1.021192
Gender	1.097170	1	1.047459
Education	1.073192	1	1.035950
Residential location	1.110759	2	1.026609
Question 13C Climate change is real and serious	1.059707	1	1.029421
Pref. home load-bearing material	1.124724	3	1.019783
Forest sector relation	1.083702	1	1.041010
Familiarity with wooden buildings	1.113982	1	1.055453

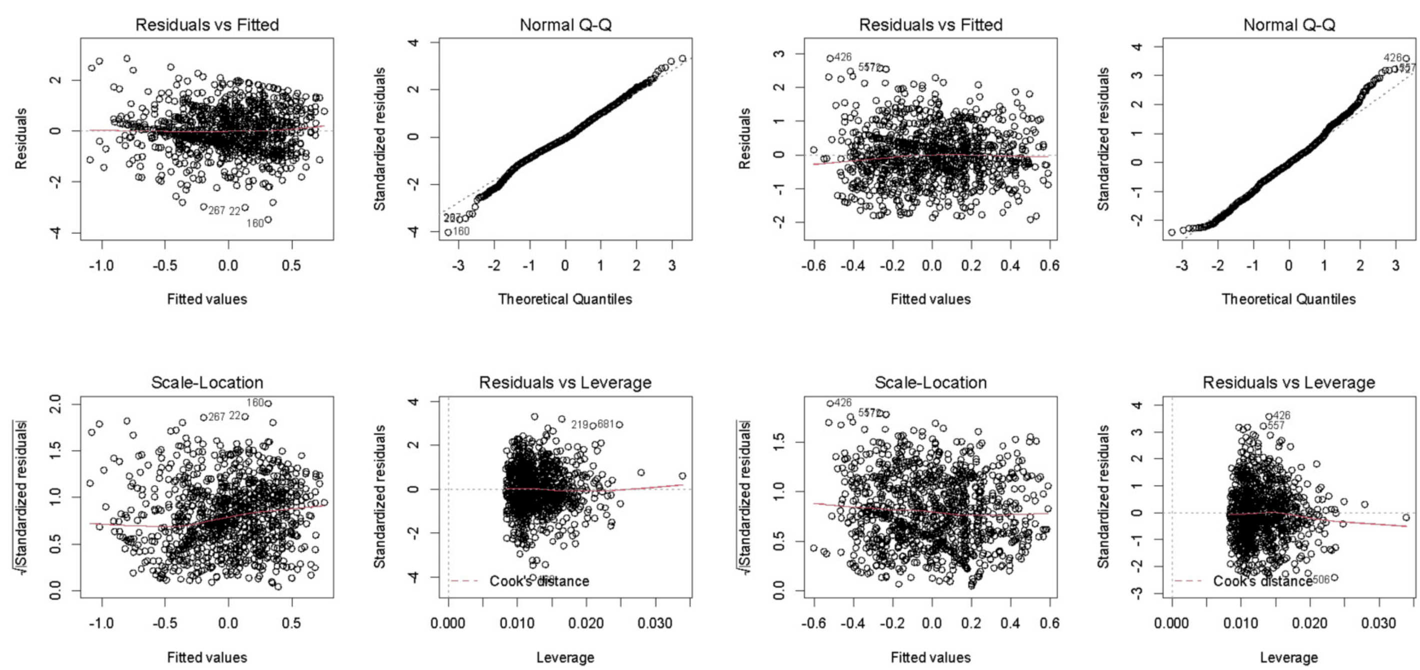
Table B2. GVIF for Swedish data.

	GVIF	df	GVIF^(1/(2*Df))
Age groups	1.068678	2	1.016744
Gender	1.083243	1	1.040789
Education	1.050466	1	1.024923
Residential location	1.095504	2	1.023066
Question 13C Climate change is real and serious	1.036017	1	1.017849
Pref. home load-bearing material	1.196949	3	1.030416
Forest sector relation	1.105109	1	1.051241
Familiarity with wooden buildings	1.133698	1	1.064752

Appendix C

Regresssion diagnostics

Figure C1. Results for "FIN—pos" model (left) and "FIN—neg" model (right).



Can. J. For. Res. **52:** 1266–1279 (2022) | dx.doi.org/10.1139/cjfr-2022-0108

Figure C2. Results for "SWE—pos" model (left) and "SWE—neg" model (right).