





Article

The Future of Wood Construction: Opportunities and Barriers Based on Surveys in Europe and Chile

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Abstract: The demand for wood has increased in recent years due to new technical possibilities and environmental concerns. This paper provides an analysis of the factors that affect the use of wood in the construction sector, and an assessment of their importance in individual countries and for groups of stakeholders. The study covers the technical, societal, political, economic, and gender aspects of wood construction, with the aim of increasing global understanding regarding national differences, the current situation, and the potential for further development. The subject was investigated using a survey, and the most important opportunities for and barriers to growth in the use of wood in the construction sector were selected, following a statistical analysis. The results indicate strong regional and cultural differences regarding the acceptance of some of the opportunities and barriers related to the development of wood construction. The findings indicate that there is a need to promote wood construction based on its technical and economic benefits rather than its societal ones. On the other hand, the current societal barriers should be addressed as a priority, together with the establishment of common and harmonized policies. The results of this study, therefore, will contribute to the generation of regional-sensitive information that can be useful for policymakers when updating the building codes in their individual countries.

Keywords: wood sector; construction; opportunities; barriers; politics; international survey

1. Introduction

Wood has been used in construction for thousands of years, and it is still the only renewable construction material available in industrial volumes. Certain properties of wood are complex in terms of its use for construction, but despite this, architects, engineers, and contractors have successfully harnessed this resource to build a wide range of structural

and non-structural products. “Wood construction” is defined in different ways in different countries. One definition is based on the structural material of the building, while others can be based on the main construction material on a volumetric basis [1]. These differences hamper country-wide comparisons of construction statistics, for example. Furthermore, it is understandable that normal consumers are unaware of the various definitions related to wood construction. An estimate of the carbon storage potential of new buildings in Europe between 2020 and 2040 by Amiri [2] showed that this potential is dependent on the number and the volume of wooden elements used in buildings. For indoor uses, wood also contributes to physiological and mental well-being (e.g., [3–6]). In the context of an emerging circular economy, wood is a zero-waste material that can be used for energy production after its product lifecycle ends [7].

In line with the above, climate policy instruments aim to support efficient ways to capture and store CO₂ from the atmosphere. While wooden buildings act as long-time physical carbon storage, their substitution effect, that is, the avoidance of emissions caused by the use of more energy-intensive materials, such as steel and concrete, is of even greater importance. Furthermore, there is a system-level mechanism that also plays an important role: wood product industries strongly contribute to sustainable forestry and, thus, to the size of biomass and soil carbon sinks [8].

It has been estimated that the use and operation of buildings are responsible for approximately 40% of the total energy consumption of EU member states (EU28)—40% and 27.3% in the US and China, respectively [9]—and for 36% of their greenhouse gas (GHG) emissions from energy [10]. The construction sector also uses half of the extracted materials and one-third of the water demand. Together with the related demolition, packaging, and bulky wastes, the construction sector generates one-third of all waste in the EU28 [11]. Approximately one-third of wood waste is recycled as materials (cascading), one-third is incinerated (energy), and one-third is landfilled [12]. While the construction sector has huge economic and environmental impacts, small development steps toward sustainability help to lower the environmental footprint of the sector.

Low economic competitiveness is often cited as the greatest drawback to building multistory houses from wood (e.g., [13,14]). However, recent evidence from many European countries shows that this challenge can be overcome through technological progress and innovative building practices [15–20]. In seismic-prone countries such as Chile, the advantage of wood is that it is suited to absorbing vibrations but, still, one of the most important technical challenges is to improve our understanding of the seismic behavior of mid-height timber-frame systems [21].

Hurmekoski et al. [22] state that despite the improved technical and economic competitiveness, the large-scale diffusion of wood construction in Europe has been restricted by cultural and structural hindrances, low uptake in fragmented and risk-averse construction industries, and the complex traditions and norms related to the use of wood in construction. Furthermore, Hurmekoski [23] concludes that the diffusion of wooden multistory construction is most likely to take place in the Nordic countries and parts of Central Europe that have a high societal interest in using domestic forest resources. This has gained in importance during the past half-decade but, still, the path-dependency of designers and construction industries slows down the development of larger wood construction markets.

According to the sustainability paradigm, it is essential to integrate economic, social, and cultural aspects with environmental goals in strategic development and policy actions. The European construction sector provides 18 million direct jobs, contributing 9% of the GDP of the 19 countries of the euro area [12]. According to estimates by Hetemäki et al. [24], within all construction businesses, wood construction accounts for 19% and 15% of labor and turnover, respectively. As described in the 89th Euroconstruct conference press release [25], total construction (all raw material) output in the Euroconstruct (EC-19) area grew by 2.7% in 2019, compared with 2018. New construction projects of buildings and infrastructure have been driving the market for several years, and these increased by 3.9%

in 2019, while renovations were growing steadily by around 2% a year. Total construction output reached EUR 1700 billion in the EC-19 area in 2019.

Several estimates of wood construction market development have been published over the past 15 years (e.g., [17,26–30]). Technological progress and efforts toward climate change mitigation have opened up new business opportunities in the construction sector.

The share of wood construction in total construction varies greatly between countries. Finland is the first EU member state to pursue carbon neutrality by the year 2035. The government program [31] sets a clear framework for timber construction in Finland. The aim is to double the use of wood as a building material during the parliament's tenure of four years, set the objectives for wood use in public buildings, and enhance the know-how and overall development of the wood construction value chain. Ambitious objectives for the use of wood in public construction were published in the autumn of 2020 [32]. While the share of wooden buildings in all public building construction was approximately 15% in 2020, this is expected to increase to 45% by the year 2025. The share of wooden buildings is expected to increase from approximately one-third to two-thirds in new educational buildings, and from approximately 3% to 46% in new public-owned multistory residential buildings. The anticipated development is likely to improve the competitiveness of wood as a building material and, if realized, it will surely significantly increase the use of wood in Finnish construction.

Similarly, Chile is aiming to reach carbon neutrality by the year 2050; the contribution of forest resources is fundamental to reaching this goal, as it is expected that at least 50% of the CO₂ emissions will be offset by the sequestration of growing trees [33]. Moreover, recently, the Chilean Ministry of Agriculture announced a long-term policy for the development of the forestry sector; the main objectives are to fully exploit the national forestry potential related to natural resources, industry, and the development of technical-scientific knowledge by the year 2035. In particular, this policy aims at transforming wood into one of the main components of construction materials in the country, increasing the use of wood in buildings from 18% in 2015 to 36% by 2035 [34].

The French forest-based sector is steered by several public policy processes and actors, such as the ministries in charge of forests and of the economy, the National Industry Council, the Forest-based Higher Council, the Strategic Committee for the Forest-based Sector, and other specialized committees. They issue the main national policy documents related to the forest-based sector: the French forest code and the French National Forest and Wood Program (PNFB 2016–2026) [35]. PNFB has defined the directions for forestry policy over the next ten years, comprising four objectives and an action plan, along with detailed arrangements for its roll-out at the national and regional levels. Matching actual market needs with products coming from French forests is, therefore, a major issue. The wood construction market represents nearly one-third of the use of wood. According to the “Action plan for wood construction 2030” (Plan Ambition Bois Construction 2030 [36]), the industry professionals have set themselves the following objectives beyond 2022, particularly in relation to public policies about ecological transition: (1) doubling the market share of wood in new collective housing; (2) increasing the share of wooden single-family houses from 10 to 15 percent; (3) increasing the share of wood used in renovation up to 15% and 20% in collective buildings and individual housing, respectively. In total, 12% of multistory residential houses are expected to be made of wood by the year 2025. Approximately 25% of farm buildings have been built out of wood during the past ten years and that share is not expected to increase.

Poland promotes wooden construction and aims to increase its share in the construction of single and multi-family houses. The Act of 20 July 2018 amending the Act—the Environmental Protection Law (Journal of Laws 2018, item 1648 [37]) established the program “Polskie Domy Drewniane”, the main focus of which is energy-saving wooden construction encompassing the erection of residential buildings, the management of these buildings, and the letting of residential buildings or apartments with the option of their sale. The program aims to support the erection of single-family wooden houses and apartments

in multi-family wooden houses. By the end of 2022, around 12,000 wooden flats will be built, of which 92% are to be multi-family housing (with a maximum of 4 floors) and 8%, single-family housing. The first houses are already under construction and further investments are planned for the coming years. Service and public buildings are also to be built but, as of today, the state policy does not provide any forecasts regarding their number.

Sweden strongly promotes wooden construction and aims to increase its share of multi-family houses. Local authorities and municipalities have their own plans for reducing the environmental impact of CO₂ emissions from the building sector, which directly leads to the use of more wood in the structural elements of new buildings. Today, approximately 20% of the new multistory apartment buildings are made of wood in terms of the structural weight-bearing system. This figure is increasing, not least due to new local strategy plans in various places throughout Sweden. Already, there are successful buildings, demonstrating that it is possible to build high-rise buildings in urban areas that are made only from wood. One recently finished project is Cedar House in the city center of Stockholm, which comprises 236 dwellings in four adjacent buildings of 12 stories [38]. A considerable number of lightweight beam buildings have also been constructed, showing even lower environmental impact as they consumed less material; this implies better efficiency concerning the resources used [39].

In Spain, the Act of 20 May 2021 on “Climate Change and Energy Transition” [40] includes as one objective the minimum national targets for greenhouse gas emission reductions, renewable energies, and energy efficiency for the years 2030 and 2050. By the year 2030, these emissions should be reduced by at least 23% (compared to 1990) and climate neutrality must be achieved by 2050 at the latest. To achieve these objectives, public procurement should include criteria to promote the use of sustainable building materials, considering their lifespan, while the use of materials with the smallest possible carbon footprint is clearly encouraged. In this respect, wood is the only building material named in the Act. Hence, the use of wood, and its sustainable origin, will be included in future public procurement and contract award procedures, and companies wishing to participate in public procurement will have to adapt to its use.

In line with the Resolution of the Council of Ministers no. 107/2019, “The Roadmap for Carbon Neutrality 2050” [41], Portugal has committed to carbon neutrality by 2050, mainly through more rational forest management. The roadmap introduces alternative and low-emission development pathways in four areas of intervention linked to those sectors largely responsible for greenhouse gas emissions and carbon sequestration: energy, transport and mobility, waste, agriculture, and forest and land use. The pathways will be based on three multi-faceted aspects: socio-economic scenarios, the circular economy, and social participation. One of the main objectives of the roadmap is to increase active afforestation, promote more efficient forestry practices in resource use and risk management, and improve ecosystem services that impact the bioeconomy, which directly translates into higher net carbon retention. A declared measurable objective is to reduce the emissions in buildings by up to 85% by 2050. Hence, the approved regulation foresees an increase in urban reclamation, with the reuse of building elements, recycled materials, and the use of built-up public spaces with passive buildings with a zero-energy balance, multi-functional and shared buildings with a reduced building area, as well as the use of new, more sophisticated materials with greater energy efficiency and durability, along with renewable materials with a lower carbon footprint (mainly wood and cork). Products currently used in construction (such as tiles, bricks, and floors) will be partially replaced by wood and wood-based materials; this is related to a paradigm shift in the construction sector, which is already beginning to favor materials with carbon reservoir properties. Besides this, the resolution also encourages the use of materials with a low carbon footprint in the retrofitting of buildings, while improving their energy efficiency.

While wood construction has apparently garnered political support in many countries, it also faces a variety of challenges. Few major improvements have taken place in the European construction sector over recent decades in terms of productivity, profitability,

or environmental impacts, despite attempts to adopt prefabrication and industrial mass production in construction [19,23]. This is evident, especially when compared with North America, where wood has traditionally held great importance in construction [42].

New challenges for construction have been identified at the European level, such as the cascade use of materials and low-carbon aims. Urbanization, migration, and population aging stimulate construction and urban development. The use of wood in construction is one of the most desirable paths for utilizing Europe's own resources, switching from product-based to performance/functionality-based business concepts, implementing eco-design, and adopting cascading practices [43,44]. European policy actions, such as the Green Deal, Renovation Wave, EU Circular Economy Strategy, and EU Forest Strategy, will benefit from and are expected to support the development and implementation of building with and living with wood. It is notable that construction and new bio-based products represent two of the five priority areas of the EU "Action Plan for the Circular Economy". At the same time, however, climate policy actions aim at increasing forest carbon sinks, which end would be most rapidly achieved by decreasing harvesting levels. These contradictory policy objectives confuse consumers and industry stakeholders and complicate the strategic planning of industrial investment. Furthermore, the various European regions and countries have different opportunities and specific framework conditions, which can be seen in the form of various policy actions and development priorities [44].

In the intensified discussion on obstacles to and opportunities for wood construction, much attention has been paid to the national technical standards and regulatory aspects in different countries [14,15,45]. Research has also been carried out on life cycle analysis and other sustainability impact assessments [46–48]. Numerous papers have been published regarding user preferences and change drivers in the use of wood in construction and interior materials [49–56]. These studies have been based solely or mostly on national views and data sets. A harmonized multinational data set enables reflecting the above-summarized wood construction strategies in expert and user opinions in different countries. Such analysis supports finding the most feasible approaches to implement the strategies and to reach the wood construction objectives.

While many countries have a political will and have published strategies to increase the use of wood in the construction sector, it is necessary to analyze how to translate these strategies into actions. Assessing the relevant implementation methods requires an understanding of the level of knowledge and preferences regarding wood construction among both construction sector experts and private dwellers.

The objective of this study is to analyze the factors that affect the use of wood in the construction and renovation value chains in selected European countries (Finland, France, Poland, Portugal, Spain, Sweden) and Chile. Since wood presents the potential to solve many challenges related to tremor-safe construction, Chile (a developing country with a strong wood products sector and global markets [57], high seismic activity, and an emerging wood construction sector) was chosen as a reference. This approach allows a more global outlook for problems and opportunities, as well as a broader consideration of the different perspectives of stakeholders, consumers, and national circumstances.

2. Methods

Factors influencing the use of wood in the construction sector in selected European countries have been divided into positive factors (opportunities for using wood) and negative factors (barriers limiting the use of wood). The first step of the research process was to create a list of opportunities and barriers in the aforementioned categories (Figure 1). This task was carried out by a team of experts from Poland, France, Finland, and Chile. Experts representing each country highlighted certain opportunities and barriers, which were checked for duplicates. In the second step, a list of 43 opportunities and 61 barriers was drawn up and organized into four categories: technical, economic, societal, and political. In the third step, two surveys were drawn up, based on the proposed opportunities

and barriers: one for entities directly related to the wood construction sector (producers, representatives of public administration, and experts in the field of wood construction from academia/research institutions, associations, federations, and networks), and another for the end-users (consumers). Children or elderly respondents were not included in this study. The surveys were prepared in English but were also translated into some national languages (French, Polish, Spanish) to make the respondents' task easier and to enable a complete understanding of the content [58]. In order to avoid errors in the translation process, translations were made by scientists from these countries—experts in the field of forests, wood products, and construction terminology.

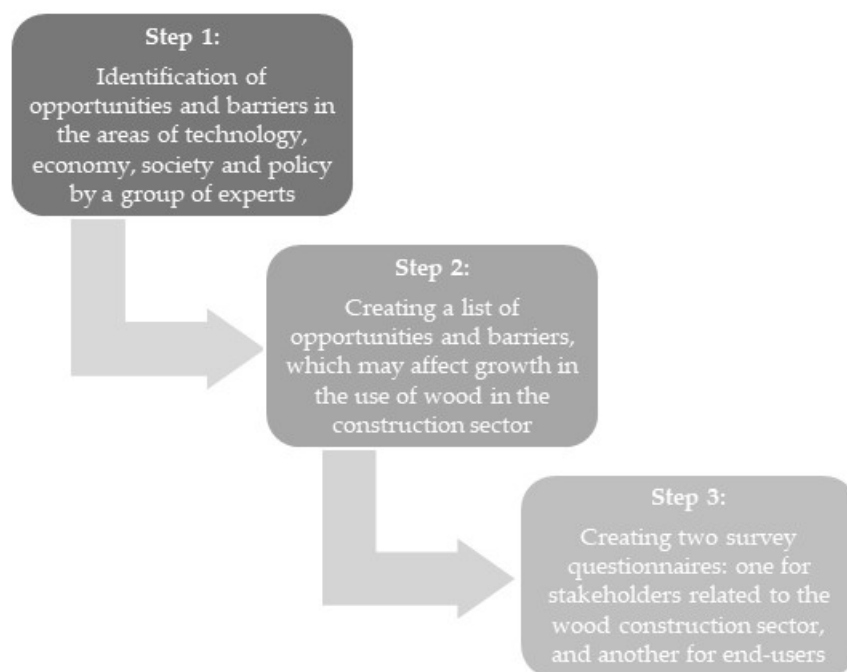


Figure 1. The process of creation of the survey questionnaires.

In both surveys, a five-point Likert scale was used as a means of measurement. This method is widely used in the social sciences and in educational research to measure human attitudes, particularly for obtaining knowledge on the degree of acceptance of phenomena, views, processes, features, etc. [59–62]. The first survey, addressed to those entities related to the construction sector, included closed questions, with the possibility of respondents' adding and evaluating their own examples. Respondents were asked to assess the importance of opportunities for and barriers to growth in the use of wood in the construction sector. The second survey, addressed to members of the public, concerned issues such as their understanding of the concept of a wooden house, opinions on wood construction, and the most important factors encouraging people to live permanently or work regularly in a wooden house.

Respondents to the survey were selected using non-probability (quota) sampling [63] because of the suitability of this method for research purposes; in the case of expert opinion surveys, convenience sampling is seen as highly appropriate [64]. Non-probability selection is conditional on having knowledge of the surveyed population. It may be more useful for research purposes than random models, see inter alia: [65–68]. The main criterion for the selection of expert respondents was their type of activity linked to the wood construction sector and their deep knowledge of the sector. Business entities were identified based on the classification of activities in a given country, modeled on the ISIC classification (International Standard Industrial Classification of all Economic Activities), and were additionally verified through an Internet search query. Relevant experts and representatives of public administration were selected by the authors from countries participating in the

study. The participants were involved in the construction sector (including, among others, not only representatives of regional and city government offices but also scientists, members of chambers of commerce, and associations related to the sector). In the case of end-users, the survey was sent to citizens from different countries, who are of active working age—this was the focus group, whereas young people or retired citizens were not included in this study. As with the experts and public administration, the end-users were selected by the authors. This process was repeated using non-probability selection. Convenience sampling does not guarantee the representativeness of the sample, but it may be used for explorative research, which was the aim of this part of the study [67,69,70].

The surveys were sent out on 20 December 2019 to the organizations involved in the study (nine partners from seven countries). Each partner was tasked with collecting 10 surveys from entities directly related to the construction sector, including 5 from producers, 3 from experts in the field of wood construction from academia/research institutions, and 2 from representatives of public administration and, additionally, at least 10 surveys from end-users. To increase the number of responses and emphasize the international nature of the research, the survey that was addressed to organizations directly related to the wood construction sector was additionally sent to all project partners on 23 January 2020 (30 partners from 12 countries). The sample size was assumed to be at the level of 120 questionnaires from entities directly related to the construction sector and 90 questionnaires from end-users. Data collection was completed on 13 March 2020, approximately 2.5 months after the survey was sent out. A total of 96 responses from producers, experts, and public administration, along with 88 responses from end-users, were obtained, which indicates a response rate of 80% and 98%, respectively. The high response rate was caused by a fact that the respondents were selected in two rounds, first they were asked if they would take part in the survey, and then, after their positive answer, they were given a questionnaire to complete.

The data from surveys underwent a reduction process that consisted of data control, editing, and description, as well as tabulation and aggregation. During the data-editing process, the intelligibility of the questions was checked. In the inference phase, questionnaires that did not contain answers to all questions were also used. After the reduction process, the data were collected in tables and then processed. Moreover, to illustrate the differences between individual responses, the survey results were grouped. Respondents from European countries were grouped according to the UN's geoscheme regions, whereas Chilean respondents' results were analyzed separately. In the study these regions were represented by the following countries: Northern Europe—Finland, Sweden; Southern Europe—Spain, Portugal, Italy; Eastern Europe—Poland, Ukraine, Hungary; Western Europe—France, Germany, the Netherlands.

For the purposes of this study, the list of opportunities and barriers that may increase or limit the use of wood in the construction sector was narrowed down to 15 opportunities and 16 barriers. This was conducted using item-total correlation. Only those statements that obtained the highest Pearson's correlation coefficient (ranging from 0.53 to 0.78 for the particular statements—Table 1) were selected for the analysis. For each category (technical, societal, economic, political), three to four statements with the highest correlation coefficients were selected. Generally, with such a study, we want the correlation between each element and the whole scale to be high. Otherwise, we may suspect that the item does not measure the same construct as the others do; this is a premise for considering the removal of the item from the scale [71]. Respondents who did not reply to one or several questions, in accordance with the assumption of the item-total correlation, were removed from the list and were not included in determining the correlation coefficient. However, all answers are included in the presented results.

Table 1. Item-total correlation and reliability analysis results.

Indicator	Identified Opportunities							
	Technical		Societal		Economic		Political	
	All (k = 12)	Chosen (k = 4)	All (k = 13)	Chosen (k = 4)	All (k = 8)	Chosen (k = 3)	All (k = 10)	Chosen (k = 4)
Item-total correlation	0.23–0.68	0.66–0.68	0.49–0.78	0.68–0.78	0.52–0.77	0.73–0.77	0.56–0.74	0.68–0.74
Cronbach’s alpha	0.794	0.769	0.880	0.789	0.844	0.740	0.856	0.760
Indicator	Identified Barriers							
	Technical		Societal		Economic		Political	
	All (k = 13)	Chosen (k = 4)	All (k = 12)	Chosen (k = 4)	All (k = 21)	Chosen (k = 4)	All (k = 15)	Chosen (k = 4)
Item-total correlation	0.34–0.58	0.53–0.58	0.37–0.73	0.64–0.73	0.26–0.62	0.55–0.62	0.39–0.72	0.67–0.72
Cronbach’s alpha	0.701	0.607	0.828	0.761	0.825	0.629	0.865	0.797

k—number of scale items. Source: Authors’ own calculations based on survey results.

A reliability analysis was performed using Cronbach’s alpha coefficient to ensure that the scale items were consistent with each other [72]. This was carried out twice, first before removing individual items from the scale, and then after removing them. Table 1 indicates that Cronbach’s alpha coefficients decreased after the items were removed from the scale but were still acceptable (0.607–0.797). An important property of the alpha coefficient is that its value tends to decrease with a decrease in the number of scale items [73–75]. Selected opportunities and barriers were presented, using graphs supplemented with written comments.

3. Results

3.1. Characteristics of Survey Respondents

Detailed characteristics of the survey respondents are presented in Tables 2 and 3 on the Zenodo repository (database: <https://doi.org/10.5281/zenodo.5752898>) (accessed on 1 March 2022).

3.2. Results of Construction Sector Stakeholders Survey

3.2.1. Opportunities to Increase the Use of Wood in the Construction Sector

Figure 2 presents 15 selected opportunities that may contribute to the development of the wood construction sector. According to the respondents, the most promising opportunities were political and economic (at least 71% of the respondents in both groups agreed or strongly agreed that these opportunities could increase the use of wood in the construction sector). The highest-rated opportunity concerned the political issue of climate change, resulting in an increased search for low-emission products and buildings (P2, 82% positive answers: agree or strongly agree). Another highly rated item concerned the dynamic development of mass timber construction, taking advantage of the wide array of EWP, such as Glulam, LVL, and CLT (T2, 81%).

Interesting differences may be observed between the regions represented by the respondents (Figure 3). For respondents from Western Europe, the political aspects were considered most important, especially those concerning low-emission products and carbon storage solutions driven by climate change policies (P2 and P3). Respondents from Eastern Europe also regarded political aspects as relevant, but technical issues were most often indicated, including architectural design (T3) and the development of the engineering and construction sector (T4): 100% and 92% of respondents from this region, respectively, indicated these as being opportunities to increase the use of wood in the construction sector.

P1, P2, P3, P4 – political aspects; E1, E2, E3 – economic aspects; S1, S2, S3, S4 – societal aspects; T1, T2, T3, T4 – technical aspects

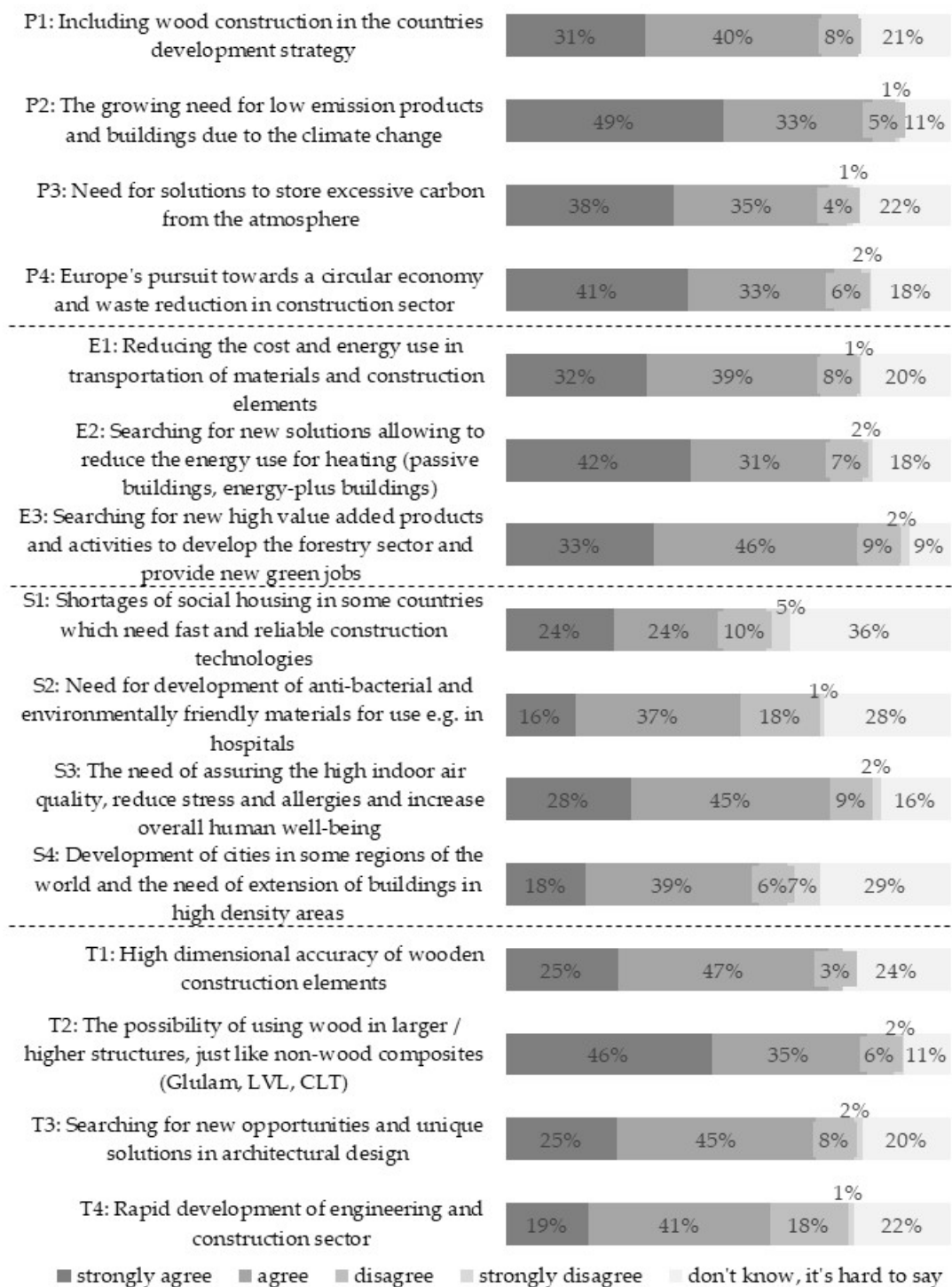


Figure 2. Respondents' assessments of selected opportunities to increase the use of wood in the construction sector ($n = 96$).

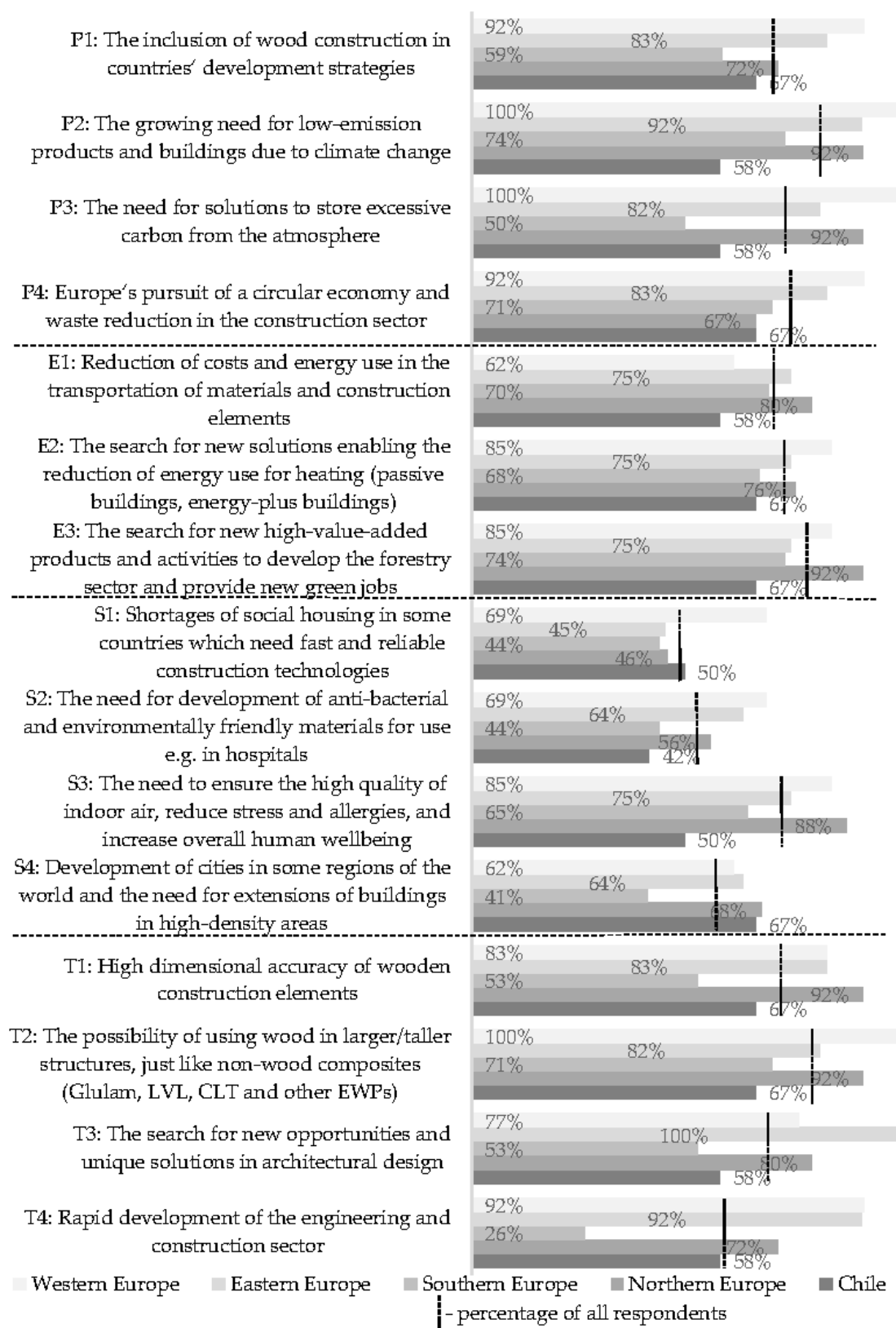


Figure 3. Respondents' assessments of selected opportunities to increase the use of wood in the construction sector, sorted by region (combined percentage of responses of "agree" and "strongly agree"; $n = 96$).

Respondents from Southern Europe, in turn, placed the most emphasis on the economic context of the development of the wood construction sector. Approximately 70% of respondents from this region agreed or strongly agreed that the search for new high-value-added products and activities (E3), as well as the reduction of costs and energy use in terms of the transportation of materials and construction elements (E1), are the main drivers of the change in construction toward increased wood use. However, it should be noted that some opportunities in the political and technical domains were also perceived as having a similar level of importance.

Northern European respondents indicated the same aspects were the most important opportunities as Chilean respondents; however, the latter were, on average, less convinced that they would play a vital role (the positive response rate for the Nordic countries was approximately 25 percentage points higher than for Chile; for P2, for example, 92% of respondents from Northern Europe selected “agree” or “strongly agree”, compared with 58% for Chile). Both the search for low-emission products and new high-value-added products and activities were perceived as relevant (P2 and E3), while the high dimensional accuracy of wooden construction elements (T1) was also frequently identified as an opportunity.

Among the surveyed groups of respondents, none of the regions indicated societal aspects were the most important opportunities; respondents considered these to be the least likely drivers for the development of the wood sector in construction.

The selected opportunities that may increase the use of wood in the construction sector were also analyzed in terms of the responses given by various types of respondents (see Figure 4). Considerable differences were observed for particular categories and items.

In the case of political opportunities, these differences accounted for up to 25 percentage points, depending on the type of respondents. An example is the perceived role of circular economy transformation and waste reduction in the development of the wood construction sector (P4), in which 83% of respondents from associations, federations, and networks and 81% of respondents representing academia and research institutions agreed or strongly agreed that this may be an important opportunity, while for respondents from public administration, the share was only 57%. The role of wood construction and wood products in climate change mitigation was more often acknowledged and was among the highest-rated opportunities in all groups of respondents.

The largest difference in ratings concerns the potential role of innovative architectural designs as a driver of wood construction development (T3), in which 92% of respondents from associations, etc., and 87% of those from public administration responded with “agree” or “strongly agree”, while only 50% of business respondents did so. Another interesting difference relates to the perception of wood construction as a sector providing high-value products and services contributing to green growth (E3): 100% of respondents from associations, federations, and networks indicated this as a vital opportunity, while other groups rated it much lower. Additionally, associations and business representatives seemed to perceive aspects related to human wellbeing (S3: air quality, stress, allergies) as more important in the context of wood construction development than did the representatives of administration and academia. In the business group, this aspect was the most highly rated of all. The opposite situation was observed with regard to trends in city development (S4), where respondents from public administration and academia more often answered with “agree” or “strongly agree”.

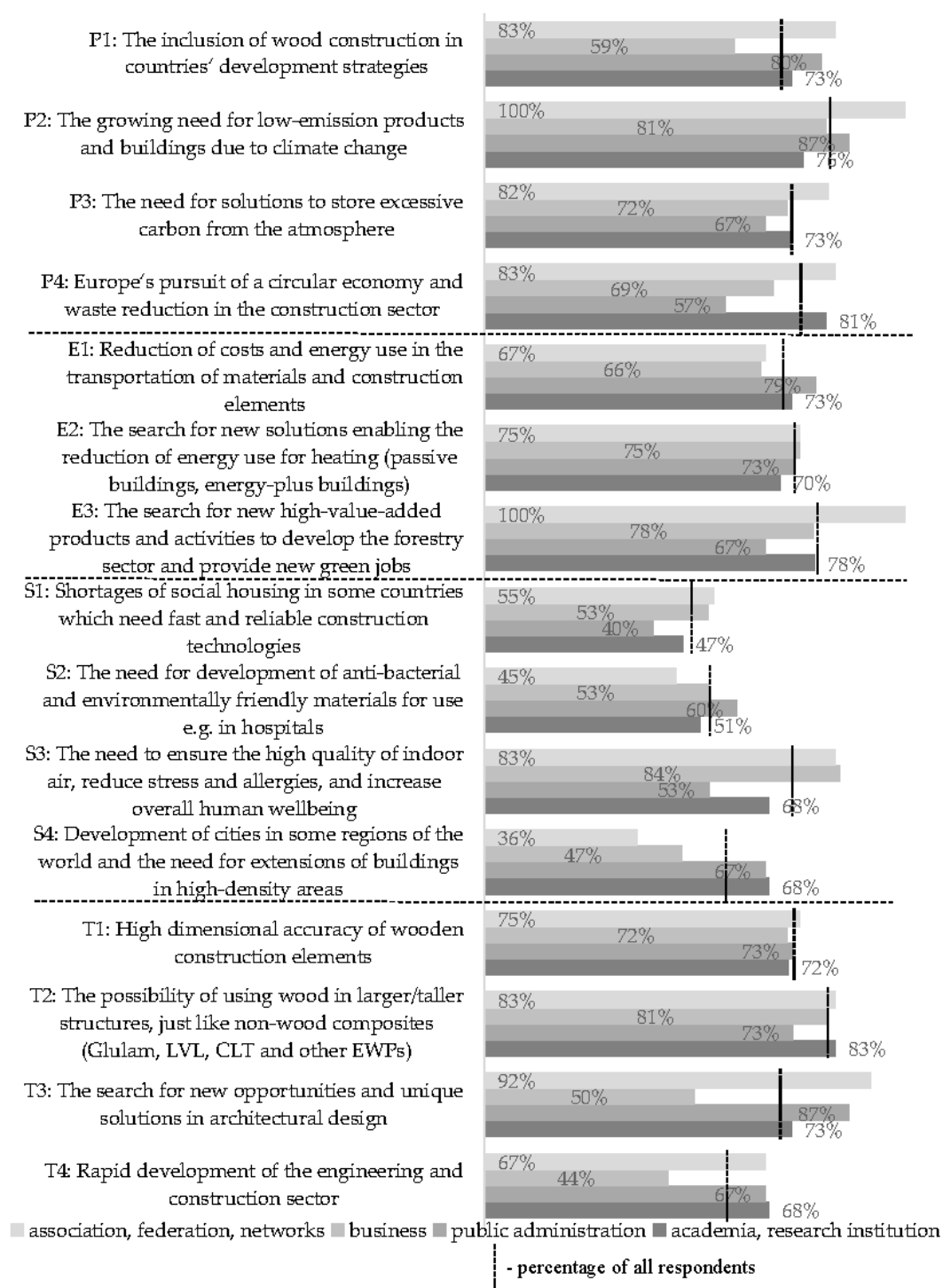


Figure 4. Respondents' assessments of selected opportunities to increase the use of wood in the construction sector, shown by the type of respondent (combined percentage of responses of "agree" and 'strongly agree'; $n = 96$).

There were also opportunities that were considered equally important by all groups of respondents. This applies to the search for solutions to improving the energy performance of buildings (E3), the high dimensional accuracy of wood products (T1), and engineered wood products enabling the construction of tall timber buildings (T2). Mass timber was also indicated as the most promising opportunity by representatives of academia and research institutions.

The differences between the responses given by women and men are mostly relatively small (within a few percentage points). In general, women indicated that economic and social aspects may have a greater impact on the development of the wood construction sector, while men attributed more importance to political aspects.

3.2.2. Barriers Limiting the Growth in the Use of Wood in the Construction Sector

The next step was to analyze the barriers that may limit growth in the use of wood in the construction sector (Figure 5). According to the respondents, these were mostly related to societal and political trends: 60–80% of respondents agreed or strongly agreed with the statements concerning barriers in these categories. Respondents most often indicated that the popular view of wooden construction as being exposed to high fire risk significantly impedes the development of the sector (84% of respondents agreed or strongly agreed with this statement). Other highly rated answers concerned the low public awareness of the qualities of wooden buildings (S2) and a lack of ambitious research and innovation policies (P4). Economic and technical aspects were not acknowledged so often: 25–44% of respondents agreed or strongly agreed that the selected economic factors were relevant obstacles to the increased use of wood in construction, while in terms of the technical aspects, the range was 14–56%. The settling of the building (T3) was perceived as the least important barrier (only 14% responded with “agree” or “strongly agree”).

Unlike in the case of opportunities, the perceptions of barriers to the use of wood in construction are less dependent on the respondents’ region (Figure 6). However, it may be observed that there is a relevant difference between the perceptions of respondents from Northern Europe and the other studied regions. Specifically, Northern European respondents attributed less significance to many of the obstacles proposed in the survey in comparison with other regions, especially Eastern and Southern Europe. For example, 91% of Eastern European respondents agreed or strongly agreed that a lack of incentives for local wood sourcing (P1) was an important barrier to wood construction development, while in Northern Europe, the figure was 38%. Similarly, respondents from Eastern Europe attributed importance to the low availability of publications (S1), while the positive response rate (agree or strongly agree) in Northern Europe was 51 percentage points lower.

Another striking difference concerned the lack of wood construction promotion programs (P3), which was rated as a considerable barrier by respondents from all regions except Northern Europe. Public awareness concerning wood and eco-construction (S2 and S3) also seems to be divergent between regions, with respondents from Northern European countries leading in this area, and other regions lagging behind. A low level of knowledge among the public regarding the features and advantages of wood construction (S2) was also the most indicated barrier by Western and Eastern European respondents (respectively, 100% and 92% of respondents agreed or strongly agreed). In Northern and Southern Europe, among the surveyed people, the fire risk associated with wooden buildings (S4) was the most frequently indicated barrier, followed by the lack of ambitious innovation and research policy (P4).

Respondents from Chile, on the other hand, placed the most emphasis on the lack of wood construction promotion programs (92% of respondents agreed or strongly agreed that this was a barrier).

Considering the same barriers in terms of the types of respondents (Figure 7), it can be seen that, for the representatives of associations, federations, and networks the most important barriers limiting the increase in the use of wood in the construction sector were primarily political, especially related to the lack of promotional programs and an ambitious research and innovation policy (P2, P3, and P4; all respondents from this group agreed or strongly agreed with these statements). In the case of business respondents, societal aspects were identified as the most relevant (for example, S4—the popular belief that timber construction means a high fire risk—was indicated as a barrier by 88% of respondents), while for respondents from academia, research institutions, and public administration, both the political and societal aspects were equally important.

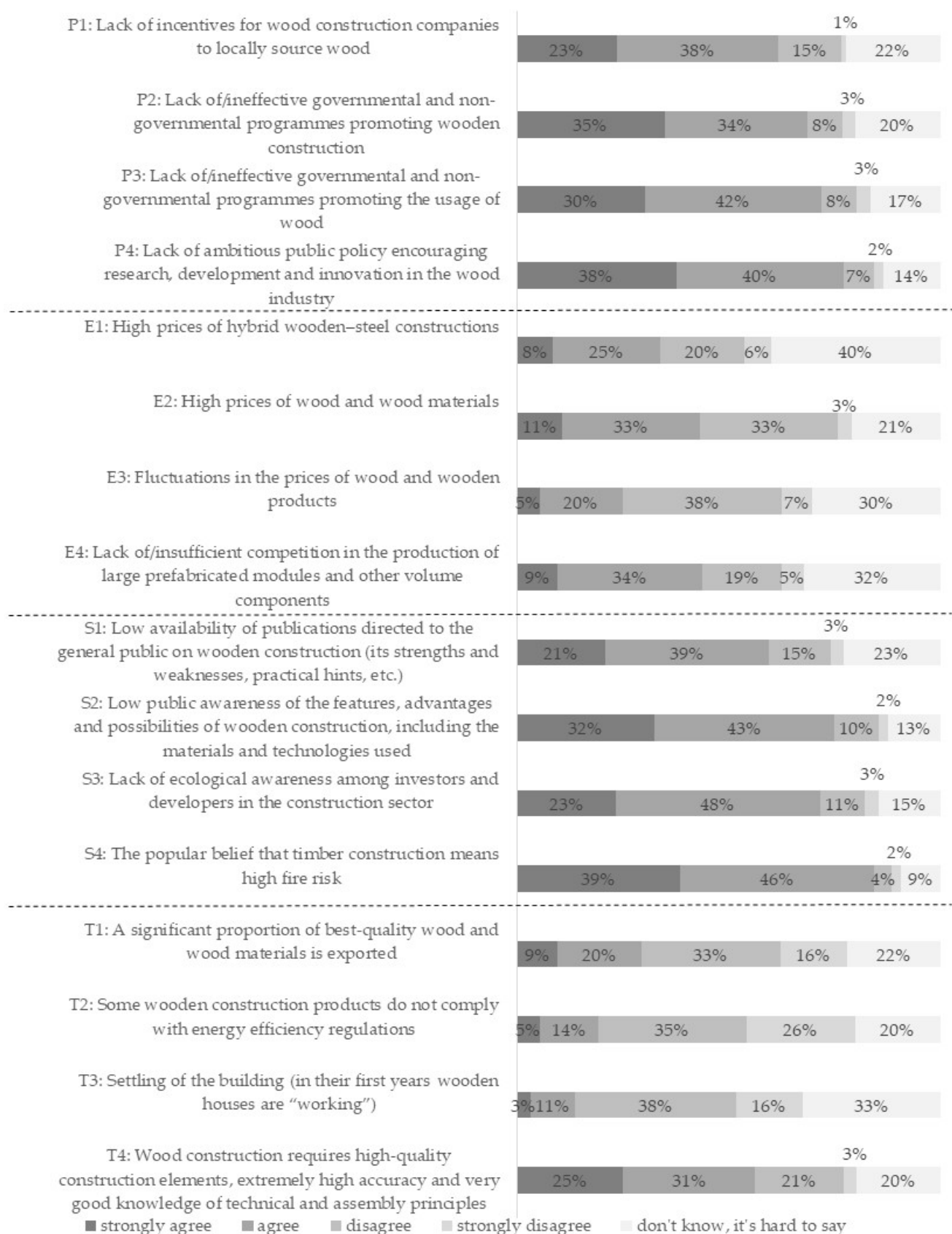


Figure 5. Respondents' assessments of selected barriers limiting growth in terms of the use of wood in the construction sector ($n = 96$).

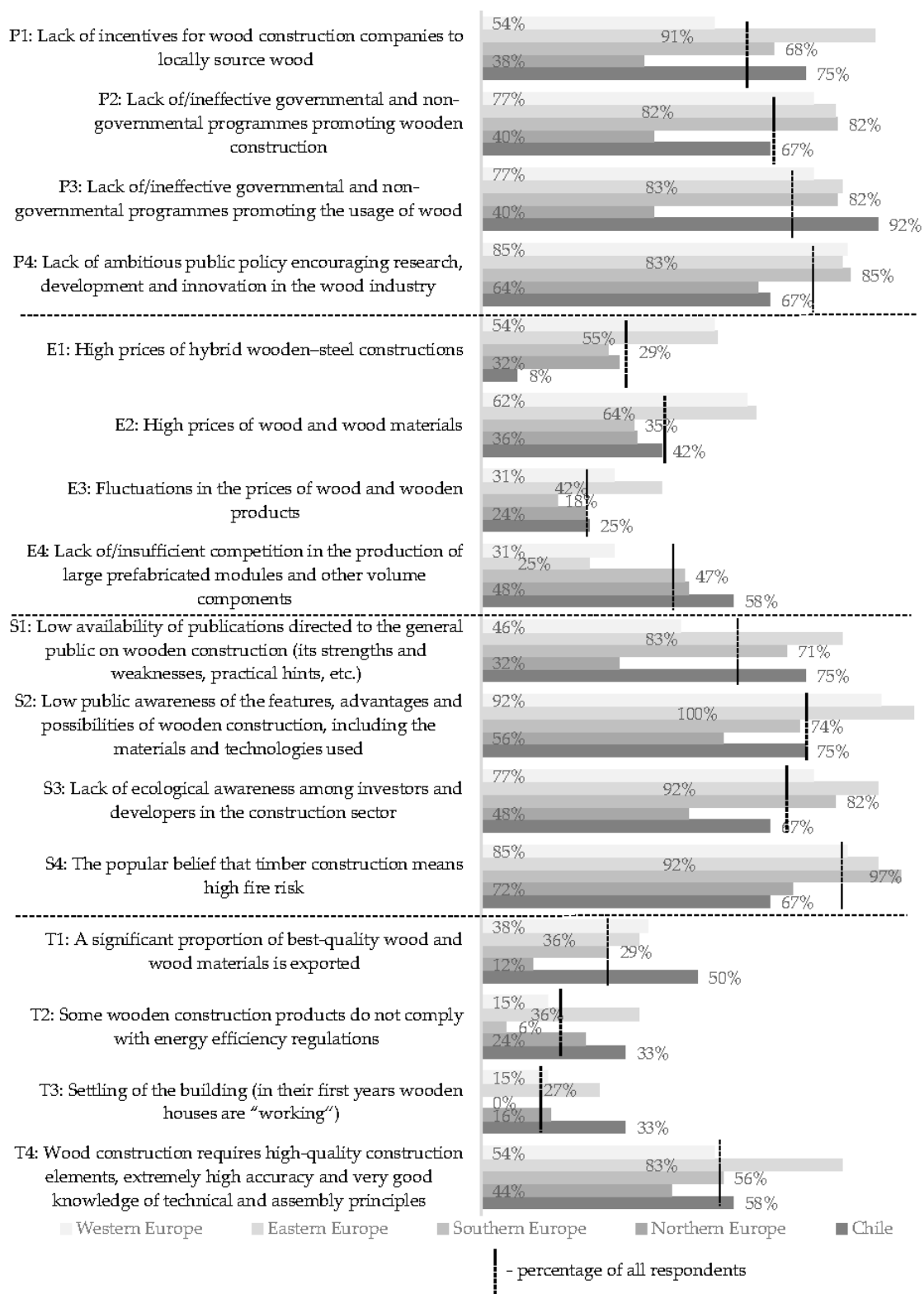


Figure 6. Respondents' assessments of selected barriers limiting growth in the use of wood in the construction sector, by region (combined percentage of responses of “agree” and “strongly agree”; $n = 96$).

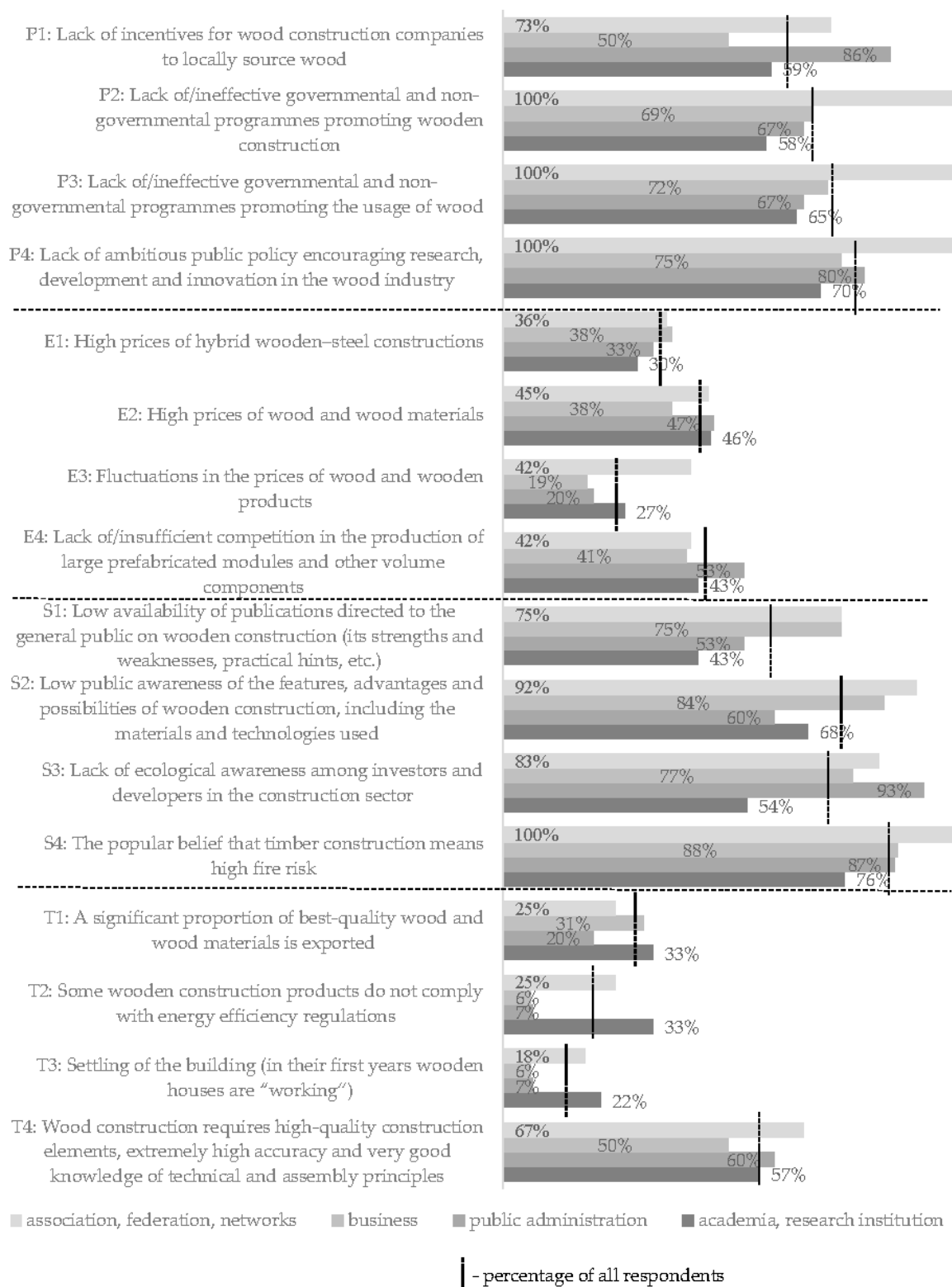


Figure 7. Respondents’ assessments of selected barriers limiting growth in the use of wood in the construction sector, shown by the type of respondent (combined percentages of responses of “agree” and “strongly agree”; $n = 96$).

In general, the representatives of associations, federations, and networks perceived many barriers as being more severe than other groups of respondents, especially in the case of the political and societal aspects. For instance, while 100% of respondents from associa-

tions, etc., viewed the lack of promotional programs and an ambitious innovation policy (P2, P3, P4) as considerable obstacles to the development of the wood construction market, only 58–70% of the representatives of academia and research organizations expressed such a view. In turn, public administration representatives perceived certain barriers as being more important than other groups did, including the lack of eco-awareness in the construction sector (S3) and the lack of incentives to locally source wood (P1). On the other hand, the representatives of associations and businesses indicated the low availability of publications (S1) as a barrier much more frequently than those from public administration and academia or research institutions.

The selected barriers that may limit growth in the use of wood in the construction sector were also analyzed in terms of the respondents' gender. As in the case of opportunities, there are small differences between the answers given by women and men (1–3 percentage points for half of the statements). This is especially the case with social and technical barriers. The greatest differences between the responses given by women and men relate to economic and political barriers (in general, more women indicated the former as significant, and more men, the latter).

3.3. Results of End-User Survey

The understanding of the term “wooden house” depends on the respondent's origin. In European countries, the dominant belief is that it is a year-round single-family house (59–75% of respondents chose this statement, depending on the region of Europe), while Chilean respondents associated it mainly with a summer house (nearly 67% of respondents)—Figure 8. More than ten percent of the Northern European respondents associated it with a multi-family house of several stories, and more than 6% of the Southern Europeans associated it with a public building.

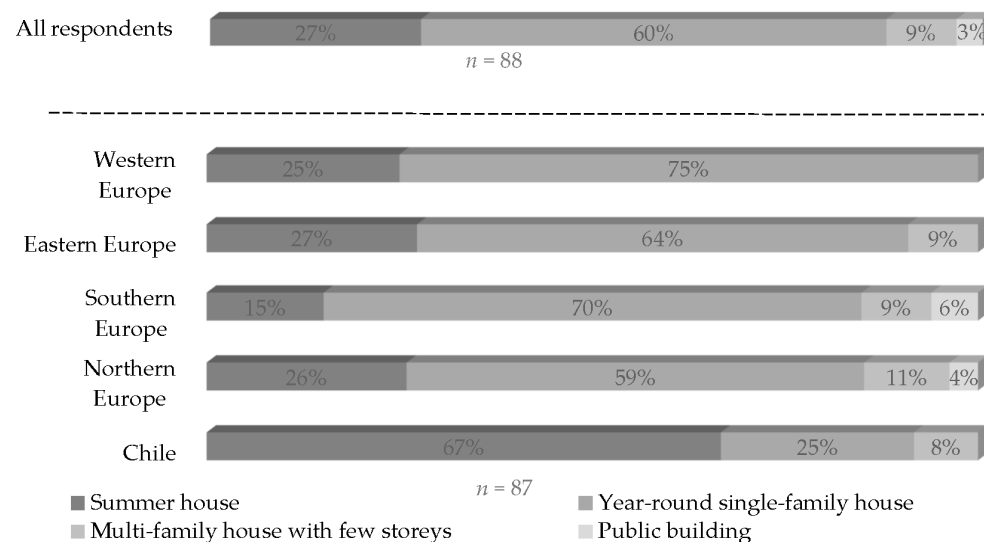


Figure 8. Personal understanding of the meaning of the term “wooden house” by respondents, with breakdowns by region.

With regard to opinions on wooden houses, the vast majority of respondents believe that wooden houses are healthy and friendly for residents (83% of respondents agreed or strongly agreed with this statement; Figure 9). The same number of positive responses was given to the statement that a wooden house can be built in a shorter time than a masonry building. Over half of the respondents agreed that a wooden house cools down quickly but also heats up quickly, and a similar number agreed that building a wooden house is cheaper than building a brick house. More than one-third of the respondents disagreed or strongly disagreed with the statement that the maintenance of a wooden house is cheaper than that of a brick house, while 43% expressed no opinion on that subject.

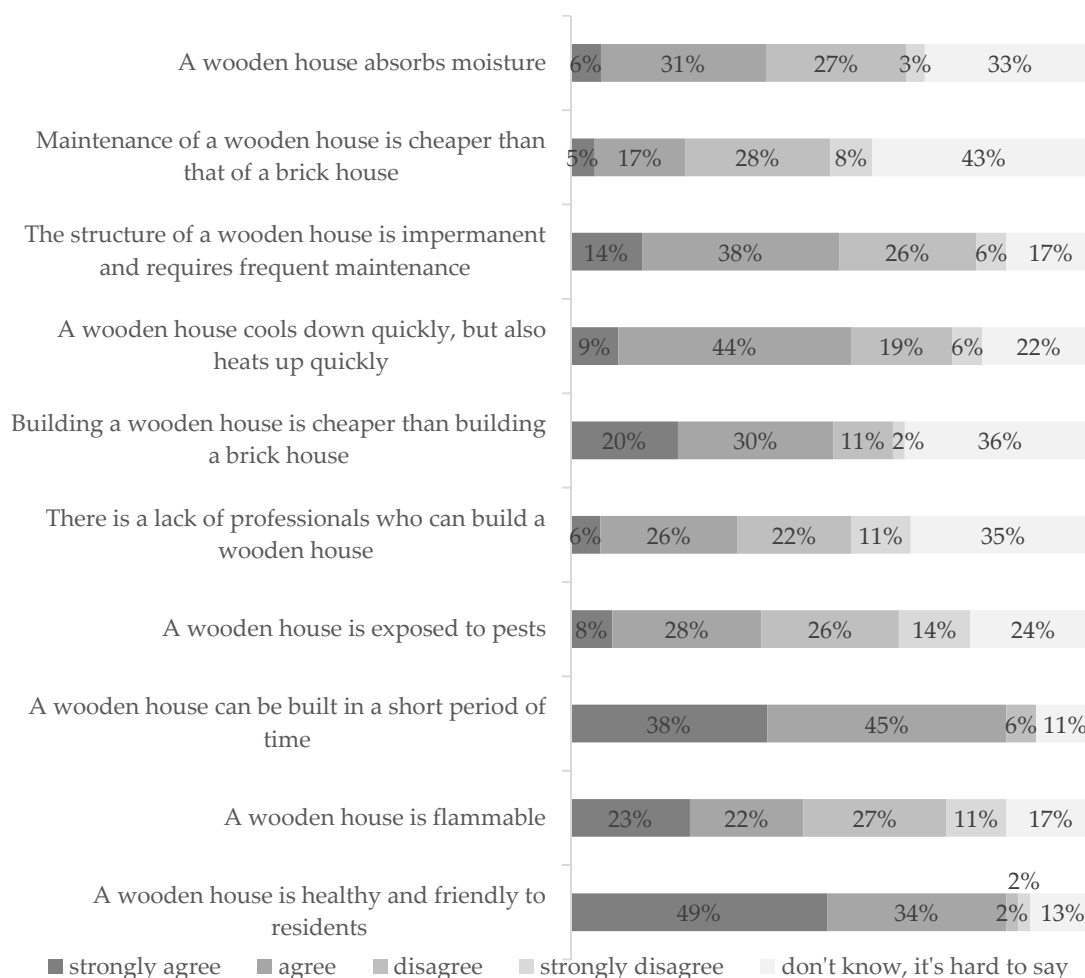


Figure 9. End-users' assessments of statements regarding wooden houses ($n = 88$).

In the case of negative statements regarding wooden houses, almost half of the respondents agreed or strongly agreed that such houses are impermanent and require frequent maintenance (52%), and that they are flammable (45%). In addition, over one-third of respondents agreed with the statements that wooden houses are susceptible to moisture (37%) and are prone to pests (36%). On the other hand, 32% of the respondents agreed with the statement that there is a lack of professionals on the market who are capable of building wooden houses.

Looking at particular regions of Europe and Chile, it is seen that several of the statements were similarly assessed by all groups of respondents, for example, "A wooden house can be built in a short period of time", where the largest and smallest percentages of respondents agreeing with the statement differed by 22 percentage points (100% in Western and Eastern Europe, and 78% in Southern Europe; Figure 10). Similar, relatively small differences in the responses of respondents from different regions were recorded for the statements: "A wooden house absorbs moisture" and "A wooden house is healthy and friendly for residents" (25 percentage points in each case).

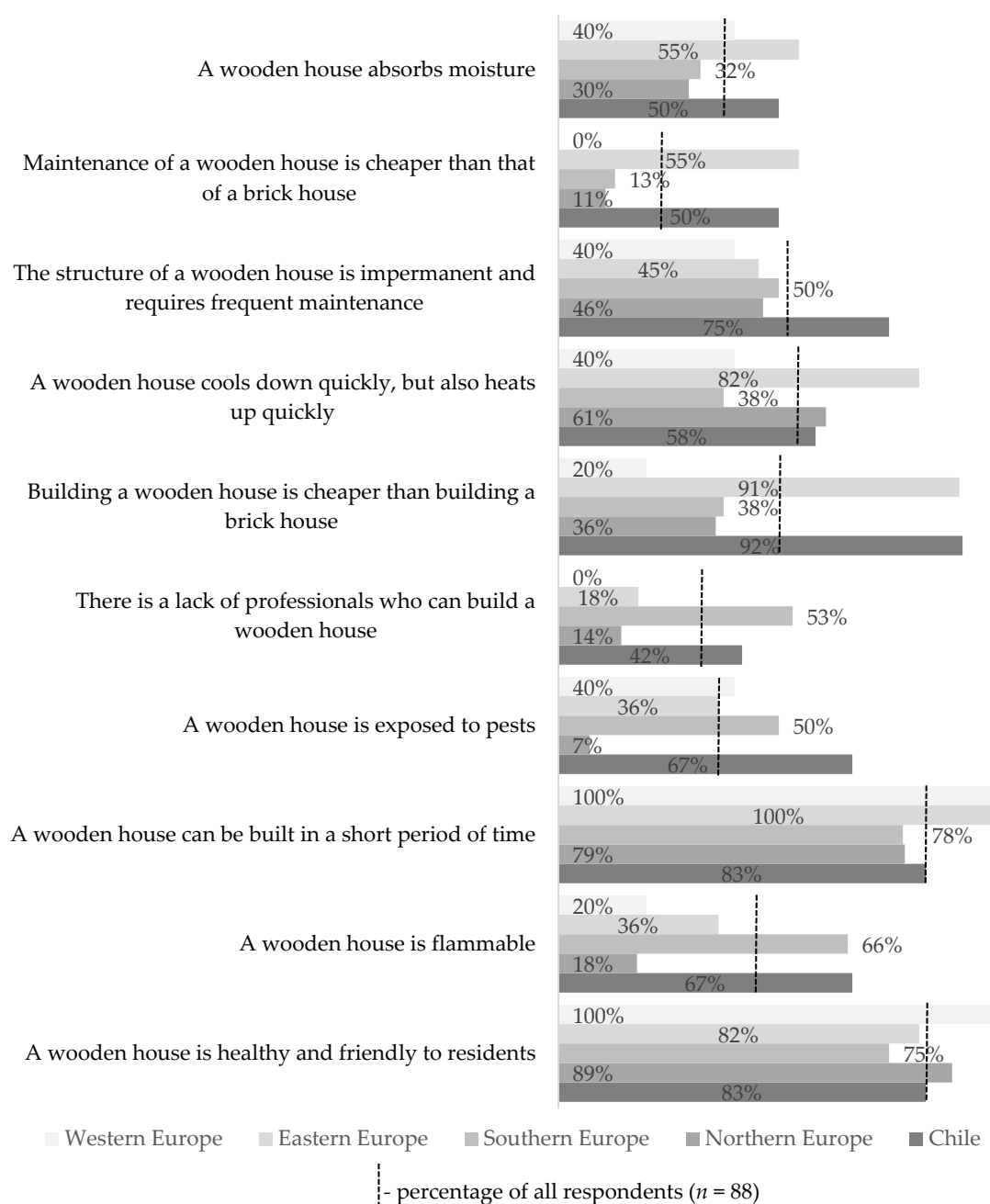


Figure 10. Assessment of statements regarding wooden houses, sorted by region (combined percentage of responses of “agree” and “strongly agree”; n = 87).

Usually, the divergence of answers between regions was even greater. This applies especially to the statement, “Building a wooden house is cheaper than building a brick house”, where the number of respondents agreeing or strongly agreeing was 91–92% in Chile and Eastern Europe, but only 20% in Western Europe. Large differences in the responses of survey participants from different regions were also found for the statements: “A wooden house is exposed to pests” (67% of respondents from Chile agreed with this statement, against 7% of respondents from Northern Europe) and “Maintenance of a wooden house is cheaper than that of a brick house” (50–55% of respondents from Chile and Eastern Europe, against 0% for Western Europe).

Comparing the responses concerning the advantages and disadvantages of wooden houses between genders, there are slight differences (usually within 5 percentage points) between women and men.

End-users participating in the study were also asked what would motivate them to live in a wooden house (Figure 11). The most important factors, as assessed by the respondents, included: “Guarantee of safety, quality and durability of the structure” (88% of respondents agreed or strongly agreed), “The ecological nature of wooden construction” (84%), and “Lower construction/maintenance costs of a wooden house” (79%). The factors “Availability of modern projects and design” and “Government subsidies for construction costs” were also rated as important by respondents (71% and 67%, respectively, agreed that these were motivating factors). The least often identified as a motivating factor was “Favourable credit conditions” (57% positive responses).

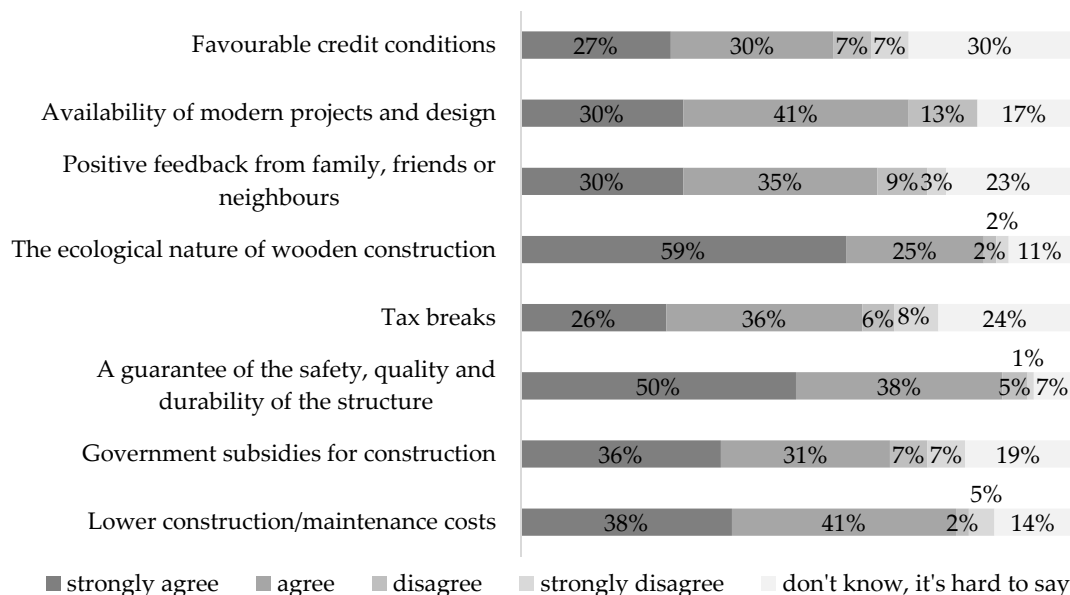


Figure 11. Assessment of the factors motivating people to live in a wooden house ($n = 88$).

Considerable differences in the responses may be observed between regions. For example, “Positive feedback from family, friends or neighbors” gained positive responses from all respondents from Western Europe, but only 45% of those from Eastern Europe, while “Favourable credit conditions” had 91% positive responses in Eastern Europe, but only 36% in Northern Europe (Figure 12). Another factor characterized by a large regional difference was “Government subsidies for construction”, where the difference in the numbers of positive responses between respondents from Chile and Northern Europe was 46 percentage points. These three above-mentioned factors were also the most important motivators to live in a wooden house in the regions in question (apart from the two previously mentioned, “Guarantee of safety, quality, and durability of the structure” and “The ecological nature of wooden construction”, which were highly important for all groups of respondents).

The latter two factors, which are the most important incentives to live in a wooden house for respondents in general, also produced the smallest differences in responses between regions. For “The ecological nature of wooden construction”, the difference between the largest and smallest numbers of positive responses (for respondents from Chile and Western Europe, respectively) was 12 percentage points, while for “Guarantee of safety, quality and durability of the structure”, the difference was 19 percentage points (between respondents from Western and Southern Europe).

Analyzing the factors that would motivate people to live in a wooden house in terms of gender, it is seen that women respondents gave higher percentages of positive responses than men, except for the factor “The ecological nature of wooden construction”.

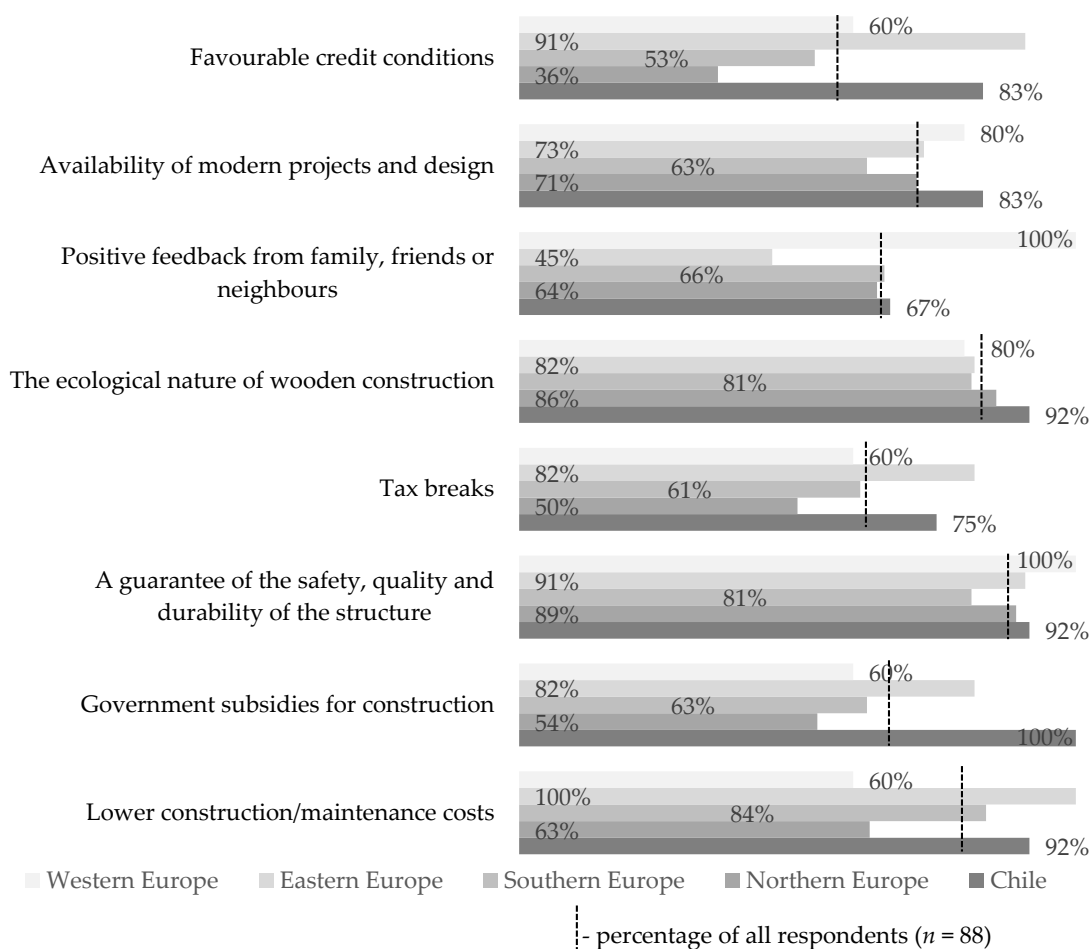


Figure 12. Assessment of factors motivating people to live in a wooden house, sorted by region (combined percentage of responses of “agree” and “strongly agree”; $n = 87$).

4. Discussion

This study aimed to find out end-user and wood construction expert opinions regarding wood as a building material in several European countries and Chile. All countries included in the study have a published strategy to increase the use of wood in construction, mostly due to environmental reasons but also due to the technical performance of wood components. The empirical results of this study—based on limited expert and consumer samples—support choosing these methods to implement the strategies in different countries.

As in many previous studies, the answers strongly depended on the region and the organizational affiliation of the respondent (e.g., business, research, public administration) (e.g., [44,58,76–78]). According to our results, the political context has the greatest impact on increasing the use of wood in construction in Eastern Europe, while technical opportunities seem to be the most important factors in Western Europe. Southern Europe appears to focus on economic opportunities, whereas Northern Europe and Chile are equally affected by all the proposed categories of opportunities. All respondents assessed social opportunities as being the least important factors affecting the development of wood construction.

The differences between regions may be explained by the different states of development of the relevant wood construction markets and divergent historical and cultural contexts [58,76–78]. For example, the Nordic countries differ from the other regions because of their high dependency on forest resources and their established culture of wood use, which is manifested by wood’s major or even dominant market share in several building types. Independently of the regions, almost all respondents from associations, federations, and networks agreed with the proposition that the “Search for new opportunities and

unique solutions in architectural design may contribute to increasing the use of wood in construction”, while only half of the respondents from the business sector agreed with this statement. Only small differences were detected between genders: women rated the economic and social aspects higher, and men the political ones.

Responses concerning barriers to the use of wood in construction were less influenced by the respondents’ region of origin. All respondents agreed that societal and political barriers most typically limit the development of wood construction. Slight differences were observed between the responses of women and men. In general, women more often emphasized the importance of economic barriers, and men the political ones.

Most of the end-users (consumers) understood the term “wooden house” as referring to a year-round single-family house. However, the perception of meaning varied depending on the respondent’s origin. Most respondents from the European regions indicated the above interpretation, while the Chilean respondents probably associate wooden houses with a summer house or a temporary housing solution [79]. In Chile, the currently predominant building types, such as reinforced masonry houses and reinforced concrete buildings, are more often chosen because of—among other factors—their tested adequate seismic performance [80,81].

According to the Ministry of the Environment [82], in Poland, at least three-quarters of respondents, regardless of their region or gender, agreed with the proposition that wooden houses are healthy and friendly to their inhabitants and that they can be built rapidly. Half of the respondents of that study indicated that wooden houses have lower construction costs than brick houses. On the other hand, more than half of the respondents believed that wooden houses are impermanent and require frequent maintenance, and almost half of them considered wooden houses to be insecure in terms of fire risks. We obtained similar results in our study, where a lower awareness of the characteristics of wood construction was particularly visible in Chile and Eastern Europe. Moreover, it can be stated that men expected lower construction costs more often than women for wooden houses, but men were also more concerned about their fire performance.

End-users expressed very positive opinions concerning the proposed aspects of wood construction, which might encourage them to live in a wooden house. The most important factors turned out to be the guaranteed safety, quality, and durability of the structure, as well as its ecological sustainability. West European residents identified positive feedback from family, friends, or neighbors as important sources of motivation to choose to live in a wooden house, while Eastern and Southern European residents emphasized the lower construction and/or maintenance costs. Northern Europeans appreciated the availability of modern building construction and design. In turn, for Chilean respondents, the most important incentive to live in a wooden house was a government subsidy for construction.

From the viewpoint of the Nordic countries, the results of this study support the public wood construction aims. Our results indicate that Nordic people do not expect public support for wood construction, but rather, market-driven development. Thus, instead of subsidies, the implementation of Nordic wood construction strategies should focus on R&D, securing financial conditions for investments, and facilitating building codes and city-planning strategies that are compatible with industrially produced wooden elements and their wide use in urban and rural construction.

In the case of Spain and Portugal, it is obvious that there is room for the further promotion of wood construction in the legislation (national and regional), the Climate Change Act (Spain) and The Roadmap for Carbon Neutrality 2050 (Portugal) being the first steps in this direction. In this study, the Spanish and Portuguese respondents identified more severe barriers to this promotion than respondents from other European regions and Chile. Furthermore, they highlighted, more than other regions, the importance of high-value-added products and ambitious research and innovation systems. These aspects are not considered in the current legislation.

According to our results, “The search for new opportunities and unique solutions in architectural design” is currently the best chance for increasing the use of wood in

construction in Poland. Despite the promotion of wood construction, the governmental program, and the increase in the number of wooden buildings built in Poland, this type of construction is still limited due to outdated regulatory guidance [83].

In the case of France, the political opportunities related to the increased use of wood in the construction sector were assessed as the most important factors due to the availability of forests. French policies related to wood construction are currently being reviewed and updated, and the results of this study should be acknowledged in this process to achieve wider acceptance among consumers and facilitate the implementation of these policies. Moreover, the construction price of French wooden houses is higher than masonry houses.

Similar to some other countries previously mentioned, Chilean national policies aim at increasing the share of timber buildings, as well as increasing the use of wood in buildings. These objectives can be explained in terms of several reasons, with an emphasis on two: (i) Chile is among the largest producers of wood products worldwide [57]; and (ii) the carbon neutrality goal that Chile has set by the year 2050 (at least 50% of the CO_{2eq} emissions will be offset by the sequestration of growing trees [33]). The latter finding is in agreement with the results of the survey, where the search for low-emission products was perceived as being relevant by the respondents from Chile.

Certain limitations of our study material were identified. These limitations restrict the data analysis, as well as the possibilities of generalizing the results. The numbers of respondents were small in some geographical areas, in Western and Eastern Europe in particular. On the other hand, we concentrated on studying the perceptions of people who are of active working age, whereas young and retired people were not included in this study. Thus, one should avoid drawing detailed conclusions regarding the regional or age classification differences. One apparent deficit is related to the lack of 18–25-year-old students who will be the ones making the major procurement and policy decisions in the coming decades. Therefore, it would be advisable to consider the age-grouping of the respondents' responses in future studies. However, the actively working respondents in our study were highly motivated and the proportion of unreliable responses was low. Despite the small number of respondents, the results were generally consistent and there is no reason to expect erroneous interpretations or a systematic bias.

Strong regional and cultural differences in the acceptance of and interest in wood construction were also observed in previous European studies (e.g., [84–87]). In addition, many overseas countries naturally differ in this respect from Europe, having had either a longer experience of wood construction, as in the United States, or a shorter experience, as in Australia, New Zealand, and Chile [21,42,88,89].

The efficiency of construction processes and the very necessary renewal of the construction sector can be boosted with industrial prefabrication and element manufacturing [13,18,29,90]. Novel end-user-driven design and building solutions can increase customer value in both residential and public construction and strengthen the role of construction in the bio-circular economy [91]. The roles of environmental performance, health and wellbeing, and climate policies have strengthened during the past decade in the European construction sector, due to consumer preferences and regulatory requirements [54,85,92–94].

According to Nykänen et al. [85], professionals and researchers in the European construction sector consider building design and construction much more often as weaknesses or threats than as strengths or opportunities for multistory wood construction. However, the role of design and building processes in future development appeared to be much smaller than the role of political support and common interest in green building and sustainability. The threats were mainly related to the low level of ambition of large building companies regarding wood construction, the assumption that wood is more expensive than concrete or steel in construction, the lack of familiarity among building companies with contemporary wood construction, and the lack of capacity of education systems to provide enough professionals for wood construction.

Critical opinions have been expressed by professionals and experts concerning the inflexibility of building regulations and variable city planning and building permit practices

among public authorities. Such obstacles affect the market potential of wood construction, lead to extra costs, and delay decisions in both private house and public building projects [85,95–99]. On the other hand, growing support among national and local authorities for the use of wood in multistory construction has been evidenced in several countries [85,100]. Franzini et al. [100] found that local authorities appreciated engineered wood products that increase the speed of building processes.

Many traditional barriers to wood construction, such as perceptions concerning fire safety, acoustics, and durability, as well as a lack of business skills, have either faded or disappeared during the last decade in countries with a longer history of building with wood [14,42,101]. The influence of architects and designers on the choice of building materials has been reported to still be very strong [51,85,102,103].

Despite the cultural and social differences in Europe, consumers and other end-users in macro-regions share many views on wood construction. In a study by Viholainen et al. [87], the citizens of Finland, Sweden, and Norway attributed the acceptability of the use of wood to clearly different factors than did the citizens of Austria, Denmark, and the UK, but respondents from all countries gave high levels of approval for the use of wood.

In a recent study in the Nordic countries, urban consumers proved to be the least positive toward wooden buildings but increasing their knowledge of wood's functionalities and technical capabilities seemed to relieve their prejudices [104]. A similar phenomenon was observed in North America, where—for example—home builders who had learned about one engineered wood product were likely to be early adopters of other new wood products [42]. On the other hand, an appreciation of a close-to-nature milieu and aesthetic values in housing decreased prejudices against wood [84,104]. Understanding of housing needs and ownership structure in the different consumer segments, together with great diversity in the supply of wooden houses, is required to support promotional efforts, which should focus more on identifying prejudices and solving problems rather than on continuing to argue solely for the benefits of wood [104,105].

5. Conclusions

A survey of stakeholders, manufacturers, and end-users was carried out in six European countries and Chile. The different countries have comparable views on timber construction. Analysis of the feedback should be used to define technical, normative, and economic roadmaps, to remove the barriers to the use of wood as a 21st-century building material.

The findings can be used for the promotion of wood construction and to influence public decision-makers and future policies in the sector. In this sense, the results of the surveys indicate public views that are translated into specific and reasonable conclusions.

Even if wood construction is perceived as a positive thing in general, as much as one-third of the respondents in this study appear to have biased beliefs concerning the performance of a wooden building, for example, in relation to fire hazards and moisture behavior. It is evident that the wood construction sector must disseminate facts to consumers more actively and in an understandable way to address the prejudices and garner more popularity. The results indicate that wood construction is mostly perceived as faster than other construction methods, with the high quality of the structure, a guarantee of safety, and better performance in terms of sustainability.

The study indicates a need to promote wood construction based on its technical and economic benefits rather than the societal ones. High quality and proven economic savings of wood construction, together with the visibility of unique solutions based on the architectural design possibilities that timber construction offers—as indicated by the professional groups surveyed—are crucial for promoting wood construction.

Only slight differences in opinions about wood construction were found between women and men. The same conclusion is applicable to the different regions and roles (stakeholder/end-user) studied. No specific recommendations are, thus, needed to address this issue. In the case of Finland and Sweden, wood products are generally accepted in con-

struction, and small-sized buildings are predominantly wooden. While public procurement plays a key role in large-scale wood construction, the municipal decision-makers should be equipped with updated and objective information regarding the technical–economic performance of wood. In the case of Spain and Portugal, although the current legislation is aligned with the results of the survey (promotion and awareness of climate-neutral materials such as wood) it should be considered as just a starting point when considering the favorable opinions of the respondents about promoting wood construction. In the case of Poland, there is still a great need to promote wooden construction and its advantages, especially among end-users; moreover, there is a need to update construction law and include detailed guidelines for wooden structures. The socio-economic situation in France, and the leading role of the construction sector in the resulting territorial rebalancing plans, constitute a major opportunity for the wood construction sector, which is currently growing. This study aimed at filling this information gap by identifying the specificities of actors and their level of commitment. In the case of Chile, although the policies implemented are a move in the right direction, public authorities still need to address that there is a lack of knowledge of these programs among the population (e.g., wooden houses are still perceived as summer houses by a significant fraction of the population) and there are some technical challenges that need further investigation (e.g., the understanding of the seismic behavior of mid-height timber framing systems).

There are obvious differences between various areas and countries in Europe, but the main findings can be extended to the whole of Europe. Regarding future development, it is justifiable to expect that the non-studied countries face similar challenges and opportunities to the ones identified in this study.

This study results in a general conclusion regarding the perception of respondents and the different regulations in the different countries. There is a larger difference between the regulations of the different countries (in terms of wood construction promotion) than the opinions of the respondents in those countries. In other words, European respondents showed comparable and favorable opinions regarding wood construction promotion, while not all the regulations are in line with these opinions.

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