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ENGINEERED WOODS FOR SUSTAINABLE USE OF LOCAL RESOURCES

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Abstract

Wood is a versatile building material that has been used in construction processes for centuries. Nowadays, its natural features, such as renewability, allow it to be used as a substitute for more common materials like reinforced concrete. Furthermore, it can counteract the climate crisis due to its natural storage of CO_2. Its use as a climate-friendly building material that can improve the performance of structures and the comfort of end-users must be achieved by proper forest management. Using wood and its derived engineered products, like glulam and cross-laminated timber (CLT), could be a valid way to support the "short" forest-wood supply chain. Italy, like other countries, is improving its knowledge about the mechanical and technological characteristics of some local wood species to be used to produce glulam elements. The use of local timber types indulges in renewability, sustainability, and bio-economy, improving the life cycle of the industrial ecosystem with long-term actions. Unfortunately, the regulatory apparatus in force has not yet adequately accepted rapid technological developments. The standards must be updated to avoid the "short" forest-wood supply chain losing all the connected benefits. The paper focuses on an analysis of the most common standards in force today (with a focus on European standards) for the use of CLT in the structural field. The analysis shows the need to investigate the properties of the CLT panels further, focusing on the influence of the wooden species to favor the use of local timber.

Keywords: *Cross Laminated Timber; Wood; Sustainability; Standards; Structural Engineering*

Introduction

The construction industry has the most significant impact on the environment. It must consider different aspects, such as economic, social, and environmental sustainability, starting from the design to the end of the structure's life. In this scenario, wood is crucial in construction today as a natural and renewable material. It is appreciated for its technical, economic, and environmental advantages that favor the well-being and comfort of the end user. Until a few years ago, living comfort was synonymous with higher construction costs. Today, this is no longer the case, and comfort matters go hand in hand with energy saving [1]. Wood buildings are increasingly appreciated for reducing environmental impact and improving comfort features.

Wood, by its nature, provides good thermal and acoustic insulation, excellent olfactory perception, and easy moisture control due to its hygroscopic properties. Several studies in France [1], China, and Canada show how users perceive wood positively based on parameters such as age and gender [2]. However, the perceptions and experiences of users are not often considered when solving housing problems. This could cause the failure of bioeconomy enterprises, whose strategies depend on understanding people's expectations and experiences [3], [4]. People are

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influenced by social, cultural, economic, and psychological factors [5], more rarely by technical ones. Users base their choices mainly on aesthetics and well-being and less on environmental friendliness. Instead, the use of wood could help achieve the proposed environmental protection goals. Since wood as a building material strictly depends on people's familiarity with it [6], its use could improve its appreciation and achieve economic and social benefits and greater environmental respect.

Wood as a building material involves a whole supply chain starting from the forest. Proper forest management allows raw materials to be harvested in an environmentally friendly way. Subsequently, the harvested wood must be graded and processed to produce elements for structural use. The low environmental impact, speed of construction, light weight, and versatility of use represent a perfect solution for the proper planning of urban regeneration of cities projected into the future, whether for the construction of residential buildings, offices, schools, museums, sports facilities, recreational and exhibition spaces, or for the transformation of existing buildings, including extensions and elevations. Wood allows targeted and non-invasive interventions in the urban context, adapted to current ideas, needs, and possibilities, combining structure and architecture. The use of timber in construction is indeed related not only to the creation of new structures but also to the enhancement of the built environment, and recently, more wood-based systems are being used for integrated structural and energy retrofitting of existing buildings [7].

Moreover, in the current climate crisis, there is an urgent need to implement structurally safe and environmentally sustainable measures by following sustainability policies and achieving energy savings through good thermal insulation of the building envelope. In this perspective, wood is the ideal material, as it can combine good structural and energy characteristics. Wood-based structural systems can be used to realize framed structures, endoskeletons, and exoskeletons or to improve masonry walls' local in-plane and out-of-plane behavior using mortars reinforced with wood-based fibers or wood-based panels. The latter can also be used as external curtain walls for frame structures, possibly integrated with insulating layers, which improve the already high thermal inertia of wood, thus creating a "package" able to improve the internal thermo-hygrometric comfort of buildings with high energy savings.

Further consideration should be given to the wooden structures of monumental buildings [8], [9], [10], where both floors and roofs were made in past centuries with wooden structures of great value—natural, architectural, and artistic. These are perfectly preserved, but in some cases, and mainly due to calamitous events such as earthquakes and floods, they have suffered damage that requires careful analysis of residual capacities and consolidation interventions in line with the conservation requirements of cultural heritage bound [11]-[18]. In the southern regions of Italy, wooden structures were generally made of chestnut wood using traditional techniques, and they are suitable for preserving their aesthetic, functional, and material aspects. In this context, methods to safeguard horizontal wooden floors and improve the strength and deformability of structural elements must be available [7], [10], [19]. Similarly, the restoration of roof structures [11], [12], which are often made of chestnut trusses, must be carried out, for which modern techniques can be used both for advanced calculation and for the realization of special pieces and wood-wood connections [11], [12] through numerically controlled cutting machines.

The procedural process of this chain has several regulatory limitations depending on the country in which it takes place. The following sections briefly compare some goals achieved in the processes involved.

Problem statement

The overarching goal of this study is to explore the possibility of making CLT panels with local wood. To produce CLT panels, the raw material must be certified (for example, CE marking in Europe), and the correct forest management is the first condition for certifying wood (as raw material), which is almost absent in Italy. In the event of proper forest management, CLT panels must also be certified to make them available on the market.

The standards in force are not fully exhaustive regarding the certification test procedures on CLT panels because they refer to glued laminated wood (GLULAM). The last mentioned is engineered wood compacted by in-glued lamellae with fibers oriented in a single direction. At the same time, the CLT panels are made of glued layers that are differently oriented. The single layer of the CLT has the fibers oriented in a single direction, but the layers of the panel are arranged so that the fibers between the two layers are rotated by 90°.

This paper aims to highlight the regulatory gaps in the production chain of engineered wood and the results achievable by using local woods.

Through the analysis of the wood supply chain, the research of the standards in force, the procedures for CE marking, and the deficiencies and needs for the production and marketing of CLT using local essences are highlighted.

Overcoming the identified limits would allow for the encouragement of the short wood supply chain, which could have positive effects on the local economy.

The paper is divided into sections that deal with two main topics as follows:

a) the supply chain and the related regulations in force (Section 3)

b) the regulatory framework concerning the use of CLT for structural purposes (Section 4).

In conclusion, section 5 presents the findings of the analyses and their conclusions.

Wood supply chain

Forests cover about 30% of our planet. Tree species are enormously different due to their diverse geographic locations within the same area. Fig. 1 shows some trees with their leaves.

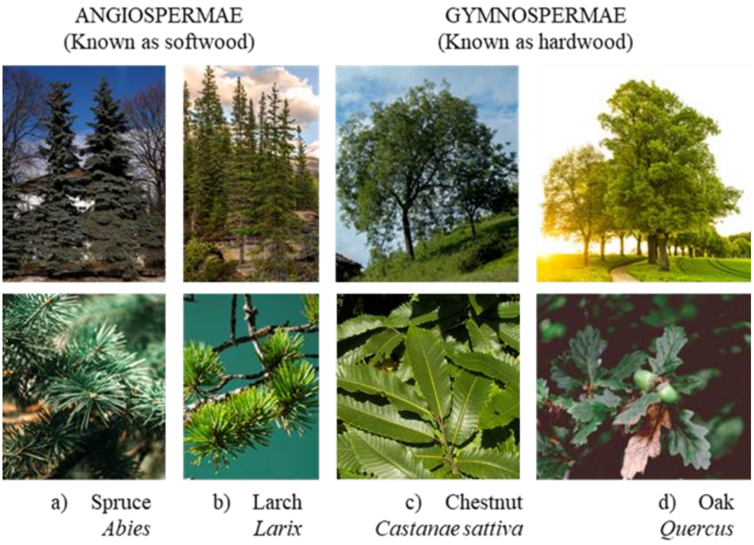

Fig. 1. Examples of *ANGIOSPERMAE*: a) spruce, b) larch; *GYMNOSPERMAE*: c) chestnut, d) oak

In the past, skilled carpenters selected and classified wood based on their common sense, knowledge, and experience. Since mechanical properties have a wide dispersion of values, a regulatory classification is mandatory to ensure consistent structural behavior and a reliable understanding and design of structural elements. Today, this is only achievable through enlightened forest management.

Forest management activities and regulations started at different times and in various ways from nation to nation, and there are still countries where they have not yet begun [20]. The regulatory framework is fragmented (Appendix A, Table 1A). The Consolidated Law for Forests and Forest Supply Chains (TUFF) was published only in Italy in 2018.

Wood production involves many companies. In all its parts, this supply chain addresses environmental sustainability problems and puts into practice the basic principles of the circular bio-economy [21]. To date, wood is an engine of the world economy. The transition to sustainability and digitalization (Green Deal) passes through sustainable public and private investments in infrastructure and sustainable construction. More and more subjects are operating in the so-called impact finance or investments from which economic returns and environmental and social improvements are expected. The E.U. Climate Change Commission clarifies [22] that timber construction solutions can mitigate the global warming problem. This study is based on LCA (Life Cycle Assessment) data and the EPD (Environmental Product Declaration) of products used in building construction. Then, the rise of wood in the construction sector represents a significant opportunity to reduce greenhouse gas emissions. It should be noted that a substantial part of this reduction is in the amount of carbon stored. In Italy, the federation of wood industries, Federlegno®, has made an estimate (Table 1) of carbon stored in a wooden house, assuming the use of coniferous wood (spruce) installed with the currently most widespread building systems (CLT panels).

Table 1. The amount of CO_2 stored in constructions using Federlegno-Arredo methodology: Legno Clima® [23]

Floor area	Amount of wood used	CO_2 stored
100 m^2	9 - 13 m^3	9.2 tons CO_2eq.
150 m^2	13 - 16 m^3	11.3 tons CO_2eq.
200 m^2	16 - 21 m^3	14.9 tons CO_2eq.
250 m^2	21 - 25 m^3	17.7 tons CO_2eq.

Wood and the management of CO_2 emissions

Forests are a reliable resource for meeting the need to limit greenhouse gas emissions. The Kyoto Protocol [24] requires most industrialized countries to limit greenhouse gas emissions, considering the contribution of their carbon forest sink. In detail, a carbon sink is a net absorption balance of CO_2 by ecosystems. Human afforestation, deforestation, and forest or agricultural management affect carbon stock levels, while forest management and wood use promote the reduction of CO_2 emissions. Plant ecosystems play a key role in the carbon cycle. They act as reservoirs and storage, regulating atmospheric and biosphere fluxes and indicating climate change. In this framework, the CO_2 stored by vegetation plays a fundamental role. It is estimated that numerous indices were chosen according to the available data and the type of analysis to be conducted.

Among these, the main parameter used in literature is the total biomass. This includes (Fig. 2) both above-ground biomass (AGB) [25] and below-ground biomass (e.g., live roots, fine and coarse dead litter associated with the soil). Because of the difficulty of collecting remotely sensed data on underground biomass, the focus is on AGB [26]. This is defined as the above-ground dry mass of living or dead tree or shrub (woody) matter, expressed as mass per unit area [27]. The AGB calculation allows for determining the amount of carbon sequestered by vegetation since dry biomass comprises about 47.5% of carbon [28].

The estimation of AGB can be performed basically through three methods: the direct or physical method, the semi-empirical indirect method (allometric equations), and the indirect method (remote sensing). These operations are known as precision forestry.

The need to enhance the value of a product, trace its origins, and certify its characteristics remains central to the wood economy through the possibility of transforming greenhouse gas (GHG) emission reduction into tradable carbon credits. A carbon credit represents an emission reduction of one ton of CO_2 or an equivalent amount of other greenhouse gases that can be traded on the market (for this reason, the unit of measurement of credits is called CO_2e). The buyer of credits can purchase them to offset some or all of their greenhouse gas emissions. The presence of a market in which carbon credits are traded among operators even far apart makes it possible to reward the most efficient solution for reducing the greenhouse gases in the atmosphere, which is often linked to investments in developing countries (for example, it costs less to make a power plant more efficient or to plant a forest in a developing country than in Europe). However, the possibility of buying credits even at low prices can lead operators to escape from the responsibility concerning the activities they directly conduct (in other words, by buying credits, one buys a kind of "right to pollute"). Nonetheless, land use, forestry change, and conservation of existing forest carbon stocks have the most significant potential (Fig. 3) for rapid climate change mitigation.

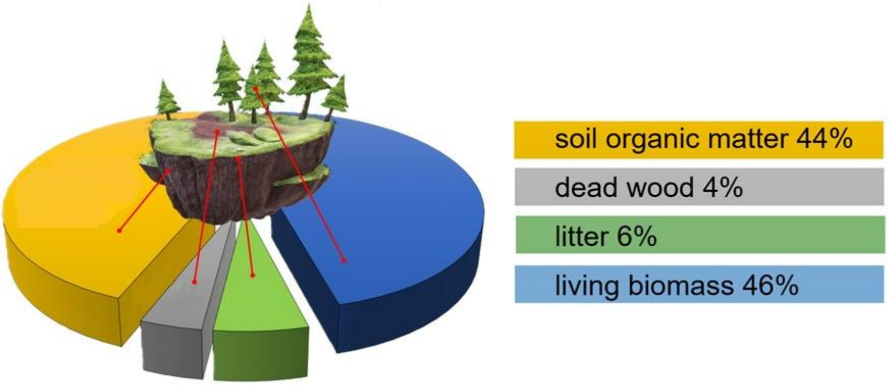

Fig. 2. A typical carbon sink (Italian forest) [%]

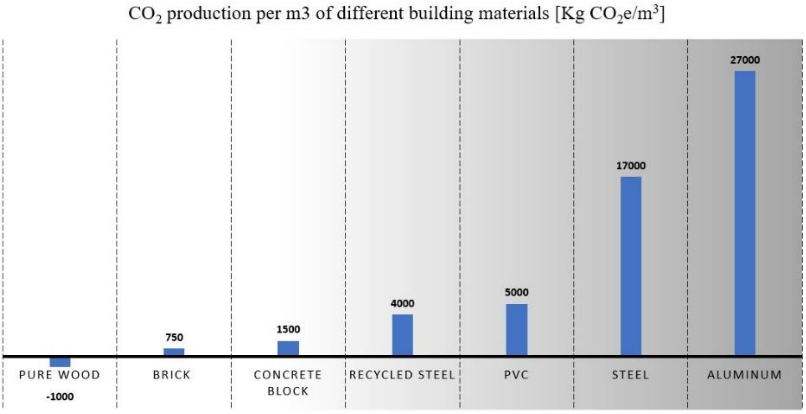

Fig. 3. Comparison of CO_2 production per m^3 of different building materials, where the carbon storage effect in the material is also included. Source: CEI-Bois (European Confederation of Woodworking Industries), 2011

The Kyoto Agreement [24] provides two systems for managing these credits:

Emission Trading System, ETS, or the so-called "cap and trade." A cap on emissions is established, and those who enter the agreement, if they exceed it, can buy (trade) the credits of those who emit less. In this way, one does not necessarily have to reduce one's emissions but can compensate for them by purchasing those of others.

Clean Development Mechanism, CDM. Under this system, CO_2 emitters can offset emissions by financing projects that reduce them in developing countries.

The first system, the ETS, is expected to trigger a "cost-effective" circle in that the price of carbon credits would tend to increase over time, thus incentivizing low-carbon production.

This scenario pushes countries to enhance and use internal resources. In Italy, currently available data establish that the Italian forest volume tends to grow (Fig. 2). At the same time, the annual harvest is lower than the growth rate. Table 2 compares the situation of Italy and the European Union average.

Table 2. Comparison between Italian Forest and European Union average [29]

	Italy [%]	**E.U. average [%]**
Forest cover	38,3	35,0
Annual growth of forest area 1990-2020	0,80	0,30
The ratio of the harvest to annual growth.	32,0	75,0
Area covered by forestry management	18,0	70,0

This implies that Italy would not need to import wood for industry from abroad. The import is forced for lack of certified wood as required by the law in force. Therefore, despite the presence of essential certification systems in Italy, such as the Forest Stewardship Council (FSC®) and Program for the Recognition of National Forest Certification Schemes (PEFC®), Italian woods are not certified, thus requiring the import of certified timber for structural use. The lack of certification is not due to the poor quality of the wood or the defects it presents. Hence, it is necessary to be able to unify the rules at the national level to enhance a resource that is strongly present in the territory.

The Italian Forest management

The Italian Forests cover about 11 million hectares and are the custodians of the environmental heritage regarding biological, ecosystem, and cultural diversity. Moreover, they can play a key role in suppressing global climate change, and their management becomes a challenge to contribute concretely to solving the current climate crisis. Today, wood and forest are usually equated, although there is a clear distinction between them. An Italian Forest occupies an area of at least 2.000 m² and is usually maintained or controlled by humans. A forest, instead, is an uncultivated and wild land (Fig. 4a) with much larger dimensions of at least 10.000 m².

The regulatory framework "Consolidated text on forests and forest chains" strongly constrained and protected forest-related activities. This framework established the areas that "do not fall within the definition of forest: the formations of artificial origin carried out on agricultural land also as a result of adherence to agri-food measures or as part of the interventions provided for by the common agricultural policy of the EU." In a few words, new forest plantings are disconnected from the forest discipline and, therefore, from a series of strongly limiting constraints. From this highly economic perspective, the entire wood supply chain takes on value, starting from regulated management (Fig. 4b) and continuing to produce semi-finished products necessary for the construction or upgrading of buildings. This process complements the strong revaluation of the use of solid and engineered wood (e.g., CLT) in construction.

Fig. 4. Example of a managed forest

In this way, forest management regains its centrality and implementation in forest planning. Furthermore, it ensures public interest and mandates the establishment of a National Forest Strategy to enhance the stakeholders involved in wood and non-wood products.

The short forest-wood supply chain

The use of local wood could be a flywheel for the bioeconomy. Regulatory limitations do not stop the use of sustainable materials for local reinforcement and improving the overall response of existing structures. This requirement is also part of the 2030 Agenda goals: There is a need to improve the structure's sustainability, making it more resource-efficient and improving the use of green technologies. Using CLT panels can drive the revival of the forest-wood supply chain. Italy is also moving in this direction. The reinvigoration of the "short" forest-wood chain would ensure the adoption of clean and environmentally friendly technologies. Forest life is encouraged by the management of local forests and, thus, the controlled felling of shrubs. The cut wood can be used to produce CLT and more. Production waste, in turn, can produce heat (pellets and firewood).

It should be noted that wood products, CLT, and others would continue to store CO_2, and only at the end of their useful life, having disposed of heat production, would go on to release it. In this way, more live shrubs serve as storage for CO_2, and storage would also be present in new or reinforced structures. The amount of CO_2 stored must be added to the share saved by choosing wood rather than another building material such as steel or concrete. One must then add all the percentages of emissions that are held with the considerable reduction in transport required to supply the raw material when it is not in the production territory. In addition, the use of local woods would provide excellent value to Mediterranean forests.

CE marking of wooden products

The main objective of the short forest-wood supply chain is to enhance local essences. Therefore, wood products must have specifically certified characteristics to be used and put on the market. For example, the CE marking of construction products is not a product certification. Accreditation rules refer to ISO/IEC 17065, a mandatory certification under the European Construction Products Regulation (CPR) EU 305/2011.

Further certifications are provided for wood. Specifically, the FSC® (Forest Stewardship Council) Certification provides two types of certificates:

The Forest Management certification: it is issued to forest managers and owners whose management practices meet the requirements of the FSC® Principles and Criteria.

Chain of Custody certification: a traceability system that allows the manufacturer/dealer to prove the origin of the material throughout the supply chain. All supply chain components (forests, sawmills, wholesalers, processing centers, etc.) up to the shopkeeper must be certified to keep the chain of custody intact. This certification scheme is internationally recognized.

The PEFC® Certification (Program for Endorsement of Forest Certification) is instead voluntary. It certifies the sustainable management of a forest and is similar to a chain of custody. However, unlike the FSC, it has national accreditation.

The certifications mentioned above are increasingly required to ensure compliance with Minimum Environmental Criteria (CAM), even if, in this scenario, there are no harmonized standards for engineered wood, such as cross-laminated timber (CLT panels).

Regulatory framework for structural use of engineered wood

As shown in the previous sections, the use of wood and its derived engineered products could be a valid way to support the "short" forest-wood supply chain. Using local timber types improves the life cycle of the industrial ecosystem with long-term actions. Unfortunately, the regulatory framework in force has not yet adequately accepted rapid technological developments.

The standards must be updated to avoid the “short” forest-wood supply chain losing all the connected benefits.

The engineered wood

Engineered wood was created to overcome some of the natural defects of the raw material. The term "defect" indicates an anomaly or irregularity in the material that could limit its specific use. In the case of structural wood, defects mean all anomalies that cause a loss of mechanical performance; the most common defects are knots, deviated grains, and shrinkage slots.

The knot (Fig. 5a) is the connection between the branch and trunk that remains joined to the stem during the growth of the tree. It is an unavoidable defect: trees cannot exist without knots, but their presence causes localized weakening of the structural element. Conifers are rich in small-diameter knots, unlike deciduous trees, which present fewer but large-diameter knots.

Fig. 5. Example of node (a); shrinkage slot (b)

Wood grain shows the course of the fibers concerning the geometric axis. When the grain is straight and parallel to the geometric axis, the structural element has the maximum allowable mechanical performance. When the grain deviates, the performance decreases as the grain inclination increases.

Shrinkage cracks (Fig. 5b) are a completely physiological defect that occurs when the felled tree releases the internal water unevenly. Furthermore, shrinkage gives the wood a list of features such as more excellent dimensional stability, less buckling, lower density, greater thermal insulation power, reduced vulnerability to mold attack, and greater mechanical strength. It starts with tree cutting, mainly done during the vegetative break in winter. Then, the tree is pruned, and the logs are left intact or sawn depending on subsequent uses. After cutting, the logs are put out to dry. Water stagnation on the trunks should be limited by avoiding contact with the soil and promoting good air circulation to prevent the attack of fungal species.

Engineered wood generally consists of wood slats arranged in glued or nailed layers [30], [31], [32], [33], [34], [35]. These engineered woods allow for better performance than can be achieved with solid wood, and engineered wood is a viable alternative to more common structural materials [35], [36]. It is, therefore, possible to build tall and medium-sized buildings and improve the response of existing structures. Since it is not possible to build new structures in densely populated urban areas today, intervening on existing buildings [9] can be a viable alternative to improve the seismic safety of the existing heritage [37], [38], [39], bringing it in line with current regulations while also improving the energy impact [40]

An example of engineered wood is cross-laminated timber (CLT).

Cross-Laminated Timber

CLT is a building material developed and used in Europe and valued in several countries, such as Canada, Japan, America, and New Zealand [41], [42]. As a result, it has become one of the world’s most widely used building materials [43]. CLT panels consist of orthogonally glued layers of wood, always in odd numbers, symmetrical concerning the middle layer (Figure 6a).

Sizes can vary from 50 to 500 mm thick and depend on the application. Width and length are adjustable up to a maximum of 20 meters. Its success is due to the ability to use durable materials to build large buildings and reinforce existing structures [8], [44]. Moreover, CLT panels, made to the prescribed dimensions (Fig. 6b), can be laid on-site in a few days.

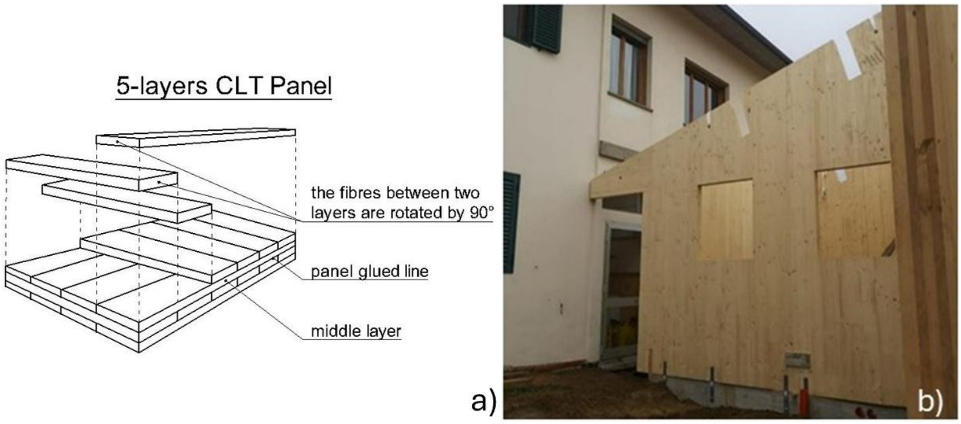

Fig. 6. CLT panel: a) scheme of 5-layer CLT panels, b) installation example

Unfortunately, regulatory compliance has not followed [45] research activity and rapid technological and construction progress. The potential targets achievable with CLT in preserving existing structures have amplified the need to overcome these limitations. In fact, in the absence of a specific technical law, CLT is assimilated to glued laminated timber, another engineered wood, which, having the grain of the layers in the same direction, requires different calculation methods.

Analysis of technical standards

The use of CLT is closely related to regulatory aspects ranging from product certification to technical design standards. In the following, the main national and international standards for the use of CLT panels are analyzed. In Europe, certification of wood products is applied according to harmonized standards (Appendix B, Table 1B).

In the international context, the rapid technological and construction progress of the CLT has not been followed by regulatory adaptation (Appendix B, Table 2B).

Appendix B summarizes the current regulatory situation. The rules and guidelines are exhaustive for laminated wood (GLULAM) in terms of material tests, information on sampling, bending tests, shear tests, and guidelines, but not for cross-laminated timber (CLT). There is a wrong tendency to assimilate CLT into glulam. For example, there are still no rules regarding glues indicating how to carry out laboratory tests when the fibers of the various layers are not parallel.

When CLT is used, it is “assimilated” to glulam, although several authors have shown that the gap between the expected and experimental results is significant, to the detriment of safety.

To determine the behavior of the bonding surfaces of CLT panels, in the absence of specific technical regulations, some authors carried out several tests according to the standard UNI EN 392:1997 [46] (Fig. 2b). Since this standard was developed for laminated wood, no indication about the orientation of the fibers with respect to the application of the load is provided. This aspect greatly affects the panel resistance. Several studies have demonstrated indeed that it is evident how the orientation of the individual layers takes on considerable importance in terms of both resistance and “quality” of breakage.

Apparently, the situation is different in America. Yeh formally describes the development of the ANSI/APA PRG 320 [47]. This standard was born as an agreement protocol to encourage economic exchanges between the Canadian and the American markets. It indicates the procedure to be followed for the accreditation of CLT panels. But, although it refers to the CLT, it actually recalls the indications for glued laminated timber.

As shown in Table 3, regardless of the geographical area of use, the CLT brings regulatory limitations that are basically referred to as glued laminated timber (GLT).

Table 3. A quick comparison between the regulations in force on GLT (glulam) and CLT [48].

	Italy		**Germany**		**USA**		**Canada**		**New Zealand**		**Japan**	
	GLT	CLT	GLT	CLT	GLT	CLT	GLT	CLT	GLT	CLT	GLT	CLT
Material Test	✓	-	✓	✓	✓	✓	✓	✓	✓	-	✓	✓
Information on sampling	✓	-	✓	✓	✓	-	✓	-	✓	-	✓	-
Bending test	✓	-	✓	✓	✓	-	✓	-	✓	-	✓	-
Shear test	✓	-	✓	✓	✓	-	✓	-	✓	-	✓	-
Glue	✓	-	✓	✓	✓	-	✓	-	✓	-	✓	-
Guidelines	✓	-	✓	-	✓	-	✓	-	✓	-	✓	-

To better understand how the regulatory procedures in force allow determining this information, the authors performed two types of laboratory tests on spruce CLT panels (already available on the market and commonly used in building construction) to determine the in-plane (slipping test) and out-of-plane (bending test) mechanical behavior [46].

The bending test shows that the experimental displacement values are much higher than the theoretical ones. In contrast, the slipping test shows the influence of each layer's orientation on strength and breakage mechanism. The results of laboratory tests underscore the need for further study of the mechanical behavior of these panels.

Discussion

Wood elements used for structural purposes must be certified according to regulations in force (such as CE marking), which impose performance requirements starting from the forest where the raw material is taken (forest management).

The challenge is to encourage the development of the forest-wood chain to enhance the local wood resources and the territory. Consequently, using local species for structural purposes, in terms of solid and engineered wood production, could positively impact many fields.

Currently, in many geographical areas, such as Southern Italy, the wood supply chain has not yet been implemented in compliance with current regulations. Forestry is not aimed at using wood in the structural and civil engineering field; unfortunately, the wood harvested is mainly used for energy production. Too many forest companies in these areas continue to adopt management based on maximizing cuts, preferring wood volume over production quality. This contradicts the high standards required for CE marking of timber-based structural elements.

This approach makes using local resources to produce marketable solid and engineered wood impossible. However, the analysis of technical standards highlights the lack of specific guidelines to properly determine the mechanical properties of CLT panels, also obtained using local wood species.

This could be achieved by networking the already existing competencies in this area. The research institutions and the companies in the field (forestry, sawmills, further processing firms, and specialist construction companies) could boost a wide-ranging experimental campaign on "new local products" that could drive a regulatory update and a more and more sustainable wood-based structural element production.

Conclusions

Wood plays a crucial role in the global economy. The European Commission on Climate Change believes wood-building solutions can reduce global warming. The rise of using wood as a building material represents a significant opportunity to reduce CO_2 emissions and facilitate the "short" wood supply chain.

The use of local wood and engineered wood made up of local wood to build new constructions and restore existing ones would promote the "short" wood supply chain, also achieving some of the goals set by Agenda 2030, such as (i) promoting sustainable development, consumption, and production; (ii) improving life on earth; and (iii) encouraging the development of environmentally friendly technologies and sustainable industrialization.

There is a need to create maximum synergy between producers and the first processing and construction companies that intend to work in the construction field using local wood with significant savings in supplying raw material transport and CO_2 emissions.

Acknowledgments

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APPENDIX A

Table 1A. Main international standards for forest management

Year	Standard	
2019	The European Green Deal, which aims to achieve carbon neutrality in Europe by 2050, assumes particular importance for the forestry sector, the strategic and programmatic guidelines set out in the UN Strategic Forest Plan for 2017- 2030 and the 2030 Agenda for Sustainable Development.	European Union
2017	UN Forest Strategy Plan for 2017-2030, adopted by the United Nations Forest Forum (UNFF), with a global framework to ensure sustainable management and stop deforestation and forest degradation. The plan identifies 6 Global Goals and 26 Associated, voluntary, and universal Goals to be achieved by 2030.	United Nations
2015	Agenda 2030 for Sustainable Development, which defined the new strategic framework of the United Nations, identifies 17 global goals of a universal nature (Sustainable Development Goals - SDGs) and 169 targets. The main objectives of interest for the national forestry sector, which define relevant targets for forest management recognizing the close link between human welfare and the health of natural systems, are life on earth (O.15), Health and well-being (O.3), Water (O.6), Energy (O.7), Work and economic growth (O.8), Responsible production and consumption (O.12) and Climate (O.13).	United Nations
1994	The Convention on Combating Desertification (UNCCD) of 17 June 1994, ratified by Law No. 170/1997, recognizes a major role for forestry measures as a means of combating desertification.	United Nations
1992	The United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, with the Principles on Forests, gave substance to the concept of Global Forestry Services (GFS), defining its three main dimensions: ecological (conservation of forest resources), social (positive social impacts), and economic (efficient organization of the supply of forest products or services).	United Nations
1992	The Convention on Biodiversity (CBD), signed in Rio de Janeiro on 5 June 1992, was ratified by Italy through Law n. 124/1994, which, with its Protocols and the Strategic Plan for Biodiversity 2011-2020 and the 20 Targets of AICHI, committed countries to “take effective and urgent action to stop the loss of biodiversity”.	United Nations
1992	The Convention on Climate Change (UNFCCC), adopted in New York on 9 May 1992, ratified by Italy with Law n. 65/1994; implemented by the Kyoto Protocol (1997), ratified by Italy with Law n. 120/2002, and the Paris Agreement (2015), ratified by Italy with Law 204/2016, recognizes a significant role for forests in climate change mitigation and adaptation policies because of their ability to fix and store carbon in wood products and soils, for renewable and alternative energy production to fossil fuels and carbon storage in wood products.	United Nations
1991	The Alpine Convention and the Mountain Forests Protocol, since 1991, have been committed to promoting sustainable development and ensuring a standard policy for the Alps, with an international agreement signed between the Alpine countries and the European Union.	European Union
1990	Pan-European Process of Ministerial Conferences for the Protection of Forests in Europe (MCPFE, now Forest Europe) was launched in 1990 to promote protection and GFS throughout Europe, with ministerial conferences of Strasbourg (1990), Helsinki (1993), Lisbon (1998), Vienna (2003), Varsovian (2007), Oslo (2011), Madrid (2015), and the recent Convention of Bratislava (2021) which have led and will lead to the definition and signing of Declarations and Resolutions, partly transposed by national legislations. The decisions of Forest Europe commit to the use of a set of pan-European criteria and indicators for the monitoring of forestry policies, with a focus on how to promote GFS: adaptation to climate change and role of forest mitigation, supply of timber and other spontaneous forest products, conservation of biological and cultural diversity, mitigation of hydrogeological risk and regulation of the water cycle.	European Union
1973	The Convention on International Trade in Endangered Species, Flora and Fauna (CITES) was signed in Washington on 3 March 1973 and ratified by Law No. 874/1975.	United Nations

APPENDIX B

Table 1B. Harmonized standard for CE marking

Year	References
2015	EN 13986:2004+A1:2015 – Wood-based panels for construction
2014	EN 15497:2014 – Structural solid wood with finger joints
2013	EN 14080:2013 – Wooden structures - Glulam glued
2010	EN 14229:2010 – Structural wood - Wooden poles for overhead lines
2005	EN 14081-1:2005+A1:2011 – Wooden structures - Solid structural wood of rectangular section
2004	EN 14374:2004 - Wooden structures - LVL laminated structural wood

Table 2B. Main international references for Cross Laminated Timber (CLT)

Year	Standards	
Structure		
2019	Circular January 21, 2019 n.7 “Instructions for the application of the «Update of the “Technical standards for construction”» referred to in the Ministerial Decree of 17 January 2018	Italian Standards
2018	Norme tecniche per le costruzioni (NTC 2018). D. Min. Infrastrutture e Trasporti 17 gennaio 2018 (Technical standards for construction (NTC 2018))	Italian Standards
2012	ETAG 007 - Guideline for European technical approval of timber building kitS	European Normalization
2008	Assessment and reduction of seismic risk of cultural heritage with reference to the Technical Standards for constructions referred to in D.M. 14/01/2008.	Italian Standards
2007	CNR-DT 206/2007 Istruzioni per la Progettazione, l’Esecuzione ed il Controllo delle Strutture di Legno (Instructions for Design, Execution and Control of Wooden Structures)	Italian Standards
1995	EN 1995-1-1:2014 - Design of wooden structures - Part 1-1: General regulations - Common regulations and regulations for buildings	European Normalization
Materials		
2021	UNI EN 16351:2021 Timber structures - Cross laminated timber - Requirements	European Normalization
2019	ISO 16696-1:2019 Timber structures -- Cross laminated timber Component performance, production requirements and certification scheme	International Organization for Standardization
2016	EN 14081-1:2016 Wooden structures - Structural wood with rectangular cross-section classified according to strength - Part 1: General requirements	European Normalization
2016	EN 338:2016 - Structural wood - Resistance classes	European Normalization
2016	EN 14358:2016 - Wooden structures - Calculation and verification of characteristic values	European Normalization
2013	EN 14080:2013 - Wooden structures - Glued lamellar wood and glued solid wood – Requirements	European Normalization
2013	EN 14081-2:2013 Wooden structures - Structural wood with rectangular cross-section classified according to strength - Part 2: Machine classification - Additional requirements for initial type tests	European Normalization
2012	EN 14081-3:2012 - Structural wood with rectangular cross-section classified according to strength - Part 3: Machine classification; additional requirements for factory production control	European Normalization
2011	EN 13353:2011 - Solid wood panels (SWP) – Requirements	European Normalization
2008	ISO 16572:2008 Timber structures -- Wood-based panels -- Test methods for structural properties	International Organisation for Standardisation
2001	EN 12775:2001 - Solid wood panels - Classification and terminology	European Normalization
Laboratory Tests		
2017	ISO 8375:2017 Timber structures -- Glued laminated timber -- Test methods for determination of physical and mechanical properties.	International Organization for Standardization
2016	EN 384:2016 - Structural wood - Determination of characteristic values of mechanical properties and density	European Normalization

2015	EN 16351:2015 - Wooden structures - Cross board – Requirements	European Normalization
2012	EN 408:2012 - Structural wood and glued lamellar wood - Determination of certain physical and mechanical properties.	European Normalization
2008	EN 13354:2008 - Solid wood panels (SWP) - Bonding quality - Test method	European Normalization
2008	Guidelines for the certification of technical suitability for the use of innovative wood materials and products for structural use.	Italian Standards
2004	EN 314-1:2004 - Plywood Panels - Gluing Quality - Part 1: Test Methods.	European Normalization
1997	EN 313-1:1997 - Plywood panels. Classification and terminology. Classification.	European Normalization
1997	EN 392:1997 - Glued laminated wood. Resistance to shear test of glueing surfaces.	European Normalization