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# **Perception of Timber Accelerating Change at MIND**

**Deliverable**

**Scientific review report (based on existing literature). Rev 02**

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## Table of contents

Abstract .....	4
Highlights .....	4
1 Introduction .....	4
2 The timber construction sector in Italy: an overall view .....	6
2.1 Sales and companies operating in the country.....	6
2.2 The variation in the price of raw material .....	10
2.3 Import and export evidence for the Italian market .....	13
2.3.1 Export.....	13
2.3.2 Import .....	15
2.4 State of the art of the Italian forests .....	17
2.4.1 Hectares of forest in Italy.....	17
2.4.2 Forest management certifications (PEFC e FSC).....	20
2.5 Summary and considerations about information obtained .....	21
3 Timber buildings in Italy, Europe, and worldwide .....	21
3.1 Structural system solutions adopted .....	25
3.2 End-of-Life scenarios.....	27
3.2.1 Reuse and recycling .....	27
3.2.2 Energy conversion.....	27
3.2.3 Landfill.....	27
4 Policies aspects: list of standards that regulates the use of mass timber building in Italy .....	28
4.1 Regulatory instruments .....	29
4.2 Economic instruments .....	29
4.3 Information tools .....	29
4.4 Voluntary policies .....	30
4.5 Research and development tool.....	30
5 Economic and financial aspects.....	31
6 Life Cycle Assessment method applied to the mass timber industry.....	33
6.1 Energy Performance Certificate: a review introducing the LCA method.....	34
6.2 Dynamic LCA as a tool to evaluate carbon storage .....	36
6.3 Environmental Product Declaration analysis: a key factor for the Italian market.....	37
7 Conclusions .....	39
References .....	41

## List of Tables

Table 1. Revenue for the Italian mass timber sector in 2020 .....	6
Table 2 - Number of mass timber buildings designed every year in Italy in the period 2017-2021.....	8
Table 3 - Geographic distribution of mapped companies .....	10
Table 4 - Comparison of the purchase price for 1 m <sup>3</sup> of wood.....	11
Table 5 - Volumes of wood products exported worldwide by Italy.....	14
Table 6. Volumes of wood exported by Italy to the main commercial partners .....	14
Table 7. Italian exported products per typology .....	15
Table 8 - Imported wood products (excluding the furniture sector) in 2019 by Italy .....	16



Table 9. Countries from which Italy imports wood products per revenue.....	16
Table 10. Wood products imported per typology .....	17
Table 11. Amount of forests in Italy covered by special protection programs. ....	19
Table 12. Sustainable forest management programs in Italy (PEFC, FSC Italy) .....	20
Table 13 - Summary of limiting aspects for forestry harvesting.....	21
Table 14. Data concerning each country about multi-story buildings.....	22

## List of Figures

Figure 1. Revenue for the Italian mass timber sector in 2020.....	7
Figure 2 - Analysis of the Italian revenue for mass timber buildings.....	8
Figure 3. Distribution of the Italian companies according to their revenue .....	9
Figure 4 - Development of global softwood lumber demand (in a million m <sup>3</sup> ).....	11
Figure 5. Variation of timber prices monitored in the most important markets (Forest Economic Advisors, 2021) .....	12
Figure 6. Variation of wood price in Trentino – Adige (Portale del legno Trentino, 2022) .....	12
Figure 7. Volumes of wood exported in EU countries (including Switzerland) by Italy.....	14
Figure 8. Italian exported products per typology .....	15
Figure 9. Wood products imported per typology .....	17
Figure 10. Italian surface covered by forests.....	18
Figure 11. Distribution of the property of Italian forests [%] .....	19
Figure 12. Incidence of protection programs recognized in Italy. ....	20
Figure 13. Multi-storey buildings realized every year .....	23
Figure 14. Comparison between the year of realization with the number of stories .....	23
Figure 15. Distribution of multi-story buildings per each country.....	24
Figure 16. Distribution of multi-story buildings per typology adopted in every country .....	26
Figure 17. Scheme about the end-of-life of timber-based materials .....	28
Figure 18. Scheme of policies classification (Wiegand and Ramage, 2022) .....	30
Figure 19. LCA of two housing units: the best-class A and the worst-performance-class G. ....	35
Figure 20. Climate footprint values of populations of housing units .....	35
Figure 21. 0/0 and -1/+1 approach .....	37
Figure 22 - Distribution of GWP value on modules A1 - A3 according to EPDs.....	39



## Abstract

Initially developed in Austria and Germany in the 1990s, mass timber is increasingly used in building applications, considered a suitable alternative to conventional materials, such as reinforced concrete and steel. The growing interest in this construction technology is also connected with advantages over the others in terms of the potential impact on climate change, thanks to the lower primary non-renewable energy demand in the transformation under certain boundary conditions. These advantages are fundamental to completing the decarbonization of the construction sector by 2050 in line with European Commission targets. Despite this, mass timber continues to have large-scale application limitations in part related to its perception. The activity described in this document aims to address, raise awareness and overcome negative barriers to the perception of structural timber applied to buildings. A list of potential barriers limiting the diffusion in the Italian construction market emerged during 3 workshops organized in 2022 (25 March, 17 June, and 16 September) with the stakeholders, i.e., real estate operators, public administrations, insurance and banking, and academic institutions. Based on the workshops' outcomes and reviewing the existing literature, the authors provide an overall view by giving economic data, i.e., revenue, import and export, and state of the Italian forests. Policies, economic, financial, and environmental aspects are subsequently analyzed, and presented some possible solutions.

## Highlights

- Italy is the 4<sup>th</sup> European market of wood products in terms of sales.
- Sales and companies are mainly localized in Lombardy, Veneto, and Trentino Alto-Adige.
- Specialized manufacturers realize 61% of the commissioning.
- The price of raw materials is affected by high fluctuation over time.
- Italy exports semi-finite wood products and finite building products (mainly to Germany and France).
- Italy imports mainly semi-finite products from European countries.
- Countries with a structured and old tradition also have high-rise buildings.
- Multi-story buildings were designed prevalently considering a hybrid solution (timber-concrete or timber-steel).
- Italy is 36% covered by forests, but their exploitation is considered inconvenient.
- In Italy, there are several certifications to guarantee the reliability of timber constructions and negotiate with credit institutions.
- In recent years credit institutions developed facilitated financial products for timber constructions.

## 1 Introduction

In this report, the authors described the outcomes of the scientific review implemented, based on the existing literature, on sustainability aspects arising from the application of mass timber in the Italian context, covering technical, economic, financial, political, and environmental aspects. The work developed by Politecnico di Milano (Department of Energy) is part of the “Perception of Timber – Accelerating Change at MIND” project coordinated by Climate-KIC Holding B.V. with the participation of



5 other consortia partners, i.e., Lendlease, Waught Thistelton Architects (WTA), University College of London, Arup, and Stora Enso, and co-founded by Build by Nature.

<b>Acronyms</b>			
ARCA	ARchitettura Comfort Ambiente	INFC	Inventario Nazionale delle Foreste e dei serbatori di Carbonio
CLT	Cross Laminated Timber	LCA	Life Cycle Assessment
DfMD	Design for Manufacturing and Disassembling	LEED	Leadership in Energy and Environmental Design
DNSH	Do Not Significant Harm	LLRS	Lateral Load Resisting System
EPC	Energy Performance Certificate	MIND	Milan INnovation District
EPD	Environmental Product Declaration	PEFC	Programme for the Endorsement of Forest Certification
EU	European Union	S.A.L.E.	Wood Building Reliability System
EUAP	Official list of protected areas	TWB	Tall Wood Building
EWP	Engineered Wood Products	UK	United Kingdom
FAO	Food and Agricultural Organization	USA	United States of America
FSC	Forest Stewardship Council	WTA	Waught Thistelton Architects
GHG	GreenHouse Gas	WTE	Waste To Energy
GLRS	Gravity Load Resisting system		
GLT	Glued Laminated Timber		
GST	Glued Structural Timber		
GWP	Global Warming Potential		

The project aims to address, raise awareness and overcome negative barriers to the perception of structural timber applied to buildings. The report was compiled by considering information from reliable existing literature, suitably reworked, and synthesized to produce a document that touches in depth on various subject topics. A list of potential barriers limiting the diffusion of structural timber in the Italian construction market emerged during 3 workshops organized in 2022 (25 March, 17 June, and 16 September) with the stakeholders (real estate operators, public administrations, insurance and banking institutions, academic institutions), i.e.:

- lack of technical skills and knowledge;
- the Italian regulations related to the use of structural timber;
- lack of economic return on the investment in the short term;
- availability of raw materials;
- costs of raw materials and finite products;
- traceability and reliability of the entire supply chain;
- lack of confidence in insurance for timber building projects;
- historical data loss;
- lack of data sharing between stakeholders;
- lack of reliable open-access information;
- lack of technical education;
- lack of dialogue between stakeholders and the Public Administration.

In this document, the authors provide an overall view of the Italian market by giving economic data (revenue, import and export, and state of the Italian forests). Policies, economic, financial, and environmental aspects are subsequently analyzed and presented as possible solutions.



## 2 The timber construction sector in Italy: an overall view

In this section, data related to the Italian market are presented, providing: (i) the companies operating in the country (they are classified per revenue and specialization); (ii) the fluctuation of the price of raw material over the years; (iii) import and export of wooden product in Italy, and (iv) a state of the art of Italian forests, providing a brief overview for potential further improvement of the supply chain. The outcomes highlights:

- Italy is the 4<sup>th</sup> European market in terms of sales;
- sales and companies are mainly localized in Lombardy, Veneto, and Trentino Alto-Adige (North-East Italy);
- specialized manufacturers realize 61% of the commissioning;
- the price of raw materials is affected by high fluctuation over time;
- Italy exports semi-finite wood products and finite building products.
- Italy mainly exports wood products to other European countries, Germany and France.
- Italy imports mainly semi-finite products from European countries.
- Italy is 36% covered by forests, but their exploitation is not convenient

### 2.1 Sales and companies operating in the country

[FederlegnoArredo](#), from now on also referred to as “Federlegno”<sup>1</sup>, presents a technical report related to the Italian market every year. This section highlights the information considered relevant to the present document's goal. Federlegno evidences that in 2020 Italy became the 4<sup>th</sup> European market in terms of sales, with orders of mass timber buildings of around € 812 million - € 1.39 billion, also considering other realizations (FederlegnoArredo, 2021). In 2020, the most important markets in Europe were Germany (€ 2.84 billion), followed by Sweden and the UK (around € 1.5 billion each). Table 1 and Figure 1 present the synthesis of the data collected and elaborated by Federlegno.

Table 1. Revenue for the Italian mass timber sector in 2020

Destination	Sales demanded [mln €]	Sales demanded [%]
Residential buildings	543	39 %
Non-residential buildings	269	19 %
Other realizations	573	42 %
Total	1 390	100 %

<sup>1</sup> Italian federation of wood, cork, furniture and furnishings industries. It represents the Italian wood-furniture sector in all components of its supply chain, from raw material to finished product, in Italy and abroad.

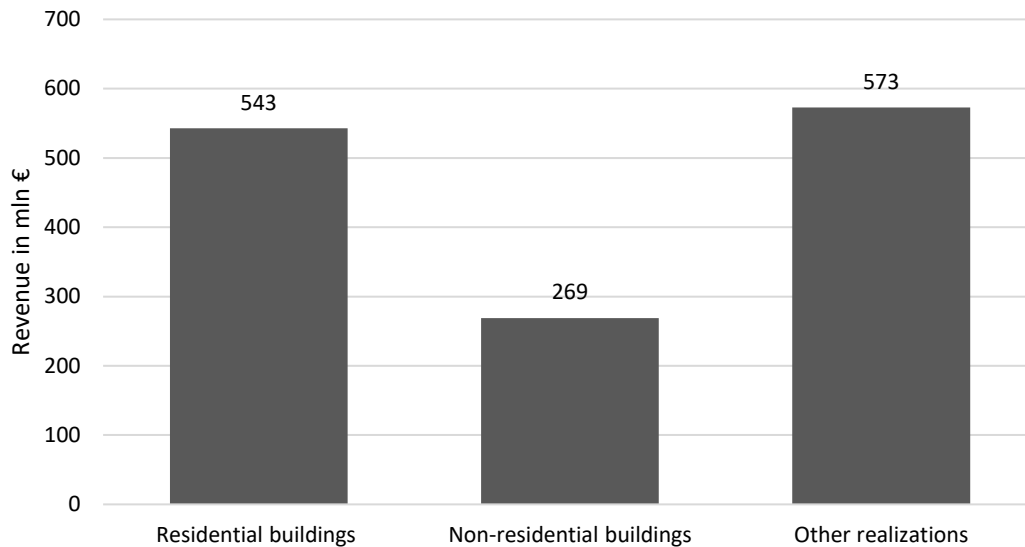


Figure 1. Revenue for the Italian mass timber sector in 2020

In the same year (2020), it is possible to notice that sales deemed (for residential and non-residential buildings) were generally localized in Lombardy, Veneto, and Trentino Alto-Adige (Northeast Italy). An analysis of building permits shows that 3 340 new buildings for civil use were designed or realized considering the adoption of mass timber, about 6% of all new constructions.

In addition, since buildings require a high level of complexity in all the phases of construction, it is important to highlight the following:

- 65.0% of the commissioning (i.e., designs, manufacture of semi-finite products, construction phase, etc.) realized in Italy were designed and built by specialized manufacturers;
- 30.5% is made by enterprises that limit their action on the assembly phase in the construction field;
- only 4.5% (the rest) are brokers, i.e., companies buying the service abroad, mainly from Austria.

In Figure 2, the data presented are summarized, reporting the percentage of dwellings developed by specialized producers, assemblers/manufacturers, and foreign companies involved and the revenues headlining, allowing the correlation between the number of realizations and profit to be visualized.

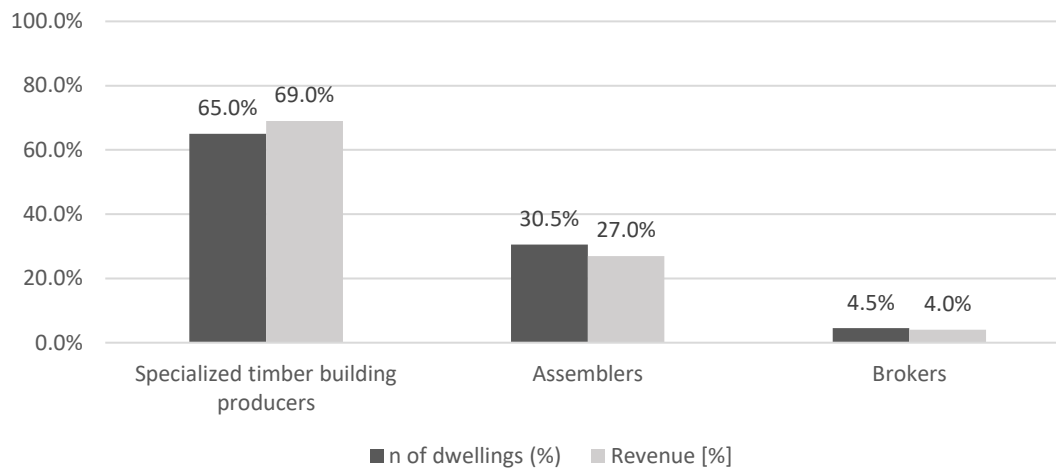


Figure 2 - Analysis of the Italian revenue for mass timber buildings

Table 2 shows the number of wooden buildings constructed annually in Italy from 2017 to 2021. The progressive increase in the annual number of multi-story mass timber buildings in Italy can be justified by the steady and progressive increase in the experience and knowledge of professionals in the field.

Table 2 - Number of mass timber buildings designed every year in Italy in the period 2017-2021

Year of reference	Number of timber buildings realized	Increasing in percentage
2017	3 130	-
2018	3 144	+ 0.4%
2019	3 154	+ 0.3%
2020	3 069	- 2.8%
2021	3 400	+ 9.7%

Federlegno also conducted research to identify the state of the companies operating in the Italian mass timber sector. The survey is based on data collected during 2020 on 312 enterprises. The analysis sample was reconstructed by excluding companies that went bankrupt during the year and did not report data. In addition, the sample includes new companies that have completed at least one wooden building (amounting to 38 new companies).

In Figure 3, the results obtained are summarized. The graph relates the number of companies classified according to 4 groups of incomes (1<sup>st</sup> bar chart) and the revenue generated by each group (2<sup>nd</sup> bar chart). The sampled enterprises were then divided into 4 groups according to their annual income produced exclusively in the timber building sector, as follows:

- annual revenue lower than € 1 million;
- annual revenue included between € 1 million and € 5 millions;
- annual revenue included between € 5 millions and € 10 millions;
- annual revenue higher than € 10 million.

The distribution of enterprises by turnover is typical of the Italian economic fabric, with a strong presence of small and medium-sized enterprises. Firms operating in the wood construction sector with revenues of less than 1 million euros account for 58% of the sample analyzed (equal to 181 out of 312) – 1<sup>st</sup> bar chart. The percentage would rise to 90% if companies with revenues of less than 5 million euros



were also included. Only 3% of the analyzed sample exceeds 10 million euros in annual revenues (9 out of 312). Looking at the 2<sup>nd</sup> bar chart, it was found that companies with annual revenues over €10 mln produce 40% of the total revenues related to the Italian wood construction market. Thus, these are solid and structured companies that manage to provide a service that is appreciated in the Italian market.

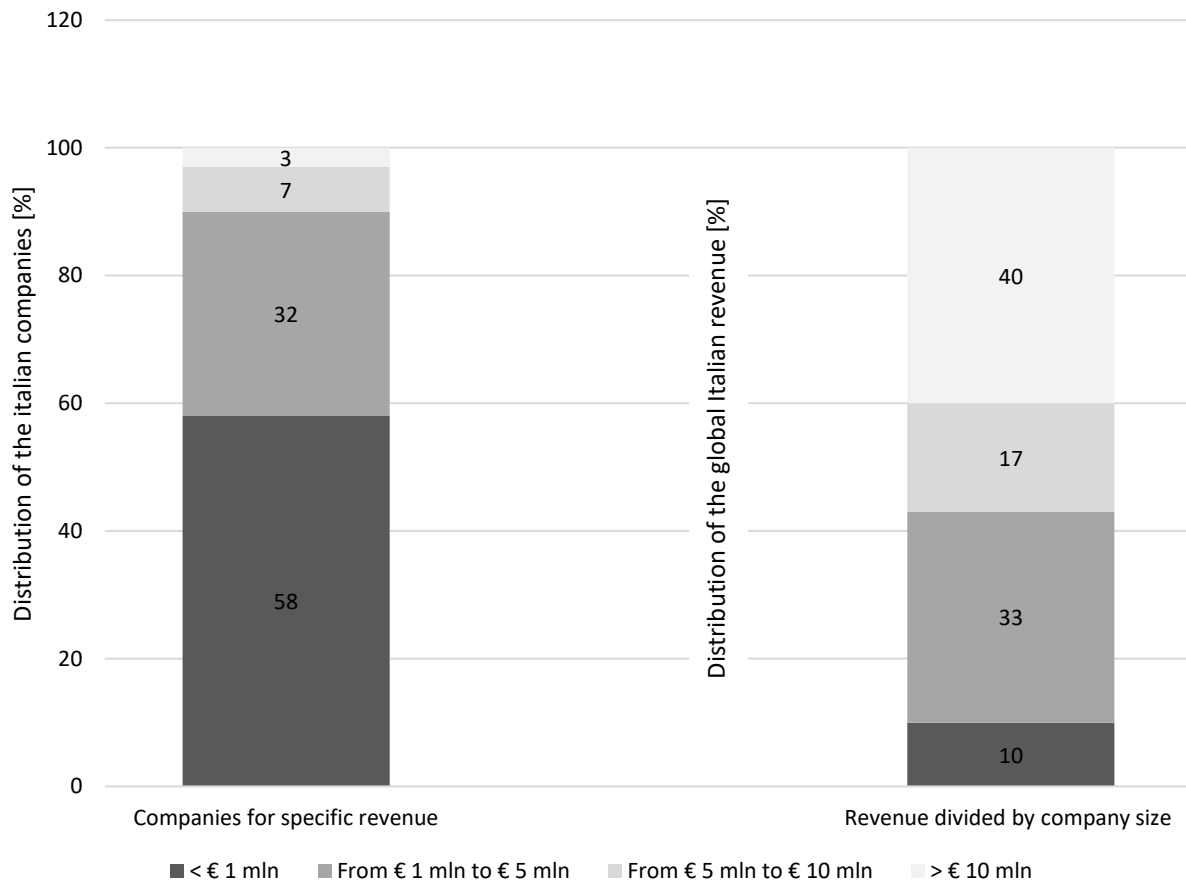


Figure 3. Distribution of the Italian companies according to their revenue

Federlegno produced a mapping on the geographic distribution of companies by considering the companies in the sample analyzed that had their production site in Italy as of 2020. Thus, out of a sample of 312 companies, 208 were used for mapping.

As stated, considering the data of 208 companies out of 312, the Italian companies are mainly located in 3 Italian Regions out of 20 located in Northeast Italy (Lombardy, Veneto, Friuli Venezia Giulia, and Trentino-Alto Adige), which account for 60% of the total. The rest 40% is distributed in the rest of the territory, with an interesting prevalence between Northwest (Piedmont, Valle d’Aosta, and Liguria - accounting for 12% of the Italian enterprises) and Centre (Toscana, Marche, Umbria, Lazio, Abruzzo - accounting for 17% of the Italian enterprises).

Federlegno also analyzed the mapped companies' revenue distribution from a geographical point of view. The greatest concentration is in Northern Italy, but it is mainly located in the Northeast (61% of the total annual revenue). Lombardy alone produced 15% of the revenue among the mapped companies over the year 2020.



The housing units built by the mapped enterprises were constructed mainly between Lombardy (240 units out of 781 surveyed, or 31%) and Northeastern Italy (220 units out of 781 surveyed, or 28%). The sector is growing in the rest of Italy, although most of the activity is concentrated between these two areas. Table 3 summarizes the results presented.

Table 3 - Geographic distribution of mapped companies.

Region of Italy	# of operators	% of operators	% of revenue	# of residential and non-residential units	% of residential and non-residential units
Nord-Ovest (Piedmont, Valle d'Aosta; Liguria)	24	12%	7%	35	4%
Lombardy	46	23%	15%	240	31%
North East (Veneto, Trentino-Alto Adige, Friuli Venezia Giulia)	73	37%	61%	220	28%
Emilia-Romagna	14	7%	5%	94	12%
Centre Italy (Tuscany, Marche, Umbria, Lazio, Abruzzo)	44	17%	11%	168	22%
South Italy (Molise, Campania, Basilicata, Puglia, Calabria)	3	2%	0%	14	2%
Sicily and Sardinia	4	2%	1%	10	1%

## 2.2 The variation in the price of raw material

This section is intended to provide insight into the global demand for wood and the variability of raw material costs over the years. Market demand and purchase price are closely related to each other. In addition, geopolitical causes or significant events that can disrupt economic balances can lead to substantial price fluctuations in a short period.

Over the past 2 years, the geopolitical situation, caused mainly by the Russian invasion of Ukraine, and the economic consequences of the Pandemic have significantly altered trade flows. The increasing demand for raw materials, highlighted by Forest Economic Advisors, has slowed its availability.

From a global perspective, Forest Economic Advisors underlined that the trend of global demand for softwood-sawn timber progressively increased, passing from 240 million of m<sup>3</sup> demanded in 2009 to 375 million of m<sup>3</sup> in 2022, as illustrated in Figure 4 (Forest Economic Advisors, 2021). The geopolitical situation is also a problem for Italy. In 2021, Russia, Ukraine, and Belarus supplied 5.3% of the wood that Italy imports each year for its demand (Mancini, 2022).

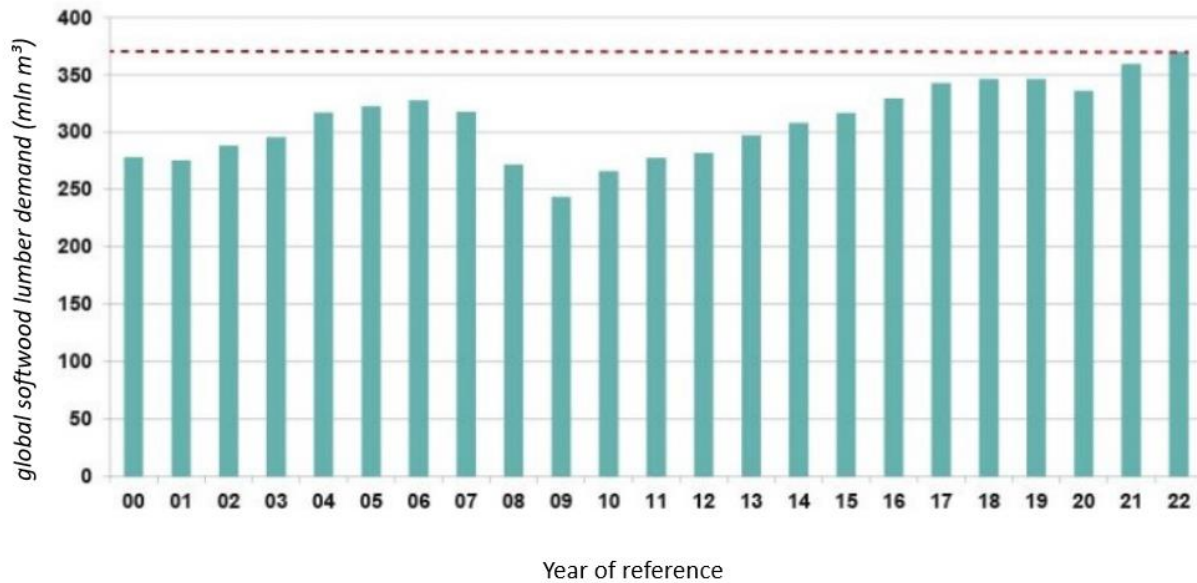


Figure 4 - Development of global softwood lumber demand (in a million m<sup>3</sup>)

The purchase price of wood in the global market has been subject to change over the years. The examples brought by Forest Economic Advisors and Portale del Legno Trentino demonstrate this. Forest Economic Advisors monitored the variation in the indexes and showed that the highest variability occurred mainly in Europe, China, and the United States of America (USA), compared with Japan. Table 5 shows the variation of the wood indexes in the most important markets for 1 m<sup>3</sup> of raw material, while Figure 5 shows the trend along 2012-2021 for 1 m<sup>3</sup> of sawn wood.

Table 4 - Comparison of the purchase price for 1 m<sup>3</sup> of wood

Market	Lower price of 1 m <sup>3</sup> of raw material [\$/m <sup>3</sup> ]	Higher price of 1 m <sup>3</sup> of raw material [\$/m <sup>3</sup> ]	Variation in percentage
Europe and the UK	220	360	+ 163%
USA	200	650	+ 325%
Japan	350	450	+ 128%
China	150	250	+ 166%



Figure 5. Variation of timber prices monitored in the most important markets (Forest Economic Advisors, 2021)

The same trend was also registered locally (Trentino-Alto Adige Region). The semestral variation of the sawn wood price destined to three semi-manufacturer products (logs, rough truss, and packaging products) is compared. Portale del Legno Trentino (Figure 6) showed that the price for a 1 m<sup>3</sup> of wood passed from 48 €/m<sup>3</sup> (2019) to 170 €/m<sup>3</sup> (2021) (Portale del legno Trentino, 2022).

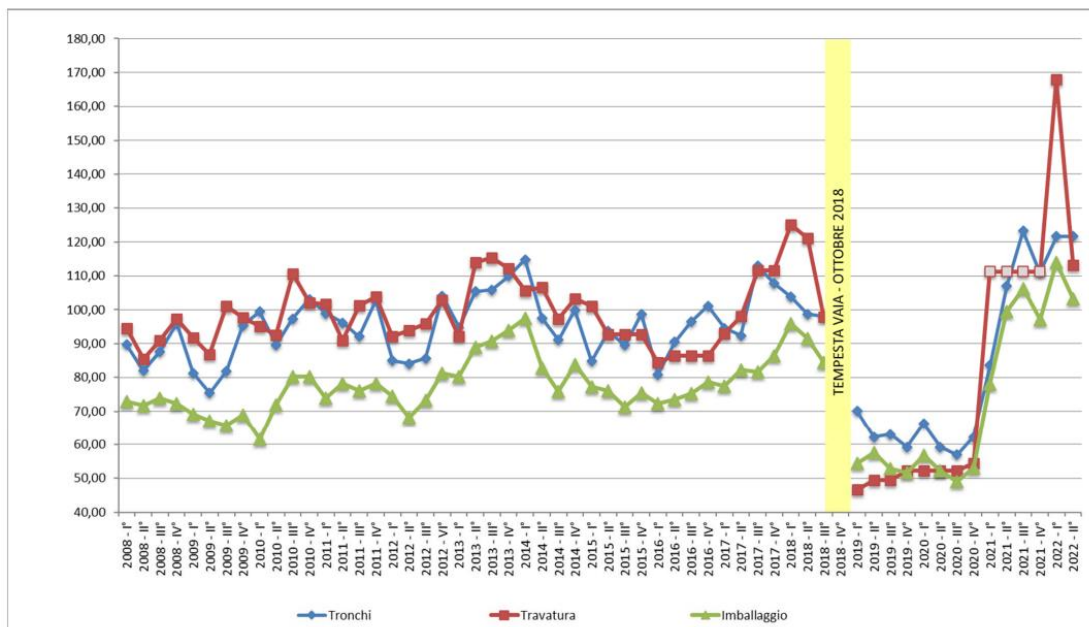


Figure 6. Variation of wood price in Trentino – Adige (Portale del legno Trentino, 2022)



### 2.3 Import and export evidence for the Italian market

Historically Europe had an approximate balance in production and consumption of softwood lumber, but since the last decade, Western Europe became a net exporter for the first time in 2004 (FederlegnoArredo, 2021). Europe is now the world's largest exporting region of softwood lumber, with ever-increasing exports in the last five years because of two key factors:

- softwood lumber production in Western Europe has increased more rapidly than consumption. Germany, Austria, Sweden, and Finland lead this production upsurge;
- in Eastern Europe, the recovery in softwood lumber consumption lags behind the increase in production volume. Production recovered to pre-1990 levels by 2000, but consumption is still much lower.

Looking at the construction sector, the use of Engineered Wood Products (EWPs) is constantly growing worldwide starting in the 2000s, demanding different types of products both for structural and non-structural destinations. Around 70 % of the end uses of wood products are related to construction, including structural and non-structural frames, scaffolding, interior and outdoor products, window frames and doors, floors, roof trusses, and facades. The other major uses include manufacturing furniture and packaging materials (Hurmekoski, 2016).

The worldwide growth in demand is mainly affected by different aspects. The urbanization growth rate is one of them, caused by the global increase in the population. It was estimated that by 2060 an additional 76 billion m<sup>2</sup> of floor area would be needed to satisfy the construction demand (Güneralp *et al.*, 2017). However, focusing the attention on the European market, where it was registered a stagnation in the population growth rate, the demand for timber products for urbanization is mainly driven by net-zero carbon regeneration and refurbishment aspects influencing urban policies and decisions (Göswein *et al.*, 2022). In addition, especially in some European countries, EWP for buildings is increasingly adopted considering qualitative, social, and environmental perceptions by the end users (Harju, 2022). Looking at the Italian case, with the data collected by the National Observatory, it was possible to provide an overview of the amount of raw material imported or exported in terms of revenue. The same work was done by analyzing import-export in terms of product. This analysis provides an overview of the Italian wood industry's trade relations with other partners and concerning which products. The data showed that Italy imported € 3.33 billion worth of wood products, compared with exports of € 2.75 billion. In addition, in 2019, Italy was the 21<sup>st</sup> major exporter of lumber, covering 1.6% of world wood demand (Ministry of Foreign Affairs and International Cooperation, 2021). The analysis excluded considerations and data about the furniture industry, which is analyzed in another report by the Osservatorio.

The following sections aim to illustrate the Italian timber market's export and import.

#### 2.3.1 Export

As written above, in 2019, the Italian wood industry exported €2.075 billion worth of products worldwide. The leading destination was France (€300 million in revenue) and Germany (€262 million in revenue). Other trade partners are mainly European, as shown in Table 5 and Figure 7, representing 71.28% of the total exports. An important market share went to the United States (€152 million and



7.33% of the exportations), while China bought wood products made in Italy for €58 million and 2.80%. Table 6 and Figure 7 summarize the data collected and show the impact of the exported sales for every commercial partner (Ministry of Foreign Affairs and International Cooperation, 2021). Table 7 and Figure 7, on the other hand, represent the export volume of the Italian wood industry by product type. Italian companies mainly export semi-finished products (56.7% of exports) and finished building products (21.5% of exports).

Table 5 - Volumes of wood products exported worldwide by Italy

Location	Sales [million €]	Sales [%]
Europe	1 479	71 %
Africa	111	5 %
America	207	10 %
Asia	256	12 %
Oceania and other territories	22	1 %
<b>Total</b>	<b>2 075</b>	<b>100 %</b>

Table 6. Volumes of wood exported by Italy to the main commercial partners

Demanding countries	Sales [million €]	Sales [%]
Germany	262	12.6 %
France	300	14.4 %
Switzerland	125	6.0 %
United Kingdom	114	5.5 %
Austria	101	4.9 %
Other European countries	577	27.8%
USA	152	7.3 %
China	58	2.8 %
Rest of the world	386	18.6%
<b>Total</b>	<b>2 075</b>	<b>100.0 %</b>

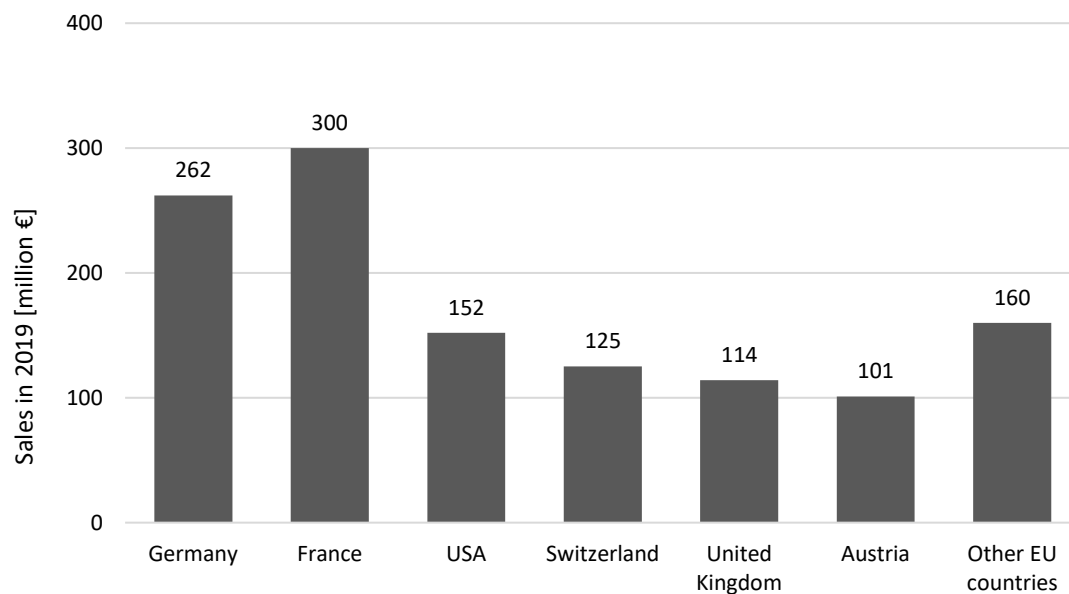


Figure 7. Volumes of wood exported in EU countries (including Switzerland) by Italy



Table 7. Italian exported products per typology

Exported wood-based product	Sales [million €]	Sales [%]
Planed and sawn wood	433	20.9 %
Veneer sheets and wood-based panels	761	36.7 %
Assembled parquet floors	65	3.1 %
Wooden doors and windows (excluding armored doors)	174	8.4 %
Other timber elements and joinery for building construction	208	10.0 %
Wood Packaging	131	6.3%
Other miscellaneous wood products (excluding furniture)	303	14.5%
Total	2 075	100.0 %

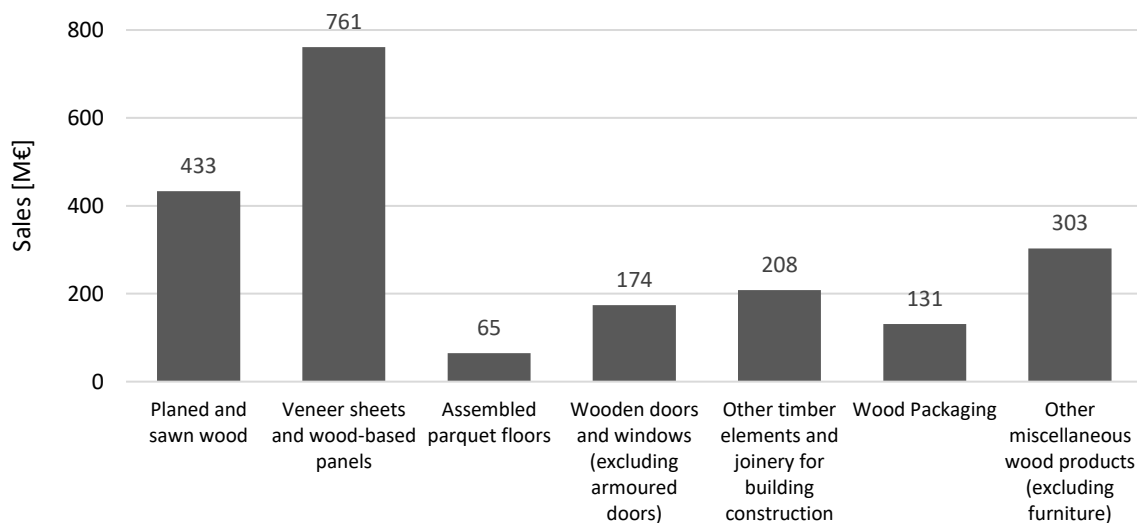


Figure 8. Italian exported products per typology

### 2.3.2 Import

In 2019, Italian companies imported wood products worth 3.33 billion euros, mainly from the European market (86.1%). The leading sellers came from Austria (26.1% of the imported volume), Eastern European EU countries, Poland, Hungary, and Romania, with 13.2%. Data analysis showed that a significant amount of imported (precisely 23.3%) came from other European countries (i.e., Serbia, etc.). This share also includes products from Russia, Ukraine, and Belarus, which weighed about 5.3 % of imports in 2020.

Table 8, Table 9, and Figure 9 summarize the data collected and show the impact of the imported sales for every commercial partner. Table 10 and Figure 9, on the other hand, represent the import volume of the Italian wood industry by product type (Ministry of Foreign Affairs and International Cooperation, 2021). Italian companies mainly export semi-finished products (56.7% of exports) and finished building products (21.5% of exports). Comparing the results obtained by analyzing the volume of exports, it could be said that the Italian industry is composed of a considerable number of quality manufacturing companies capable of transforming the raw material into the finished product for the market. Tracing



the supply chain of wood required from Italy, it was found that by 2020, 80% of the raw material would come from abroad (Mancini, 2022). The reason for this should be mainly due to cost, and the data used for this analysis fails to focus attention on this phenomenon as it estimates revenue volumes. The origin of the types of imported products could not be determined a priori, but it could be assumed that semi-finished products come from countries where labor costs are lower.

Table 8 - Imported wood products (excluding the furniture sector) in 2019 by Italy

Location	Sales [million €]	Sales [%]
Europe	2 870	86.1 %
Africa	117	3.5 %
America	112	3.4 %
Asia	233	7.0 %
Oceania and other territories	1	0.0 %
<b>Total</b>	<b>3 333</b>	<b>100.0 %</b>

Table 9. Countries from which Italy imports wood products

Location	Sales [million €]	Sales [%]
Austria	869	26.1 %
Germany	263	7.9 %
France	192	5.8 %
Portugal	110	3.3 %
Slovenia and Croatia	163	6.6 %
Poland, Romania, and Hungary	110	13.2 %
Other European countries	134	23.3 %
China	111	4.9%
Rest of the world	110	9.0 %
<b>Total</b>	<b>3 333</b>	<b>100.0 %</b>

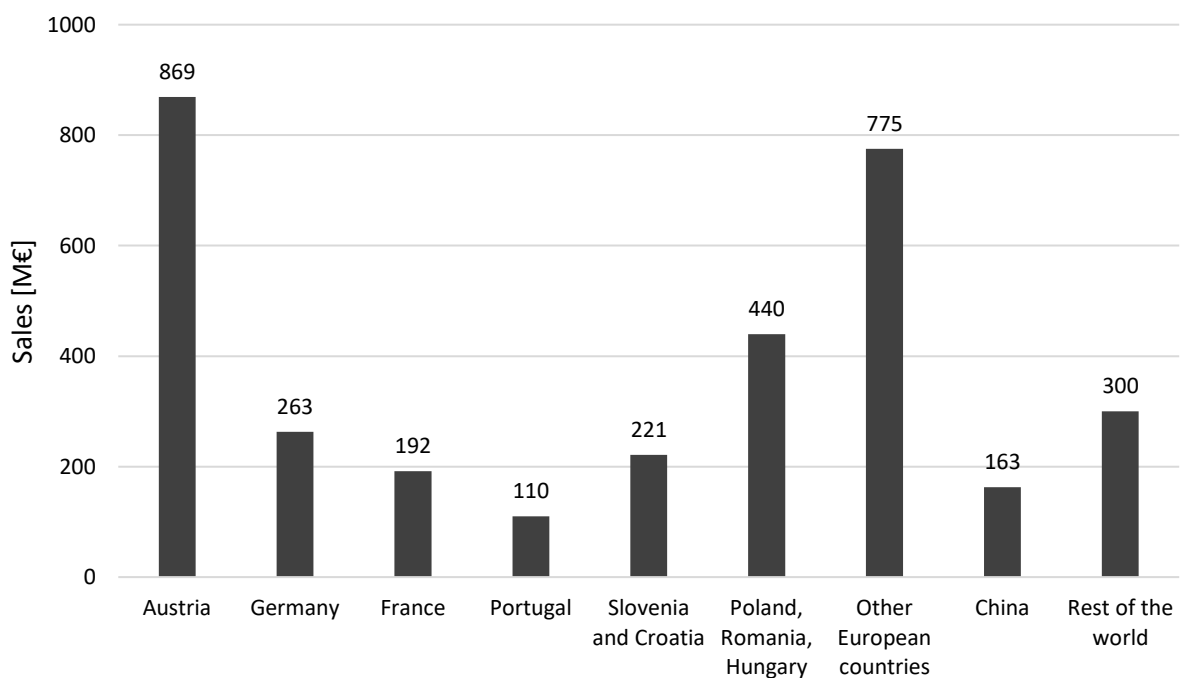


Figure 9. Countries from which Italy imports wood products per revenue





Table 10. Wood products imported per typology

<b>Imported wood-based product</b>	<b>Sales [million €]</b>	<b>Sales [%]</b>
Planned and sawn wood	1 246	37.4 %
Veneer sheets and wood-based panels	895	26.9 %
Assembled parquet floors	108	3.2 %
Wooden doors and windows (excluding armored doors)	41	1.2 %
Other timber elements and joinery for building construction	374	11.2 %
Wood Packaging	198	5.9 %
Other miscellaneous wood products (excluding furniture)	472	14.2%
<b>Total</b>	<b>3 333</b>	<b>100.0 %</b>

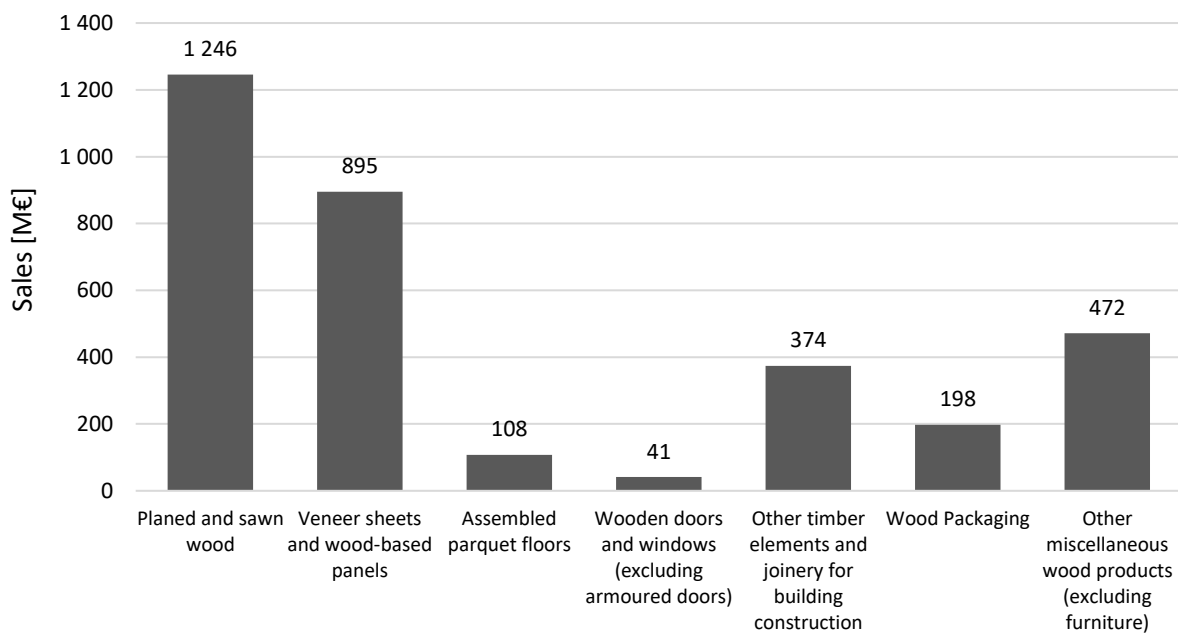


Figure 9. Wood products imported per typology

## 2.4 State of the art of the Italian forests

Forests are considered the most important natural carbon stock. For this reason, they play an important role in climate change mitigation. Hence, sustainable harvesting management is strictly recommended to preserve deforestation. Practice changes in treatment intensity or natural disturbance may result in more or less carbon stored in the forest (Lippke *et al.*, 2011). The carbon in an individual forest stand for any given treatment regime will cycle periodically, rising with periods of regeneration and growth and falling with periodic harvest removals. The section introduces a focus on forestation and management in Italy.

### 2.4.1 Hectares of forest in Italy

The surface of Italian territory in which the prevalence of forests is determined by the data provided by the national inventory report (Ministry of Agriculture Food and Forestry, 2005). The data refers to a pool conducted from 2002 to 2006, selecting as the reference year 2005 and focusing on areas already destined for arboriculture. The analysis presented in this document also considered the data published in the 3<sup>rd</sup> “*Inventario Nazionale delle Foreste e dei serbatoi di Carbonio*” (Arma dei Carabinieri, 2015), a

periodic sample survey aimed at the knowledge of the quality and quantity of the country's forest resources, a source of forest statistics at the national and regional level. The *Inventario Nazionale delle Foreste e dei serbatoi di Carbonio* (INFC) is a monitoring tool that produces concrete knowledge in support of forestry and environmental policy carried out by Arma dei Carabinieri through the Comando delle Unità forestali, Alimentari e Agroambientali.

In 2015 the area covered by forests in Italy increased over the last decades, according to the provisional results, investing around 36% of Italian territory (Ministry of Agriculture Food and Forestry, 2020). Specifically, there are 9 165 505 hectares of forests and 1 816 508 hectares of other wooded lands, totaling 10 982 013 hectares. The classification is based on the Food and Agricultural Organization's definition of forestry requisites (FAO, 2020). So, according to FAO:

- forests are identified as “*Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use*”;
- the other wooded lands are defined as “*Land not classified as “Forest”, spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes, and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use*”.

The areas covered by forests in Italy are increasing: in fact, from 2005 to 2015, the forest area has gained by more than 514 480 hectares (+ 4.9% of areas covered by forests compared with the 2005 situation). The Italian Ministry of Agriculture, Food and Forestry estimated that the forestry growing rate is 52 856 hectares per year (Ministry of Agriculture Food and Forestry, 2020). Figure 10 summarizes the data collected over the decades by INFC and includes an estimation for 2022 based on the growth rate provided. Of which it can be estimated that 41.8 % (from elaborations of the Politecnico di Milano) is coppice, the more common silvicultural system, while the rest is not classifiable.

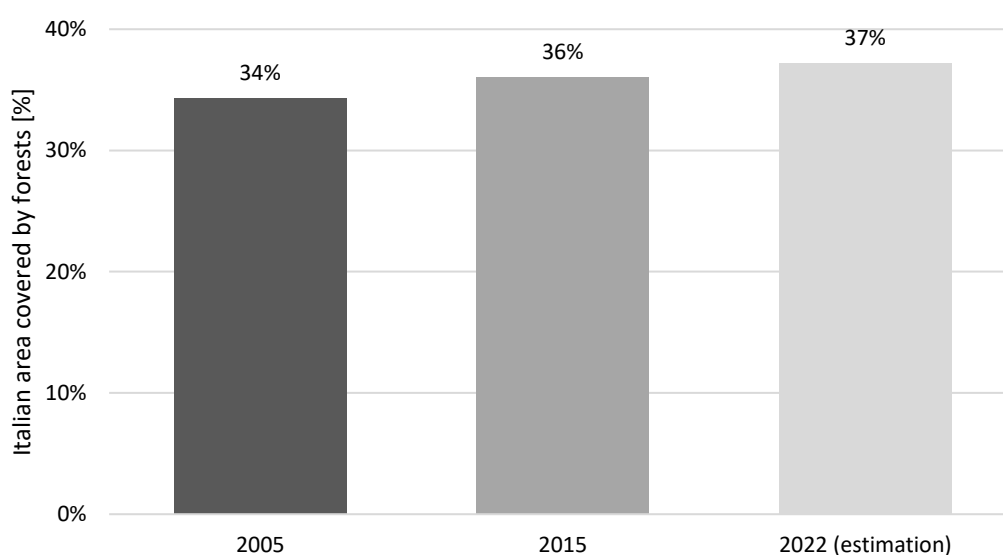


Figure 10. Italian surface covered by forests

According to INFC, 66.20% of the forest area is privately owned, whereas 33.50% is public. The division did not consider the protected areas since parts of national or regional parks are privately owned. Figure 11 summarizes the data provided.

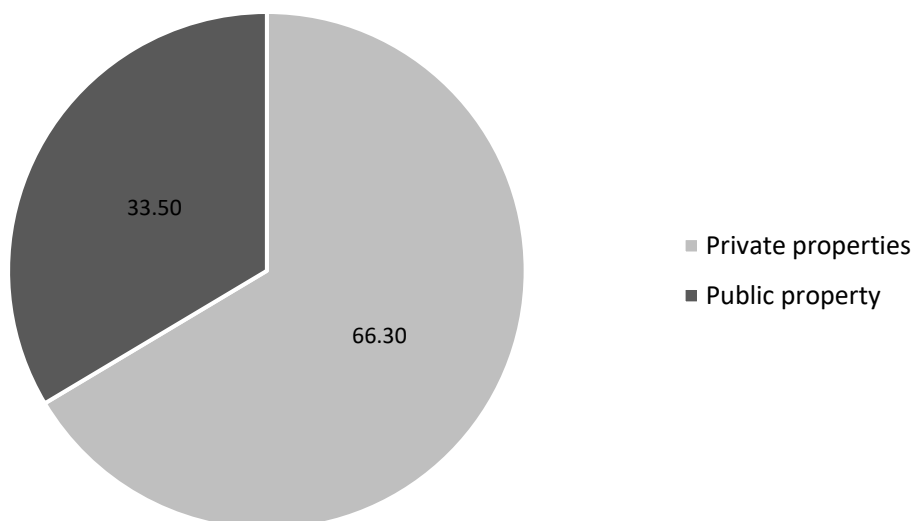


Figure 11. Distribution of the property of Italian forests [%]

As mentioned, around 36% of the territory is covered by forests, which are protected by landscape restrictions imposed by Decree n. 42/2004 (Gazzetta Ufficiale, 2004). The law recognized the landscape constraint status for the individuated forested areas and declared them protected. The constraint was also interconnected with the forestal constraint definition integrated by Decree n. 34/2018 (Gazzetta Ufficiale, 2018). All the aspects concerned with surface management and the intervention are limited. They have to be previously approved by a special commission after an official request that is also evaluated from an environmental point of view. In addition, it was estimated that 80.90% of the national forest surface is under restrictions for hydrological protection, according to *Regio Decreto* n. 3 267 of 30 December 1923 (Gazzetta Ufficiale, 1924). Despite the massive presence of lands covered by forests, in Italy, only 96 750 hectares are covered plantations. Only 18% of the forest area is managed based on a forest management plan (Corpo dei carabinieri Forestali, 2022).

The forested surfaces covered by protection or legislative protocols in Italy are estimated to equal 3 857 652 hectares. Table 11 and Figure 12 presented below introduce a division in the areas and identify their use destination (CEE, 1992; Marchetti *et al.*, 2012).

Table 11. Amount of forests in Italy covered by special protection programs.

Type of protection	Area [ha]
Natura 2000 & Natura protected area (EUAP)	1 521 403
Network Natura 2000	1 902 432
National parks	256 112
Regional parks	131 750
Protected area	45 955
<b>Total</b>	<b>3 857 652</b>

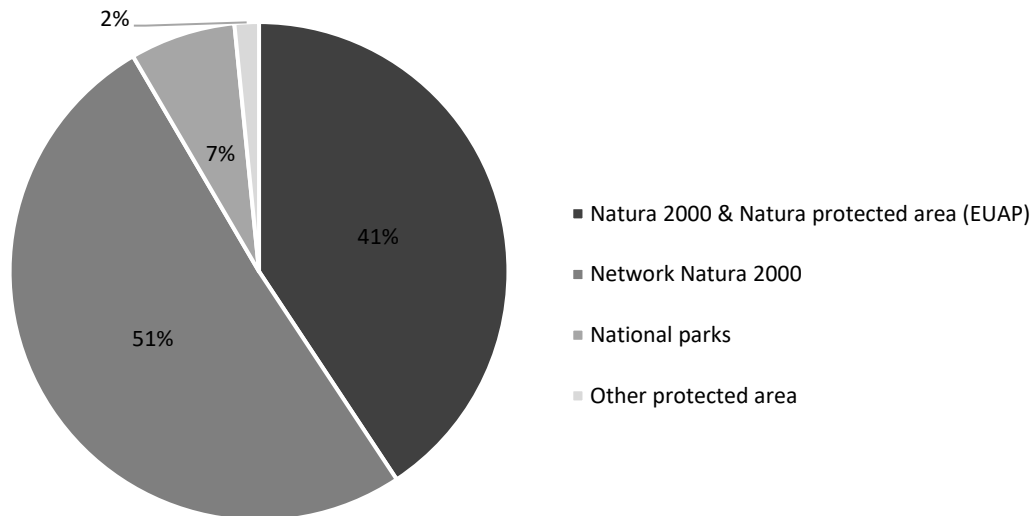


Figure 12. Incidence of protection programs recognized in Italy.

The harvesting rate is nowadays estimated by various indirect methods that lead to different results, with utilization rates ranging from 18.4% to 37.4% of the annual increment. More than 60% of the timber is harvested in Italy, mainly as firewood, but, despite the inaccuracies, the Italian harvest remains well below the European average (that accounts for 73% of the annual increment), in a range of around 6 to 9 million m<sup>3</sup> (Forest Europe and FAO, 2020). It means low anthropogenic pressure on the Italian environment and a high dependence on foreign wood and timber for industry (Corpo dei carabinieri Forestali, 2022).

#### 2.4.2 Forest management certifications (PEFC e FSC)

The most important forest certification schemes in Italy (but also in Europe) are the Forest Stewardship Council (FSC) (Washburn and Miller, 2003) and the Programme for the Endorsement of Forest Certification (PEFC) (Berger *et al.*, 2020). The FSC chain of custody is more attractive for wood processing, furniture, and pulp and paper industries. At the same time, the PEFC was more interesting for the building sectors and the sawmills. The schemes adopted use different methods to define the forest area; since PEFC considers the forest area legally defined, FSC considers the forest management unit, which may include grasslands (Ministry of Agriculture Food and Forestry, 2020). Table 12 summarizes the forest lands covered by sustainable forest management programs. Finally, it is reported evidence about the presence of a Chain Of Custody-certified forests. Chain of custody certifications are protocols designed to help organizations prove certified material's traceability as it flows through all supply chain points. They are independent and are not limited to organizations already holding certification to other schemes and are available regardless of organization size.

Table 12. Sustainable forest management programs in Italy ( FSC, 2014; PEFC, 2014)

Type of certification			PEFC	FSC
Sustainable forest management	Forest area	Hectares	874 962	63 744
		Number of certificates	36	11
		Hectares	5 989	4 213



	Plantation and poplar tree plantation	Number of certifications	16	7
	Total area (*)	Hectares	880 951	66 361
		Number of certificates	52	18
Chain of custody	Number	Of sites involved	1 095	3 275
		Of certificates	743	2 558

(\*) Approx. 45 492 of the 947 342 [ha] have PEFC and FCS certifications, corresponding to 6 certificates.

## 2.5 Summary and considerations about information obtained

This concluding section is intended to summarize data collected from various inventories and lay a preliminary basis for a hypothetical exploitation of forests to increase the production of raw materials exclusively for the Italian construction market. Assuming that a decision is made to increase Italian production and allocate it to the construction market, several technical, legal, and economic aspects should be considered.

In previous sections, it was mentioned that forests cover 36% of the land area. Those areas are fully protected by the naturalistic constraint of Legislative Decree 42/2004, while 80.9% of forests are further under hydrogeological constraint, so the possibilities of land use become difficult from a legal point of view. In addition, only 83% of forests can be considered high forests (i.e., if only forests with closed-canopy trees have reached full maturity were considered). Finally, 12.6% of the forest area is under protected area constraints – considered as national and regional parks, so interventions are limited to keeping the forestry health.

On the technical aspect, since most of the structural wood solutions on the market come from spruce, it is helpful to consider the occurrence of conifers. In Italy, the coverage of conifers is 6% of the entire territory (about 658 921 ha). In addition, since these are species that grow at higher heights, one would think that cutting and subsequent transport to the ground would be particularly challenging. In conclusion, contrary to the forest cover figure, the projections regarding increased forest exploitation for a purely Italian supply chain are not the best. Several technical, geographic, legal, and economic factors make importing raw materials from countries more economically advantageous. Table 13 summarizes the information obtained (Corpo dei Carabinieri Forestali, 2021).

Table 13 - Summary of limiting aspects of forestry harvesting

Limiting aspect respect on the total forestry surface	Area [ha]	Area [%]
Part considered as high forests	9 165 505	83.33%
Forests protected by D.Lgs 42/2004	10 982 013	100.00%
Forest area protected by hydrogeological constraint	8 884 449	80.90%
Forests considered as protected areas	3 857 652	12.60%
Private areas	7 281 075	66.30%
Forest area covered by coniferous trees	658 921	6.00%

## 3 Timber buildings in Italy, Europe, and worldwide

Timber structures have historically suffered the idea that it was impossible to construct buildings of considerable height without affecting the structural elements' strength from a static and seismic point of view. The improvement of the technologies that occurred starting in the 90s allowed the realization of multi-story buildings with higher floors. It was possible because of several main events (Salvadori, 2021):



- several countries updated their building code;
- new technological developments;
- improvement in production;
- reduction of material cost;
- and in some countries, governmental support.

However, the overall focus has often been on the tallest buildings and not on analyzing and observing the evolution of multi-story wooden buildings (5 or more stories). This section presents information about the state of the art of mass timber multi-story buildings realized worldwide. The traction is connected to the research conducted on 149 case studies by Salvadori (2021), realized considering using a full-timber structure or a hybrid solution (reinforced concrete-timber or steel-timber).

According to recent studies, the systematic design and construction of multi-story buildings using Engineered Wood Products (EWPs) solutions started in early 2004. Some authors anticipate the data to 2000, considering case studies with 3 and 4 stories (Svatoš-ražnjevi and Orozco, 2022). From 2004, the number of case studies constantly increased, reaching 40 in 2019 (Figure 13). Table 14 shows each country analyzed, giving a preliminary categorization based on (Salvadori, 2019):

- the number of case studies collected;
- the number of mid-rise buildings (buildings from 5 to 7 stories);
- the number of high-rise buildings (buildings of 8 or more stories);
- the highest number of floors recorded for a case study.

Table 14. Data concerning each country about multi-story buildings

Country	First realized	# of case-studies	# of mid-rise	# of high-rise	Highest case study [# of stories]
Austria	2004	16	14	2	24
Norway	2005	17	10	7	18
Switzerland	2006	19	17	2	16
UK	2006	23	17	6	11
Germany	2007	19	17	2	10
Netherlands	2008	3	2	1	9
Canada	2009	10	6	4	18
Sweden	2010	15	7	8	9
Australia	2012	9	3	6	10
Finland	2012	10	6	4	14
Italy	2012	13	11	2	9
New Zealand	2012	1	1	-	6
France	2013	19	10	9	12
USA	2013	14	13	1	8
Spain	2014	5	5	-	7
Taiwan	2014	1	1	-	5
Belgium	2015	2	2	-	6
Chile	2019	1	1	-	6

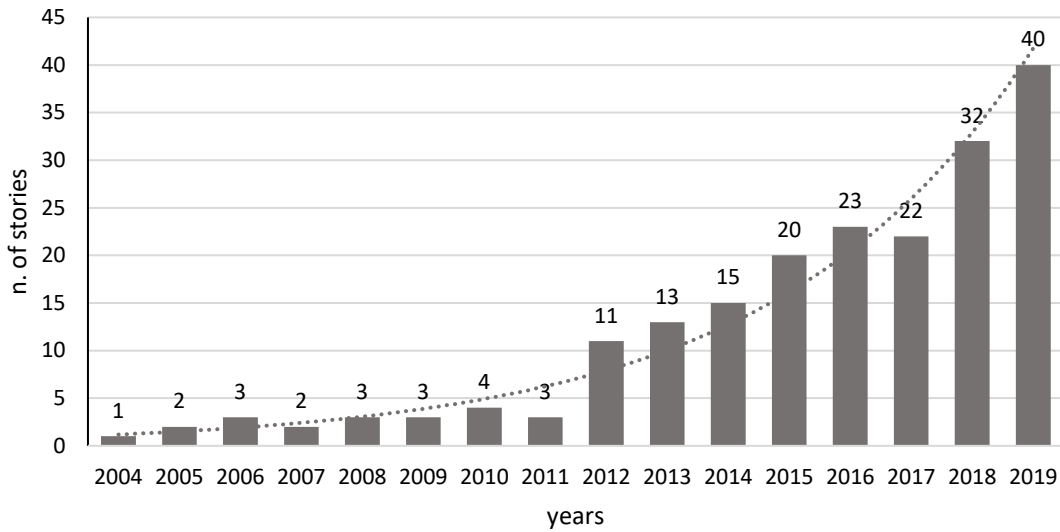


Figure 13. Multi-story buildings realized every year

Figure 14 compares, per each country analyzed, the year of realization of the first multi-story building with the maximum number of stories. E.g., Austria realized its first multi-story building in 2004, reaching a high of 24 stories over the period 2004 – 2019. It was found that countries with a structured and old tradition also have high-rise buildings. The correlation, coupled with the increase in the number of case studies per year, confirms the need for in-house expertise to be formed over time.

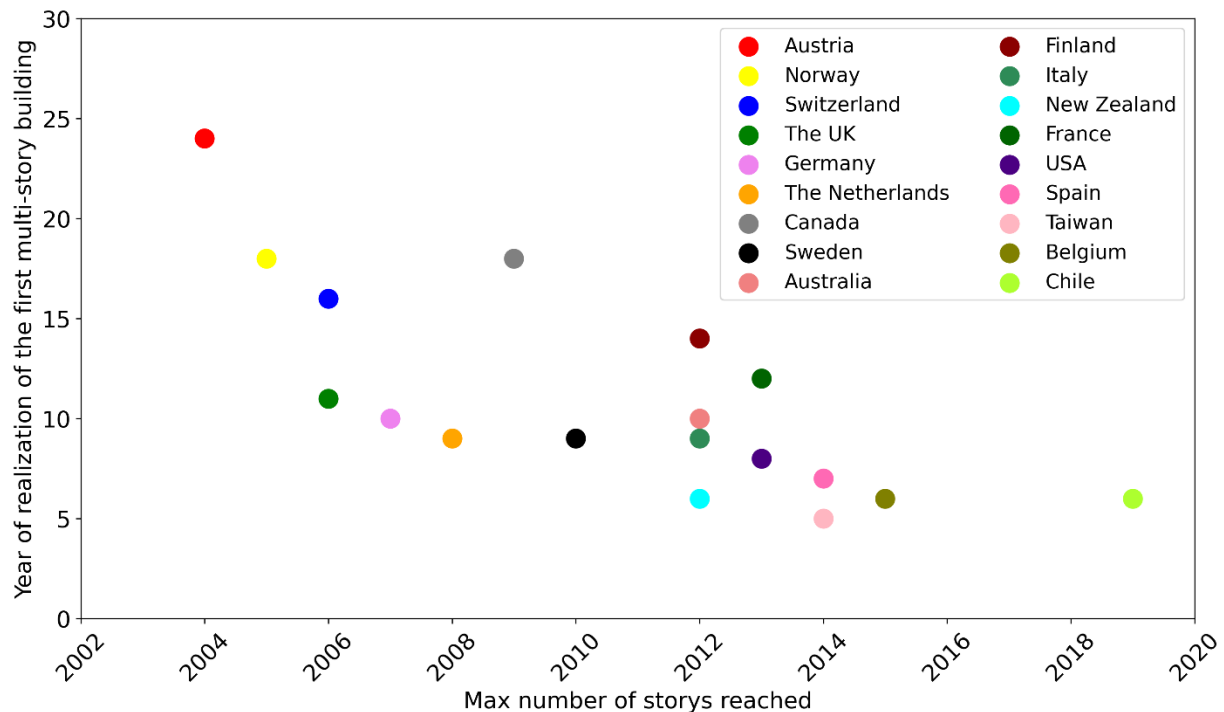


Figure 14. Comparison between the year of realization with the number of stories



Figure 15 provides an overview per country of the number of multi-story buildings realized, classified according to the number of stories. In Italy, 13 multi-story buildings have been realized, mainly with development by a number of floors realized relatively low. In fact, 10 out of 13 mapped buildings do not exceed 7 floors. Overall, no buildings with more than 10 floors have been realized. The result of this survey confirms what was said earlier about the need for in-house expertise that can grow over time. Although the Italian data show interest in wood buildings, the stigma suffered over the years regarding their limitations in adequately resisting seismic stress is evident. This distrust is still apparent in countries with high seismic activity, such as Chile, Taiwan, and New Zealand.

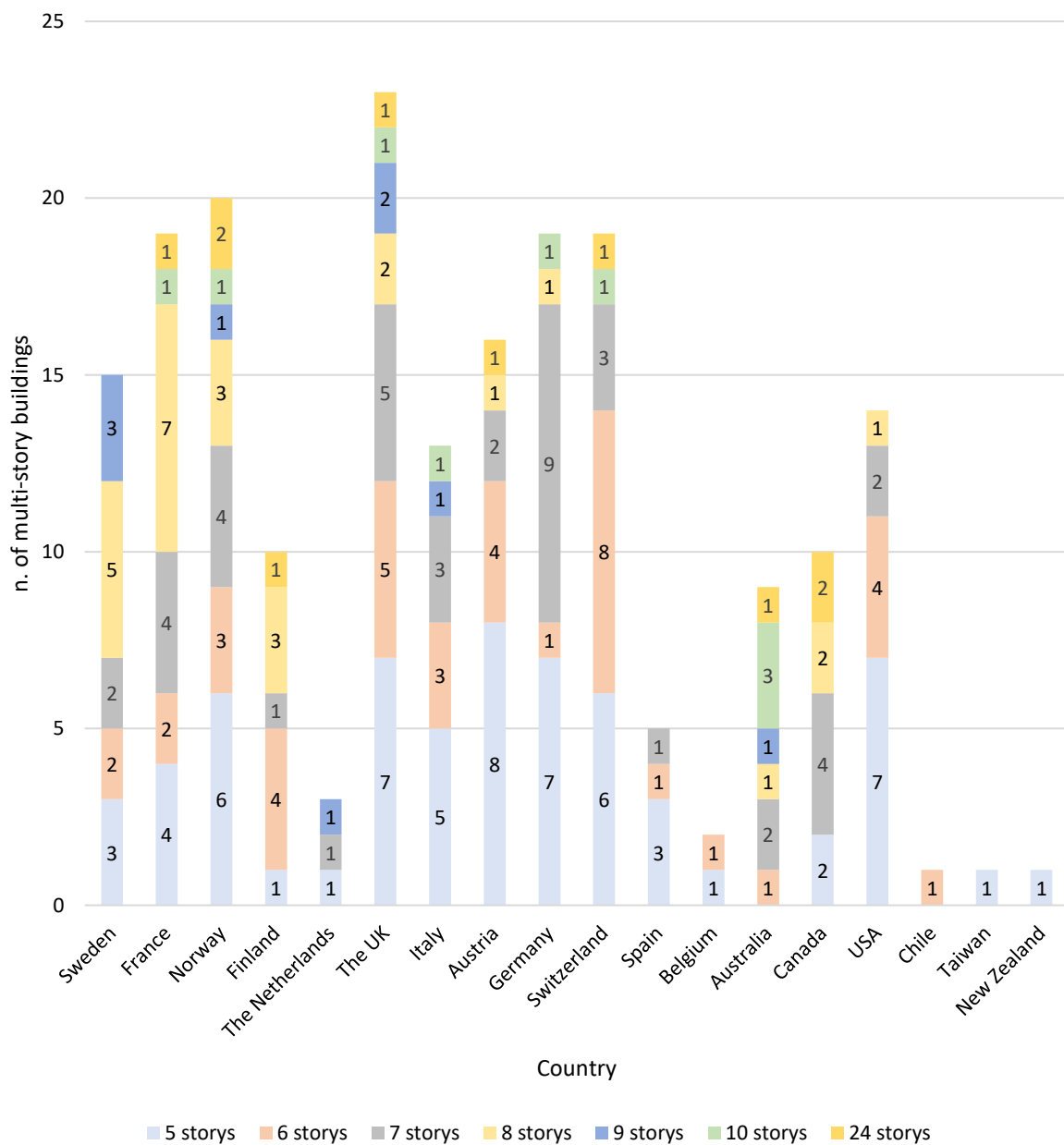


Figure 15. Distribution of multi-story buildings per each country





### 3.1 Structural system solutions adopted

Most of the case studies were designed considering a hybrid solution, combining structural timber elements with reinforced concrete and steel elements. 80% of all the selected case studies have either a podium, a core, both, and other steel elements integrated into their structures, confirming that the vast majority of the cases are “timber-based” projects, and only a minority of them have been designed with an all-timber structure (20%). 108 case studies (55%) are based on the penalized concept. Of these projects, the majority (73 case studies) have a panelized timber-concrete structure (Salvadori, 2021). Frame structures form post-and-beam structures, post-and-slab structures, as well as exoskeleton structures where vertical supports (other than the core) are limited to the exterior. Elements of the frame are usually joined to a core based on variations in stiffness. Timber frames are implemented with bracing systems to achieve additional lateral stability. Those systems could shear walls, diagonal EWPs, or steel beams, and steel cross bracing are added. Floor slabs can be made of different EWP combinations, such as Cross-Laminated Timber (CLT) slabs, ribbed slabs, or CLT or glulam-concrete composite floors (Pastori, Sergio Mazzucchelli and Wallhagen, 2022).

There are many methods for making wooden structures, and depending on various conditions, they are selected to achieve the requirements.

Salvadori (2021) tried to schematize and summarize the different techniques adopted to see if there was a geographical distribution. It is important to mention that the proposed categorization is not strict, and examples of mixed solutions caused by declared exigences could occur. Below, every structural system is described in more detail:

- Panelized all-timber: The structure is mainly composed of CLT load-bearing elements. The presence of other structural materials or wood point elements is negligible.
- Panelized timber-concrete: Structures composed of CLT load-bearing elements with a concrete structure to compensate for and supplement load resistance.
- Panelized timber-steel: Structures composed of CLT load-bearing elements with a steel structure to compensate for and supplement load resistance.
- Panelized timber-concrete-steel: Hybrid solutions among the three subcases described above;
- Post-and-beam all-timber: Beam-to-columns timber structures where the presence of other structural solutions, either wooden or made of traditional materials, is negligible.
- Post-and-beam timber-concrete: Beam-to-columns timber structures supported by a concrete structure to compensate for and supplement load resistance.
- Post-and-beam timber-steel: hybrid solution among beam-to-column timber structures supported by steel elements.
- Post-and-beam timber-concrete-steel: hybrid solution among beam-to-columns timber structure supported by the presence of concrete and steel elements;
- 3D Modular Element all-timber: in this system, solid or timber frame walls and floor elements are prefabricated and assembled to form a 3D module. The core of the building could be erected separately (made of EWPs) or modularly like the rest of the buildings.
- 3D Modular Element timber-concrete: hybrid variations supported by concrete elements.



Figure 16 shows the distribution of the technologies adopted per country. As mentioned before, panelized structures are the most adopted by designers. From the mapped cases in Italy, there is a prevalence of load-bearing wall structures built with CLT. Concrete structural elements support the structures in some cases to compensate for any limitations in load-bearing capacity. In this context, Italy has never had a 3D modular structure designed with wood elements that do not require the support of other traditional structural elements. With this in mind, the prototype developed by WTA for the MIND area would fit in as the first example of a building made in Italy using this technique.

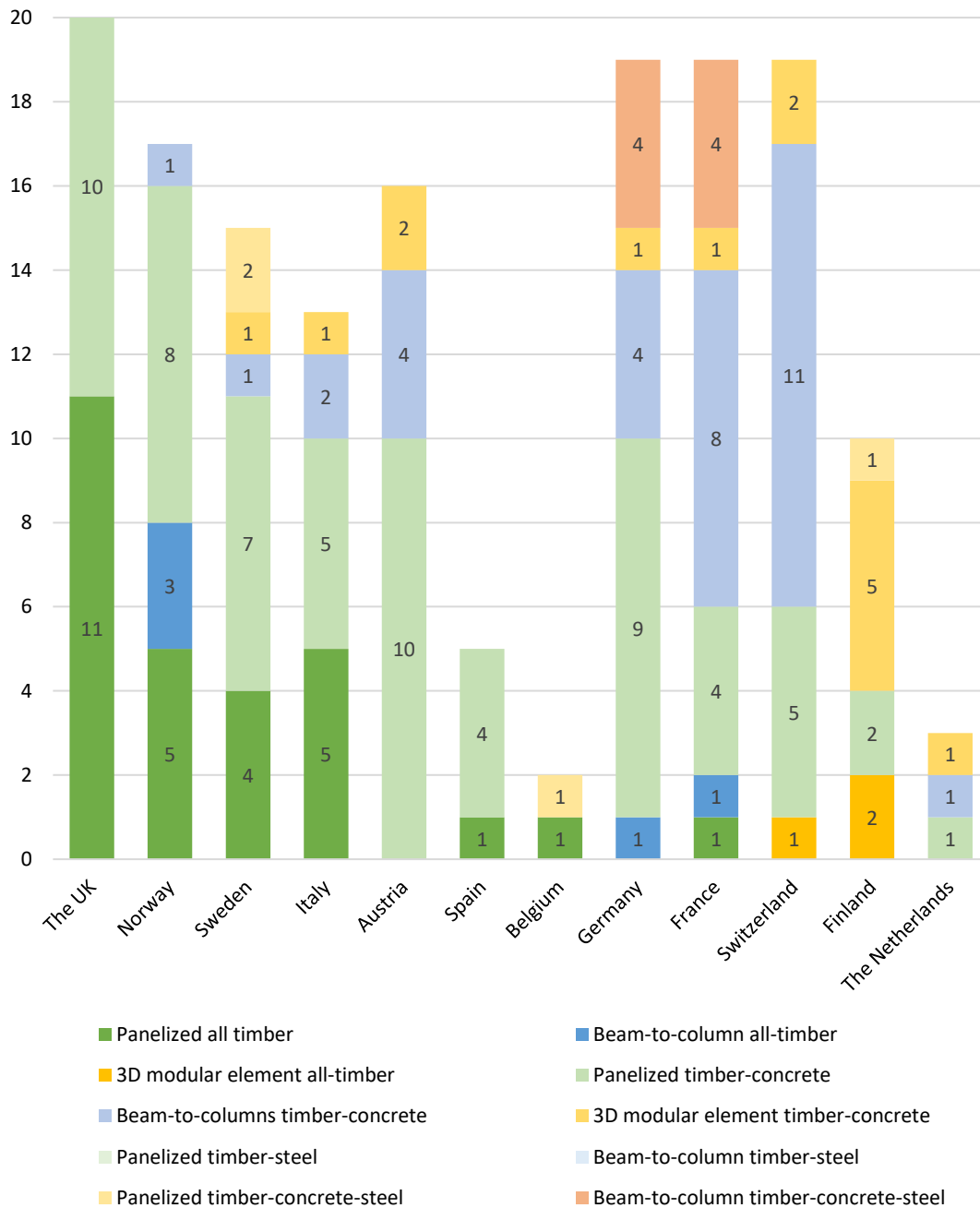


Figure 16. Distribution of multi-story buildings per typology adopted in every country



### 3.2 End-of-Life scenarios

It is ideal to employ wood in products with a design lifespan that (at least) matches timber rotation periods (Ramage *et al.*, 2017) to satisfy the sustainable use of wood resources. The European Commission, in 2013, established a cascade use principle for wood for construction, which suggests wood be used in the following order of priority: reuse, recycling, bioenergy, and disposal (Committee on the Environment, 2013; European Commission, 2013). Timber elements can be reused, such as wood plastic composites or fibreboard panels, or down-cycled into competing uses for pulp and fuel at their end-of-life. On the other hand, fuelwood is a single-use product with a short lifespan and is often burnt inefficiently (Pearson, T., Swails, E. and Brown, 2012; FAO, 2014). Waste to Energy (WTE) plants usually do not reach 50% in efficiency, considering both electrical and thermal. In this section, the authors discuss end-of-life scenarios, i.e., reuse, recycling, energy conversion, and landfill.

#### 3.2.1 Reuse and recycling

Reuse is seen worldwide as a priority for timber elements, so companies and institutions are multiplying the efforts to diffuse the best practice. For instance, several policies ask for timber building products to be dismantled easily at the end of their service life. Products can be reused for the same application or sent to other uses after a simple reshaping and the correct response to the minimum requisites once checked (Design for Manufacturing and Disassembling – DfMD). According to the principle of ‘preparing for reuse’ in the waste framework directive (European Commission, 2008), wood products are encouraged to be designed with ease of disassembly and reuse as a consideration. Reused wood is now considered a resource, and many countries are increasing the quantity of wood processed for a second life. The UK is regarded as one of the leading countries in recycling wood-based materials. The Wood Recyclers Association (WRA) has calculated that almost 60% of the UK’s waste wood is getting recycled (HSE, 2021).

#### 3.2.2 Energy conversion

Wood-based products can produce energy through direct combustion or conversion of biogas fuel before burning (Schneider, 1977). The energy conversion of wood-based materials depends on the presence of contaminants. Clean wood wastes without being contaminated with harmful substances are allowed to be burned in normal power stations, while contaminated wood containing adhesives (e.g., formaldehyde glue, etc.) can only be used for energy generation in special stations equipped with appropriate combustion facilities (Ramage *et al.*, 2017; Jungmeier *et al.*, 2018).

#### 3.2.3 Landfill

The landfill is the least favored end-of-life scenario. Treated wood wastes containing hazardous components and the ash disposed of wood burning must go to a landfill. However, many governments (e.g., Sweden, Austria, and Germany) have already banned landfilling of wood waste, while many others have discouraged landfilling through taxation (Ramage *et al.*, 2017). The objective is not only to reduce dependency on landfilling but also to encourage energy recovery, material recovery, and recycling. Recycling extends the service life of wood and, therefore, the carbon sequestration period, but it also reduces the demand for raw materials with the associated emissions caused by production processes.

In landfills, biodegradation takes place on wood waste. Most of the cellulose and hemicellulose in wood is biodegradable and quickly decompose to small components, while lignin is resistant to biodegradation in an anaerobic environment and can remain for very long periods (Tuomela *et al.*, 2000).

Figure 17 resumes the processes that occurred to timber-based materials for their end-of-life. After the demolition and disassembly, wood could be affected to reuse, energy recovery, or landfill processes.

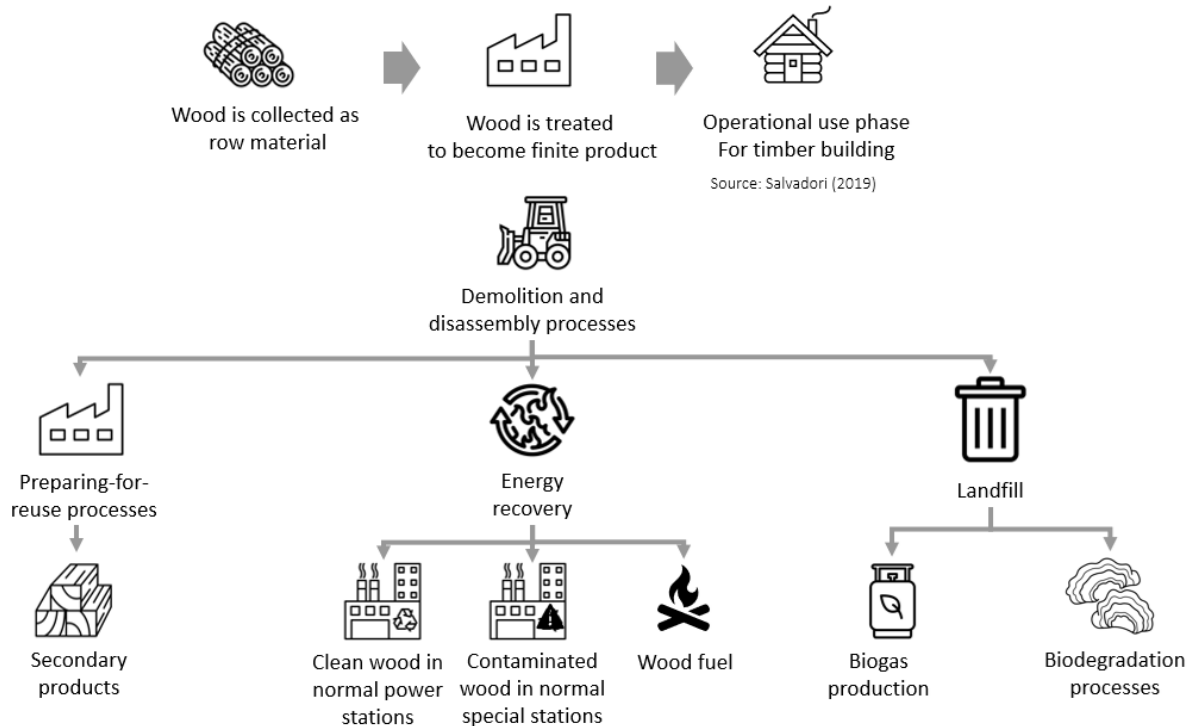


Figure 17. Scheme about the end-of-life of timber-based materials

#### 4 Policies aspects: list of standards that regulates the use of mass timber building in Italy

The section aims to review the most relevant aspects of policies directly involved in timber construction, providing just an overview of the state of the art of regulations directly related to the use of mass timber. Where possible, an attempt will be made to provide a more detailed overview of the legislative aspects of a few countries considered virtuous. Finally, an attempt will be made to focus on the Italian case, showing the main values to be considered from a technical point of view and which regulations to consider. The potential benefits of the material are evident, yet, numerous social, economic, technical, and political issues pose difficulties with using wood in construction (Dumler, Werther and Steenhansen, 2020).

First, preliminary research shows that few authors have addressed the topic of applied wood policies in the construction sector. Moreover, the regulatory contexts across countries substantially limit multi-story wood construction development (Wiegand and Ramage, 2022). For this reason, Governments have implemented numerous policies for facilitating the development of tall timber structures, developing the business, and helping to spread the knowledge and the diffusion of timber-based multi-story buildings. These policies include easing restrictions, funds for research and development, information campaigns, certifications on environmental performance, and other wood-use policies. There is still a gap in the literature on the relationship between these policies and individual high-rise buildings



(Wiegand and Ramage, 2022). From a historical point of view, the built environment has always been shaped following guidelines and principles defined by Public Administrations considering the impact of the construction sector on the environment for sustainability issues. However, since the 1990s, in industrialized countries, this paradigm has changed and transformed public policies. First, from prescriptive to performance requirements; second, from regulation to market-based and voluntary arrangements; and third, from private initiatives to subsidiary research and development. In this context, five policy instruments for a sustainable built environment exist (i.e., regulatory instruments, economic instruments, information tools, voluntary policies, research and development tools). Wiegand and Ramage (2022) studied timber policies and showed that numerous policies implemented at national, regional, and municipal levels facilitated the development of Tall Wood Buildings (TWBs). Policies based on Regulatory Instruments often act defining code requirements, restriction easings, or zoning planning issues. Complying with these requirements is challenging and expensive, so governments implemented several policies to facilitate the development of TWBs. However, it is important to mention that part of these policies implemented acted through economic instruments, voluntary policy tools, and research and development tools simultaneously. In addition, the adoption of competitions or calls for applications (voluntary policy tools) granted projects with subsidies (economic instruments) for conducting research and development activities (research and development tools) became good tools to facilitate the development of the sector. Complementary, some of these policies acted through information tools, providing recommendations of best practices and technical assessments (Wiegand and Ramage, 2022).

#### **4.1 Regulatory instruments**

Regulatory instruments are mandatory; therefore, they set an obligation to either use a technology-based or achieve a performance-based standard. The easing of explicit restrictions on TWBs development was crucial for allowing the development of TWBs. Pioneers' projects in Finland, UK, and Sweden were first envisioned after these code updates. Additionally, the adoption of performance-based codes made viable the construction of TWBs. Professionals involved in TWBs developed tests, simulations, and reports for achieving the performance values required. Fire safety was often highlighted as the most relevant barrier; structural and acoustic requirements were also mentioned. Even zone planning regulations promoted wood use in buildings.

#### **4.2 Economic instruments**

Economic instruments are financial incentives associated with the environmental impact of a particular activity. In the past, public administration from North Europe offered economic support for developing selected timber-based buildings. In general, funds are destined to support research and development of the entire supply chain.

#### **4.3 Information tools**

Information tools aim to communicate relevant information regarding sustainability themes. They are subdivided into three subcategories. First, public information campaigns raise public awareness of environmental issues. Second, technological information diffusion programs provide technical information for producers aiming to change behavior. And third, environmental labeling schemes offer information about the environmental performance of a product and its certification. Examples of



information tools applied in Europe were destined at all levels to provide general information about technical support or spread benefits to the population.

#### 4.4 Voluntary policies

Voluntary policy tools can be unilateral when adopted by a business without public involvement, negotiated when they result from a public-private agreement, and selective when participation in governmental programs is voluntary. Public organizations generally use policies based on voluntary policy tools for deciding how to assign funds for supporting projects about timber construction. Additionally, policies based on voluntary environmental assessment, such as labeling schemes, were developed and sponsored.

#### 4.5 Research and development tool

Research and development tools are based on a public-private partnership, which comprises public funds to support R&D activities. They generally facilitated the diffusion of mass timber buildings or a public-private agreement to comprise funds. Figure 18 below summarizes the relationship between the policy types and gives some examples to support them (Wiegand and Ramage, 2022).

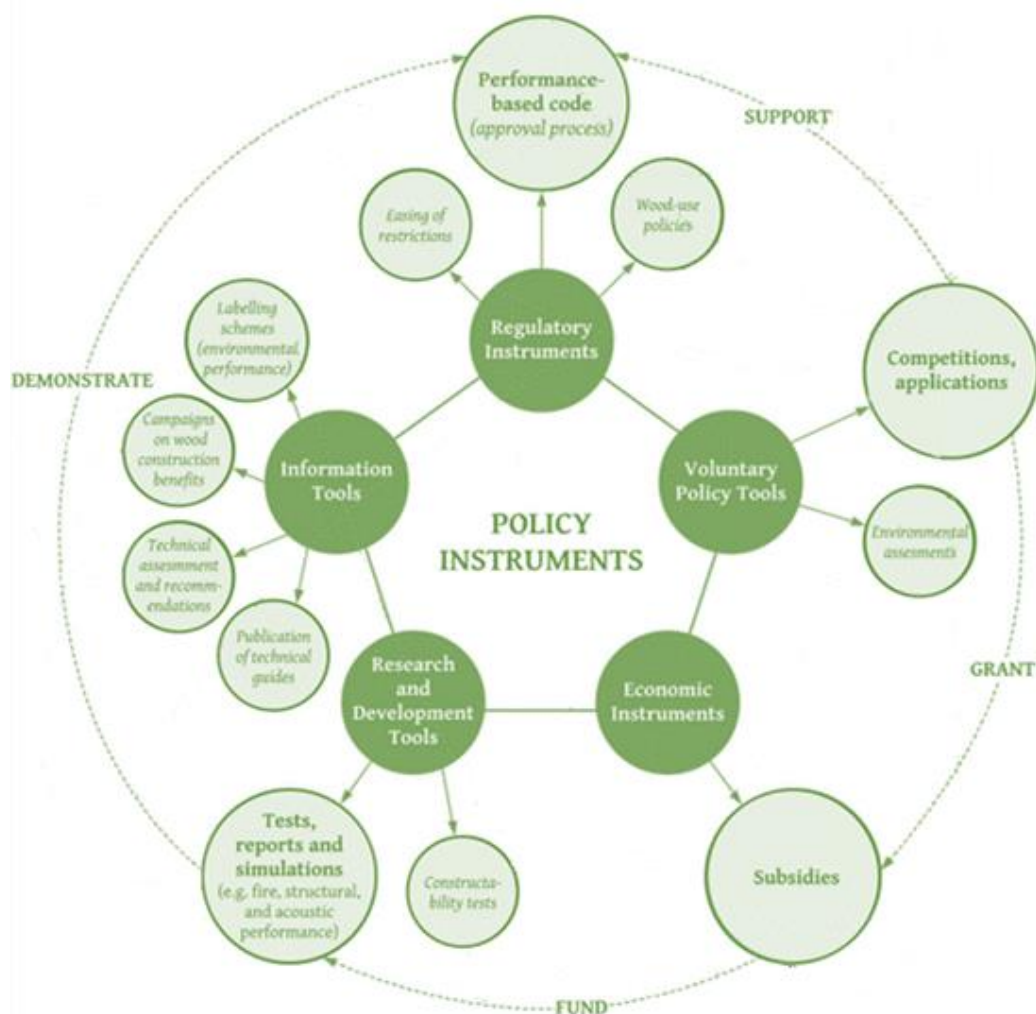


Figure 18. Scheme of policies classification (Wiegand and Ramage, 2022)



## 5 Economic and financial aspects

More than 60% of wood consumption currently goes into construction as supporting material and structural components (Svatoš-ražnjevi and Orozco, 2022). Wood construction is a primary destination and is growing worldwide, paired with the renovated interesting of the institutions for sustainability issues. Europe, in particular, is the continent with the farthest-reaching sustainable ambitions presented in the European Green Deal – a set of policy initiatives with the aim of making the European Union (EU) climate neutral by 2050 (European Commission, 2019). As part of the Green Deal, Europe has launched the Renovation Wave. Currently, roughly 75% of buildings in the EU are not energy efficient, yet 85-95% of today's buildings will still be in use in 2050 (ECESP, 2021). The focus on ESGs (Environmental Social, and corporate Governance) not only by private individuals but also by public bodies and institutional investors is increasing the importance of green building within the construction sector. Fiscal advantages and financing choices are now guided by the possibility of improving new buildings' environmental (and social) impact. This attention has not waned even in the current period of crisis linked to the health emergency. The budget planned for the coming years by Europe, 'Next Generation EU', wants to accompany the transition towards sustainability and digitization (Green Deal) through sustainable public and private investments also in infrastructure and the sustainable construction sector.

There is also a growing number of players in the so-called Impact Finance (investments from which one expects not only an economic return but also an environmental and social improvement): Cassa Depositi e Prestiti with 'Green, Social and Sustainability Bonds', banking foundations (with special purpose vehicles, dedicated to residential investment and energy saving), investment funds specializing in real estate with a lower environmental impact (FederlegnoArredo, 2021). The manufacturing of furniture products or the construction of buildings using wood and wood products both include reference to the sustainable and responsible sourcing of materials from forests (Platform on Sustainable Finance: Technical Working Group 1–993., 2021). European taxonomy and ESGs: drivers for mass timber buildings

The central gap for financial institutions was to evaluate analytically and systematically when a project could have considered sustainable. To meet the European Union's climate change and energy targets for 2030 and reach the objectives of the European Green Deal, the action plan on financing sustainable growth called for the creation of a standard classification system for sustainable activities: the EU taxonomy document (European Commission, 2018).

The EU taxonomy is a classification system establishing a list of environmentally sustainable economic activities. It could be crucial in helping the EU scale up sustainable investment and reach the European environmental targets. The EU taxonomy would provide companies, investors, and policymakers with appropriate definitions for which economic activities can be considered environmentally sustainable. In this way, it should create security for investors, protect from greenwashing, help companies to become more climate-friendly, mitigate market fragmentation, and help shift investments where they are most needed. The EU taxonomy document is the primary tool that sets 6 environmental objectives of climate change mitigation and adaptation, sustainable water use, pollution prevention and control, protection of biodiversity, and transition to a circular economy (European Commission, 2018).

Among the sectors and the actions declared, the construction and the forest management sector is deeply evaluated to give the interested stakeholders the tools for assessing potential sustainable



projects. Among the 'Do Not Significant Harm' (DNSH) actions related to forest management with a view to the transition to a circular economy, reference is made to a progressive reduction of primary biomass suitable for the manufacture of wood-based products with long-term circularity potential (European Commission, 2021). It is also required for all forest restoration and management processes and forestry to preserve the environment's biodiversity (European Commission, 2021). Concerning the constructions, the European taxonomy does not expressly refer to mass timber constructions but promotes initiatives where this technology could be welcomed. In particular, the introduction of the Life Cycle Assessment method (ISO, 2006, 2021) or the cradle-to-grave assessment of the building's energy and environmental impact is mentioned for buildings with a gross floor area greater than 5 000 m<sup>2</sup> (Alessi *et al.*, 2019). In an application context such as this, constructing timber under certain conditions could be advantageous for financing institutions (Platform on Sustainable Finance: Technical Working Group 1–993., 2021). In addition, the EU taxonomy introduces the following constraint: *“At least 80% of all timber products used in the new construction for structures, cladding, and finishes must have been either recycled/reused or sourced from sustainably managed forests as certified by third-party certification audits performed by accredited certification bodies, e.g., FSC/PEFC standards or equivalent”*.

In the past, financial institutions were reluctant to grant loans to those who wanted to build a timber building due to the perception of its limited technical performance and durability. To protect themselves against the possibility of a bad investment, lending institutions tended to either reject applications or finance a smaller amount than a building constructed with traditional technology. Insurance companies, concerned about the durability of the materials used, also tended to issue insurance products at a higher cost than traditional ones. Introducing specific certifications, which have acted as guarantors for the technology, has partially reduced these gaps. Today, it is possible to access credit lines or insurance products at lower prices than in the past. The examples below concern two certifications that directly relate to timber constructions, but many others could be easily accessed by opting for a building made of mass timber elements:

- Leadership in Energy and Environmental Design (LEED) certification (LEED, 2013);
- ARchitettura Comfort Ambiente ARCA (Habitech, 2023);
- Sistema Affidabilità Legno Edilizia - Wood Building Reliability System (S.A.L.E.) certification (FederlegnoArredo, 2020).

In particular, S.A.L.E. is the private protocol born from the collaboration between [Assolegno](#) and [Conlegno](#) to identify companies that comply with current regulations and can guarantee comfortable, durable, and quality constructions. For this reason, many credit institutions and insurance companies require it as an essential condition for issuing a mortgage. The protocol does not apply to the individual timber building constructed but rather to the operating/production methods implemented by the builder to guarantee the conformity of the work in its various phases through an initial inspection visit to the factory and building site and a periodic surveillance visit on an annual basis. In other words, S.A.L.E. is an effective tool for the protection of the 'wood-building' supply chain, aimed at enhancing the work of companies with technical-organizational solid skills in the management of the various phases of construction: from the acceptance checks of materials to the executive design, and from the prefabrication of elements in the factory to the technical criteria for site management.





In recent years, the protocol became the certification required to demand specific financial and insurance products related to mass timber buildings. Below is reported a not completed list of products that are accessible after the presentation of S.A.L.E certification:

- MUTUO CASAVERDE, provided by Banca Popolare Etica, mortgage loan of first home;
- MUTUO IPOTECARIO, provided by Gruppo Banco BPM, offers the additional possibility of being financed with work progress.

Other institutions that recognize the certification are: Gruppo IntesaSanpaolo, Federazione Marchigiana BCC, UBI Banca, and Unicredit Leasing. Zurich Insurances, AVIVA, and Allianz provide insurance products for mass timber buildings.

## 6 Life Cycle Assessment method applied to the mass timber industry

The section aims to show the potential benefits introduced by applying the Life Cycle Assessment (LCA) methodology to the construction sector. Within a cradle-to-grave assessment and under certain boundary conditions, the application of structural timber would have unquestionable advantages over other so-called traditional technologies in terms of the potential impact on climate change, thanks to the lower primary non-renewable energy demand in the transformation. (Hegeir *et al.*, 2022; Younis and Dodoo, 2022) A study of multi-story residential buildings with structural material options of cross-laminated timber (CLT), prefabricated timber modules (modular), and precast concrete demonstrated that CLT and modular buildings offer 37% and 17% lower life-cycle non-renewable primary energy consumption, respectively, compared to precast concrete (Janjua, Sarker and Biswas, 2019).

Generally speaking, applying energy requalification or urban regeneration techniques has become a significant issue within European policy. Given the ambitious Greenhouse Gas (GHG) emissions reduction targets by the EU that demand a decrease in emissions of 55% by 2030 (compared with 1990) and the achievement of carbon neutrality by 2050, effective research-based solutions to mitigate the cities' climate footprint become inevitable urgency. The EU should implement the path towards these targets, avoiding significant harm to other environmental objectives (i.e., climate change adaptation, sustainable use and protection of water resources, transition to a circular economy, pollution prevention and control, preservation and restoration of biodiversity and ecosystems). Looking at the construction sector, currently, around 75% of the building stock in the EU is energy-inefficient. Approximately 85% of these buildings will still stand by the year 2050, a target to achieve carbon neutrality in the EU (Galimshina *et al.*, 2022). A 40–80% reduction in current annual anthropogenic GHG emissions by 2050 was proposed as the likely requirement if we achieve a 50–70% probability of staying below a pre-industrial relative temperature increase of 2 °C (Guest *et al.*, 2013).

The LCA method is commonly used to evaluate the achievable benefits and ensure the renovation scenarios' cost-effectiveness. The main advantage of this analysis is the possibility of assessing a building during its whole life cycle and including all stages from the materials' production to their end of life (Famiglietti *et al.*, 2021). LCA has been widely used across the globe to assess the economic and environmental impacts of the building sector. Sustainability indicators facilitate measuring buildings' sustainability performance and set criteria for that performance. The assessments have been based on the average service life of the buildings concerned. The “carbon footprint” concept is the most

commonly used indicator in building sustainability assessments, underlining the urgent need to deploy more diverse environmental impact categories to avoid burden-shifting among environmental, social, and economic objectives (Janjua, Sarker and Biswas, 2019; Andersen *et al.*, 2021)

Adopting an LCA method to evaluate the environmental profile of a timber-based construction is helpful to underline an aspect related to land use and land use change, which is not visible while performing the analysis with traditional energy performance tools. In fact, focusing only on GHG emissions poses a risk of burdens shifting to other environmental aspects. For instance, human-managed land has proven to have an enormous impact on the environment's ability to sequester carbon. Therefore, land use and land use change (direct and indirect) are important aspects to consider when evaluating if increasing the use of wood in buildings can reduce the environmental impact of buildings (Ritter *et al.*, 2013; Andersen *et al.*, 2021)

### **6.1 Energy Performance Certificate: a review introducing the LCA method**

A review of the existing Energy Certification Certificates (EPC) for housing units, included in the Energy Performance of Buildings Directive 2010/31/EU (European Parliament, 2010) and the Energy Efficiency Directive 2012/27/EU (European Parliament, 2012), should be proposed to consider the potential benefits of sustainable constructions beyond the operational phase. This help to promote sustainability in construction and indirectly adopt the use of mass timber on a more comprehensive scale. EPCs were introduced to:

- decarbonized building stock;
- create a stable environment for investment decisions;
- give property buyers better information about energy efficiency.

Currently, the labeling scheme is limited to evaluating the primary energy consumption during the operational phase. This approach represents an efficient tool for buildings with limited energy performance where the emissions associated with the construction materials have an incidence with respect to the entire life cycle of around 20-30%. For new buildings - nearly Zero energy buildings (nZEB), the emissions associated with the embodied energy reach an incidence around 50% (or even more), and therefore it is necessary to enhance the design choices that, through a wise choice of the materials used.

This initiative will promote the review of the actual computational model adopted for the EPCs, implementing the labeling of buildings according to the emissions generated during the whole life cycle (embodied and operational emissions). The new labeling method will classify buildings more consistently, promoting sustainable building constructions concerning greenhouse gas emissions produced. Figure 19 and Figure 20 show indicative results (not considered final) developed by the Department of Energy (RELAB group) – Politecnico di Milano. Figure 19 compares life cycle emissions (EN 15978) from two constructions, with the best-class A and the worst performance-class G according to the current labeling scheme. Figure 20 shows instead (i) the average climate footprint values of populations of buildings belonging to the 7 classes of the current labeling scheme (A to G) divided by embodied and operational emissions and (ii) the distribution of these populations.

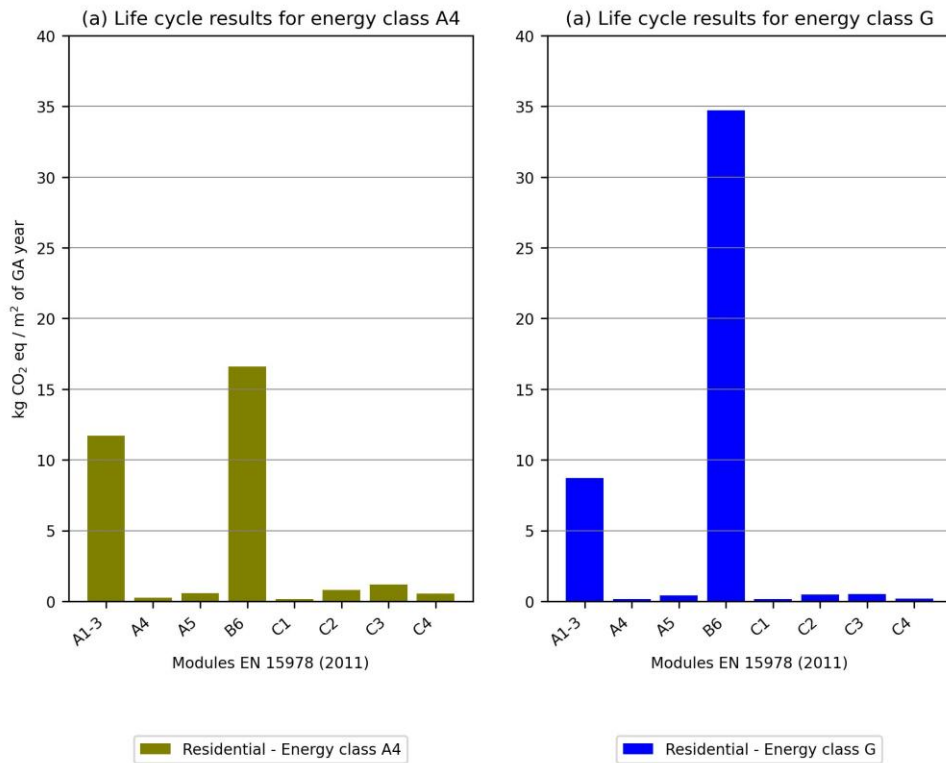


Figure 19. LCA of two housing units: the best-class A and the worst-performance-class G.

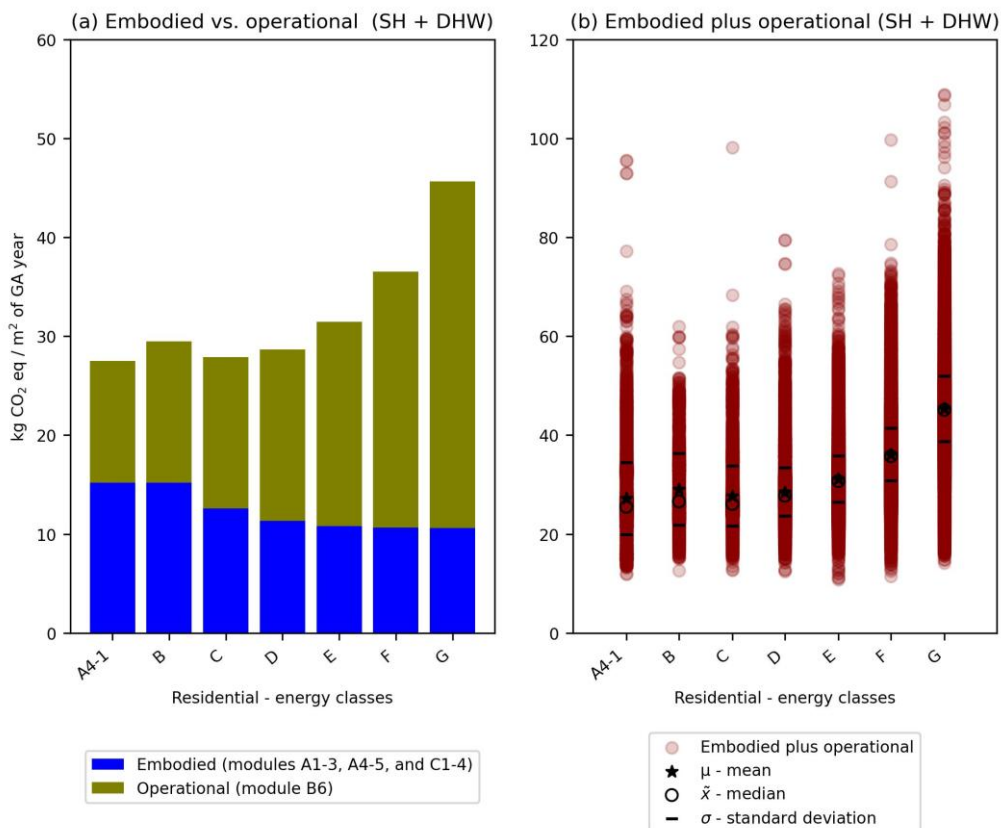


Figure 20. Climate footprint values of populations of housing units



It will permit the Municipalities to have a holistic view of the building stocks, monitoring and elaborating statistical analysis to implement sustainable policies that do not neglect the embodied carbon in the construction materials. E.g., in Denmark, the LCA study is mandatory for all buildings whose construction is completed after January 1, 2023. In addition, buildings larger than 1,000 m<sup>2</sup> must meet the threshold of 12 kg of CO<sub>2</sub> equivalent per square meter per year. This implementation is partially described by Famiglietti *et al.* (2022).

## 6.2 Dynamic LCA as a tool to evaluate carbon storage

Timber is worldwide recognized to have a low climate production process. As stated before, the process is less energy-intensive with respect to other materials. For this reason, increased use of wood in buildings is often promoted as a strategy to reduce the embodied GHG emissions of buildings. Through photosynthesis, wood absorbs and sequesters CO<sub>2</sub> from the air. The carbon sequestered by wood and other bio-based materials is commonly referred to as biogenic carbon. At the end of life, when the wood either decomposes or is incinerated at incineration plants, the sequestered carbon is released back into the air, resulting in an equivalent or higher increase of atmospheric CO<sub>2</sub> biogenic. However, when seeking to quantify the embodied GHG emissions of a building or other products, these inherent mechanisms of wood cause further complexities. Consequently, skepticism regarding the 'true' environmental potential of wood in construction remains (Andersen *et al.*, 2021).

As mentioned, a forest's growing and management process can be controlled to optimize carbon storage. A forest sequesters carbon thanks to its sustainable management, but the process is not constant throughout the entire life cycle (Salvadori Vittorio, 2021). After the initial growth, the CO<sub>2</sub> sequestering capacity of a forest reaches an equilibrium point and reduces the carbon uptake. As trees die and rot, they release CO<sub>2</sub> back into the atmosphere. The forest reduces the number of trees in its group, and the remaining trees grow taller and more robust, but the carbon balance remains consistent (Creutzburg *et al.*, 2017).

On the contrary, the benefits of timber in construction are strongly connected to the managed forests from which the timber is coming (Hafner, Winter and Takano, 2012). The positive benefits mentioned before could be lower adopting timber from places where forest depletion is a serious problem (Ramage *et al.*, 2017). In addition, carbon storage should be stored for a long period (Hafner, Winter and Takano, 2012). Looking at the Italian case, in 2020, the stock of organic carbon in Italian forests amounts to 1.24 billion tonnes, or an average of 141.7 tonnes per hectare for the four pools: epigeal biomass, necromass, litter, and soil. The latter alone represents 57.6% of the carbon stock (Ministry of Agriculture Food and Forestry, 2020).

Regarding the carbon storage assessment, several methodologies have been developed. The first is the 0/0 approach, also called the "carbon neutral" approach. It does not consider biogenic carbon stored and assumes 0 uptakes of CO<sub>2</sub> biogenic and 0 release of CO<sub>2</sub> biogenic at the end of life (Hoxha *et al.*, 2020). The second is the -1/+1 approach, and it considers both the negative uptake of CO<sub>2</sub> biogenic in module A1 (raw material supply) and the positive release of CO<sub>2</sub> in module C4 (waste disposal) of the EN 15804 and EN 15978 standards (CEN, 2011, 2019). The last approach is recommended by European standards (i.e., EN 15804 and EN 15978). The -1/+1 approach misleads results in cases where only the uptake of biogenic carbon is included in the assessment. Still, it has the advantage of increasing the transparency of the biogenic carbon flows throughout the life cycle (Andersen *et al.*, 2021). Both



approaches (0/0 and -1/+1) do not consider the time the carbon is stored in the building envelope and the time needed for the material to regrow. Guest *et al.* (2013), based on the work developed by Levasseur *et al.* (2010), proposed a dynamic carbon storage methodology to solve this issue, producing specific characterization factors. In this methodology, biogenic global warming potential (GWP) is proportional to the period of material regrowing and the years the material is kept in a building component. Guest *et al.*, analyzing the GWP factors, indicate that the current assumptions in the literature significantly overattribute biogenic CO<sub>2</sub> storage benefits, as carbon-flux dynamics have not been adequately and systematically addressed. In addition, a detailed consequential life cycle assessment, including direct and indirect land use change, is required to determine the degree to which climate change can be mitigated with bio-energy/storage systems.

The dynamic approach is mainly recommended in scientific papers because it permits an evaluation more consistently and transparently of carbon flux and the rotation period of the forest. On the contrary, using the dynamic approach outside the scientific domain might be more complicated from a computational modeling point of view. In addition, dynamizing the characterization factors could de-responsibilize manufacturers by shifting the environmental burden to future generations.

Figure 21 resumes how 0/0 and -1/+1 approaches are implemented during the entire life cycle of a productive process.

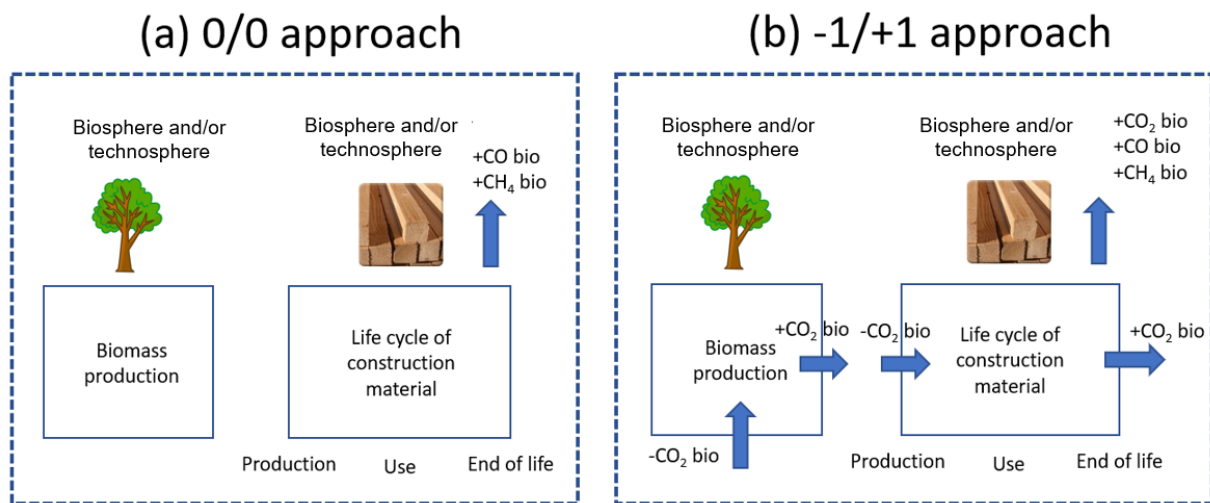


Figure 21. 0/0 and -1/+1 approach

### 6.3 Environmental Product Declaration analysis: a key factor for the Italian market

As mentioned above, to correctly assess the environmental profile of products (goods and services), the methodology called LCA, standardized in Europe by EN ISO 14040 and 14044, should be followed. LCA is the leading methodology for environmental metrics, representing a valuable tool to evaluate quantitatively, according to a comprehensive and scientifically reliable computational modeling, the eco-profile of buildings and building materials. The LCA method permits the assessment of embodied carbon and other impact categories (i.e., land use, water use, eutrophication, resource use, etc.). Once the evaluation has been conducted, the results to be communicated externally must be critically reviewed according to EN ISO 14044, and the environmental communication must follow the guidelines provided by ISOs 14020 (i.e., EN ISO 14024, EN ISO 14021, EN ISO 14025, EN ISO 14026, or EN ISO 14027).



A suite of standards was also implemented to measure the sustainability of constructions in compliance with EN ISO 14040-44. This suite included EN 15804 and EN 15978. EN 15804 is the reference standard for developing Life Cycle Assessment-based studies, reported in Environmental Product Declarations (EPD; EN ISO 14025), advising on the core rules for the product category of construction products. EN 15978 suggests calculation methodologies at the building level.

EPDs are drawn up on behalf of individual companies to issue the certificate for the products concerned. The data used for drafting purposes may be experimental or come from publication data. For this reason, comparisons between different products may yield different values.

In this section, the data published in the EPDs were analyzed for: (i) Cross-Laminated Timber, (ii) Glued Laminated Timber, and (iii) Glued Structural Timber products for the European market. In total, 27 declarations were collected from 2 schemes ([International EPD system](#) and [Institut Bauen und Umwelt](#)) and categorized by: (i) product type, (ii) supplier, (iii) Life Cycle Inventory database adapted for carrying out the LCA studies, (iv) standard adopted version +A1 (2011) or +A2 (2019) of the EN 15804. The analysis showed that most EPDs were assessed using: the [Gabi](#) library (21 out of 27) and the [ecoinvent](#) library (6 out of 27). In addition, only 6 EPDs were issued following the updated version of EN 15804 (+A2 2019).

Figure 22 summarizes the results obtained from this analysis. The results showed high variability between the values reported in the EPDs. In the case of the Global Warming Potential, for example, the resulting values for module A1-A3 (corresponding to the raw material management and manufacturing part of the product) are within a range between -750 [kgCO<sub>2</sub>eq/m<sup>3</sup>] and -380 [kgCO<sub>2</sub>eq/m<sup>3</sup>]. In particular, it is noticeable that the EPDs drawn up by companies that claim to manage their forests return more conservative values than those working with secondary data. The analysis of EPDs revealed that companies without primary data on forest management refer to a publication dating back to 2012 on data collected for the German market (Rüter, S. and Diederichs, 2012). The figure shows the three different typologies of products analyzed (i.e., Cross Laminated Timber - CLT, Glued Laminated Timber - GLT, and Glued Structural Timber - GST), the version of the EN 15804 used for the analysis (i.e., +A1 or +A2), and the data published in ecoinvent 3.8 EN 15804 (Wernet *et al.*, 2016) using the EF 3.0 method - EN 15804 version (Fazio *et al.*, 2018). The values by analyzing only modules A1-3 and adopting the -1/+1 approach are negative, highlighting the benefit associated with carbon storage. As indicated above, this benefit is eliminated (biogenic emissions equal to or higher than zero) by including in the assessment also module C4, which is related to the end-of-life phase of the product.

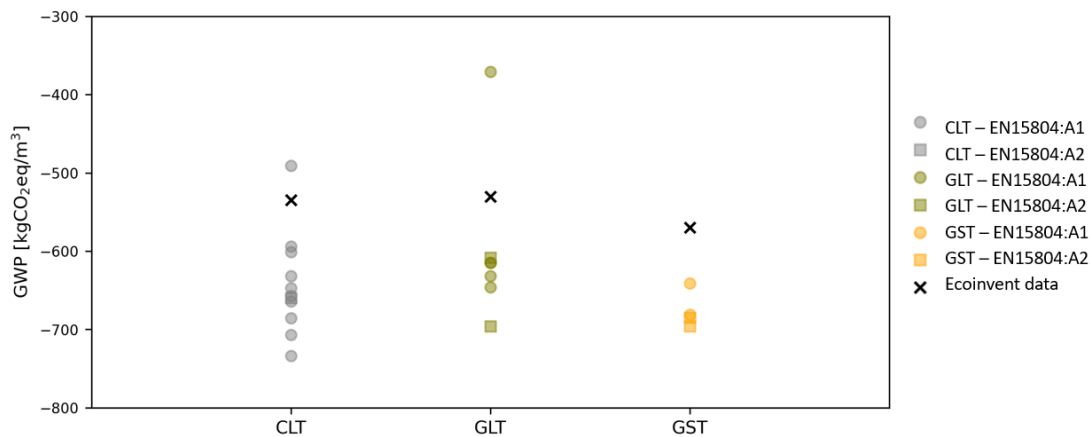


Figure 22 - Distribution of GWP value on modules A1 - A3 according to EPDs

## 7 Conclusions

Based on the existing literature, the report described the outcomes of the scientific review on sustainability aspects arising from the application of mass timber in the Italian context, covering technical, economic, financial, political, and environmental aspects. The work, developed by Politecnico di Milano (Department of Energy), is part of the “Perception of Timber – Accelerating Change at MIND” project coordinated by Climate-KIC Holding B.V. with the participation of 5 other consortia partners, i.e., Lendlease, Waught Thistelton Architects (WTA), University College of London, Arup, and Stora Enso, and co-founded by Build by Nature. The project aims to address, raise awareness and overcome negative barriers to the perception of structural timber applied to buildings. A list of potential barriers limiting the diffusion of structural timber in the Italian construction market emerged during 3 workshops organized in 2022 (25 March, 17 June, and 16 September) with the stakeholders (i.e., real estate operators, public administrations, insurance and banking institutions, academic institutions). Based on these barriers, the report was compiled by considering information from reliable existing literature, suitably reworked, and synthesized to produce a document that touches in depth on various subject topics.

The report provides an overall view of the Italian market by giving economic data (revenue, import and export, and state of the Italian forests). Policies, economic, financial, and environmental aspects are subsequently analyzed and presented as possible solutions. The outcomes obtained can be summarized as follows:

- Italy is the 4<sup>th</sup> European market in terms of sales;
- sales and companies are mainly localized in Lombardy, Veneto, and Trentino Alto-Adige;
- specialized manufacturers realize 61% of the commissioning;
- the price of raw materials is affected by high fluctuation over time;
- Italy exports semi-finite wood products and finite building products.
- Italy mainly exports wood products to other European countries, Germany and France.
- Italy imports mainly semi-finite products from European countries.
- countries with a structured and old tradition also have high-rise buildings;



- multi-story buildings were designed prevalently considering a hybrid solution (timber-concrete or timber-steel);
- Multi-story buildings were designed prevalently considering a hybrid solution (timber-concrete or timber-steel).
- Italy is 36% covered by forests, but their exploitation is not convenient
- There are different types of instruments and policies introduced in Europe to encourage the increase of mass timber buildings
- In Italy, there are certifications to guarantee the reliability of timber constructions and negotiate with credit institutions
- In recent years credit institutions developed facilitated financial products for timber constructions

It is clear from the results obtained that training related to technical knowledge and skills is crucial for market development in Italy. Although the nation turns out to be the 4<sup>th</sup> European market, the market is mainly concentrated in a small portion of the territory (Northeast). It is also noted that the market is very selective, giving more space to specialized companies that control a large part of the production chain (specialized manufacturers realize 61% of the commissioning). This barrier is also reflected in the number of stories: countries with a structured and old tradition also have high-rise buildings.

Outcomes from discussions regarding the Italian import/export situation and preliminary forest mapping show that purchasing raw materials from countries abroad is currently more convenient. It is not always possible to determine whether the origin of the purchased wood comes from certified forests, which may reduce the quality of the whole building. It would be interesting to promote initiatives to support the conscious exploitation of Italian forests, which can respect limitations and biodiversity. Actions should be announced to identify areas that can be used today or actions that can use that material without damaging the system.

In addition, outcomes from the research inherent in the policy and finance parts demonstrated the presence, both domestically and abroad, of legal initiatives or legal-financial instruments capable of boosting the wood construction market. The same result could also be achieved in Italy by trying to readapt to the context initiatives already started in other European states.

Moreover, the outcomes of this work could be further improved with an Italian supply chain project that improves the data quality collected better to define the sector's strengths, weaknesses, opportunities, and threats. The project could involve the various stakeholders involved in the supply chain: from raw material production, processing, installation, product disassembly, and end-of-life treatments, allowing for improved environmental data for LCA assessments, Life Cycle Cost Analysis, and Environmental Product Declarations (EPD). But also to optimize the production chain by proposing energy-efficient solutions in the supply chain, making the best use of national forests, limiting price fluctuation by trying to create a local supply chain as much as possible, and promoting the transfer of technical expertise with dissemination activities. Some of these proposals are already being pursued by Federlegno, as seen from the numerous reports posted on the [website](#). A synergy between universities, industry players, and trade associations could potentially produce an innovation project creating a more significant boost for the wood construction sector in Italy.



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