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TOFOLA

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Table of Contents

Executive summary 1
PART 1. Analysis of Timber Supply Basins for Traditional Wooden Boat Construction 2
1. Technical and Structural Characteristics of Nautical Timber 3
1.1 Wood structure and properties 3
1.2 Mechanical properties of wood 4
1.3 Exotic woods commonly employed in boatbuilding 6
1.3.1 Hardwoods 6
1.3.2 Softwoods 8
1.4 Wooden boatbuilding technologies 9
1.4.1 Clinker and carvel planking technology 9
1.4.2 Cold-moulding and strip-planking technology 12
1.4.3 Traditional construction techniques related to Venice Lagoon Gondola boats 14
2. Mapping of Local Forest Species 16
2.1 Veneto Region 16
2.1.1 Basic data regarding Veneto forest areas 16
2.1.2 Veneto local species used for nautical applications 19
2.1.3 State-owned forests and the importance of Cansiglio, Somadida and Cajada forests 20
2.2 Friuli Venezia Giulia Region 24
2.2.1 Local species in Friuli Venezia Giulia forests 24
2.2.2 Friuli Venezia Giulia local wood species used for nautical applications 25
2.3 Croatia 28
2.3.1 Local species in Croatian forests 28
2.3.2 Croatian local wood species used for nautical applications 31
3. Raw Market Analysis 32
3.1 Key aspects and threats for the implementation of a wood supply chain based on local species 32
3.1.1 Key aspects of a local short supply chain 32
3.1.2 Main issues threatening the development of a local short supply chain 32

3.1.3 Examples of local short supply chains: Italian and Veneto chains 34
3.2 Timber market analysis 39
3.2.1 Availability of wood from local forests 39
3.2.2 Pricing of wood from local forests 43
4. Production Needs and Sustainability Considerations 49
4.1 Production Needs 49
4.1.1 Primary timber types used in boatbuilding 49
4.1.2 Economic sustainability considerations 50
4.1.3 Technical considerations 51
4.2 Sustainability Considerations 52
PART 2. Sustainability of the Timber Supply Chain in the Nautical Sector 58
1. Analysis of Timber Supply Chain for Nautical Use 58
2. Mapping of Nautical Sector Entrprises 62
3. Mapping of Schools and Training Institutes 72
3.3.1 Active courses 72
3.3.2 Past courses 73
Bibliography 76
List of figures 78
List of Tables 79

Executive summary

This report explores the supply basins for timber used in the reconstruction and construction of traditional wooden boats, with a dual focus on historical practices and contemporary needs within the nautical sector. The study is structured into two main parts: the identification of suitable timber supply sources and an analysis of sustainability within the wood supply chain in collaboration with the nautical sector.

The first part of the report aims to identify the most suitable supply basins for timber intended for traditional wooden boat construction. This is achieved through the following key analyses:

- Technical and Structural Characteristics of Nautical Timber;
- Mapping of Local Forest Species;
- Raw Material Market Analysis;
- Production Needs and Sustainability Considerations.

The second part of the report focuses on the sustainability of the timber supply chain for the nautical industry, emphasizing local supply chains and collaboration with key industry stakeholders. The main points of analysis include:

- Analysis of Timber Supply Chains for Nautical Use;
- Mapping of Nautical Sector Enterprises;
- Mapping of Schools and Training Institutes.

The present Deliverable aims at providing a comprehensive assessment of the timber supply basins and sustainability challenges related to traditional wooden boatbuilding. By integrating historical knowledge with contemporary market analysis, the report offers insights into ensuring a sustainable and efficient supply of high-quality timber. Furthermore, it highlights opportunities for collaboration between forestry management, boatbuilding enterprises, and educational institutions to support the preservation of traditional craftsmanship while meeting modern sustainability standards.

PART 1. Analysis of Timber Supply Basins for Traditional Wooden Boat Construction

Wood is one of the oldest materials ever utilized by humans. For millennia, it has served as both a construction and decorative material in civil and marine applications. Its widespread historical use highlights its distinctive qualities. A significant advantage is its availability in numerous species, sizes, shapes, and conditions, making it suitable for nearly any requirement. Wood boasts a high strength-to-weight ratio and exceptional long-term performance. Additionally, its natural beauty and aesthetic appeal play a crucial role.

In boatbuilding, wood was the first material ever used and remains essential today, ranking as the second most-used material after fiberglass (Figure 1). While modern shipyards rarely construct new wooden vessels, a few specialized yards continue working with wood to meet the demands of owners who appreciate the refined craftsmanship of wooden boats. The durability of wooden boats stems from both their aesthetic appeal and the remarkable mechanical properties of the material. Another advantage is the ability to modernize, refit, and restore these vessels over time.

In recent decades, wood has regained attention due to the growing need for more sustainable materials in industrial applications and increased public awareness of its environmental benefits compared to other materials. In this context, wood offers valuable characteristics, including low embodied energy, minimal carbon impact, and sustainability.

Wood requires little energy-intensive processing and has a lower embodied energy compared to many other materials, such as steel, concrete, aluminum, or plastic. Regarding carbon impact, forests and green vegetation play a crucial role in the carbon cycle by removing carbon dioxide from the atmosphere through photosynthesis, leading to significant carbon sequestration. Lastly, wood is a renewable resource: with responsible forestry and harvesting practices that ensure the long-term health and diversity of forests, a continuous supply of wood products can be maintained indefinitely.

In the following sections, the main properties of wood, as well as the characteristics of commercially important species, will be presented as provided in [1] and re-elaborated in [2]. Then, the application of wood as boatbuilding material and the technologies commonly used in this sector will be explained.

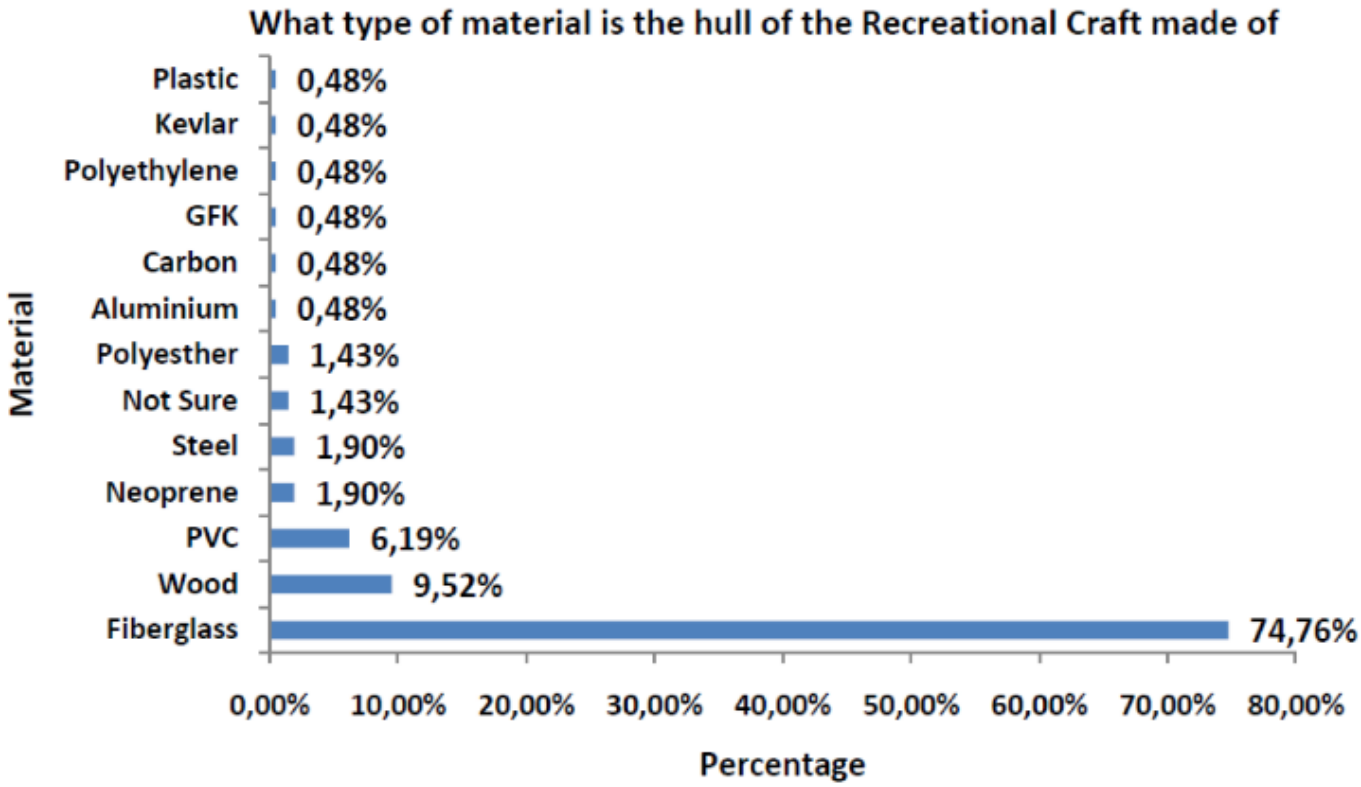


Figure 1 - Most-used materials in boatbuilding [3].

1. Technical and Structural Characteristics of Nautical Timber

1.1 Wood structure and properties

Wood trees are divided into two main classes: hardwoods and softwoods.

Botanically, *hardwoods* are angiosperm: their seeds are enclosed in the ovary of the flower. Anatomically, hardwoods have a porous structure. This means they contain vessel elements, which are wood cells with open ends able to form a continuous tube for transporting water or sap along the tree. Typically, hardwoods are plants with broad leaves that fall in autumn or winter.

Botanically, *softwoods* are gymnosperms or conifers: their seeds are not enclosed in the ovary of the flower. Anatomically, softwoods have a nonporous structure due to the absence of vessels. Softwoods are usually cone-bearing plants with needle- or scale-like evergreen leaves. Some softwoods lose their needles during autumn or winter.

In both softwoods and hardwoods, the wood in the trunk of the tree is typically divided into two zones, each of which serves an important function distinct from the other. The actively conducting portion of the stem in which cells are still alive and metabolically active is referred to as sapwood. Heartwood is the darker-coloured wood present in a zone around the centre of the tree and is surrounded by a lighter-coloured zone called sapwood.

Wood, like many natural materials, is hygroscopic: it takes on moisture from the surrounding environment. Moisture exchange between wood and air depends on the relative humidity and temperature of the air and the current amount of water in the wood. This moisture relationship has an important influence on wood properties and performance. Many of the challenges of using wood as an engineering material arise from changes in moisture content or an abundance of moisture within the wood. Moisture content (MC) is usually expressed as a percentage calculated through the following formula:

$$MC = \frac{m_{water}}{m_{wood}}(100\%) \quad [1]$$

Where m_{water} is the mass of the water and m_{wood} is the mass of the oven-dry wood. Operationally, the moisture content of a given piece of wood can be calculated by equation [2] where m_{wet} is the mass of the specimen at a given moisture content and m_{dry} is the mass of the oven-dry specimen.

$$MC = \frac{m_{wet} - m_{dry}}{m_{dry}}(100\%) \quad [2]$$

Wood exposed to an atmosphere containing constant humidity will, in time, reach a steady moisture-content condition, in which it does not gain or lose moisture. This condition represents the hygroscopic balance point and the numerical value of the stable moisture content is called the equilibrium moisture content (EMC) of the wood. This value depends on the relative humidity and air temperature. The conventional normal condition of wood is defined by an equilibrium moisture content equal to 12%: this value refers to the hygroscopic balance point in an environment characterised by average 65% relative humidity and air temperature of 20 °C. The equilibrium moisture content equal to 12% is the reference moisture-content value for which wood mechanical properties are measured.

1.2 Mechanical properties of wood

Wood may be described as an orthotropic material: it has unique and independent mechanical properties in the directions of three mutually perpendicular axes: longitudinal, radial, and tangential (Figure 2). The longitudinal axis L is parallel to the fibre (grain); the radial axis R is normal to the growth rings (perpendicular to the grain in the radial direction); and the tangential axis T is perpendicular to the grain but tangent to the growth rings.

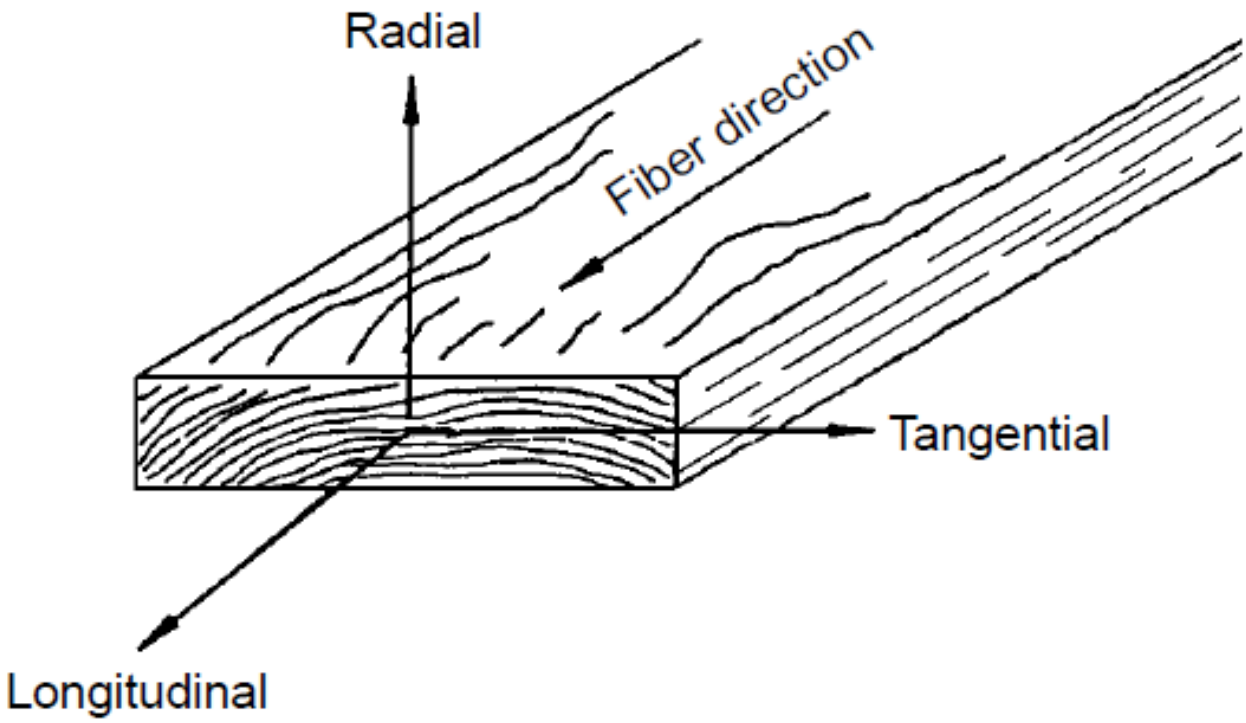


Figure 2 - Three principal axes of wood [1].

Strength properties most measured and used for design of wood construction include the following quantities: i) modulus of rupture in bending; ii) maximum stress in compression parallel to grain; iii) compressive stress perpendicular to grain; iv) and shear strength parallel to grain. Additional measurements are often made to evaluate work to maximum load in bending, impact bending strength, tensile strength perpendicular to grain, and hardness.

Less common quantities measured and classified as strength properties include torsion, toughness, rolling shear, fracture toughness, and properties related to time such as creep, creep rupture or duration of load, and fatigue strength.

Due to the natural growth characteristics of trees, the mechanical properties of wooden products may be affected by certain characteristics. For example, variations in specific gravity may have significant impacts. This quantity represents an excellent index of the amount of wood substance contained in a piece of wood; consequently, it reflects also the presence of gums, resins, and extractives, which contribute little to mechanical properties. Furthermore, wood may contain natural defects (i.e., pitch pockets) or cross grain, knots, and localized slope of grain. The impact of such flaws is due to several factors that include the following: i)

interruption of continuity and change in the direction of wood fibres; ii) changing of stresses directions because of grain irregularities; and iii) lack of bond between annual growth layers in the tree. Other characteristics able to influence wood mechanical properties are moisture content, temperature, time under load, aging, exposure to chemical agents, and chemical treatment. As an example, properties of wood decrease when heated and increase when cooled reversibly but suffer also an irreversible effect when exposed to elevated temperatures. All these aspects must be considered when assessing actual properties or estimating actual performance of wood products.

1.3 Exotic woods commonly employed in boatbuilding

1.3.1 Hardwoods

Angelique (Dicorynia guianensis) is native to French Guiana and Suriname. Two forms are commonly recognized based on the heartwood colour: the heartwood that is russet-coloured when freshly cut and becomes superficially dull brown with a purplish cast is referred to as *gris*, whereas the heartwood that is more distinctly reddish and frequently shows wide purplish bands is called *rouge*. The grain is generally straight or slightly interlocked. Angelique is rated as highly resistant to decay and resistant to marine borer attack. The wood is suitable for ship decking, planking, and boat frames.

Azobé (Lophira alata) is native to West Africa and extends into the Congo basin. The heartwood is dark red, chocolate-brown, or purple- brown with conspicuous white deposits in the pores (vessels). The texture is coarse, and the grain is usually interlocked. The wood is strong and very difficult to work with hand and machine tools, and tools are severely blunted if the wood is machined when dry. Azobé can be dressed to a smooth finish, and gluing properties are usually good. Drying is very difficult without excessive degrade. The heartwood is rated as very durable against decay but only moderately resistant to termite attack. Azobé is very resistant to acid and has good weathering properties. It is also resistant to teredo attack. The heartwood is extremely resistant to preservative treatment. Due to its characteristics, such wood is very useful for demanding constructions outdoors. In ship- and boatbuilding, Azobé is considered as one of the best essences for keel construction of wooden working and fishing boats.

Greenheart (Chlorocardium rodiei) is native to Guyana. The heartwood varies from light to dark olive green or nearly black. The texture is fine and uniform, and the grain is straight to wavy. The heartwood is rated as very resistant to decay fungi and termites. It is also very resistant to marine borers in temperate waters but much less so in warm tropical waters. Greenheart is used principally when strength and resistance to wear are required as, for example, for ship and dock building.

Iroko consists of two species *(Milicia excelsa* or *Milicia regia)*. *Milicia excelsa* is the most common species and is native to tropical Africa from the Ivory Coast southward to Angola and eastward to East Africa. The heartwood varies from a pale yellowish brown to dark chocolate brown with light markings occurring most conspicuously on flat-sawn surfaces; the sapwood is yellowish white. The texture is medium to coarse, and the grain is typically interlocked. Iroko can be worked easily with hand or machine tools but with some tearing of interlocked grain. The wood dries rapidly with little or no degrade. The heartwood is very resistant to decay fungi and resistant

to termite and marine borer attack. Because of its colour and durability, Iroko has been suggested as a substitute for teak, even though they do not belong to the same family. Its durability makes it suitable for boat building, piles, other marine work, and railroad crossties.

Lignum vitae (Guaiacum sanctum) is native to the Pacific side of Central America as well as southern Mexico. Lignum vitae is one of the heaviest and hardest woods on the market. The wood is characterised by its unique green colour and oily or waxy feel. The wood has a fine uniform texture and closely interlocked grain. Its resin content may constitute up to one-fourth of the air-dried weight of the heartwood. Lignum vitae wood is used chiefly for bearing or bushing blocks for ship propeller shafts.

Mahogany is a name currently applied to several distinct commercial products. The original mahogany wood came from the American West Indies. This was the premier wood for fine furniture cabinet work and shipbuilding in Europe as early as the 1600s. A related African wood, of the genus Khaya, has long been marketed as *African mahogany* and is used for much the same purposes as American mahogany because of its similar properties and overall appearance. However, also other species are addressed as mahogany since they are reminiscent of this essence.

- *African mahogany,* such as *Khaya*, is native to West-Central Africa. The heartwood varies from pale pink to dark reddish brown. The grain is frequently interlocked, and the texture is medium to coarse, comparable with that of American mahogany. The wood is easy to dry, but machining properties are rather variable. Nailing and gluing properties are good, and an excellent finish is readily obtained. The wood is easy to slice and peel. In decay resistance, African mahogany is generally rated as moderately durable, which is below the durability rating for American mahogany. Principal uses for African mahogany include furniture and cabinetwork, interior woodwork, boat construction, and veneers.
- *American mahogany* is native to areas ranging southern Mexico through Central America into South America as far south as Bolivia. The heartwood varies from pale pink or salmon coloured to dark reddish brown. The grain is generally straighter than that of African mahogany; however, a wide variety of grain patterns is obtained from American mahogany. The texture is rather fine to coarse. American mahogany is easily air- or kiln-dried without appreciable warp or checks, and it has excellent dimensional stability. It is rated as durable in resistance to decay fungi and moderately resistant to dry-wood termites. Both heartwood and sapwood are resistant to treatment with preservatives. The wood is very easy to work with hand and machine tools, and it slices and rotary cuts into fine veneer without difficulty. It also is easy to finish and takes an excellent polish.
- *Sapele (Entandrophragma cylindricum)* is reminiscent of mahogany and belongs to the same *Meliaceae* family. It is native to Sierra Leone, Angola, Ivory Coast, Congo, Nigeria, Ghana and Uganda. The heartwood ranges in colour from that of American mahogany to a dark reddish or purplish brown. The lighter-coloured and distinct sapwood may be up to 10 cm wide. The texture is rather fine. The grain is interlocked and produces narrow and uniform striping on quarter-sawn surfaces. The wood works fairly easily with machine tools, although the interlocked grain makes it difficult to plane. Sapele finishes and

glues well. The heartwood is rated as moderately durable and is resistant to preservative treatment. It is used in the manufacture of furniture, joinery, veneers, luxury flooring, and boatbuilding.

White Oak (Quercus alba) is native to South, South Atlantic, and Central United States. The sapwood of the white oaks is nearly white and roughly 2 to 5 cm wide. The heartwood is generally greyish brown. Heartwood pores are usually plugged with tyloses, which tend to make the wood impenetrable to liquids. Consequently, most white oaks are suitable for tight cooperage, although many heartwood pores of chestnut oak lack tyloses. Its heartwood has good decay resistance. It is a durable, stiff, and strong wood able to hold fastening exceptionally well. It is easily steam-bent and thus excellent for boat frames. It can be used also for all backbone members such as keel, stern, etc.

Okoume (Aucoumea klaineana) is native to West-Central Africa and Guinea. The heartwood is salmon-pink in colour, and the narrow sapwood is whitish or pale grey. The wood has a high lustre and uniform texture. The nondurable heartwood dries readily with little degrade. Sawn lumber is somewhat difficult to machine because of the silica content, but the wood glues, nails, and peels into veneers easily. Okoume offers unusual flexibility in finishing because the colour, which is of medium intensity, permits toning to either lighter or darker shades.

Spanish Cedar is native to tropical America, from southern Mexico to northern Argentina. The heartwood of Spanish cedar varies from light to dark reddish brown, and the sapwood is pinkish to white. The texture is rather fine and uniform to coarse and uneven. The grain is not interlocked. The wood dries easily. Although Spanish cedar is not high in strength, most other properties are similar to those of American mahogany, except for hardness and compression perpendicular to the grain, where mahogany is definitely superior. Spanish cedar is considered decay resistant; it works and glues well. Spanish cedar is used locally for all purposes that require an easily worked, light but straight grained, and durable wood. It is commonly used for fine furniture and boat building.

Teak (Tectona grandis) is native to India, Burma, Thailand, Laos, Cambodia, Vietnam, and the East Indies. The heartwood varies from yellow brown to dark golden brown and eventually turns a rich brown upon exposure to air. Teakwood has a coarse, uneven texture (ring porous), is usually straight-grained, and has a distinctly oily feel. The heartwood has excellent dimensional stability and a very high degree of natural durability. Teak is generally worked with moderate ease with hand and machine tools. However, the presence of silica often dulls tools. Finishing and gluing are satisfactory, although pre-treatment may be necessary to ensure good bonding of finishes and glues. Teak is one of the most valuable woods, but its use is limited by scarcity and high cost. Because teak does not cause rust or corrosion when in contact with metal, it is extremely useful in the shipbuilding industry and is currently used in the construction of boats, furniture, and flooring.

1.3.2 Softwoods

Baldcypress or cypress (Taxodium distichum) is native to South America. Sapwood of baldcypress is narrow and nearly white. The colour of heartwood varies widely, ranging from light yellowish brown to dark brownish red, brown, or chocolate. The wood is moderately heavy, moderately strong, and moderately hard. Old-growth

baldcypress has one of the most decay resistant heartwood of U.S. species; when available, it was used for ship and boat construction.

Western Redcedar (Thuja plicata) is native to Pacific Northwest and Coast of Alaska. The heartwood of western redcedar is reddish or pinkish brown to dull brown, and the sapwood is nearly white. The sapwood is narrow, often not more than 3 cm wide. The wood is generally straight-grained and has a uniform but rather coarse texture. It has very low shrinkage. This species is lightweight, moderately soft, low in strength when used as a beam or post, and low in shock resistance. The heartwood is very resistant to decay.

Douglas fir (Pseudotsuga Menziesii) is native to western North America. Sapwood of Douglas fir is narrow in old-growth trees but may be as much as 7 cm wide in second-growth trees of commercial size. Young trees of moderate to rapid growth have reddish heartwood and are called red fir. Very narrow-ringed heartwood of old-growth trees may be yellowish brown and is known on the market as yellow-fir. The wood of Douglas fir varies widely in weight and strength and is used for joinery, veneer, flooring and construction due to its properties. In boatbuilding is used for stringers, clamps, spars, and planking.

Spruce pine is native to the coastal regions of south-eastern South Carolina, Georgia, Alabama, Mississippi, and Louisiana, and northern and north-western Florida. The heartwood of spruce pine is light brown, and the wide sapwood is nearly white. Spruce pine wood is lower in most strength values than the wood of the major Southern Pine species group. Spruce pine compares favourably with the western true firs in important bending properties, crushing strength (perpendicular and parallel to grain), and hardness. It is similar to denser species such as Douglas fir in shear parallel to grain. In boatbuilding it is used for deck and hull framing where weight saving is the primary consideration.

White Pine is native to Maine, northern Georgia and the Great Lake States. The heartwood of eastern white pine is light brown, often with a reddish tinge. It turns darker on exposure to air. The wood has comparatively uniform texture and is straight-grained. It is easily kiln-dried, has low shrinkage, and ranks high in stability. It is also easy to work and can be readily glued. Eastern white pine is lightweight, moderately soft, moderately low in strength, low in shock resistance, and low in stiffness. White pine was widely used in the past for sailing ship construction and laid deck in yacht building.

1.4 Wooden boatbuilding technologies

Construction technologies must consider both the mechanical properties and the processability of the materials used. Below, some of the most traditional, renowned and widely adopted wooden boatbuilding techniques are discussed, highlighting their respective advantages and disadvantages.

1.4.1 Clinker and carvel planking technology

Clinker planking technology

Clinker planking (also known as lap-strake) is a method in which hull planks' edges overlap each other and are fixed together over very light scantlings (Figure 3).

Planks may be fastened together through several ways: i) copper or iron rivets consisting of a square nail and a dish shaped washer called a rove; ii) iron nails with the pointed nail ends protruding on the inside of the boat, bent over and back into the wood in the form of a hook; iii) screws; and iv) adhesives, notably epoxy.

A structural benefit of clinker construction is that it produces a vessel that can safely twist and flex around its long axis (running from bow to stern). However, there is an upper limit to the size of clinker-built vessels, due to torsional forces; indeed, their increase in proportion to displaced weight has an impact on the forces incident on the hull and subsequently on the maximum length achievable through this technology.

Furthermore, clinker constructions do not readily support the point loads associated with lateen or sloop sailing rigs. The same problem in supporting concentrated loads makes positioning a centreboard or deep keel very difficult. Auxiliary timbers can be added as necessary compromise but always with some loss of the fundamental benefits of the construction method itself.

Clinker planking remains a useful method of construction for small wooden vessels, especially sea-going dinghies that need to be light enough to be readily moved and stored when out of the water. For other applications, carvel planking is now more appealing.

Figure 3 - Clinker-built sailing vessel (https://www.denmanmarine.com.au/gartside-10-traditional-clinker-dinghy-c28/).

Carvel planking technology

Carvel planking is a method in which hull planks are laid edge to edge and fastened to a robust frame. Through this method, a smooth planking of the exterior hull can be obtained (Figure 4).

Carvel construction gives a heavy but rigid hull, capable of taking a variety of sail rigs. The great rigidity of carvel construction has always been exploited to face torsional forces on longer vessels, in opposition to clinker planking.

In traditional carvel methods, a small gap was left between each plank; this gap was then caulked with any suitable soft, flexible, and fibrous material, sometimes combined with a thick binding substance. Typical caulking materials were oakum and cotton. Problems arose when boats had been beached for too long: in those situations, the planks would dry and shrink and needed a re-caulking operation to be on fit for navigation. To solve this negative aspect, the modern technique variation implies the use of narrower planks that are edge-glued instead of being caulked. With modern power sanders, a much smoother hull is produced, as all the small ridges between the planks can be removed. This method started to become more common in conjunction with the widespread availability of waterproof glues. Therefore, as traditionally nails provided the fastening strength, now glue is in charge of it.

Figure 4 - Carvel-built vessel (http://bertan.gipuzkoakultura.net/23/ing/11.php).

Comparison between clinker and carvel planking

Clinker was the predominant method of ship construction used in Northern Europe before carvel. Due to the plank overlapping in clinker method, a carvel boat has a smoother surface, giving the impression to be more

hydrodynamically efficient since the exposed edges of the clinker planking appear to disturb the streamline and cause drag (Figure 5). A clinker certainly has a slightly larger wetted area, but a carvel hull is not necessarily more efficient: for given hull strength, the clinker boat is overall lighter than a heavily-framed carvel hull. A clinker vessel whose ribs occupy less space than a carvel vessel's is more suitable for cargo, which is bulky rather than dense.

However, there is an upper limit to the size of clinker-built vessels, which was exceeded by several orders of magnitude in later large sailing vessels implying carvel-built method.

Clinker requires relatively wide planking stock compared to carvel, as carvel can employ stealers to reduce plank widths amidships where the girth is greatest. The need for sufficient lap to accept the clench fastenings drives towards wider planks in proportion to thickness than can be employed in carvel. In several areas of construction, including framing, deck, etc., clinker is still as capable as carvel.

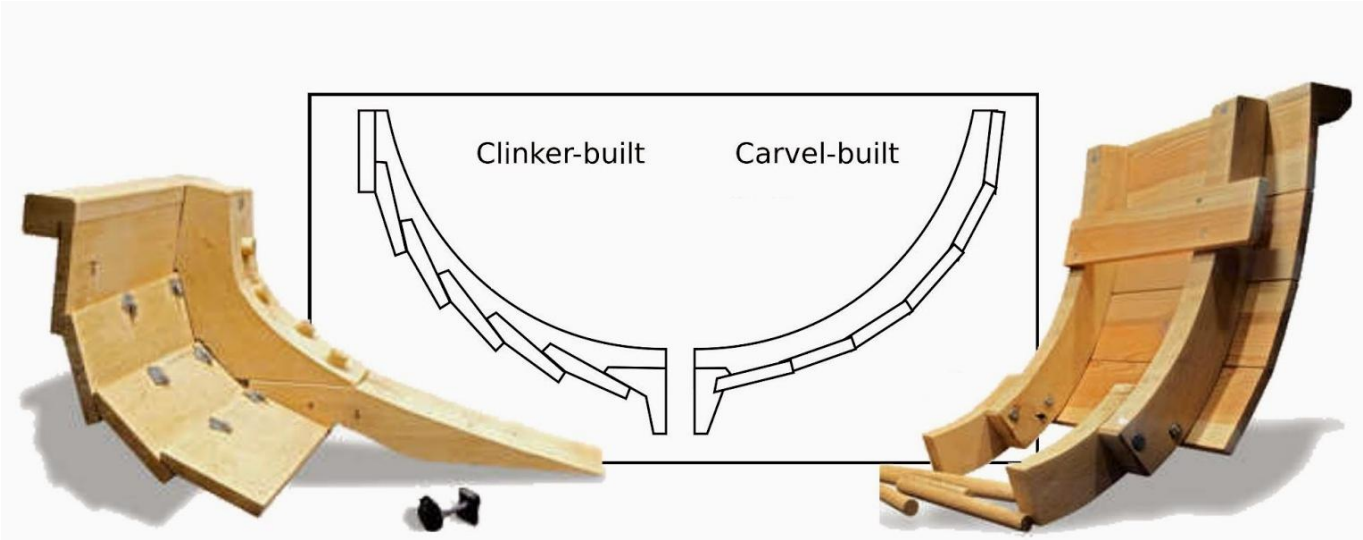


Figure 5 - Comparison between clinker planking and carvel planking..

1.4.2 Cold-moulding and strip-planking technology

The term cold-moulding covers a number of related building technologies, but essentially consists of gluing layers of thin wood skins or planks together like a multi-layer sandwich [4]. The result can be considered a composite material and is very different from traditional wooden boatbuilding in which separate pieces are fixed together with metal fastenings or (sometimes assisted by glue) so that each part can move very slightly in relation to its neighbours. A cold-moulded hull is rather like the shell of a nut; the waterproof outer shell is also the strong structure that makes the nut so tough. Cold-moulding is one of the best ways of using wood because it accentuates its good properties and gets round most of the problems. A related technology is the

strip-planking technique, which is a simple and efficient construction method often used in combination with cold-moulding.

Strip-planking is a form of carvel planking that involves an easy technological process to build a strong and rigid wooden structure with a remarkable strength-to-weight ratio, high fatigue resistance and resilience.

As explained in [5], it consists in stratifying a number of wood strips with different thickness, with the natural grains properly oriented. The wood strips are kept together by means of a proper adhesive. The first step involves arranging a pattern made of a series of transversal frames in order to reproduce the boat hull form and to lay the definitive stringers (Figure 6a). The transversal frames serve as support for the longitudinal strips that run in the fore-aft direction (Figure 6b). When strip-planking and cold-moulding technologies are combined, the external surface of the strip layer, after being smoothed by grinding, represents the base for the successive veneer layers (Figure 6c), which consist of wide, thin, highly flexible bands that easily fit the hull shapes. Commonly, longitudinal strips have a rectangular cross section having edges arranged with semi-circular mouldings (one concave and the other convex as shown in Figure 6d, middle image), in order to both fit the hull transversal curvature and guarantee a better bonding between adjacent strips. Ideally, strips should have a length that allows them to run from stern to bow in a unique piece, but this situation hardly occurs; often, strips must be jointed together. Generally, scarf joints are used, with the strip ends bevelled (slope approximately 1:7), overlapped and glued together.

A combined strip-planked and cold-moulded construction is shown as example in Figure 7. The use in combination of cold-moulding and strip-planking technologies is attractive as a way of building up a substantial hull thickness without the need for normal carvel planking or very many layers of cold-moulding. Indeed, the long strips involved in strip-planking may suffer from seam failures and damages, being very difficult to repair. A combination of a layer of strip-planks followed by one, two, or three skins of cold-moulded veneers is worth considering when lengths are over 12 m. In such constructions, the external veneer layers would protect the internal strips in case of slight damages.

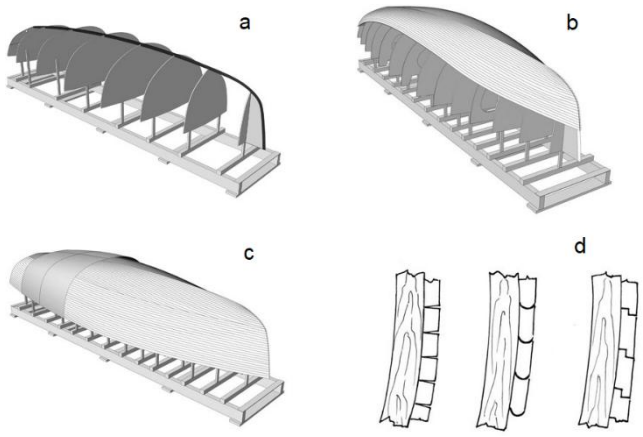


Figure 6 - Combined strip-planking and cold-moulding and strips preparation..

Figure 7 - Strip-planked hull [5].

1.4.3 Traditional construction techniques related to Venice Lagoon Gondola boats

The construction process represented in the technical drawing of Figure 8 starts with preparing the *cantiere* and the *corbe* (Figure 9a and b). The *cantiere* represents a wooden beam having the same length and curvature of the gondola itself that is anchored to the ground. On this line, the builder will establish the boat's structure, which consists of 33 transverse frames known as *corbe* and the end posts called *asta de pope* (aft end) and *asta de prova* (fore end). The *corbe* are made up of elm *sanconi*, which form the framework of the boat's sides, and longitudinal oak planks, which connect the *sanconi* in pairs.

In the second phase, the three fundamental frames are built (Figure 9b): the *maistra de meza barca* (midship section), the *maistra de pope* (aft section), and the *maistra de prova* (fore section). Next, two long oak planks that run along the hull for its whole length and form the sides of the boat are installed. These longitudinal planks are called *serci (or cerchi)* and their curvature is achieved by wetting and heating them with fire, using bundles of marsh reeds (Figure 9c). The *serci* are fixed to the above-mentioned sections and to the forward and aft ends. Then, the builder fixes all the frames but the four at the bow and the four at the stern of the unit (Figure 9d).

In the third construction phase, the work is divided between two craftsmen: one working at the stern and the other at the bow. The *serci* alone cannot cover the uppermost parts of the stern and bow, so four wooden pieces called *cimonelle* are prepared. V-shaped ribs designed to support the boat's two extremities, called *volti*, are installed. With this, the structure of the sides is complete. Then, the gondola is covered at both ends through the so-called *sucheto da pope* (aft) and *sucheto da prua* (forward) as shown in Figure 9e.

In the fourth construction phase, the gondola is turned upside down (Figure 9f) and placed on two trestles to allow working on the bottom. The *serci* are wet and heated, and with the help of wooden props, the bow and stern are bent to give the gondola its characteristic curvature. To reinforce the hull, two fir planks called *copi* or *coppi* are added, forming the lower part of the side (Figure 9g). The differences in level between the various elements are smoothed out. Any gaps between the pieces are filled with oakum to prevent water infiltration.

In the fifth phase of construction, finishing touches are applied (Figure 9h). The *soralai* – four planks where the gondolier places his foot while rowing *(puntapiedi)* – are installed (Figure 9i), along with small wooden crosspieces to protect passengers' feet. The gondola is decorated and painted with five coats of black paint.

The gondola is completed with the construction of the oars and *forcole*, the latest featuring a forked support for the oar, positioned 40 cm from the gondola's side edge.

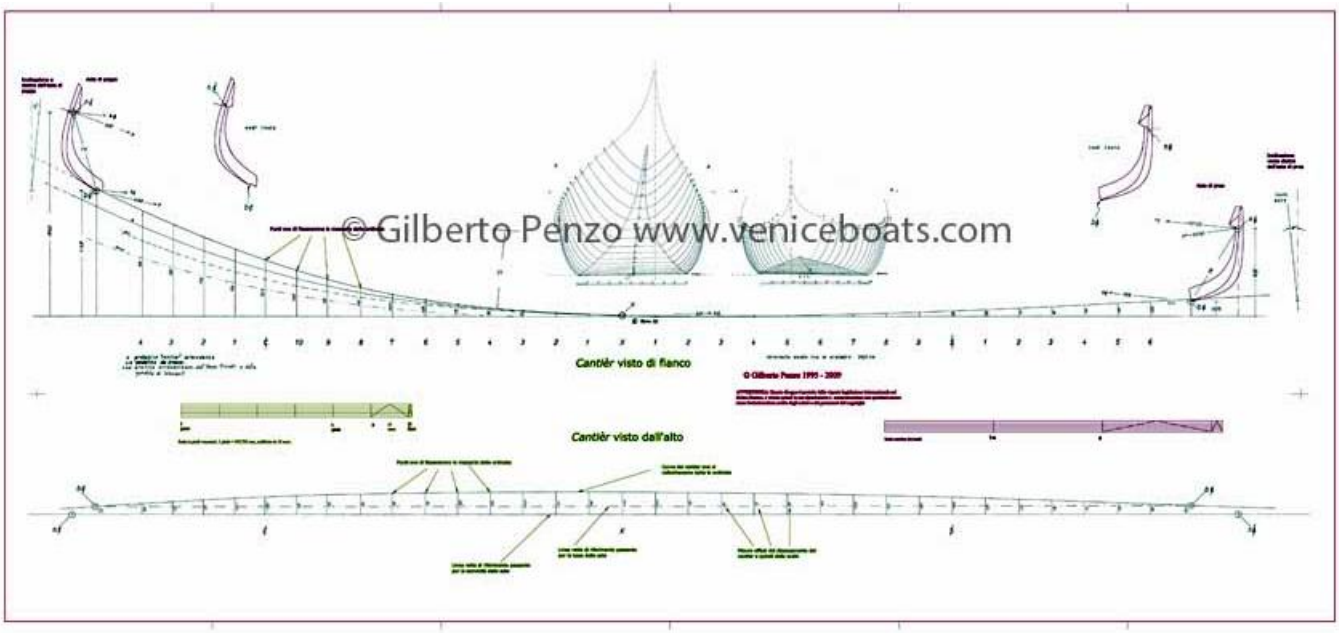


Figure 8 - Gondola's construction drawing (https://www.veniceboats.com/images/progetto%20Gondola%20serie%20completa%201.jpg).

Figure 9 - Gondola's construction process (https://cjalzumit.wordpress.com/2022/08/24/costruzione-della-gondola/).

2. Mapping of Local Forest Species

2.1 Veneto Region

2.1.1 Basic data regarding Veneto forest areas

Veneto region has between 412,000 and 415,000 hectares (ha) of forested area (depending on the investigated sources), slightly more than the neighbouring regions in the northeast as shown in Figure 10 [6]. The forest

area of Veneto region, including both woods and other wooded lands (areas that are in rural landscapes and urban settings that meet the thresholds for the FAO classification but for which the land use is not classified as forest), constitutes 25% of the regional surface area accounting for 465,625 ha [7]. These forests are distributed as follows: 28% in the elevation range below 600 meters, 22% between 600 and 1,000 meters, 30% between 1,000 and 1,500 meters, and the remaining 20% 1,500 meters above sea level.

The extent of the various forest categories is directly correlated to the altitudinal distribution of forest stands. In the mountain and sub-mountain zones, conifers predominate, covering 29% of the entire forested area of the region, excluding pine stands and anthropogenic formations, with a clear prevalence of spruce forests. In the broadleaf formations, there is widespread presence of beech forests and spruce-beech forests, which represent 21% of the forested area. In the hilly areas, where soil fertility is low, hornbeam-oak forests are widespread (20%), while in more fertile areas, chestnut and oak forests are found (6%), and where water availability is higher, maple-ash forests are present (2%).

Figure 11 shows the forest area in Veneto region classified by forest categories and by province as reported by the "Rapporto sullo stato delle foreste e del settore forestale in Veneto 2020" [6]. The evolution of the forest area in Veneto region is reported in Figure 12, which shows an increase in hectares starting from 1936 but a decrease in terms of conifer trees.

A more detailed subdivision in terms of tree species of the forest areas in Veneto region is given by Figure 13 – Subdivision of the forest area in Veneto region [7]., in which the majority of broadleaf forests over coniferous ones is given in percentage terms (59% over 41% on the total forest areas mapped in Veneto region).

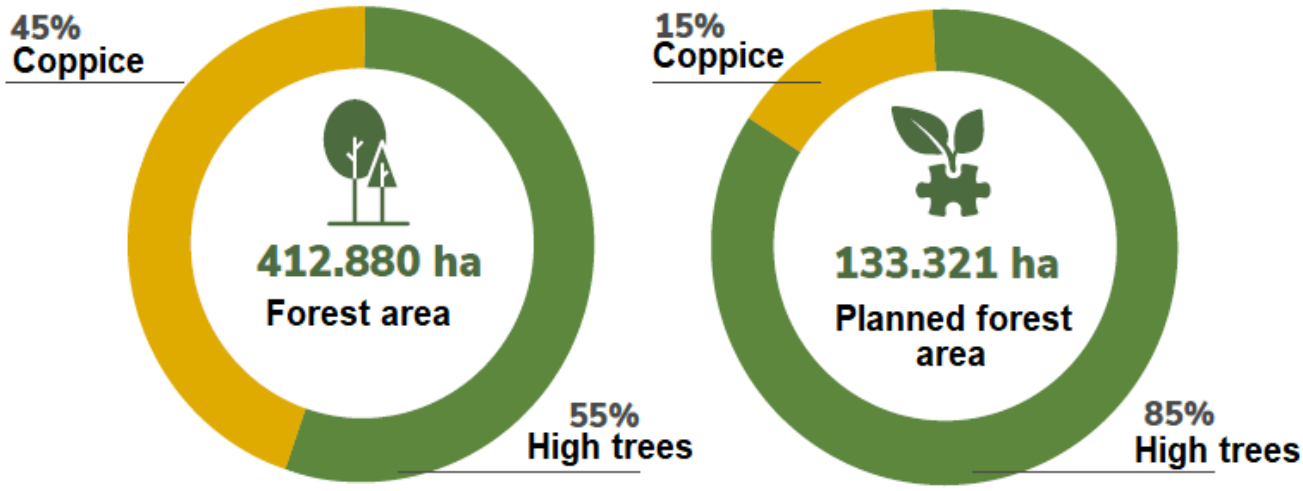


Figure 10 - Macroscopic subdivision in coppice and high forests of areas and planned areas in Veneto region [6].

	Forest category (ha)																		
	Fir forests (*Abies*)	Maple-ash and maple-linden foresst	Alder forests (*Alnus*)	Shrublands	Birch forests (*Betula*)	Chestnut and Oak forests (Castanea and Quercus)	Beech forests (*Fagus*)	Antropogenic formations	Coastal formations	Euganian formations with Mediterranean elements	Larch and Swiss pine forests (*Larix and Pinus*)	Larch forests (*Larix*)	Hornbeam-ash and ash-oak forests (*Carpinus, Fraxinus and Quercus*)	Pine forests (*Pinus*)	Spruce-beech forests (*Pigea and Fagus*)	Scots pine forests (*Pinus sylvestris*)	Oak-hornbeam and hornbeam forests (*Quercus and Carpinus*)	Willow forests and other riparian formations	Total
Belluno	16,555	6,909	2,877	1,912	223	1,429	32,291	15,359	-	-	31,836	24,451	19,103	39,510	10,647	12,468	4,053	2,814	**222,437**
Padova	-	-	-	-	-	1,781	-	2,356	-	789	-	-	773	-	-	-	50	704	**6,453**
Rovigo	-	-	-	-	-	-	-	237	117	-	-	-	-	-	-	-	55	581	**990**
Treviso	5	25	1	332	-	4,368	5,186	11,346	-	-	-	4	12,146	-	-	3	454	3,073	**36,943**
Venezia	-	-	-	-	-	-	-	618	386	-	-	-	1	-	-	-	118	465	**1,588**
Verona	70	76	-	1,243	12	2,430	7,958	4,984	-	-	19	1,120	26,629	185	-	-	565	749	**46,040**
Vicenza	6,389	2,093	1	867	-	10,255	29,540	11,888	-	-	2,317	2,276	22,497	9,313	-	183	68	743	**98,430**
Total	**23,019**	**9,103**	**2,879**	**4,354**	**235**	**20,263**	**74,975**	**46,788**	**503**	**789**	**34,172**	**27,851**	**81,149**	**49,008**	**10,647**	**12,653**	**5,363**	**9,129**	**412,880**

Figure 11 - Forest area (ha) classified by forest categories and by province, excluding Sappada municipality [6].

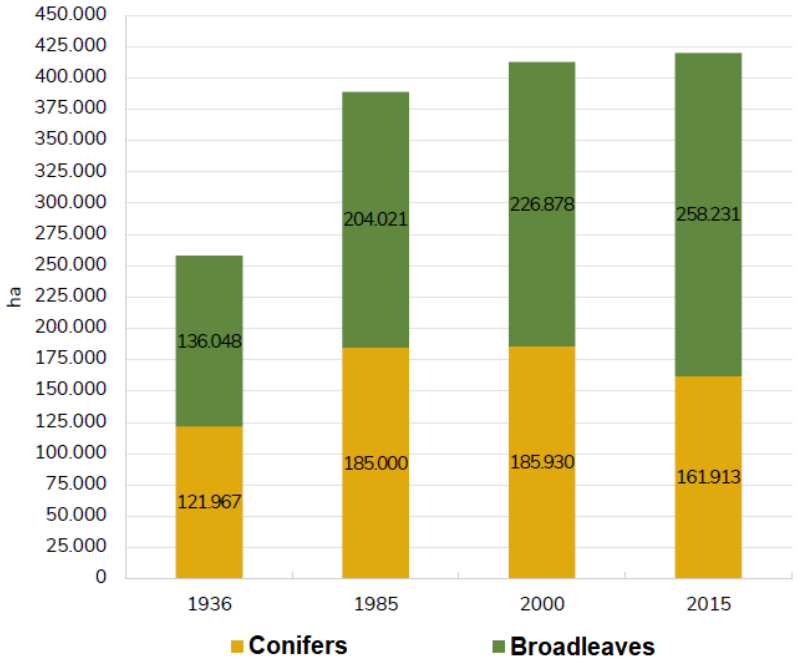


Figure 12 - Evolution of forest area in Veneto region from 1936 to 2015 [6].

Category and species	Surface [ha]	%
Larch and Swiss pine forests *(Larix and Pinus)*	40,876	10
Spruce forests *(Picea abies)*	96,703	24
White fir forests *(Abies alba)*	7,097	2
Scots pine and Mugo pine forests *(Pinus sylvestris and mugo)*	12,985	3
Black pine, Calabrian pine, and Heldreich's pine forests *(Pinus nigra, laricio* and *heldreichii)*	3,505	1
Mediterranean pine forests	747	0
Other coniferous forests, pure or mixed	-	0
Total coniferous forests	**161,913**	**41**
Beech forests *(Fagus)*	67,196	17
English, Downy, and Sessile Oak forests *(Quercus robus, pubescens* and *patraea)*	14,567	4
Cerris, Frainetto, and Valonia Oak forests *(Quercus cerris, frainetto* and *macrolepis)*	374	0
Chestnut forests *(Castanea)*	18,302	5
European hophornbeam forests *(Ostrya carpinifolia* and *Carpinus betulus)*	82,687	21
Hygrophilous wood forests	10,085	3
Other deciduous forests	37,350	9
Holm oak *(Quercus ilex)*	2,988	1
Coark oak *(Quercus suber)*	-	0
Other evergreen broadleaf forests	-	0
Total broadleaf forests	**233,549**	**59**
Artificial poplar groves	1,747	0
Plantations of other broadleaf trees	343	0
Subalpine shrublands	19,265	5
Temperate shrublands	2,615	1
Mediterranean scrublands and shrublands	712	0
Other forests	**24,682**	**6**
Total	**395,462**	**106**

Figure 13 – Subdivision of the forest area in Veneto region [7].

2.1.2 Veneto local species used for nautical applications

Due to the maritime heritage of Venice, the local tree species present in Veneto region have always been exploited during the years [8].

Lazzarini, 2021 focuses the attention on the constructions built in the Venice *Arsenale* between XVI and XVIII centuries [9]. In those years, oak wood was the main material used in shipbuilding with specific reference to galleys' hull and structures. Besides oak, literature refers to the employment of larches and firs in smaller quantities, mainly for structural details and masting. The number of trees necessary for the construction of galleys varied on the basis of the dimensions of the vessel and of the construction period, as novel building technologies and naval architecture approaches emerged with the passing of years and had a direct impact on the hull shapes. As for the galley oars, the only species used in those years was beech wood.

When the evolution took place with the introduction of new units such as warships replacing galleys, the demand for construction wood increased, always favouring oak as the main timber. Other species employed were larches, elms, ashes, whereas for the oars the choice was still based on the use of beech wood.

Moving to the present day, the types of wood that characterise boat construction in the Venetian lagoon are mainly larch, oak, mahogany, and iroko. These woods are chosen for their resistance to humidity, saltwater, and wear, ensuring the durability of traditional Venetian boats such as gondolas, *sandoli*, and *bragozzi*.

Specifically, eight types of wood are used in the construction of a gondola: oak, fir, elm, cherry, larch, walnut, lime are part of the tradition, while mahogany was recently introduced. The *trasti* (transverse planks connecting the sides of the gondola) are made of cherry wood due to its superior flexibility, which facilitates bending. Conversely, key structural components such as the *nerve* (upper bands fixed on top of the *sanconi*, the vertical ribs), the sides, the *corboli* (lower transverse planks inserted into the sanconi), and the *piane* (horizontal planks forming the boat's bottom) are constructed from oak, chosen for its high strength and durability. French oak is preferred for its superior resistance to rot, despite being less visually appealing. In contrast, Yugoslavian oak, while aesthetically superior and often used in furniture making due to its attractive grain and colour, is more susceptible to deterioration in a marine environment. Consequently, material selection prioritizes performance over aesthetics to ensure the longevity of the vessel.

Besides the type of wood, its origin is also considered a key factor in ensuring quality and emphasises the meticulous care taken by boatbuilders in constructing gondolas in their own *squeri* (http://daticultura.regione.veneto.it/data/veneto/cbcv/beneculturale/bdi-e9d318e495563c9ee2bdf6a81b2d052b).

2.1.3 State-owned forests and the importance of Cansiglio, Somadida and Cajada forests

As in various regions of Italy, also in Veneto there are state-owned forests whose origins and histories differ significantly. These forests are often linked to different historical periods, during which medieval dominations, bishops, ecclesiastical orders, or wealthy lords and notable figures owned extensive forested estates from north to south. With the establishment of the Italian State, the government became the owner and administrator of many such forests and pastures, both in mountainous and hilly areas.

The Luzzati Law of 1910 promoted the acquisition of forested lands for the establishment of the State Forestry Domain, leading to the creation of the Special State Forestry Domain Agency, which managed over 500,000

hectares of forests until the 1970s. From 1970 to 1977, responsibilities for forest management were transferred from the State to the Regions. This transfer facilitated the development of economic activities directly connected to forest resources and the livelihood of local populations. Providing employment even in challenging pre- and post-war periods, forests have played a crucial social role, offering job opportunities to hundreds of workers engaged in planting young trees and implementing hydraulic-forestry improvements.

In the Veneto Region, the Regional State Forest property covers approximately 16,000 hectares, distributed across various areas (Figure 14). These forests are managed by the Veneto Agency for Innovation in the Primary Sector – Veneto Agricoltura and are certified within the PEFC schemes (Programme for Endorsement of Forest Certification). Over a century of history, preserving traditions, woodworking techniques, and the customs of skilled labourers engaged in timber harvesting and wood craftsmanship, these forests have continuously provided construction timber and firewood, enhancing their economic significance.

The Cansiglio Forest, located between the provinces of Belluno, Treviso and Pordenone, represents a cradle of history and civilization. Formerly the "Bosco da Reme" of the Serenissima Republic of Venice, for centuries it has supplied high-quality timber and other assortments. Specifically, Cansiglio timber represented the prime source of beechwood for the production of oars for the boats of Venice. This has supported the development of economic activities closely tied to the forest and the livelihoods of local populations. Nowadays, several pilot actions demonstrated that it is possible to create forest-wood supply chains that enhance the value of local timber. An example is represented by the pilot project "Assi del Cansiglio" (https://www.nationalgeographic.it/ambiente/2021/10/liniziativa-assi-del-cansiglio-unambiziosa-sfida-ecologica-e-imprenditoriale), which aimed at restoring the historic and prestigious use that has always been made of Cansiglio wood. Before the implementation of this pilot project, Cansiglio timber used to being employed only as firewood. The deployment of the project was made possible thanks to a strong synergy and alignment with other key local stakeholders. First and foremost, Veneto Agricoltura, which manages the historic forest, but also with those advocating for its environmental integrity keeping in mind that the Cansiglio Forest has always been a productive forest rather than a strictly protected reserve.

Another significant project aimed at highlighting the importance of Cansiglio forest for the Serenissima Republic of Venice started in 2022 with the challenge of ensuring that the last remaining "mussin" in Venice could participate in the 2022 Historical Regatta (https://live.comune.venezia.it/it/2022/01/tradizioni-lultimo-mussin-veneziano-restaurato-la-regata-storica-2022). A mussin is a boat for leisure that can be rowed by four oarsmen or by two with an equal number of passengers (Figure 15). The promoter of the project was the Società di Mutuo Soccorso Carpentieri e Calafati, a society founded in 1867. The wood for the functional recovery of the "mussin" was provided by the "Consorzio legno della Regione Veneto", symbolizing the ancient bond between the city and the Cansiglio forest. Specifically, three wood species were employed for the restoration: oak, elm and larch (Figure 16). The city's Councillor for Craftsmanship also expressed his support for the initiative, symbolically demonstrating the attention of the Municipal Administration to such an important sector for the preservation of the city's traditions.

The project aimed at re-establishing the importance of Venice as the home to unique realities like the Squeri, the traditional Venetian boatyards. These are crucial institutions for the preservation and enhancement of professional figures such as master boatbuilders, who represent the continuity of a centuries-old tradition.

	Province	Total surface [ha]	Wooded area [ha]	"Rete Natura 2000" area [ha]	Commission [m^3]	Current increase [m^3]	Sustainable Forest Management Certificate
Cansiglio forest	Belluno Treviso	4,342.00	3,539.00	4,342.00	1,225,271.00	21,097.00	PEFC n. 52601
Destra Piave forest	Belluno	629.00	496.00	629.00	45,223.00	754.00	NA
Giazza forest	Verona Vicenza	1,489.32	1,222.03	1,489.32	132,288.00	1,616.00	PEFC n. 52601
Malgonera forest	Belluno	276.00	276.00	276.00	ND	ND	NA
Monte Baldo forest	Verona	3,963.04	2,285.56	3,121.13	173,952.20	1,646.00	PEFC n. 52601
Piangrande forest	Belluno	229.00	183.00	229.00	19,870.00	430.00	NA
Sinistra Piave forest	Belluno Treviso	1,487.00	1,074.00	1,487.00	241,346.00	3,052.00	NA
Valdadige forest	Verona	1,528.34	1,262.19	945.30	83,736.00	707.00	NA
Valmontina forest	Belluno	1,065.00	396.00	1,065.00	39,086.00	778.00	NA
Ca' Mello Oasis	Rovigo	110.00	80.00	424.00	ND	ND	ND
Bocche di Po reserve	Rovigo	424.00	ND	424.00	ND	ND	NA
Bosco Nordio reserve	Venezia	113.00	112.00	113.00	18,184.00	272.00	PEFC n. 52601
Total	**23,019**	**15,655.70**	**10,925.78**	**14,544.75**	**1,978,956.20**	**30,352.00**	**-**

Figure 14 - Veneto state-owned forests [6].

Figure 15 - Mussin boat (courtesy of Consorzio Legno Veneto and Società Mutuo Soccorso Carpentieri e Calafati).

Figure 16 - Mussin boat after recovery (courtesy of Consorzio Legno Veneto and Società Mutuo Soccorso Carpentieri e Calafati).

Other important forests present in Veneto region are the forests of Somadida, Cajada and Montello.

The Somadida Forest is the largest forest in Cadore and is located in Palus San Marco, surrounded by the majesty of the Cristallo, the Sorapiss and the Marmarole peaks [10]. It is an uneven-aged alpine forest that extends for about 1650 hectares, in which conifers, even large ones, prevail, especially Norway spruce and silver spruce, with the presence of beeches and larches. In the past, this forest was used by the Serenissima as a reserve of wood for its naval fleet. In fact, the Somadida forest has provided timber to the Republic of Venice for many years – from 1493, the year in which the Magnifica Comunità Cadorina donated this forest to the Serenissima Republic, which exploited it until 1797 when it passed under French rule. To commemorate the history that links Somadida to the Republic of Venice, in 2019 an exact copy of the raft called "RASO" was made, which was used to transport the long logs used in the construction of the masts of warships (Figure 17). The logs departed from here and arrived via the river journey to the Venice arsenal.

The Cajada forest, in the Dolomiti Bellunesi National Park, has represented for centuries another fundamental source of timber supply for the construction of ships in the city of Venice. The distinctive features of this landscape include extensive forest environments of spruce, silver fir and beech. These trees were renown in Venice shipyards as plants "da matadura" in terms of round wood for masts, antennas and flagpoles (firs and larches) and "da palamento" in terms of trees used to manufacture oars (beeches and maples).

Finally, Montello forest was renown due to its oak wood that was used in Venice shipyards. Montello is a unique hilly relief located within the province of Treviso. Its singularity is due to the fact that it cannot be considered a mountain due to its height, as it has a maximum height of 371m reached in Colesel Val dell'Acqua, but it is not even a true hill, as it is a compact and massive relief and is not divided into several ridges like the "usual" hills. The Montello has an elliptical shape, extends for about 13km from east to west, and is outlined to the north by the river Piave. During the Republic of Venice, Montello was managed and exploited in a well-organized way and it was called "the wood of the doges", because the wood of its trees was used by the Arsenal of Venice to build ships, especially the emerged part.

Figure 17 - RASO raft still present in the Somadida forest (https://auronzomisurina.it/ambiente/foresta-di-somadida/).

2.2 Friuli Venezia Giulia Region

2.2.1 Local species in Friuli Venezia Giulia forests

The forestry situation in Friuli Venezia Giulia is characterized by a great variety of natural landscapes, thanks to its geographical location, which spans from the Alps to the Prealps and coastal plains as reported in [11], [12] and graphically through Figure 18. The region is rich in forests, extending for more than 320,000 hectares which cover about 60% of its territory, playing a fundamental role in biodiversity conservation, protection against

hydrogeological instability, and ecological balance. The total timber volume of the forests is 77,420,548 m³ (239 m³/ha).

The region's forests are mostly mixed, with a combination of broadleaf trees and conifers, and develop according to the geographical and altimetric diversity with the main formations located in the mountain and hilly regions. The most common local tree species that can be found in Friuli Venezia Giulia are reported below.

- Beech *(Fagus sylvatica):* it is one of the most widespread species in the forests of Friuli Venezia Giulia, particularly in the mountainous and hilly areas. Beech thrives in rich, deep soils and is often found in mixed forests. It is valued for its resilience and the quality of its wood.
- European Silver Fir *(Abies alba):* the silver fir is one of the most common conifers in the mountainous forests of the region, especially at higher altitudes. It is mainly used for timber production and industrial purposes, such as paper.
- Scots Pine *(Pinus sylvestris):* this species prefers drier, poorer soils and is found mainly in lower areas and hilly regions. Scots pine is important for timber production, particularly for construction.
- Oak *(Quercus robur):* oak is a broadleaf species that, although not as prevalent as beech, is still present in various areas, particularly in lower zones of the region. It is known for its hard, durable wood, historically used for construction and furniture-making.
- Chestnut *(Castanea sativa):* chestnut is particularly widespread in hilly and foothill areas. Historically, its wood and fruit were essential for local populations. Today, it is also cultivated for commercial purposes.
- Larch *(Larix decidua):* larch is a conifer found mainly in mountainous areas, at higher altitudes. It is valued for its durability and the long-lasting quality of its wood, which is used for construction and furniture making.

In terms of forest management, Friuli Venezia Giulia region is aimed at conserving natural resources, preventing hydrogeological risk, and promoting sustainable forest practices. Figure 19 and Figure 20 show silvo-pastoral properties of the region, subdivided by management units, municipalities and management districts. All these forests are PEFC certified and are managed to pursue the following objectives: sustainable timber production, livestock and pastoral activities of the alpine huts, natural conservation, and the promotion of tourism and recreational use The goal of Friuli Venezia Giulia region is to maintain a balance between utilizing timber resources and protecting the natural environment through practices such as reforestation and integrated forest management. Additionally, the forests of Friuli Venezia Giulia are important for biodiversity, as they host numerous species of flora and fauna. The region has been involved in reforestation and conservation projects to preserve the quality of its forests and reduce the impact of climate change.

2.2.2 Friuli Venezia Giulia local wood species used for nautical applications

With reference to wooden boats, in Friuli Venezia Giulia local wood has historically been used for the construction of traditional crafts such as *battane*, *sandoli*, and other typical lagoon and river vessels of the region. Local woods are often combined with more exotic species such as mahogany or iroko to enhance

durability. Among all the species that can be found in Friuli Venezia Giulia region, the most commonly used are reported below.

Oak is valued for its strength and water resistance and it is used for load-bearing structures and the most stressed elements of boats. Larch, due to its spread in the mountainous areas of Friuli, is chosen for its durability and ability to withstand atmospheric agents, often used for exposed parts such as decks and sides. Elm is traditionally used in shipbuilding for its toughness and flexibility, making it ideal for structural components subjected to mechanical stress. Ash is selected for its high elasticity and is used for oars and parts subject to torsion, whereas poplar is used for secondary elements due to its lightness and ease of processing.

Figure 18 - Forest areas in Friuli Venezia Giulia (IRDAT, 2022).

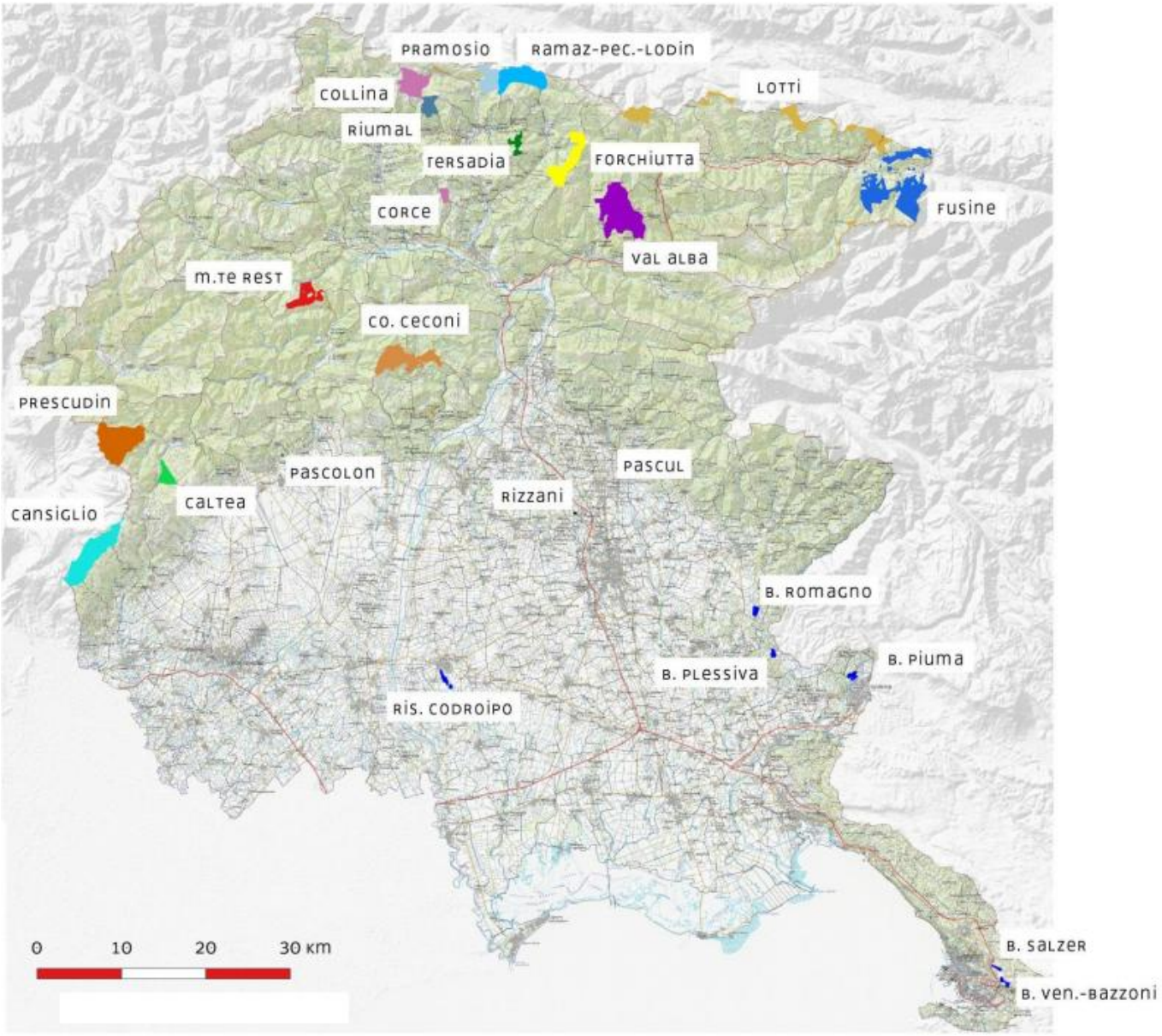


Figure 19 - Regional forest of Friuli Venezia Giulia [11].

Management units	Municipalities	Surface [ha]	District	Total surface [ha]
Cansiglio	Caneva, Polcenigo, Budoia (PN)	1,547	Pordenonese	4,602
Prescudin	Barcis (PN)	1,647		
Caltea	Barcis (PN)	257		
Vivaio Pascolon	Maniago (PN)	5		
Conte Ceconi	Vito d'Asio, Clauzetto, Tramonti di S. (PN)	1,146		
Monte Rest	Socchieve (UD)	495	Carnia	4,190
Collina Grande	Paluzza, Ravascletto, Rigolato (UD)	750		
Pramosio	Paluzza (UD)	494		
Pecol di Chiaula, Lodin, Ramaz	Paluzza, Paularo (UD)	1,054		
Forchiutta	Paularo (UD)	815		
Corce	Zuglio (UD)	114		
Tersadia	Paularo, Ligosullo, Treppo Carnico (UD)	144		
Riumal	Ravascletto (UD)	324		
Val Alba	Moggio Udinese (UD)	1,977	Canal de F. - Val Canale	6,162
Fusine (with Marzano)	Tarvisio, Malborghetto (UD)	2,923		
Lotti	Tarvisio, Malborghetto, Pontebba (UD)	1,262		
P. ris. Codroipo, B. Romagno, P. Rizzani	Codroipo, Cividale, Prepotto, Pagnacco (UD)	132	Bassa	280
B. Pless, B. Piuma, B. Salzer, B. Ven.-Bazz.	Cormons, Dolegna, Gorizia, Trieste (GO-TS)	108		
Parco Rizzani	Pagnacco	37		
Vivaio Pascul	Tarcento (UD)	3		
Total	-	**15,234.00**	-	**15,234.00**

Figure 20 - Summary of regional forests of Friuli Venezia Giulia [11].

2.3 Croatia

2.3.1 Local species in Croatian forests

In Croatia, the forested areas are diverse, with a variety of tree species that reflect the country's range of climates and geographical features as reported by the European Environment Agency in Figure 21. The local forest trees in Croatia can be broadly divided into broadleaf (deciduous) trees and coniferous (evergreen) trees. Croatia's diverse climate and topography, ranging from coastal to mountainous and continental areas, support a rich variety of tree species that play essential roles in the ecology, economy, and cultural heritage of the country. Sustainable forest management ensures the preservation of these forests while maintaining their economic importance.

Some of the most common and notable local tree species found in Croatian forests are depicted below.

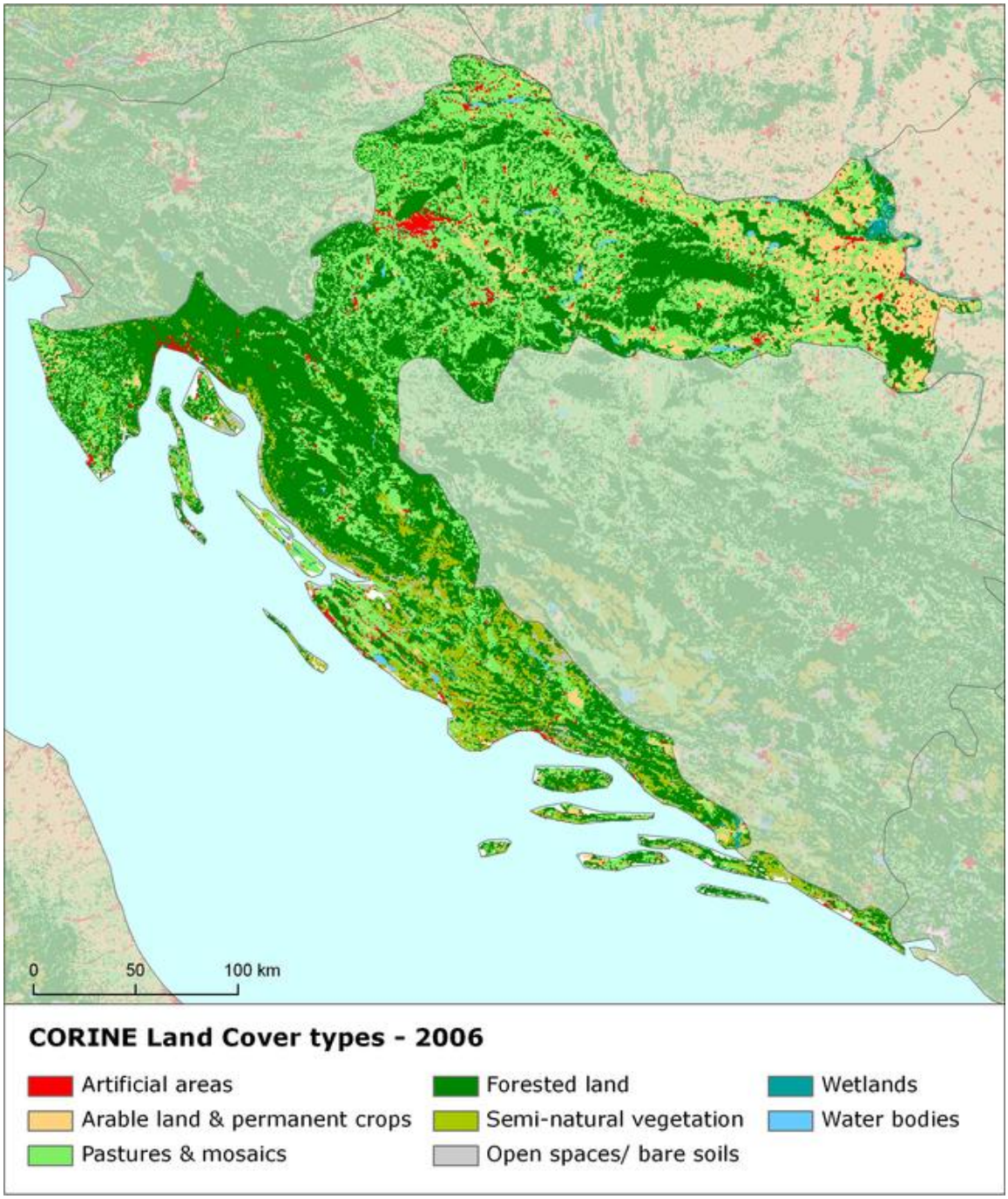


Figure 21 - Croatian forested areas (https://www.eea.europa.eu/data-and-maps/figures/land-cover-2006-and-changes/croatia).

Broadleaf Trees

- European Beech *(Fagus sylvatica):* beech forests are particularly widespread in the central and northern parts of the country. This species thrives in fertile, moist soils and is often found at mid-altitude areas.
- Pedunculate Oak *(Quercus robur):* the pedunculate oak is a dominant species in Croatia's lowland and hilly areas. It is known for its strong and durable wood, historically used in construction and furniture making.
- Sessile Oak *(Quercus petraea):* similar to the pedunculate oak, the sessile oak is found in the higher altitudes and is common in the woodlands of Croatia.
- Hornbeam *(Carpinus betulus):* common in the forests of Croatia, especially in the lowland and hilly areas, hornbeam is often found in mixed forests alongside oaks and beeches.
- Black Locust *(Robinia pseudoacacia):* native to North America but widely naturalized in Croatia, black locust is used for timber production, particularly in the construction of railway ties, and is also used in afforestation projects.
- European Ash *(Fraxinus excelsior):* ash trees are found in Croatia's forests, particularly in the river valleys and lowlands. Ash wood is commonly used in furniture making and tool handles.
- Silver Linden *(Tilia tomentosa):* this species of linden is found in warmer areas of Croatia. The wood is used in carving and making traditional products like musical instruments and furniture.
- Chestnut *(Castanea sativa):* chestnut trees are found in many parts of Croatia, particularly in the coastal and hilly regions. The wood is valuable for furniture making and construction, and the nuts are an important food source.

Coniferous Tree

- Scots Pine *(Pinus sylvestris):* a widespread conifer in Croatia, Scots pine is particularly common in the mountainous and coastal regions. It is used for timber production, especially for construction and paper manufacturing.
- Black Pine *(Pinus nigra):* black pine is found in the Dalmatian coastal regions and is valued for its durable wood. It is commonly used in the production of high-quality timber.
- Norway Spruce *(Picea abies):* spruce forests are common in the higher elevations of Croatia. The wood is primarily used for construction, paper, and furniture manufacturing.
- European Silver Fir *(Abies alba):* silver fir is common in the mountainous regions of Croatia, especially in the central and northern parts. It is used for timber and paper production.
- Aleppo Pine *(Pinus halepensis):* found along Croatia's Mediterranean coast, Aleppo pine is well-suited to the dry, rocky conditions. It is used for timber and resin production.
- Cedar *(Cedrus libani):* while not as widespread as other species, Lebanon cedar is found in some coastal areas, primarily for ornamental and reforestation purposes.

Other Notable Species

- Mountain Pine *(Pinus mugo):* found mainly in the higher elevations of Croatia's mountains, mountain pine is a smaller, shrubby species used for forestry and soil erosion control.
- Juniper *(Juniperus communis):* this evergreen shrub/tree is commonly found in the coastal and mountainous regions of Croatia, especially in rocky and dry areas.

2.3.2 Croatian local wood species used for nautical applications

In terms of employment, in Croatia local wood has a long tradition of being used in various industries and crafts, due to its availability and the diversity of tree species found in the country.

As Croatia is quite famous for its strong maritime heritage and nautical tradition, also ship- and boatbuilding relies on the employment of several species of local woods. Local species like pine, oak, and larch has been traditionally used to build wooden boats, especially along the Dalmatian coast. These species are valued for their strength, durability, and resistance to the marine environment.

Specifically, oak is valued for its robustness and water resistance, used in the load-bearing structures of boats, whereas elm is chosen for its toughness and flexibility, ideal for components subjected to mechanical stress. Ash is used for its elasticity, particularly suitable for oars and parts subject to torsion, and pine is employed for its lightness and ease of processing, often used for secondary or interior elements.

These local woods have traditionally been used in the construction of boats such as the *batana*, wooden hulls employed by fishermen along the Adriatic coast, including the Rovinj area. Furthermore, wooden boats, including traditional vessels like the *gajeta* and *bracera* are still maintained and restored using local wood.

However, it is important to note that with advancements in technology and materials, the exclusive use of local woods has declined. Today, shipyards such as Marina Punat boatyard offer comprehensive repair and maintenance services for various types of boats, utilising a combination of traditional and modern materials to ensure quality and durability.

In terms of forests exploited for the harvesting of timber to be used in ship constructions, it is crucial to mention the fores of Montona. This extends along the valley of the river Quieto, from the Istrian Spa to Livade and along the valley of the Botonega basin. Covering an area of 275 hectares, in 1963 it was declared a special reserve of forest vegetation. Montona forest was mostly rich in oak wood and, during the golden age of Serenissima, depended directly on the Council of Ten through Provveditori living in Venice. In fact, in 1537, the forests in Montona came under the direct control of Venice.The interest towards the Montona forest was related to the rich presence of oak wood, whose importance for Venice was “foundational” as oak was renown as the most resistant wood to the corrosion of sea water. Galleys, galleons and frigates were built over time with the oaks and ash trees of the forest. Montona oak was then exploited also by the Austro-Hungarian Empire. Josef Ressel, known in the Central European world as the inventor of the ship's propeller, in the 19th century drew up an impressive study on the oaks of the forest which was slowly thinning out.

3. Raw Market Analysis

3.1 Key aspects and threats for the implementation of a wood supply chain based on local species

3.1.1 Key aspects of a local short supply chain

As emerged in LIFE CO2PES&PEF Project, 2023, the local short supply chain for wood procurement is based on a sustainable approach that contributes to climate change mitigation by promoting the efficient use of national forest resources. Sustainable forest management (https://www.fao.org/forestry/sfm/en) plays a key role by increasing CO_2 absorption and enhancing the value of wood through a circular economy model. In this context, cascading use of wood is an essential principle for optimizing its use, reducing import dependence and improving the circularity of production processes.

In order to ensure an effective organization of the short supply chain, structured forest planning is essential, including the adoption of management plans geared toward optimizing forest resources. The transformation of coppice forests into high-trunk forests makes it possible to obtain timber of higher quality, more suitable for durable production and of greater economic value. Certification and traceability are indispensable tools for ensuring the sustainability of the entire process. In this regard, the Forest Stewardship Council (https://anz.fsc.org/) and the Programme for the Endorsement of Forest Certification (https://www.pefc.org/) schemes ensure that the wood comes from responsibly managed forests, while an up-to-date forestry information system allows for accurate monitoring of harvesting and raw material use.

Another key element is the need to facilitate the matching of supply and demand through the creation of platforms, both physical and digital, that facilitate the marketing of wood. The promotion of innovative products is an opportunity to increase the value of domestic timber by incentivizing its use in strategic sectors. In addition, to make the short supply chain competitive, a system of incentives and financing is essential, including facilities for forestry and wood processing companies. Economic support can come both from public sources, through rural development programs and national funds, and from private investors interested in sustainability, such as ecosystem credit companies.

Overall, the local short supply chain for wood supply represents a concrete opportunity to enhance the national forestry heritage, improve forest resource management and strengthen the economy of the sector, with both positive environmental and socio-economic impacts

3.1.2 Main issues threatening the development of a local short supply chain

In spite of the benefits reported in the previous section, the local short supply chain for wood procurement has several critical issues that hinder its development and diffusion on a large scale. With specific reference to Italy, one of the main problems is the low utilization of domestic timber, despite the fact that Italian forests have significant production potential. Currently, 80 percent of the wood processed in Italy comes from abroad, which highlights a high dependence on imports and poor application of the cascading use principle (https://www.working-process.com/en/italy-is-the-third-largest-importer-of-wood-and-derivatives-in-the-eu/).

Most of the reasons for this poor exploitation of Italian local wood directly concern the national bureaucracy in terms of issues related to forest control and management of wooded areas, including the following ones:

- cumbersome Italian laws in the field of concession of woodland territories;
- poor technical preparation of forestry operators;
- difficulties in mechanizing the woods, steep and particularly steep terrain make it difficult to extract wood unless using expensive and demanding techniques;
- 67% of Italian forests are privately owned and consist of land measuring between 2 and 3 hectares.

The main problem is therefore the management of forest lands which, although private, could be coordinated by a control program in order to facilitate private owners by removing excess material, cleaning the area and, at the same time, providing material to the wood industry, as at a national level 81.3% of the total forest area is available for wood harvesting.

The phenomenon of wood importation is exacerbated by the lack of adequate planning and up-to-date data on available forest resources, factors that are essential to ensure efficient management of the forest stock and to ensure continuity of supply to processors.

Economic and infrastructural difficulties pose an additional obstacle to the short supply chain. Work-wood production, which requires careful forest management and longer growth times, is often less profitable than the production of firewood or biomass for energy use, which offers more immediate economic returns. In addition, the local supply chain suffers from a lack of investment in improving the logistics network, processing technologies and training of forestry workers, which are key aspects in ensuring greater competitiveness of the sector. Another issue is the strong unevenness in forest management among different Italian regions. Since forestry legislation is a regional responsibility, there are significant differences in the regulation of forestry activities and training courses for forestry professionals. In some areas, the lack of knowledge of national and European standards on sustainable forest management undermines the efficiency of the system and creates disparities between territories, making it difficult to implement common strategies for the revitalization of the supply chain. Additional weakness is added by the limited availability of incentives and financial support. Public funds for sustainable forest management are often insufficient and tied to European funding, making their use uncertain in the long run. The difficulty in attracting private investors further limits the possibilities for growth of the local supply chain.

Finally, the short wood supply chain is struggling to revive due to the lack of processing plants close to production sites, making it difficult to process the material locally. To overcome this obstacle, it would be necessary to encourage networking among producers, sawmills and companies in the sector, stimulating the emergence of a more dynamic and efficient market. Without targeted interventions, these issues will continue to hold back the development of a local short supply chain, reducing opportunities for economic growth and enhancement of the national forest heritage.

3.1.3 Examples of local short supply chains: Italian and Veneto chains

Italian wood local supply chain

The supply chain consists of 4 actors: the forest ownership composed of private individuals, public (municipalities, regions, state), and communal bodies, the forest business companies, the first processing or sawmills, and the second/third processing (carpentry, joinery, etc.), as explained in [14].

In the first link of the supply chain, namely the forest property, we are confronted with the procurement of raw material, technically speaking roundwood. The properties must then guarantee the supply of raw material, in terms of volume and quality. The critical issues of this link are multiple, as so the players involved in it. The second ring consists of the business companies related to forestry, responsible for felling and sometimes transporting roundwood. This also represents a very diverse sector, with the presence of a few firms specializing in forestry activities and many small farms and artisanal companies. The third link, first processing (sawmills), is currently the weakest part of the supply chain, while the fourth link is the most solid and healthy one and is representative of second/third companies processing (carpenters, joiners, and furniture makers).

The wood supply chain consists of a sequence of processes that lead from the forest to the finished product. This analysis first needs to clarify what the outputs of each stage of the wood production chain are. For better guidance in the following description, the wood supply chain will be divided into three macro-phases: forestry, artisanal/industrial and commercial ones.

The first macro-stage of the supply chain is composed of forests that supply raw material to primary processing plants. The forest property, in Italy is represented by both public bodies and private companies, often small or family owned. The property, in order to carry out the function of supplying roundwood, needs specific reference figures, namely agronomists and foresters, in charge of carrying out the bureaucratic procedures necessary for uses, ensure the functionality of the forest road system and often also manage the sale of roundwood. This figure is the interface between the property and the forestry companies that are responsible for cutting/felling, logging/fitting, and transportation to the sawmills.

The second macro-phase consists of the first/second/third wood processing companies. Included in this macro-phase are sawmills having the purpose of procuring roundwood and producing the sawn timber for the subsequent stages.

The third macro-phase concerns the distribution of finished products in the market: the main sector related to the wood supply chain in Italy is the furniture sector. This sector has as its first characteristic that of having, in general, a ‘short’ supply chain as regards wood raw material. In other words, furniture companies locate themselves relatively close to wood suppliers, reducing the average supply distance.

Veneto wood local supply chain

The Veneto wood supply chain has characters very similar to the model presented of the previous paragraph [14]: by performing the cutting of logs in the Veneto forests, the raw material is obtained, which is temporarily

deposited at the forest or at the first processing centres. Once the wood is ready to be processed, the raw material is transformed into sawn timber thanks to first processing plants. The sawn timber then follows the production processes that make the finished products, which are then distributed and marketed.

Forest formations in Veneto that mainly affect the timber sector are beech forests, spruce forests, fir forests, and man-made formations (Patrimonio Forestale. In Direzione generale delle foreste Mipaaft, 2018).

The first macro-phase of the supply chain in Veneto sees 30% of forest ownership entrusted to public entities, mostly represented by municipalities, state and regional domains. The single and collective private property constitutes about 70% of forest properties in Veneto. In this stage of the supply chain, forestry-processing enterprises play a key role. In accordance with the classification given by the Veneto region, a forestry enterprise is defined as any economic operator that performs work and services in forestry, i.e., activities that include forest utilization work, processing and marketing of woody material.

The second macro-phase of the supply chain is represented by the first processing enterprises specializing in the activity of sawing roundwood and mostly composed of individual or family-owned micro-enterprises. In this macro-phase, the sawmill is placed in the production process of the supply chain as an actor that processes the raw material and produces sawn timber as rough planks (wooden planks and solid beams). Semi-finished products follow the production process in second and third processing plants.

Veneto is the first Italian region in terms of employees and turnover in the furniture sector, and the proximity to the source of raw material used confirms the number of companies involved present in the region. However, the proximity to the source of raw material is not reflected in the dynamics of the supply chain, as processing companies very often do not purchase the raw material or semi-finished products in Veneto or Italy, but do so from abroad. The most involved provinces are Belluno, Treviso and Vicenza, which are home to most of the companies involved in the wood supply chain in Veneto.

As Figure 22 shows, the breakdown of firms among the various provinces outlines the clear propensity for firms in the Veneto region to deal more with the manufacture of wood products and furniture manufacturing, rather than with the cutting and planing of wood. This is represented by the ATECO classification reported in the table, where the ATECO code is a type of classification of economic activities adopted by the Italian National Institute of Statistics (ISTAT) mainly for the purpose of economic statistical surveys of national importance. The specialization of companies toward the production of semi-finished products and wooden furniture coincides with the strong competitiveness of overseas business contexts. In other words, the second macro-phase of the Veneto wood supply chain sees more firms involved in wood semi-finished wood processing than in roundwood processing, a sector in which foreign industrial complexes have a greater competitive advantage.

The third macro-phase involves the distribution of the finished product to markets: the production is marketed both in the national territory and in foreign markets. Most of the production is destined for the Italian market (55% share), while the remaining 45% of the added value produced in the wood sector in Veneto is exported to the European continent (about 31%) and to the rest of the world (for 14%) as sourced from ISTAT data.

ATECO subdivison 2017	Belluno	Padova	Rovigo	Treviso	Venezia	Verona	Vicenza	Total	
								2017	2018
CC161 Wood cutting and planing	36	58	20	102	27	63	86	**392**	**412**
CC162 Manufacture of products from wood, cork, straw and weaving materials	236	571	83	629	332	471	563	**2,885**	**2,946**
CC311 Furniture manufacturing	132	667	74	948	231	847	561	**3,460**	**3,578**

Figure 22 - Active enterprises in 2017 subdivided in terms of ATECO code [14].

The main difficulties within the supply chain stem from forest resource management, business structure and organizational limitations. Forest ownership is highly fragmented, with 70 percent of forests in private hands, often divided into small plots, and only 30 percent managed by public agencies. This subdivision hinders effective and planned resource management. Forest area planning is still not complete throughout the country, and forest roads are insufficient to allow the use of modern means for logging. Forest enterprises in the area are small in size and have a low level of mechanization and innovation. The lack of certifications and the complexity of administrative processes to obtain cutting permits create additional obstacles. This imbalance between timber availability and actual harvesting capacity prevents effective utilization of the local raw material. Difficulties also emerge in the later stages of the supply chain: first-processing companies, such as sawmills, struggle to source certified local wood, while second-processing companies, which produce semi-finished and finished products, depend heavily on imports.

These internal problems are compounded by external challenges, including strong international competition and lack of infrastructure investment. Austria and Germany, with their more competitively priced supply of lumber and semi-finished products, pose difficulties for companies in the Veneto region, especially at the initial processing stage. The lack of processing facilities and logistics dedicated to concentrating lumber is a further obstacle, pushing many local companies to purchase raw material from abroad instead of exploiting regional resources. The absence of effective national and regional policies has further weakened the sector, favouring the logic of the free market and contributing to the loss of entire production sectors. The weather event of storm Vaia, which occurred in 2018, aggravated the situation, making available huge quantities of timber that companies in the Veneto region were unable to process or market. As a result, much of the damaged wood was exported, mainly to China, highlighting the territory's poor ability to manage its resources independently.

The lack of coordination among supply chain actors leads to a disconnect between supply and demand. On the one hand, problems with forest planning and management hinder logging operations and the first stages of processing; on the other, second-processing companies must turn to foreign markets to source raw material.

However, the Veneto system also has strengths, such as a high degree of specialization of microenterprises. A model based on a widespread network of small companies could ensure greater product customization and

better-quality control, but to do so requires improved coordination among the various segments of the supply chain. As a measure to strengthen the wood sector in Veneto, the development of an integrated supply chain model would allow for more efficient management of resources and greater coordination between forestry companies, sawmills and second-processing companies. Investment in the mechanization of forestry companies would improve productivity and the capacity to harvest local wood. The strengthening of forestry and logistics infrastructures, with improved forestry roads and the creation of wood collection and processing centres, would favour greater valorisation of territorial resources. The creation of a widespread system of sawmills, supported by a centralized consortium hub, would guarantee a constant flow of sawn timber and semi-finished products, increasing processing efficiency. The promotion of local wood certification would make the product more competitive on the market, while regional and national support policies would reduce dependence on imports and encourage the processing of Veneto wood within the territory.

Friuli Venezia Giulia wood supply chain

Friuli Venezia Giulia has a long tradition of wood processing, thanks to the presence of extensive forested areas and a well-organized production system (https://www.filieralegnofvg.it/home/). The local wood supply chain encompasses several stages, from forest management to processing and transformation of the material to finished products for various sectors [16].

The tree species covered include spruce, used for the production of lumber, panels, beams, musical instruments and packaging, and silver fir, used in the production of beams, building panels, furniture and paper. Beech finds application in the production of furniture, flooring, plywood, musical instruments, and charcoal, while larch is valued for making outdoor structures, fixtures, piers, and boats because of its resistance to weathering. Ash is processed to create furniture, sports equipment, musical instruments and flooring, while chestnut is used for beams, furniture, vineyard poles and fences because of its high resistance to rotting. Finally, lodgepole pine is used in the production of window frames, rustic furniture, construction and packaging.

The wood supply chain in Friuli Venezia Giulia is developed through several stages. Forest management and harvesting take place in accordance with environmental sustainability, following the principles of silviculture and FSC and PEFC certifications. After cutting, the wood is transported to sawmills to be processed into beams, boards or panels. Next, the material undergoes drying and treatment processes to improve its strength and durability. From there, semi-finished and manufactured products are produced for various uses, including furniture, fixtures and musical instruments. Finally, the processed wood is distributed to the local, national and international markets, contributing significantly to the local economy.

A key aspect of the wood supply chain in Friuli Venezia Giulia is the focus on sustainability, with reforestation programs and efficient use of resources. In addition, the sector is investing in innovation, introducing new technologies for wood processing and developing environmentally friendly and high-performance materials. Thanks to the quality of timber and the professionalism of local companies, the region is confirmed as a reference point for the wood industry nationally and internationally.

The enterprises involved in this local wood supply chain are reported below, subdivided in terms of the different stages to which they contribute.

First transformation

- F.lli De Infanti snc. Via Val Calda 1, Ravascletto (Udine);
- Vidoni. Via Pontebbana 46, 33010 Montegnacco di Cassacco (Udine);
- Cooperativa Agricola Forestale Alto But Soc. Coop. Via Roma 43, 33020 Treppo Carnico (Udine);
- Gaspari S.r.l. V.le Basilio di Ronco, 33020 Sutrio (Udine);
- Legno Servizi Società Cooperativa. Via Div. Garibaldi 8, 33028 Tolmezzo (Udine);
- Segheria Cortolezis Rag. Luigi Elio. Via Roma 29, 33020 Treppo Carnico (Udine);
- Segheria Degli Uomini Primo. Via Canal del Ferro - Zona Artigianale Carnia, 33010 Venzone (Udine);
- Segheria Rovis Fiorindo. Via Brasil 91 Z.I.S., 33028 Tolmezzo (Udine);
- Boschive Martin Luciano. Via Statale 4, 33023 Comeglians (Udine).

Second transformation

- F.lli De Infanti snc. Via Val Calda 1, Ravascletto (Udine);
- Legnolandia. Via Nazionale 280, 33024 Forni di Sopra (Udine);
- Vidoni. Via Pontebbana 46, 33010 Montegnacco di Cassacco (Udine);
- Casanova e del Fabbro & C. s.n.c. Via Gladegne 3, 33020 Cercivento (Udine);
- Gamma Legno S.n.c. Via P. Candoni 4, 32020 Amaro (Udine);
- Gruppo Franceschino Loris S.r.l. Via Trasaghis 180, 33013 Gemona del Friuli (Udine);
- Legno Servizi Società Cooperativa. Via Div. Garibaldi 8, 33028 Tolmezzo (Udine);
- Tarussio geom. Antonio. Via G. da Udine 39, 33027 Paularo (Udine);
- Xila Holzwerk srl. via Patuscera di Entrammo 64, 33025 Ovaro (Udine).

Third transformation (wooden buildings)

- DomusGaia.
  Registered office: Piazza Mazzini 1, Tricesimo (Udine); Operating office: Via Zanini 27, Cassacco (Udine).
- F.lli De Infanti snc. Via Val Calda 1, Ravascletto (Udine);
- Legnolandia. Via Nazionale 280, 33024 Forni di Sopra (Udine);
- Vidoni. Via Pontebbana 46, 33010 Montegnacco di Cassacco (Udine);
- Casanova e del Fabbro & C. s.n.c. Via Gladegne 3, 33020 Cercivento (Udine);
- Edilteco S.r.l. Via Brasil 20, 33028 Tolmezzo (Udine);
- Gruppo Franceschino Loris S.r.l. Via Trasaghis 180, 33013 Gemona del Friuli (Udine);
- M.S.M. di Straulino Sergio & C. S.n.c. Via Peschiera 20, 33020 Sutrio (Udine);
- Xila Holzwerk srl. via Patuscera di Entrammo 64, 33025 Ovaro (Udine);
- Zanini Legnami. Via A. Candoni, 29 z. i. sud, 33028 Tolmezzo (Udine).

3.2 Timber market analysis

3.2.1 Availability of wood from local forests

This section of the Deliverable aims at providing a first overview of the local species of wood that are nowadays available on the market and are part of the timber local supply chain in the area on which the TOFOLA project is focused, i.e., Veneto and Friuli Venezia Giulia regions and Croatia.

Veneto region

The attention is focused on those species of wood that can be of great interest to both the boatbuilding sector, which still represents a symbol of the Venice lagoon, and the other fields that are involved in the third link of the Veneto timber supply chain.

From the screening of the local forests presented in Section 2.1.1, the following types of wood are particularly interesting for the restoration and strengthening of a local wood supply chain: beech is crucial for its importance in the wooden boatbuilding sector for oar production, while Norway spruce, larch and chestnut for the widespread employment in the manufacturing of furniture.

Based on this wood essences, the project CORE-WOOD developed by Rete Innovativa Regionale Foresta Oro Veneto [14] implemented a first proposal for a supply chain based on timber coming from different areas (Cadore-Comelico, Val di Zoldo, Asiago plateau, Cansiglio, and Dolomites forests) to be sold under the brand "Legno Veneto". Each wood species mentioned above corresponds to a specific area where these forest categories are present in abundance, so as to guarantee the volumes required by a sawmill, and the processing and transport would be limited within a valley. The brand "Legno Veneto" is linked to the namesake Consortium that brings together in a single organization the Local Authorities and the Region, the private and public forest owners, the forestry companies, the wood processing companies, the carpenters, the builders of wooden buildings, the joiners, the furniture factories and all the institutions and entities of the supply chain that acting toward the development of the territory and the exploitation of its resources. The importance of the Consortium is witnessed also by the interview performed to Montagna Legnami S.r.l., a wood supplier from Veneto region that underlines how building sectors, and also boatbuilding industries, are interested in local wood [17].

The main properties of the wood essences involved in the Veneto local supply chain with reference to their peculiar aspects for processing of raw timber are reported below.

- **Norway spruce from Cadore-Comelico forests:** this is the most widespread plant species in the Alps and produces a product with a light colour, honey-coloured tones, characterised by a light and soft wood, easy to work, with fast and unproblematic drying. Given its versatility in use, Norway spruce is the most important construction wood, solid or laminated. It can be used for interiors, semi-finished products, service structures (scaffolding, armatures), external cladding, windows and doors, interior wall and ceiling cladding, packaging, furniture and musical instruments (see resonance wood). Norway spruce is the main raw material for the production of cellulose, for panels obtained with wood chips,

and for energy use, both in the form of wood chips and in the form of sawdust which is processed for the production of briquettes or pellets.

- **Norway spruce from Asiago plateau forests:** this timber has a light colour with pinkish white shades, and it is easy to work given its low weight and elasticity. It is used in many processes: in particular, in its area of origin, building materials (solid wood), packaging materials and wooden window and door frames are produced.
- **Larch from Val di Zoldo forests:** this is the only Eurasian conifer that is deciduous, very long-lived (up to 800 years) and is generally cut between 100 and 140 years if pure/isolated, whereas if in association with red fir/silver fir the cutting calendar will respect the rotations of these species (100-120 years). Larch has a colour that varies from light brown to intense red-brown. Val di Zoldo larch is characterized by shades tending to bright red. In general, its wood is used for both exteriors and interiors. Given its characteristics of durability and flexibility, it is used for construction in contexts subjected to both mechanical and meteoric stress: construction of boats, bridges, underground and underwater parts. As for interiors, it is mainly used for windows (doors and windows), floors, coverings and furniture. in terms of supply chain, the larch coming from Val di Zoldo forests already has a registered trademark with a logo and a brand name that identify the certified origin of the raw material. Furthermore, the Val di Zoldo is inserted in a production chain having complete traceability of the product and of the companies involved.
- **Deciduous trees from Cansiglio and Dolomites forests (beech and chestnut):**
  - Beech is light-coloured but can take on a pinkish colour through vaporization and drying; it can also be coloured easily, allowing customization of the final product. It is a heavy and hard wood, with poor stability in shape when humidity varies (it deforms with humidity). It is easy to work, whether it is peeling, cutting, bending, milling, carving and turning. Due to its characteristics, beech is not particularly durable. It is used for the construction of furniture and interior furnishings: chairs, veneer and plywood, stairs and parquet, toys, kitchen utensils and other utensils, panels of wood material.
  - Chestnut of Dolomites is medium heavy (characterised by a high density) and is brown-coloured. It is difficult to dry, with good workability and good durability. Chestnut wood is generally used as a material for interior and exterior construction, for boats and structures in contact with water. It is also used for veneer, for coverings and parquet.

In addition to what explained above regarding the experience of “Legno Veneto” Consortium, further considerations might be made regarding the potential use of local wood species for boatbuilding. Among all the essences present in Veneto that could be used for the production of boards intended for the boat construction, the following species emerge:

- **Larch and Oak:** Traditionally used for the construction of hulls and load-bearing structures due to their resistance to humidity and favourable mechanical characteristics;
- **Ash and Beech:** used for internal parts or light structural elements;

- **Spruce:** very common tree, but less resistant to humidity, therefore suitable for parts not directly exposed to water.

However, although these species are present in Veneto, Gatto et al., 2021 emphasizes that much of the wood used comes from abroad (Austria, Slovenia, Croatia, France), especially due to the poor local availability of wood that can be worked on a large scale [7].

Belluno province

Within the Veneto region, particularly significant is the wood supply chain belonging to the Belluno province [18], which is in an area that can count on a rich presence of forests as emerged from Figure 14. Specifically, of all the wood employed in Veneto region, 56.1% comes from the Belluno province (Figure 23). Another crucial number is represented by the percentage of enterprises that uses Italian wood, as shown in Figure 24 (with reference to the 127 enterprises interviewed). In terms of timber import from foreign countries, Austria is the main reference nation for companies in the Belluno area, followed by Germany and Slovenia. Of lesser importance are Bosnia/Herzegovina and Croatia.

Another important parameter to evaluate the goodness of the wood supply chain it is the possession of specific certifications that can attest to the high quality of the harvested and processed wood. 27% of the interviewed companies adhere to forest certification standards that guarantee that the wood employed for their products comes from sustainably and responsibly managed forests. The value of this index is significant for sawmills, as 75% of them have a certification attesting to the quality of the wood.

Despite the relevant numbers exposed above, most of the timber production is exploited by the industrial sector related to the manufacturing of wooden furniture, with just 6.3% of companies that can be classified as sawmills for the production of semi-finished wood [18].

In terms of destination market, the regional market is extremely important (Figure 25). Over 80% of the turnover of the supply chain comes from products/services intended for Veneto customers/users. 13% of production is directed outside the region, while remaining in Italy. Only 6.2% of the turnover comes from sales abroad. Sawmill products account for 4% of the export market.

In terms of microspecies, conifers are the main wood trees processed in the company (52.2%), followed by broadleaves from temperate zones that represent 44.8% of the total (Figure 26). Together, these two species correspond to 97% of the type of wood used. Broadleaves from tropical zones have a marginal incidence (less than 2%). Larch, spruce and white fir are the three types of wood most frequently used by companies in the supply chain, as together they represent almost 50% of the input used by companies in Belluno province. These types of wood have with similar characteristics suitable for use in the construction of furniture, packaging, panels, tables, as well as for use in construction. Among the family of broadleaf trees coming from temperate zones, the most relevant are beech (8.2%), ash (7.3%) and oak (6.2%). Finally, the broadleaf trees from tropical zones most used are Mahogany and Teak in marginal quantities.

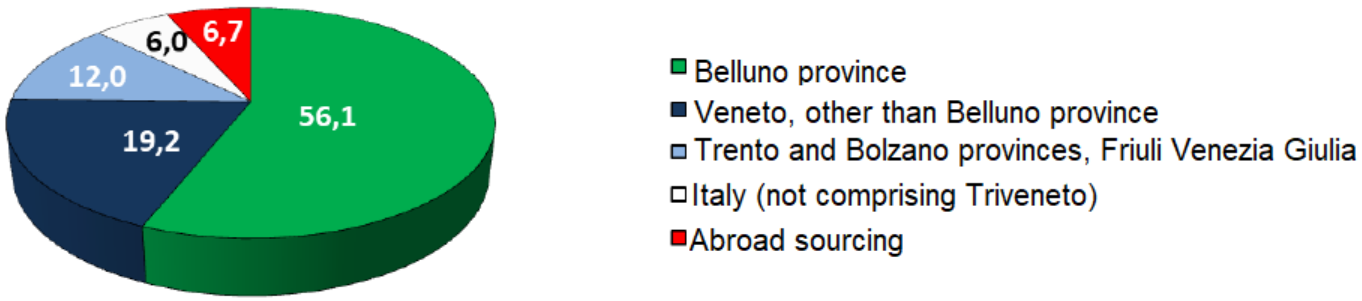


Figure 23 - Origin of wood employed in the Veneto region [18].

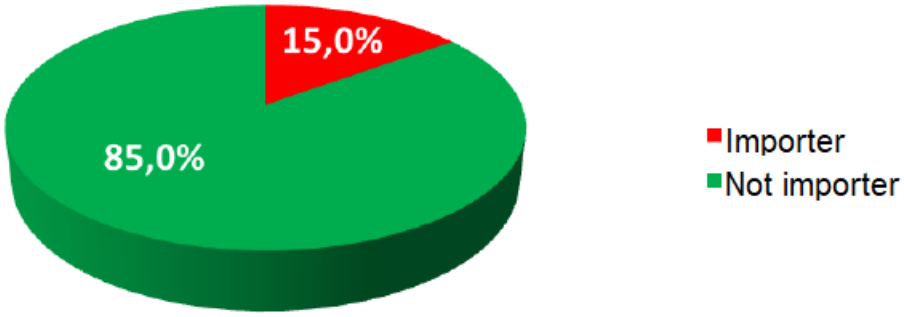


Figure 24 - Enterprises that use local wood (among the 127 interviewed in [18].

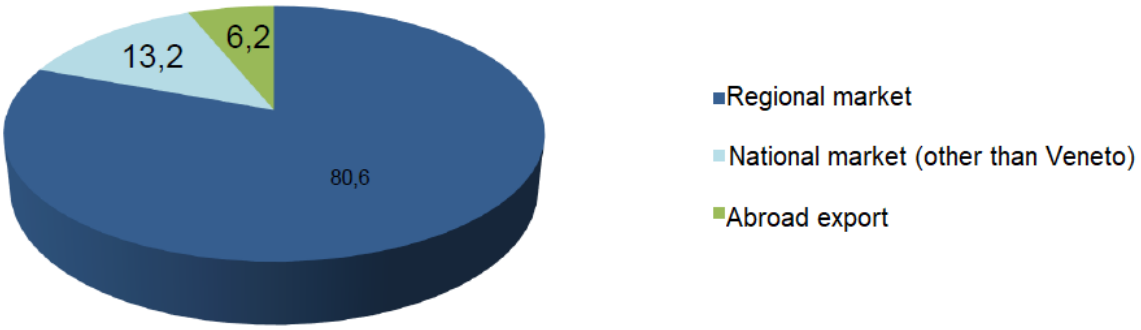


Figure 25 - Destination market with reference to 2019 annual turnover [18].

Category and species	Frequence	% on total coniferous	% on total species
Larch *(Larix)*	98	35.0	18.3
Spruce *(Picea abies)*	83	29.6	15.5
White fir *(Abies alba)*	72	25.7	13.4
Scots pine *(Pinus sylvestris)*	14	5.0	2.6
Swiss stone pine *(Pinus cembra)*	12	4.3	2.2
European yew *(Taxus baccata)*	1	0.4	0.2
Total coniferous	**280**	**100**	**52.2**
Beech *(Fagus)*	44	18.3	8.2
Ash *(Fraxinus)*	39	16.3	7.3
Oak *(Quercus)*	33	13.8	6.2
Walnut *(Juglans)*	27	11.3	5.0
Birch *(Betula)*	22	9.2	4.1
Poplar *(Populus)*	21	8.8	3.9
Maple *(Acer)*	18	7.5	3.4
Chestnut *(Castanea)*	14	5.8	2.6
Elm *(Ulmus)*	13	5.4	2.4
Hornbeam *(Carpinus)*	7	2.9	1.3
Cherry tree *(Prunus)*	1	0.4	0.2
Pear tree *(Pyrusr)*	1	0.4	0.2
Total broadleaves from temperate zones	**240**	**100**	**44.8**
Mahogany *(Swietenia)*	3	33.3	0.6
Teak *(Tectona grandis)*	3	33.3	0.6
Meranti *(Shorea)*	1	11.1	0.2
Rosewood *(Dalbergia)*	1	11.1	0.2
Other precious essences	1	11.1	0.2
Total boradleaves from tropical zones	**9**	**100**	**1.8**

Figure 26 - Tree species in the timber supply chain of Belluno province [18].

3.2.2 Pricing of wood from local forests

A thorough analysis of the local timber market for boat construction must include a survey on the potential purchase costs of the most in-demand species among end users. With reference to the local timber supply chains in Veneto and Friuli Venezia Giulia, the study has focused primarily on the market for high-quality timber that can be used in the artisanal boatbuilding sector.

Gathering data on the cost of different species has proven to be a complex task, despite consulting several timber suppliers in the relevant areas. However, the survey is still ongoing, and further updates to this section

of the Deliverable are not excluded, as they may provide additional valuable information for mapping the local supply chain. The main data reported below comes from several sources: reports related to other research projects, institutional reports and statements, as well as the answer to specific surveys given by wood suppliers.

Preliminary interesting information can be extracted by the research performed within the project called "Increase Biodiversity through Wood Production - LIFE+ InBioWood", which aimed at increasing and protecting biodiversity in areas where it has been adversely affected by intensive agriculture through the creation of permanent polycyclic plantations (https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE12-ENV-IT-000153/increase-biodiversity-through-wood-production).

One of the most interesting activities carried out within the project was based on the economic analysis of the high-quality timber market present in Veneto region, with specific reference to the wood harvested in the Valli Grandi Veronesi [19]. This geographical area is characterised by high landscape and environmental quality, which has been preserved despite transformation interventions (infrastructure, urban, and industrial) that have mainly affected the Municipality of Legnago and, more generally, the province of Verona.

The analysis, dated between 2013 and 2018, specifically targeted enterprises involved in the furniture manufacturing market, but dealt with high-quality timber that could find application also in the boatbuilding sector. The main types of companies interviewed were timber traders, sawmills, veneer mills, artisans, furniture manufacturers, window and door makers, carpentries, and flooring specialists. The interview involved 45 enterprises and asked questions related to timber market references. The interviewee was asked to list the main wood species of interest to the company (walnut, oak, poplar, fir, ash, beech, etc.) and the annual quantity processed (cubic meters, square meters, tons, etc.). Then, the interview continued by inquiring about the company's usual wood procurement methods (agency, local trader, timber auctions, direct negotiations with local suppliers, other) and, if possible, the geographical area of purchase. The next section asked for details on the average purchase quantity, the seasoning level of the wood at the time of acquisition, and whether the company had the capacity to season it on-site. Finally, the interview included a request for information on the purchase prices of the wood used in production (€ per cubic meter, € per square meter, € per ton, etc.).

Among all the 45 interviewed enterprises, 35 declared to use native plant species that could potentially serve as trees for the production of high-quality timber in permanent polycyclic plantations (walnut, oak, lime, pear, ash, poplar, elm, cherry). However, it should be emphasized that almost all of the interviewed companies stated that, in addition to native species, they also use conifers or exotic/extra-European wood species. As the re-sawn assortment emerged as the timber form primarily used by the interviewees, it was chosen as the reference to compare prices (€ per m^3) between the different species.

As it can be seen from Figure 27, the highest average price was recorded for walnut at €1371/m^3, followed by cherry at €1017/m^3, oak at €887/m^3, elm at €800/m^3 (with only one reference data), ash at €701/m^3, lime at €599/m^3, and finally poplar at €318/m^3.

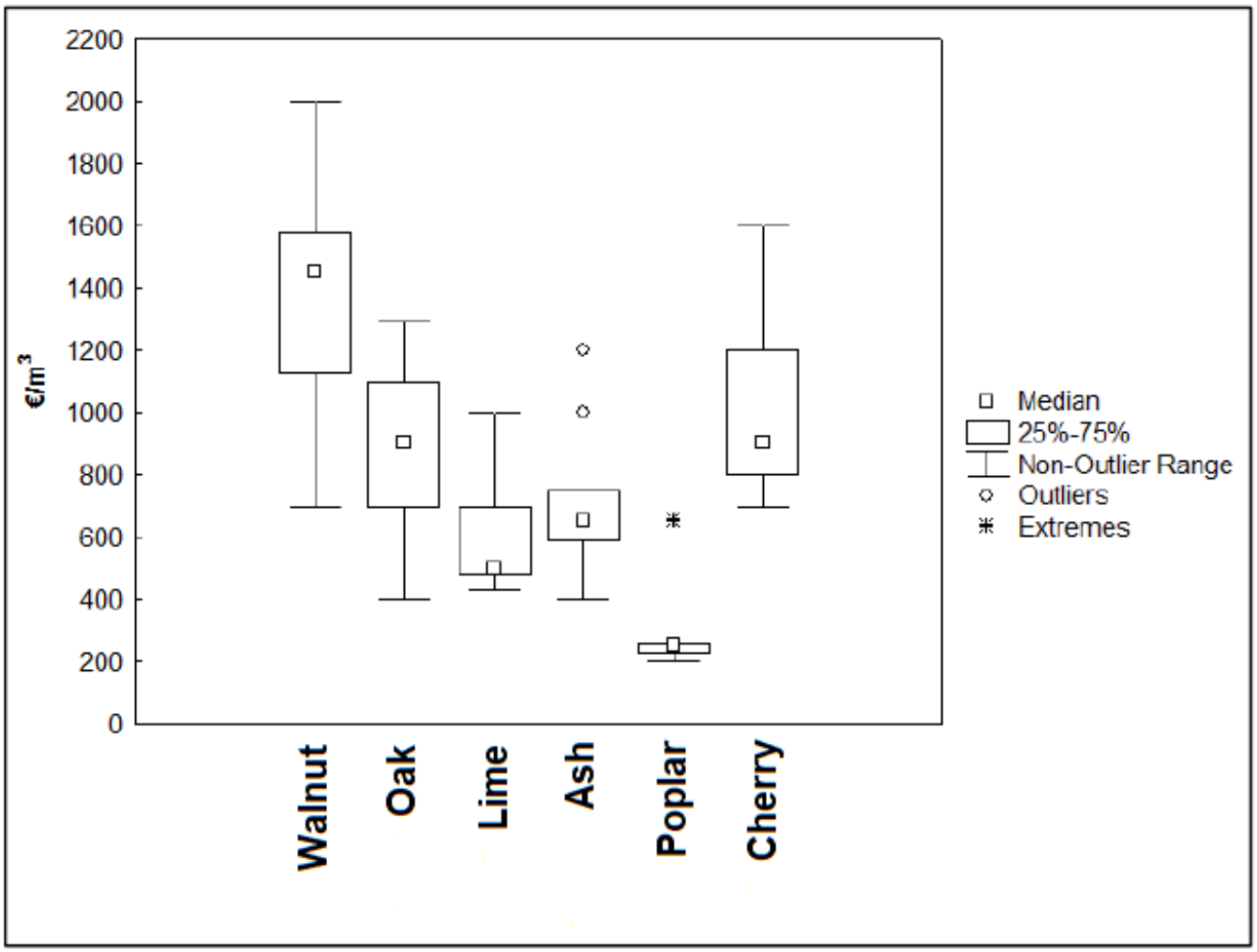


Figure 27 – 2013-2018 price trends for the various species [19].

It is crucial to consider that the price ranges reported in Figure 27 are dated between 2013 and 2018, hence were valid for the pre-Covid period and were not affected by other external events such as the Vaia storm occurred in the last months of 2018 [20]. In fact, the prices of timber coming from local forests has increased during the years, reaching almost double the price of 2018 for some types of essences.

As an example, German data reports that from May 2020 (during the Covid pandemic peak and the contraction in the sector of construction timber sector) to May 2021, for the same volume of material purchased, the cost increased from $250 to $1500 (https://www.ottolinilegnami.com/post/i-prezzi-pazzi-del-legno-2020-2021). Moving to the nearby province of Trento, already severely affected by the Vaia storm, the surge in prices for

roundwood between the 4th quarter of 2020 and the 1st quarter of 2021 was equally striking. This is evident from Figure 28, which shows the trend of the average price and quantity per year/quarter with reference to a single grade assortment of fir and referred to the historical data series 2014-2024. When referring to timber, a single assortment means a selection of wood made up of a single species or beams and pieces of uniform dimensions and quality. This type of assortment is generally chosen to ensure consistency in the wood's characteristics, such as color, grain, strength, and workability, which is particularly important in areas like cabinetmaking, the production of high-quality furniture, or in structural applications where uniformity is crucial. In other words, a single assortment excludes mixtures of different species or timber of varying quality, ensuring that all pieces have similar properties and can be treated in the same way.

The same data related to average prices and quantity are available for fir in form of logs and timber framing, as reported in Figure 29.

Furthermore, [21] provides pricing information also for two other species of wood, i.e., larch and Swiss pine. Both graphs are reported in Figure 30 and Figure 31 , respectively.

Figure 28 - Trend of price and demanded quantities of fir from Trentino region [21].

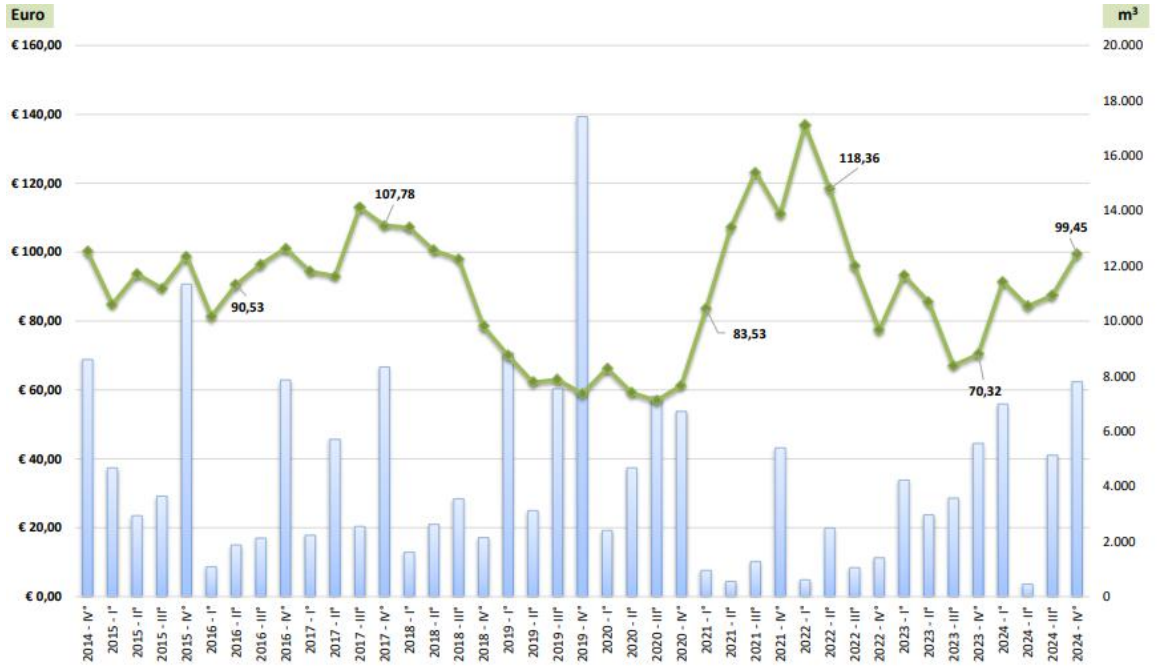


Figure 29 – Trend of price and demanded quantities of fir in form of logs and timber framing [21].

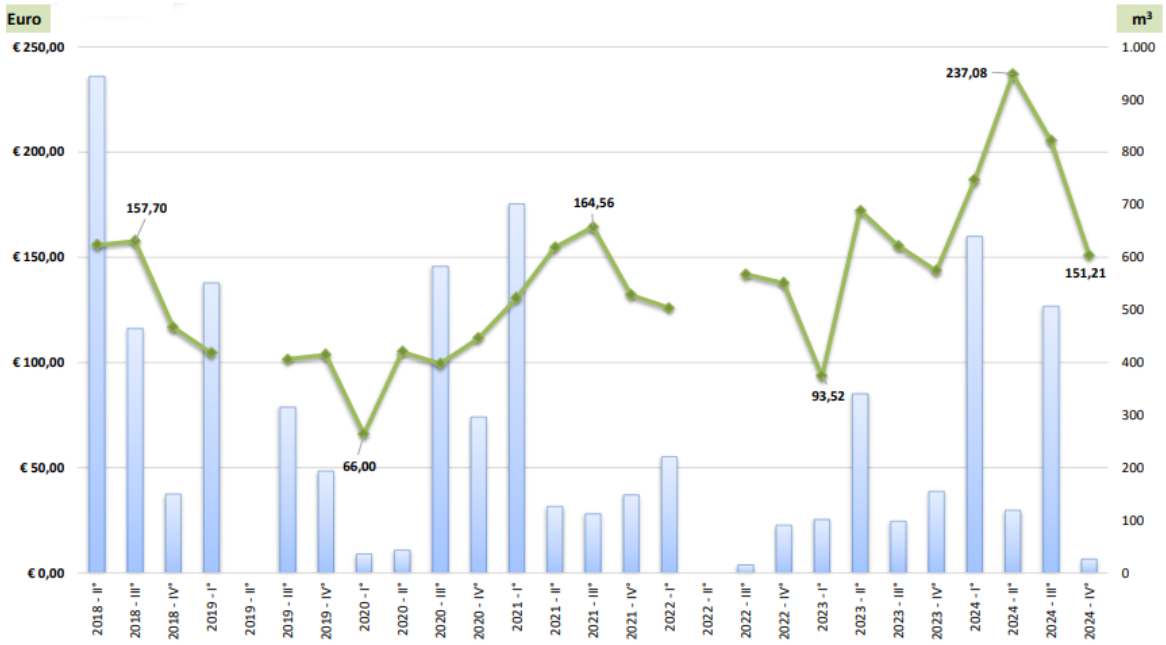


Figure 30 - Trend of price and demanded quantities of larch [21].

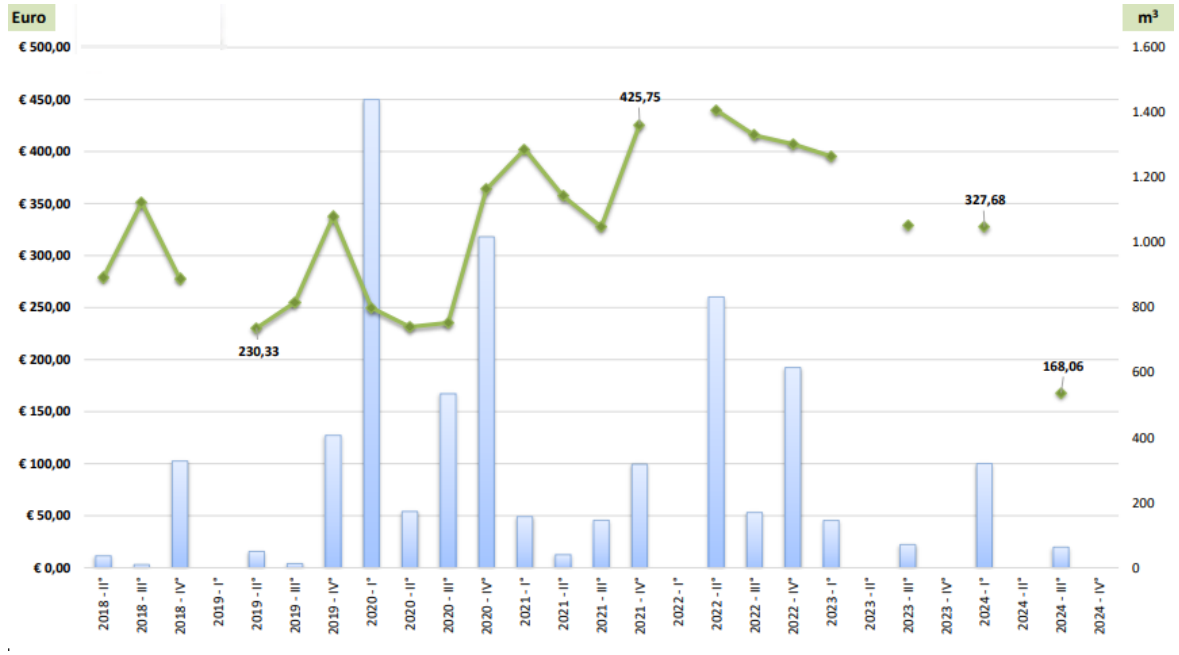


Figure 31 - Trend of price and demanded quantities of Swiss pine [21].

The causes of the increase in timber prices are multiples and related to both socio-economical and natural factors. In recent years, the demand of wood from China and the USA has significantly risen, particularly for construction timber such as spruce and larch, as these countries are able to better absorb the ongoing price hikes. This demand is part of a broader trend, with the USA and China having emerged more quickly and robustly from the health crisis compared to other nations, leading to an early economic recovery, including in the construction sector. This recovery needs raw materials, which the two countries are buying from Europe. Additionally, both countries have undergone a strong push toward sustainable construction, with China's drive being particularly marked as it aimed ad projecting a positive image to promote 2022 Winter Olympics. The supply flow of "foreign" wood to China and USA did not involve producer countries like Canada and Russia. In fact, Canada significantly reduced timber exports to the USA due to Trump's tariffs and an attack by a pest on Canadian forests, which caused the loss of forested areas three times the size of Switzerland in just three years. On the other hand, Russia introduced regulations to prevent the export of raw timber in favour of the export of processed or semi-processed timber. This has led China to secure timber from Europe in advance to support its domestic growth.

Another important factor that specifically interested European wood supply chains was the reduction in timber production in Germany. Over the past 20 years, Germany had significantly increased timber production, expanding production facilities. However, recently, Germany began to reduce timber cutting, returning to pre-boom levels. This is due both to the pandemic and to a problem similar to what Canada was facing. In Germany, as well as in Austria and northern Italy, forests are better managed, and when they suffer from pest

infestations, they act quickly to cut the affected trees to avoid greater losses. Before the health crisis, Germany had already started reducing tree cutting to allow its forests to regenerate and strengthen. Another contributing factor was the growth of sustainable construction in Italy, partly driven by the 110% bonus. Data shown a modest increase of +2.5% in 2011, which grew to +7.5% in 2018, and has further increased in recent periods. This excessive demand, combined with reduced production, created a volatile mix. Finally, the transport limitations during Covid pandemic have also played a role. This has led to reduced supplies for many months, and with the UK's exit from the European Union, additional delays were incurred.

A testimony of the current prices of the timber species most relevant to the shipbuilding sector is provided by Montagna Legnami S.r.l., a wood supplier from Veneto region that was interviewed during the project activities and reported the following values [17]:

- Walnut: 1800-2400 €/m^3;
- Pear tree: 800 €/t;
- Cherry tree: 800-1500 €/m^3;
- Oak: 1000-1800 €/m^3.

4. Production Needs and Sustainability Considerations

4.1 Production Needs

The nautical sector has a longstanding tradition of utilizing wood due to its favourable strength-to-weight ratio, workability, and aesthetic appeal. Selecting appropriate timber types is crucial for ensuring the durability, performance, and economic sustainability of marine vessels. This discussion delves into the primary woods employed in boat building, their sources, procurement costs, and considerations for economic sustainability.

4.1.1 Primary timber types used in boatbuilding

In the following, a recap of the primary types of timber currently used in boatbuilding is reported, along with their main characteristics useful for nautical applications.

- **Teak:** renowned for its exceptional durability and natural resistance to water, rot, and pests, teak is a premier choice for boat decks and high-exposure areas. Its golden-brown hue matures to a distinguished silver-grey over time. However, teak is notably expensive and challenging to source ethically due to overharvesting and political instability in producing regions.
  Plantation-grown teak coming from managed forests or plantations having some kind of certification (FSC) is available but it is quite expensive.
- **Mahogany:** valued for its rich reddish-brown colour and durability, mahogany is frequently used in luxury boat construction. While not as inherently rot-resistant as teak, proper sealing enhances its longevity. Mahogany is relatively heavy and requires diligent maintenance to preserve its integrity. Concerns regarding overharvesting and illegal logging necessitate careful sourcing to ensure sustainability.

- **Iroko:** often referred to as "African teak," iroko offers durability and rot resistance at a more accessible price point than traditional teak. Its dense grain can pose challenges during the working process. Sourced from West and Central Africa, iroko's procurement raises environmental and social concerns similar to other tropical hardwoods, including deforestation and illegal logging. Securing FSC-certified iroko is essential for sustainable use.
- **Cedar:** particularly Western Red Cedar, is prized for its lightweight nature and natural resistance to rot and insects. Its pleasant aroma acts as a natural pest deterrent, and its ease of workability makes it suitable for various boat components. Cedar's straight grain and uniform texture contribute to its aesthetic appeal.
- **Douglas Fir:** known for its excellent strength-to-weight ratio and resistance to decay when treated, Douglas Fir is a versatile and affordable option. Its straight grain and medium to coarse texture make it suitable for structural components such as masts and spars.
- **Mukulungu:** native to Central Africa, mukulungu is esteemed for its density and hardness, making it ideal for structural parts of boats. Its natural resistance to decay and termites enhances its suitability for marine environments. Mukulungu's fine to medium texture and reddish-brown to purple-brown heartwood add to its desirability.

The availability and cost of the above-mentioned timbers are influenced by factors such as geographic origin, demand, and sustainability certifications. Procurement costs may consistently vary, with premium woods like teak commanding higher prices due to their desirable properties and scarcity.

Teak is primarily harvested from Southeast Asia, with significant quantities from Myanmar, India, and Indonesia. Due to overharvesting and political issues, sourcing ethically grown teak is challenging and expensive. Mahogany is sourced mainly from Central and South America. Overharvesting and illegal logging have led to scarcity and increased prices. Iroko can be found in West and Central Africa and, similarly to other tropical hardwoods, it faces challenges related to deforestation and illegal logging. The same aspects are relevant for Mukulungu, while Western Red Cedar' cost and availability are influenced by regional forestry practices and demand. Finally, Douglas Fir is abundantly spread in the Pacific Northwest of North America: this large availability contributes to its affordability.

4.1.2 Economic sustainability considerations

The economic sustainability of using specific timbers in boatbuilding encompasses several factors, based on both technical and commercial aspects.

Durability and maintenance properties of wood are extremely important, as investing in high-quality, durable wood species like teak can reduce long-term maintenance costs, offsetting initial expenses. Also workability must be privileged, as woods that are easier to work with, such as cedar and mahogany, can lower labour costs during construction.

In terms of commercial appeal, having some sorts of sustainability certifications is a great advantage for both wood suppliers and boatbuilders. Opting for FSC-certified woods ensures responsible forestry practices, potentially enhancing the vessel's market value and appeal to environmentally conscious consumers.

4.1.3 Technical considerations

The selection of timber for boatbuilding requires careful evaluation of several technical aspects to ensure durability, structural integrity, and long-term performance in harsh marine environments.

One of the most crucial considerations is the wood's resistance to rot and decay. Boats are continuously exposed to moisture, saltwater, and biological threats such as fungi, bacteria, and marine borers, making it essential to choose timber with high natural resistance to these factors. Woods like teak, iroko, and cedar contain natural oils and resins that protect them from degradation, reducing the need for chemical treatments.

Another key factor is the wood's density and strength-to-weight ratio. The ideal boatbuilding timber must be strong yet lightweight to maintain structural durability while allowing ease of handling. High-density woods such as teak and mahogany offer exceptional durability and resistance to wear but can be quite heavy, which may not be suitable for all applications. On the other hand, medium-density woods like Douglas fir and cedar are lighter and easier to work with, though they may require additional treatments to enhance their longevity.

Dimensional stability is also a vital characteristic, as timber naturally expands and contracts with changes in moisture content. Excessive movement can lead to cracking, splitting, and joint failures, which compromise the vessel's integrity. To mitigate this, boatbuilders prefer quarter-sawn lumber, which exhibits superior stability due to the orientation of its grain structure. Certain species, like teak and mahogany, are inherently more stable, making them desirable choices for marine applications.

Workability and fastening properties also play a significant role in timber selection. Wood should be easy to cut, shape, bend, and join using traditional boatbuilding techniques, ensuring efficient construction and repairs. Some hardwoods, such as teak and iroko, are particularly durable but can be difficult to work with due to their density and interlocking grain. Conversely, softer woods like Douglas fir are more manageable but may require reinforcement to ensure they hold fasteners securely over time.

Additionally, boatbuilding timbers must resist damage from marine organisms, particularly shipworms and other borers that thrive in saltwater environments. While some woods, such as teak and greenheart, naturally deter these pests, others need to be treated with protective coatings like epoxy or preservative oils to enhance their resistance. The ability of timber to adhere well to modern adhesives, such as epoxies and polyurethane glues, is equally important. Poor adhesion can lead to structural weaknesses and delamination, which are costly to repair. Similarly, the timber must be compatible with finishes such as paints, varnishes, and sealants. Some species have naturally oily surfaces that can repel coatings, requiring specialized preparation before application.

Lastly, sustainability and availability are critical considerations in today's boatbuilding industry. Many high-quality hardwoods, including old-growth teak, are overharvested and difficult to source, making them both

expensive and environmentally unsustainable. Ethical sourcing practices, such as selecting FSC-certified timber, help promote responsible forestry while ensuring a reliable supply of quality materials. In some cases, laminated wood products or alternative timbers offer more sustainable and cost-effective options without compromising performance.

In summary, the ideal boatbuilding timber must balance durability, strength, stability, workability, and environmental responsibility. The right choice depends on the specific application, whether for hull construction, decking, framing, or interior finishing. By carefully considering these factors, boatbuilders can ensure that their vessels not only withstand the challenges of the marine environment but also remain efficient and sustainable over time.

As an example, with specific reference to gondolas, the requirements that the wood must satisfy to be employed during constructions are numerous. Before starting the building process, it is necessary to carefully analyse the wood. This must be free of defects, have a regular grain, and a curvature suitable for the elements that will be obtained from it. After selection, the wood undergoes a seasoning process that lasts about a year until it reaches its final stabilised form.

4.2 Sustainability Considerations

With reference to sustainability considerations regarding the employment of wood as boatbuilding material, Life Cycle Assessment (LCA) principles must be thoroughly applied.

"Life cycle assessment (LCA) is a *cradle-to-grave* or *cradle-to-cradle* analysis technique to assess environmental impacts associated with all the stages of a product's life, which is from raw material extraction through materials processing, manufacture, distribution, and use" [22] (Figure 32).

The purpose of LCA is to analyse the contribution of the life cycle stages of different products to the overall environmental load, in order to compare them and improve processes.

LCA can be evaluated through different approaches on the basis of the product life cycle model considered (Figure 33). A product life cycle consists of five phases: 1) raw material extraction, 2) manufacturing and processing, 3) transportation, 4) usage and retail, and 5) waste disposal. The approach referring to this whole life cycle is called *cradle to grave*, with cradle being the inception of the product in which the sourcing of raw materials occurs and grave being the disposal of the product. A variation of cradle-to-grave approach is the *cradle to cradle*, often referred to within the circular economy. Here, a recycling process able to make the product reusable replaces the waste stage, with the aim of *closing the loop* and re-inputting resources in the cycle. Finally, another possible approach is the *cradle to gate*, in which a product is assessed until it leaves the factory gates. Two alternative assessments can be applied: a study restricted to raw materials and manufacturing processes and an increased study that includes also the transportation phase to retailers. Both approaches cut out the use and disposal phase and can significantly reduce the complexity of an LCA.

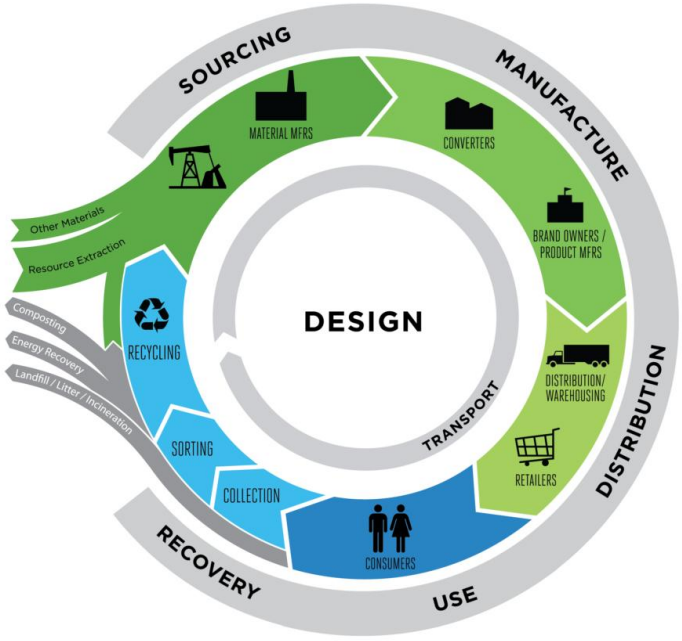


Figure 32 - Life cycle assessment (unknown source).

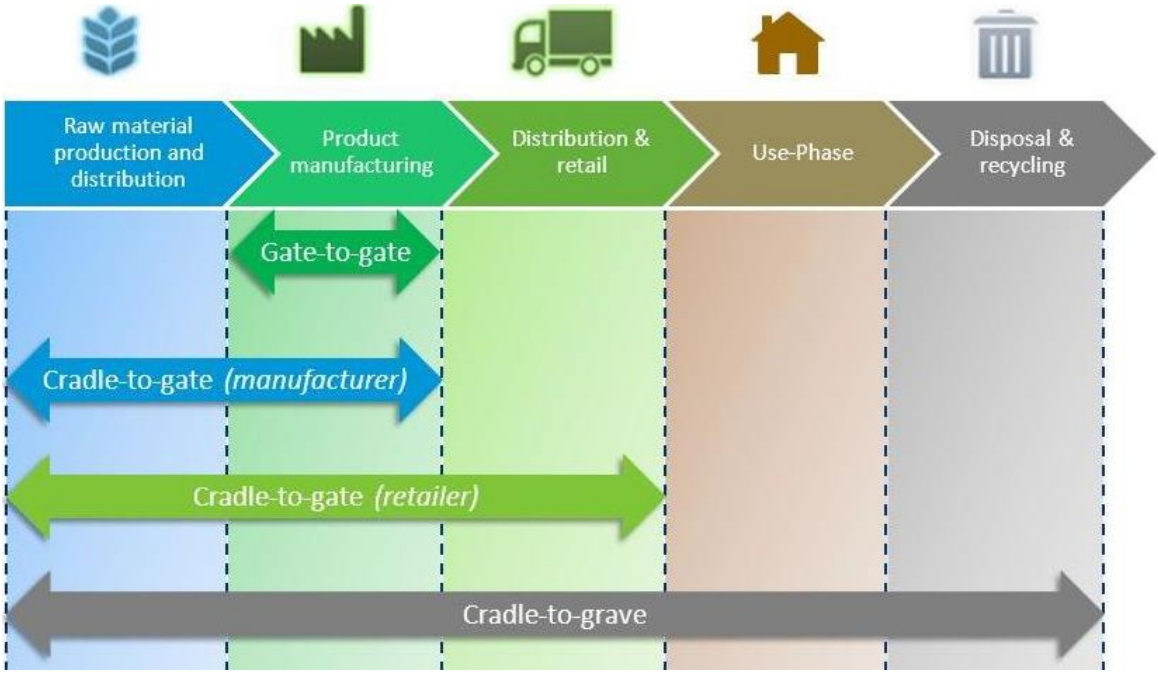


Figure 33 - LCA approaches (unknown source).

With reference to the use of wood for boatbuilding, the benefits primarily relies on wood being a natural and carbon-neutral material. However, these might be nullified by the environmental impact of crucial phases such as the extraction of timber in remote and exotic regions and its transportation to the local site of employment for vessel construction. In fact, as reported above in the present document, the most common wood species used for the manufacturing of small pleasure boats originates from North America and Africa. This fact implies the necessities to transport timber in its raw form across several countries, based on the location of the vessel production site.

In the last years, the attention towards this problem has increased, leading several researchers to perform targeted analysis to understand the real effect of adopting local wood species instead of exotic ones. As an example, the results obtained by a comparative study by Pommier et al., 2016 based on different materials commonly used in boatbuilding are herein presented. The authors evaluated a cradle-to-grave LCA based on the ISO 14040 Standard [24] on an 18-m passenger transport boat built in local wood, exotic wood, and aluminium. Furthermore, the LCA was carried out also considering composites as construction materials. The analysis was focused on the hull, in order to give primary importance to building materials that define four different scenarios:

- *Scenario 1* – aluminium hull;
- *Scenario 2* – hull made from composite stratified sandwich of glass fibres and polyester resin;
- *Scenario 3* – hull made from African wood (Okoume and Sapele);
- *Scenario 4* – hull made of French local wood (maritime pine and oak).

Since the study aims at comparing state-of-the-art construction methods in Europe, for each scenario the most used and representative technologies were considered.

Figure 34 shows the life cycle of the case-study boat and the limits of the field of study. The boat storage period is not included in the analysis, due to its continuous use, and particular attention was given to the displacement of pollution. As for the length of life of the case study, it was considered as the limiting life span of a composite hull (from 30 to 50 years) even though aluminium and wooden boats have longer lives. This fact was included in the analysis.

The study took into account the following elements for each scenario:

- Extraction of raw materials for the hull construction;
- Transformation of materials into pieces/sub-assemblies/assemblies;
- Assembly of pieces/sub-assemblies/assemblies to obtain the final product;
- Maintenance and renovation operations during working life;
- Consumption of energy necessary for propulsion;
- End of life of elements according to the waste disposal process and their transport to disposal plants.

The growth and the exploitation of wood was also taken into account (forestry phase).

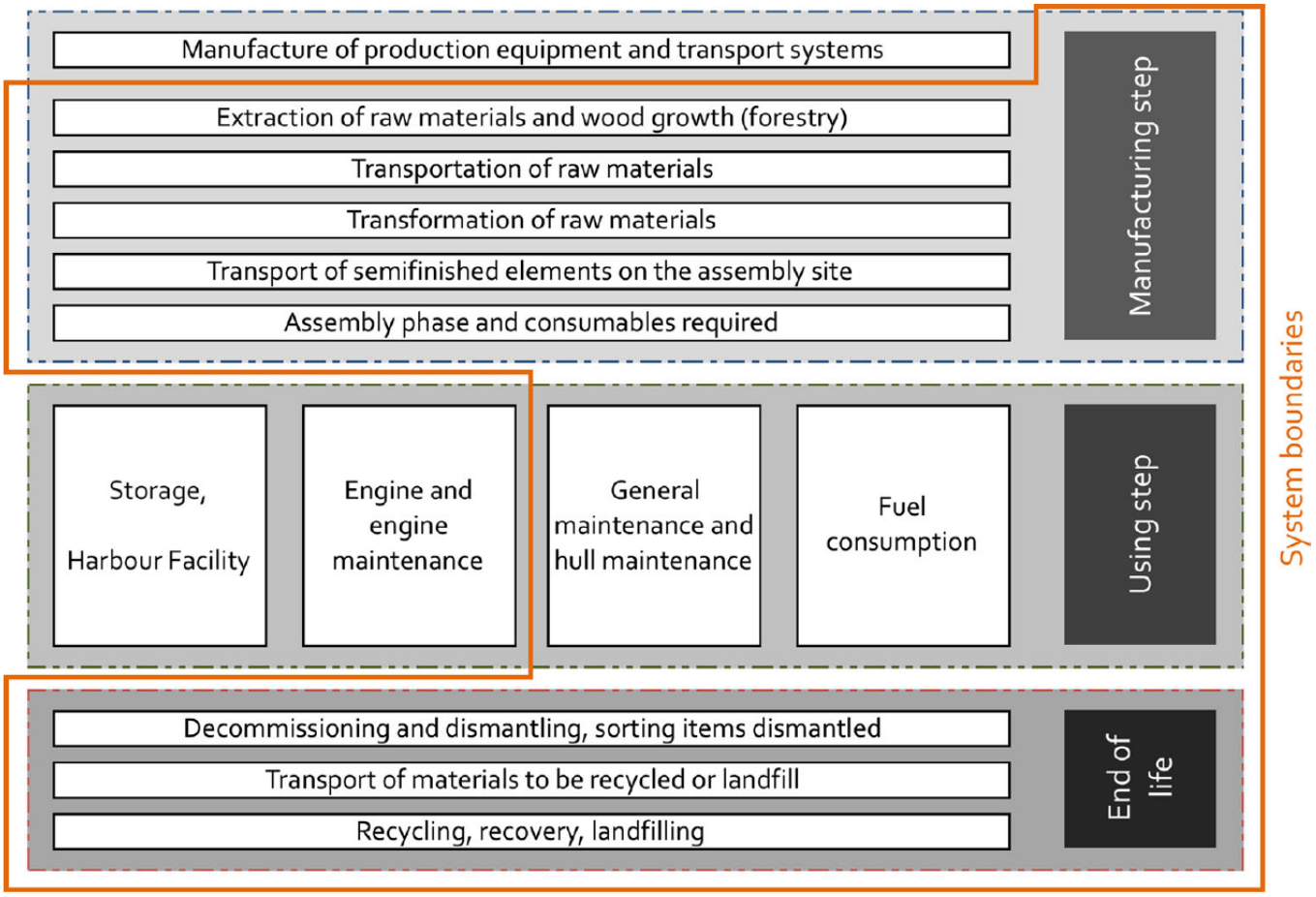


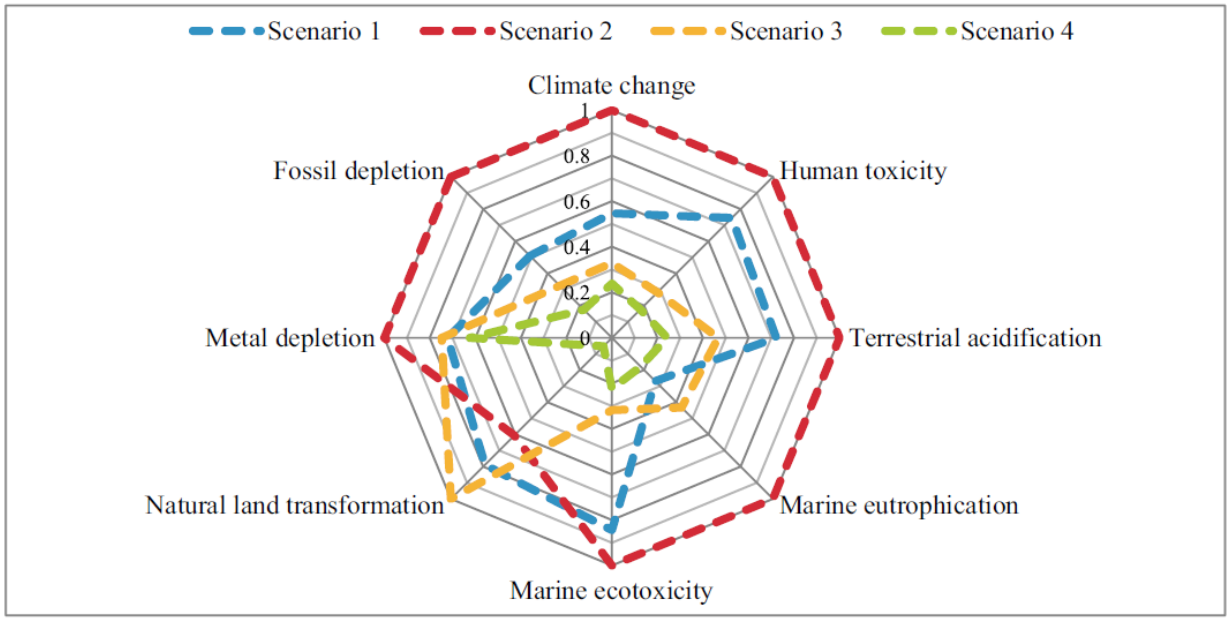
Figure 34 - Life cycle boat hull phases/boundary system [23].

The LCA impact calculation was performed through the use of Simapro® 7.3 software. Eight indicators were selected to interpret the results; these are climate change, human toxicity, terrestrial acidification, marine eutrophication, marine ecotoxicity, natural land transformation, metal depletion, and fossil depletion.

The analysis was performed on different life phases (construction, use, end-of-life) and as a whole, by taking into account the complete hull life cycle. From the global comparison of the four scenarios, the composite solution turns to be the most environmentally damaging one (Figure 35). This can be explained through the following reasons:

- Low recyclability at life's end;
- Reduced life span compared to the other three solutions;
- Heavy use of harmful compounds for human life and the environment to manufacture and maintain composite hulls.

The valuable result of the study consists in wooden boat hulls being the least environmentally damaging; the worse aspects of wooden scenarios are marine eutrophication and natural land transformation, due to the forestry phase. Surely, between the two solutions based on wood, the one implying exotic wood has a bigger impact as regards the *natural land transformation* indicator. However, they are both better than the aluminum scenario, which is often cited as the example of the most environmentally respectful solution.



Impact category	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Climate change	kg CO_2 eq	4.19E+04 (55 %)	7.67E+04 (100 %)	2.52E+04 (33 %)	1.82E+04 (24 %)
Human toxicity	kg 1.4-DB eq	2.08E+04 (74 %)	2.80E+04 (100 %)	7.90E+03 (28 %)	4.93E+03 (18 %)
Terrestrial acidification	kg SO_2 eq	1.73E+02 (72 %)	2.40E+02 (100 %)	1.12E+02 (47 %)	5.83E+01 (24 %)
Marine eutrophication	kg N eq	1.01E+01 (27 %)	3.73E+01 (100 %)	1.62E+01 (43 %)	6.66E+00 (18 %)
Marine ecotoxicity	kg 1.4-DB eq	4.77E+02 (84 %)	5.65E+02 (100 %)	1.79E+02 (32 %)	1.26E+02 (22 %)
Natural land transformation	m^2	8.40E+00 (79 %)	6.45E+00 (61 %)	1.06E+01 (100 %)	5.55E-01 (5 %)
Metal depletion	kg Fe eq	4.60E+03 (72 %)	6.38E+03 (100 %)	4.77E+03 (75 %)	3.98E+03 (62 %)
Fossil depletion	kg oil eq	1.23E+04 (51 %)	2.42E+04 (100 %)	7.84E+03 (32 %)	4.22E+03 (17 %)

Figure 35 - Comparison of the complete hull life cycle in the four scenarios excluding fuel [23].

As seen through the results of the study by Pommier et al., the employment of local wood as boatbuilding material represents a great advantage in terms of LCA considerations and reduction of environmental impact. This underlines the importance of re-discovering local forest species as highlighted in Section 2, which requires limited transportation from the timber extraction site to the boatyard.

With reference to the end of life of wooden vessels, the natural origin of the construction material surely helps in applying alternative ways of disposal and, sometimes, even recycling of the unit. However, it must be remembered that the wood used for the construction of vessels is treated with specific adhesives to ensure adherence among different structures and resins used as protective coatings. The presence of these materials, commonly based on synthetic raw substances, may threaten the complete recyclability of the unit and must be properly addressed when facing the end-of-life disposal.

PART 2. Sustainability of the Timber Supply Chain in the Nautical Sector

1. Analysis of Timber Supply Chain for Nautical Use

The timber supply chains identified in Section 3.2 involves several supplier located in Veneto and Friuli Venezia Giulia regions and Croatia. The most famous and relevant ones to the purposes supplying wood for boatbuilding constructions are mapped and reported below. The species that can found application in terms of wooden boat construction are highlighted in bold.

Veneto region

- **De Biasio Legnami S.r.l. Via Ca' Solaro 32/a, 30173 Favaro V.to (Venezia).**
  Wood essences available: **fir**, acacia, maple, afrormosia, akatio, alder, amazaque, ayous, bahia, chestnut, cedar, European cherry, American cherry, cypress, stone pine, **Douglas**, doussié, white beech/evaporated, American beech, European ash, American ash, hemlock, **iroko**, jelutong, larch, Russian larch, meranti, national walnut, yesquero walnut, **okoume**, olive, national elm, American elm, alder, rosewood, padouk, pear tree, Sweden pine, poplar, ramin**, Slavonia oak**, **American oak**, **sapeli**, sipo, **teak**, lime, toulipier, wenge, yellow pine, zebrano.
- **Ottolini Legnami S.r.l. Via Monte Corno 19, 37057 San Giovanni Lupatoto (Verona).**
  Wood essences available
  - Hardwood - walnut, beech, ash, **oak**, chestnut, European cherry;
  - Softwood - lime, poplar, ayous
  - Coniferous wood - **silver fir**, pine, larch, Swiss pine;
  - Exotic fine wood - **Douglas fir**, **iroko**, hemlock, alder, bahia, Lebanese cedar, olive, **mahogany**.
- **Rossato Legnami S.r.l. Via Broli 43, 36025 Noventa Vicentina (Vicenza).**
  Wood essences available:
  - Resinous wood - **Austrian fir**, **Sweden fir**, Lebanese cedar, stone pine, **Douglas**, hemlock, Austrian larch, Siberian larch, Sweden pine, yellow pine;
  - Broadleaf wood - acacia, white maple, birch, hornbeam, Slavic chestnut, European cherry, American cherry, white beech, steeled beech, white ash, olive ash, raw and steamed national walnut, American walnut, European elm, olive, pear, poplar, plane, **French red oak**, **Croatian oak**, **white and red American oak**, linden, toulipier.
  - Exotic wood - abura, amazakoue (Daniela walnut), aniegré (tanganyik), ayous, azobé, badi, bahia, dabema, dibetou, doussié, etimoé, , **iroko**, koto, **mahogany acajou, sapelli mahogany, sipo mahogany, meranti mahogany**, andean walnut, niangon, **okoumé**, **teak Burma**, zebrano.

- **C. & G. Venetolegno S.r.l. Viale dell'Industria 2, 31055 Quinto di Treviso (Treviso).**
  Wood essences available:
  - European conifers - **fir**, larch, pine, Swiss pine;
  - Non-European conifers -red cedar, **Douglas**, hemlock;
  - European broadleaves - **oak**, white and olive ash, beech, chestnut, walnut, lime;
  - Non-European broadleaves: **iroko, okoumé, sapelli mahogany**, meranti, walnut, toulipier.
- **Gallo Legnami S.r.l. Via dei Ronchi 4, 35127 Padova (Padova).**
  Wood essences available:
  - American hardwood - **white oak**, American cherry, sapgum, alder, American elm, toulipier, American ash, **American red oak**, American maple;
  - American softwood - red cedar, yellow pine, hemlock, **Douglas**;
  - European conifers - Norway spruce, Scots pine, Siberian larch;
  - European broadleaves - **European oak**, chestnut, linden, beech;
  - Asiatic wood – meranti, **teak**;
  - African wood – wengè, bahia, sipo, **iroko**, framirè, **sapelli**, **okoumé**, akatio.
- **Montagna Legnami S.r.l. Via Palazzetto 1, 36070 Brogliano (Vicenza).**
  Wood essences available: **fir**, acacia, maple, chestnut, cedar, cherry, stone pine, beech, ash, walnut, elm, pear, pine, poplar, **oak**, lime, olive.
- **B.L.C. S.r.l. Via Vittorio Veneto 46, 31053 Pieve di Soligo (Treviso).**
  Wood essences available: mostly **fir** and larch.
- **C.M.E. Legnami S.r.l. Via dell' Artigianato 7, 37050 Oppeano (Verona)**
  Wood essences available: **fir**, chestnut, ash, **oak**, linden, tulipier.
- **Konfort Legno S.r.l. Via Roma Sinistra 65, 30016 Jesolo (Venezia).**
  Wood essences available: **fir**, acacia, maple, afrormosia, akatio, alder, amazaque, ayous, bahia, chestnut, cedar, European cherry, American cherry, cypress, stone pine, **Douglas**, doussié, white beech/evaporated, American beech, European ash, American ash, hemlock, **iroko**, jelutong, larch, Russian larch, meranti, national walnut, yesquero walnut, **okoume**, olive, national elm, American elm, alder, rosewood, padouk, pear tree, Sweden pine, poplar, ramin**, Slavonia oak**, **American oak**, **sapeli**, sipo, **teak**, lime, toulipier, wenge, yellow pine, zebrano.
- **Castellana Legnami SNC. Via del Commercio 15, 31033 – Castelfranco Veneto (Treviso).**
  Wood essences available: **fir**, maple, black walnut, chestnut, cherry, doussié, beech, ash, thermo ash, ipè, **iroko**, larch, national walnut, elm, **oak**, **teak**, lime, tulip, wenge.
- **Alpi Legnami Srls. Via Villabona 5, 30175 Marghera, Venezia (VENEZIA).**
  Wood essences available: **fir**, larch, **oak**, elm, ash, beech, **iroko, mahogany.**

- **Derwood S.r.l. Via Fornace 2, 30030 Martellago (Venezia).**
  Wood essences available:
  - Conifers - **fir**, larch;
  - European broadleaves - chestnut, beech, European ash, walnut, **European oak**, linden;
  - American broadleaves - American red elm, cherry, tulipwood, walnut, **white oak**;
  - Exotic broadleaves - doussié, **iroko**, meranti, **okoumé**, **sapelli**, sipo.
- **Andrighetti Legnami S.p.a. Via Zona Industriale 5, Vigorovea 35020 Sant'Angelo di Piove (Padova).**
  Wood essences available:
  - European broadleaves - linden, poplar, national walnut, white ash, larch, beech, chestnut, European cherry, **oak**;
  - American broadleaves - American walnut, toulipier;
  - Exotic broadleaves - **okoumé, iroko, sapelli**.

Friuli Venezia Giulia

- **Comilegno S.r.l. Via Belvedere 30, 33061 Teor (Udine).**
  After an initial selection at the source, Comilegno provides raw materials for the manufacturing of all the products required for the interior and exterior fittings of yachts and high quality products selected in compliance with the high quality standards required by the nautical industry.
  Comilegno is indeed specialised in providing marine-resistant woods that are impenetrable, easy to work with, stable and moderately heavy.
  Wood essences available:
  - **Teak coming from Southeast Asia** is one of the most durable woods in the world, suitable for any use, from the nautical sector to furniture, thanks to its natural characteristics.
  - **TMT Marine® Hard maple**: the treatment TMT Marine® is able to enhance the stability of woods in contact with marine agents, ensure low movement and very long resistance to bad weather. This treated wood is ensure a 25years + resistance outdoors and is available in various lengths and thicknesses suitable for the most varied uses.
  - Different essences, all classified in terms of Durability of CLASS 1, resistant to marine agents and suitable for nautical use and outdoors applications.

  References from nautical sector: Lidauer – FRAUSCHER BOATS, Prestige Yachts, Morgana, Novamarine - Black Shiver Line.
  Comilegno is usually present with a representative stand at the Metstrade of Amsterdam, the world's leading platform for professionals in the leisure marine equipment industry, and at the most prestigious nautical fairs and expositions around the world (Genova and Monaco boat shows).

- **Legnonord S.p.a. Via Arturo Malignani 63, 33031 Basiliano (Udine).**
  Legnonord is specialised in supplying wood essences for marine applications (for pier and harbour structures) and boatbuilding constructions (planking and reinforcements).
  Wood essences available: **Austrian fir**, European maple, Bahia, European cherry, beech steamed, **iroko**, Austrian larch steamed, meranti, **okoumé**, Scandinavian pine, **sapelli**, yellow poplar, ayous, chestnut, **Douglas**, European ash, jelutong, larch, national walnut, Weymouth pine, European lime, Scandinavian fir, azobe, cedar, raw beech, USA ash, Austrian larch, Siberian larch, **okan**, Austrian pine, **European oak**.
  References from nautical sector: Alto Adriatico Custom S.r.l.
  Legnonord is usually present with a representative stand at the most prestigious nautical fairs and expositions around the world (Venice boat show).
- **Domini Legnami S.r.l. Via Mattei 10, 34070 San Pier d'Isonzo (Gorizia).**
  Wood essences available: mostly **white fir and spruce**.
- **G. Luvisoni & Co. S.r.l. Via Spilimbergo 168, 33035 Martignacco (Udine).**
  Wood essences available:
  - North America wood - tulipier, black walnut, **glacial red oak**, hard maple, red elm, black cherry.
  - European wood - **oak**, ash, **fir**, chestnut, larch, pine, beech.
  - African wood - **iroko**, ayous, **okoumè**, **sapele**, doussiè/pachyloba, kotò, padouk, wengè.

Croatia

- **BUKVA COMMERCIUM l.l.c. for production and trade, Nikolići 2, 47313 Drežnica.**
  Wood essences available: domestic wood such as beech, pine, hornbeam, **oak**, ash, maple, fir, spruce.
- **EXPORTDRVO. Trg Marka Marulića 18, 10000 Zagreb.**
  Wood essences available: beech, **oak**, ash, hornbeam, linden, cherry.
- **Drvona d.o.o. Antuna Mihanovića 7, 47000 Karlovac.**
  Wood essences available: **fir**, spruce, European larch, Siberian larch, pine, **oak**.
- **DRVO TRGOVINA MIKŠA d.o.o. Ilovac 6, 47000 Karlovac.**
  Wood essences available: larch, **fir**, spruce, **iroko**.
- **MPS-67. Business Park, 1 / L Belajske Poljice, 47252, Belajske Poljice.**
  Wood essences available: **fir** and spruce.
- **SIRK d.o.o. DRVENA GRADA ISTRA.Nikole Tesle 1, 52220 Raša.**
  Wood essences available: **oak, fir**, beech, larch.

- **BANI trgovina d.o.o. Obrovac 17, 51218 Drazice.**
  Wood essences: **fir**, spruce, larch, pine, **oak**, maple, ash, walnut, chestnut, steam-dried and non-steam-dried beech, lime, hornbeam, poplar, samba, **iroko, mahogany and teak**.
  Floor and ceiling coverings, battens as well as materials for boat-building.

2. Mapping of Nautical Sector Entrprises

The present section aims at providing a comprehensive list of the most renowned nautical sector enterprises in terms of wooden boatyards in the regions interested by the TOFOLA project.

Veneto

The renewed interest in the construction of wooden boats was underlined by the most famous boat shows in the world, with the Venice Boat Show leading the way (https://salonenautico.venezia.it/news/la-novita-del-wood-village-2/). During the 2024 exposition, an area of the Show was entirely dedicated to wooden motor boats, an example of the craftsmanship of Venetian shipyards. Within the Wood Village, several examples of wooden motor boats built by Venetian shipyards using ancient techniques and tools of the artisan tradition of woodworking – such as *lustrofin*, the ability to lacquer and finish boats in an incredibly beautiful way – were shown. Along seventy meters of linear pier on the Rio delle Galeazze, the excellences of the lagoon area was narrated by about twenty boats of various sizes and uses to the Show.
G.D.P Carpenteria Nautica di Giovanni Da Ponte, whose shipyard is located in the port area of Venice, brought Foxg1, a 6.50-metre long pleasure boat designed for people with disabilities: a mobile platform has been positioned in the keel that allows people to move easily on board.
FAP Cantiere Nautico, based in Marcon, brought some the models it builds by hand in its shipyard made in mahogany, a perfect synthesis between traditional woodworking techniques and modernity, given by the lines, accessories and fittings.
The **Portegrandi Marina & Service** shipyard comes from the lagoon edge near Quarto d'Altino chose to show visitors an example of his mastery, the "Marco Polo", a pleasure boat built in 1975 by the father of the current owner and restored in 2008. Built with various types of wood, from the oak and oak structure to the mahogany exterior, it stands out for its unique lines, which exemplify the almost sartorial approach of the shipyard, which does not adopt mass production but welcomes the challenges that come from its customers.
Serenella, a shipyard in Murano with 40 years of experience behind it, builds Venetian taxi boats, the fastest way to get around Venice and the islands of the lagoon. Everything is done by hand, from the drawings to the workmanship by master shipwrights. At the Boat Show, the shipyard has chosen to bring two of its models, the Serenella Express, a 10-metre boat entirely in mahogany that is characterized by its dynamic external lines and comfortable and valuable spaces inside, a modern fusion of technology and style, and Viola, also in mahogany, an open type of 7-8 metres.
From the idea of two friends, the **Dalla Pietà Wooden Boats Cultural Association** was born. The aim of the association is to encourage the preservation of wooden boats from the historic Venetian shipyard in Giudecca, founded in 1959 and representing an important piece in the history of Venetian boating. At the Wood Village

they showed four of the iconic models of the Dalla Pietà shipyard, a DP7, an Adriatico, a Laguna and a Manta, for a length that varies from 4 to 7 metres. Equivalent in the water of vintage sports cars, these boats in the last century have been able to obtain exceptional results both from a sporting point of view and at sea, earning prestigious records, some of which are still unbeaten.
Also part of the Salone Nautico last year was the **Cantiere Nautico Andrea Zane**, based in Cavallino Treporti, which has chosen to exhibit a revisited chest in Venetian wood of 5.20 metres, a restoration and a cradle of just over a meter made in 200 hours, in a nautical style, supported by two small mahogany cranes on which it swings.
Finally, the **Cantiere Venmar**, located on the Venice Lagoon, was present with its unique boats.

Below, a more detailed description of these and other renowned shipyards specialised in wooden boatbuilding is reported. The list comprises also the most famous Squeri, that are the typical Venetian shipyards where small boats such as gondolas*, pupparini, sandoli, sciopòni* and other boats typical of the Venetian lagoon tradition are created, built and repaired. The term *squero* may come from different sources: the word *squara*, which indicates a team of people who cooperate to build boats or the square, a fundamental work tool for master shipwrights, or from the Greek ἐσχάριον (eschárion), which means "building site".

- **Cantiere Navale Camuffo. Via Zambaldi 33, 30026 Portogruaro (Venezia).**
  Camuffo Shipyard is universally considered the oldest shipyard in the world, for its unparalleled quality values of unrepeatable, uninterrupted and documented history, of a boat entirely in technological wood, the superlamellar marine armor, of unlimited duration, and of incomparable performance at sea. In the eighties, the magazine Nautica wrote of Camuffo as the 'Point of reference for Italian boating and touchstone for how to navigate and experience the sea in the best comfort and absolute safety, with a real boat'.
  The activity of the shipyard began in 1438 under the doge Francesco Foscari; this date is confirmed by news from the Arsenal of Candia, where the presence of a Proto, Magister Stadii, founder with family coat of arms, is recorded, but the origin of the family is from that long stretch of coast that from Constantinople reaches the mouth of the Nile River. The arrival in Chioggia of the grandson of the founder Camuffi precedes by a few years the first document dated 23 June 1470.
  Cantiere Navale Camuffo is specialised in building boats entirely in wood. These boats have intrinsic characteristics, due to their particular construction: the solid mahogany frame covered with marine armoured superlamellar, together with the total disassembly of the boat's components, create a structural synergy with the maximum elastic coefficient, superior to any other material for shipbuilding.
  In the 1950s, Marco Camuffo, with the advent of thermosetting marine glues, plywood and marine armoured superlamellar made of cross-glued strips of marine wood that blocked the movement of the wood, eliminating external maintenance, was the first to modify the ancient pre-Columbian frame of the Camuffo, and having to replace the courses of solid wood planking with a single panel covering the entire side of a vessel, he added large longitudinal bands of solid mahogany to the sides and bottoms with glued joints to ensure a perfect and structurally robust gluing base. The load-bearing frame is reinforced by sturdy longitudinal stringers in solid mahogany that connect the frame along the entire

length of the hull from stern to bow, ensuring greater safety during navigation and even in extreme sea conditions, especially in particularly damaging torsional movements, especially in the upper Adriatic characterised by the formation of abnormal waves due to shallow waters and inconsistent winds.

- **G.D.P Carpenteria Nautica di Giovanni Da Ponte, Canale di Scomenzera 67, 30135 Venezia.**
  The team of this shipyard includes carpenters, painters, mechanics and electricians who dedicate themselves to the restoration and construction of wooden hulls in every element under the coordination of a technical office in charge of design and commercial activities.
  Its constructions are based on the use of mostly teak and mahogany. In recent years, the shipyard has specialised in units able to combine sustainability and respect for the marine environment with the traditional wooden boatbuilding technologies. An example is a vessel characterised by a high lightness and versatility powered by a silent and zero-emission electric outboard engine. An additional market value is represented by the attention towards accessibility: the shipyard implemented a project of a unit equipped with a lifting platform that, by raising up to the level of the gunwale, facilitates the entry of the wheelchair on board the boat and, by returning to the rest position, it levels itself to the floor of the boat. In this way the guest in a wheelchair can move inside the boat and drive the vehicle.
- **FAP Cantiere Nautico, Via Paganello 4, 30174 Mestre (Venezia) - Viale Don Luigi Sturzo 60, 30020 San Liberale (Venezia).**
  The shipyard was founded in 1995 and is specialised in the implementation of custom projects dedicated to the world of sailing, including the manufacturing of boats and nautical fittings and furnishings. The construction of boats is still based on ancient techniques and the use of tools coming from the artisan tradition of woodworking. FAP boats include various models ranging from 2.7 metres to over 6 metres and require at average more than 400 hours of work based on the type of model.
  FAP is also specialised with the repair, painting and maintenance of small and large wooden boats.
- **Portegrandi Marina & Service, Via Marzi 18/C, 30020 Portegrandi (Venezia).**
  Cantiere Nautico Portegrandi Marina & Service was founded in 2003 on the banks of the Silone River. Cantiere Nautico Portegrandi is a leading company among operators in the Adriatic Sea, thanks to its ability to assemble and work the finest woods for shipbuilding, the use of cutting-edge technologies and the experience of the owner's father, who was awarded the title of Maestro d'Ascia ad Honorem in 2002 as a fitting recognition of a life dedicated to the creation of wooden boats.
  Cantiere Nautico Portegrandi stands out for its high quality craftsmanship and highly specialized workforce, key factors in its success in the field of pleasure boats, ship restorations, fishing boats and yachts. The strong point is the creation of new limited edition and tailor-made boats where attention to detail, essentiality, technology and safety at sea merge into one.
- **Cantiere Motonautico Serenella, Sacca Serenella, 30141 Murano.**
  Marina Serenella provides all the services necessary for the maintenance and repair of wooden and boats, in terms of carpentry and other necessary interventions.

In 1975 Elio Salvagno, together with two other partners, founded Cantiere Motonautico Serenella and began building mahogany motor boats that soon became one the most famous symbols of Venice. The first orders came from corporations, tourism companies, and important Venetian hotels. Serenella motor boats were used as ambulances, launches for the military police and local police, and "water limousines" for luxury hotels. More importantly, they were used as taxis, the fastest method for getting around Venice and the islands in the lagoon. In 1977, the owners of the Motonautico International Company in Newport Beach, California, visited the shipyard and acquired the exclusive right to import the boats to the United States. Serenella motor boats were exported to Texas, Minnesota, Hawaii and Japan. The company then began collaborating with important shipyards and naval design firms around the world that specialize in the production of luxury yachts – Cantiere Serenella builds exclusive tenders for these yachts that are customized in every detail. These luxurious boats are now seen in many areas of the world, including France, Germany, Switzerland, the Netherlands, the United Kingdom, Russia, the United Arab Emirates, the United States, China, Japan, Australia and French Polynesia.

- **Cantiere Nautico Andrea Zane, VIA S. MAURO 299, Venezia.**
- **Cantiere Venmar, Via Malamocco 76, 30100 Lido Di Venezia (Venezia).**
  Venmar was founded in Venice in 1969 by Franco Biasini, a pioneer in the nautical sector, and then passed under the guidance of Giuseppe Telarori, who headed the company until 1992. The commercial liveliness of the lagoon city and the first important projects consolidated Venmar as a leading shipyard in the Venetian shipbuilding scene.
  Venmar shipyard is specialised in wooden boat and taxi construction, boat restoration and carpentry and mechanical works.
- **Cantieri Vizianello S.r.l. Vicolo S. Michele 7, 31032 Casale sul Sile (Treviso).**
  Cantieri Vizianello is a renowned Italian shipyard specialized in the construction of luxury boats and refit services for historic boats. Founded in 2004, the company has rapidly emerged as a leader in the nautical sector thanks to the combination of artisanal excellence and advanced technologies. Cantieri Vizianello's mission is to create tailor-made products that represent the best of Made in Italy, with a strong focus on quality and customization.
  The origins of the business date back to the mid 50s; at that time Gianni Vizianello, founder of the business, began his first experiences in the main Venetian shipyards. In the 70s, he designed and built about seventy boats in marine plywood for the IAG NAUTICA shipyard. In the following years he started his own business creating the Cantiere Nautico Vz as an individual company. He continued to work on wooden boats, gradually integrating and incorporating fibreglass with the passing of years. Moreno Vizianello then founded Cantieri Vizianello in 2004 following the transfer of the sole proprietorship "GV NAUTICA" founded in 1994. The company has developed over time its business of construction, repair, maintenance and storage of work boats.

The company satisfies the requests of clients operating in the sector who prove to be increasingly demanding with requests for advanced services that have led the company over the years to satisfy the needs of law enforcement agencies such as the Carabinieri and the Ministry of Internal Affairs.

- **Martinelli Secchieri Michele Falegname Nautico, Strada Statale Romea 578, 30015 Chioggia (Venezia).**
  The company deals with the interior renovation of boats and the repairs and renovations of wooden and fiberglass boats, through the realization of carpentry, joinery and furniture works. Thanks to the expertise acquired during the years, the company is among the top experts in the Venice area in remodelling of boat interiors through the use of artisanal manufacturing techniques combined with the use of modern tools. All the processing phases are carried out at the headquarters, using machine tools for cutting, milling, planing and sanding planks and multilayer panels of various types of wood.
- **Cantiere Nautico Agostino Amadi S.r.l. Via Pontinello 607/609, 30142 Burano (Venezia).**
  The Agostino Amadi Shipyard traces its origins to an ancient family of boatbuilders for Venice and its islands, dating back to the early 1700s. This ancient tradition has not prevented the shipyard from dedicating itself to constructions of the most modern conception, in terms of design and materials. In fact, the current production field is divided between traditional boats built by hand in wood and fishing and work boats in fiberglass: the latter normally cover a range of models from 6 to 12 metres, but can reach up to 22 metres. One of their main characteristics is versatility, for which they can be used or adapted for fishing, pleasure, or transport of people and goods purposes.
  In terms of typical boats belonging to the Venetian maritime heritage, Agostino Amadi Shipyard is renowned for the construction of *Sandolo units (S-ciopon, Mascareta da Regata, Mascareta 4 remi, Pupparin da Regata, Buranello da barcarol), Caorlina da Regata, Gondolone da parata 6-8-10-12-14 remi,* other traditional boats such as *bragozzo lagunare, burchiella, caiccio* and *sampierota*, for example.
- **Squero San Trovaso, Sestiere Dorsoduro 1097, 30123 Venezia.**
  It is one of the very few *Squeri* still in operation in Venice. The building that houses it has the typical shape of mountain houses, an exceptional circumstance for Venice. The reason is twofold: on the one hand, both the carpenters and the construction wood came from Cadore, on the other, the inclination of the square in front and the roof that partly covers it were useful in case of rain, as well as a storage for work tools. Squero San Trovaso is still renowned nowadays for the construction of gondolas, which are entirely built by hand by the few master craftsmen still in business. In this squero, they still work with the methods of centuries ago, there are no winches and the gondolas are pulled up, turned around and launched entirely by hand.
- **Squero San Isepo, Castello 450, 30122 Venezia.**
  In accordance with (http://www.smscc.it/SOCIETA/pag_squeri_sociali.htm), the ownership of the San Isepo shipyard complex was donated to the Società di Mutuo Soccorso Carpentieri e Calafati (SMSCC) by testamentary deed in 1869 by member Giuseppe Tonello, a Venetian entrepreneur who later moved to Trieste, so that it could provide financial support for mutual aid initiatives among the naval workers

associated with the Society. However, due to some later and intricate vicissitudes, the three Parties (the donor's Attorney, the SMSCC and the Municipality of Venice) finally reached a contract in 1878 in which the ownership was placed in the hands of the Municipality of Venice free of charge, with the condition that the "simple usufruct" remained in the hands of the SMSCC but until its dissolution. This approach was then definitively confirmed by the Royal Decree of 1909 and the clear evidence of its current validity lies in the fact that the Municipality of Venice does not have the deed of concession of the property and that the SMSCC still has full and free disposal of it, awaiting the cessation of its activity.
The squeri were built around the middle of the 19th century, following the classic lines of this type of artisan settlement where previously there was an open space and a three-story building. In the 20th century, following a disagreement between the managers, the area was divided by a wall, thus giving rise to the creation of two distinct squeri: *squero picolo* (smaller, northern part) and *squero grando* (bigger, southern part). The smaller squero undertook the repair and maintenance of typical lagoon boats, from *peate* to motorized *topi*, up to gondolas. The second squero, after a period in which it was dedicated to the construction of medium-sized sailing boats, was completely dedicated to the construction and maintenance of motorboats.
After 60 years of uninterrupted activity, in 2015 the bigger *squero grando* was returned to the Company. By rationalizing the use of the internal spaces, a project was outlined that includes the creation of a centre for the enhancement of lagoon craftsmanship, as well as an area open to the city where people can experience the sport of Venetian rowing and, for young people, nautical carpentry. Alongside this, the idea of a project for the development of sedentary and compatible tourism, with a guided tour of the *squero picolo* and short tours in rowing boats to the nearby *darsena granda* of the Venice Arsenal, was implemented.

- **Squero Tramontin, Sestiere Dorsoduro 1542, 30123 Venezia.**
  Founded in 1884 in the wonderful setting of the Rio dell'Avogaria by Domenico Tramontin after the experience at the famous Casal ai Servi shipyard, Squero Tramontin was one of the favourite places in Venice beloved by gondoliers, because the most beautiful gondolas in the lagoon came out of that shipyard. Their boats were called by experts the eleven-meter oared "Ferraris".
  This shipyard is still in activity and its main purposes are the construction of newly-built gondolas or the restoration and maintenance of older units. The Master shipwright Roberto Tramontin was the official supplier of the Real Casa, the Prefecture, and the Municipality of Venice. He profoundly innovated the way of building the hull of gondolas: at the stern the bottom was widened to support and compensate for the considerable weight of the gondoliers of the time and the topside was raised giving the boat a more elegant line. These design innovations were also welcomed by competing builders and they made Maestro Tramontin recognised as the Enzo Ferrari of gondolas.
- **Cantiere Nautico Crea, Giudecca 212, 30133 Venezia.**
  The Cantiere Nautico Crea was founded by Vianello Gianfranco Crea, seven consecutive winners of the Regata Storica di Venezia and, by virtue of this, officially proclaimed as the "King of the Oar". As a boy, Gianfranco Crea attended art school where he learned to master the ancient technique of wood carving

and then specialized in the nautical sector. After passing the exam of Master shipwright, he attended the School of Old Masters. After its foundation, the Crea Shipyard became soon part of the group of only three shipyards in the world entrusted with the design and production of most famous symbol of Venice, i.e., the gondola. Each gondola is customized according to the area of the lagoon in which it will navigate and the characteristics required by the gondolier.
In addition to gondolas, Cantiere Nautico Crea specializes in the design and construction of typical Venetian boats and in the restoration of vintage boats.

- **Squero Dei Rossi, Sestiere Dorsoduro 1542, 30123 Venezia.**
  Squero Dei Rossi was inaugurated in the 1980s on the Giudecca Island at the Consorzio Cantieristica Minore Veneziana, when Stefano Costantini and Roberto Dei Rossi began working there under the guidance of Corrado Costantini, known as "Buranello". Although it is a relatively young squero, it faithfully respects the traditional characteristics, being equipped with two large sheds and a slipway that slopes down into the canal. Generally, squeri have a dirt area towards the water for launching and hauling boats, while the work takes place inside the wooden sheds that rest on pillars, sometimes with an upper floor for the *squerarioli* (craftsmen's) living quarters. Even in the Dei Rossi shipyard, the wood is worked by hand, using ancient and simple tools such as the axe, the plane, the saw and the hammer. After the preparation of the *còrbe*, the gondola is put into operation on the shipyard, continuing with the *aste, sérci, nèrve, suchéti, fiubóni, còrboli, castagnòle, trasti*.

- **Le Fórcole di Saverio Pastor, Dorsoduro 341, 30123 Venezia.**
  The name of this shipyard comes from the *fórcola*, which is the oarlock – i.e., the support on which the oar is pivoted to row on Venetian boats. Each different boat have a different *fórcola* with a different shape, which depends also on the rowing position, physical characteristics and rowing style of each individual rower.
  The shipyard was founded by Saverio Pastor in 2002 after his experience with the recognised last master rowers: Giuseppe Carli, the "king of *fórcole*", and Gino Fossetta, the "wizard of oars". Since 1980, Pastor has been working on his own and then joined Spazio Legno: with this company he restored the laboratory at the Arsenale where he worked until 2001, while the carpentry sector of Spazio Legno movedin 1998 to the 19th century warehouses restored by the Consorzio della Cantieristica minore Veneziana on Giudecca. Starting in 2002 with *Le Fórcole* shipyard, he collaborates with the rowing champions to increasingly improve the performance of *fórcole* and oars. He experiments with new materials while always remaining tied to traditional construction methods and tools. In 2002 he also founded the association *El Felze*, which brings together all the artisans involved in the construction of gondolas and its furnishings, as well as the elements of the gondolier's clothing.

Some of the above-mentioned squeri and shipyards belong to the Association *El Felze*, which is a Venetian Association that aims at reuniting the artisans who contribute to the construction of the gondola (https://www.elfelze.it/). The main statutory intensions of the *El Felze* Association are reported below:

- Protect the construction and creative traditions that have developed over the centuries around the production of the gondola with its furnishings, decorations and accessories;
- defend the artisan tradition of gondola construction from the progressive loss of the cultural reasons that underlie it;
- promote the transmission of the craft to facilitate generational change and avoid the definitive disappearance of all knowledge of construction techniques;
- promote the traditional crafts (even those that have disappeared and that we would like to see rediscovered) with collective initiatives;
- initiate interventions that incentivize and reward members and their collaborators, making them more aware every day of what their work represents, with the focus of representing not only an economic activity but above all a cultural project;
- bring back to Venice those artisan activities connected with the construction of the gondola that no longer find physical space in the lagoon city
- promote initiatives that help the smaller shipyards that may be in difficulty for due to the increased management costs, difficulty in finding labour, increasingly restrictive environmental regulations; define the reference protocols to guarantee the traditions, quality and originality of the products produced by the associates;
- distinguish the products that respect the essential quality parameters (against the many illegal and boastful ones) using our brand;
- encourage an internal debate aimed at solving common problems related to the laboratories, the workforce, the market
- be recognized by the institutions as a reference to be consulted for decisions concerning the gondola and minor shipbuilding
- establish a constructive and constant relationship of collaboration with the gondoliers
- involve the national and international bodies interested in safeguarding the Intangible Cultural Heritage
- seize the opportunities that will arise in the future to spread in Italy and in the world the history, legends and secrets of the gondola which, among the typical wooden lagoon boats, is certainly, for the difficulty of construction, for beauty and elegance, the most illustrious and representative.

The importance of the *El Felze* Association towards the re-establishment and reinforcement of a local wood supply chain is essential, as its members in terms of squeri and shipyards can represent the most interested users of essences coming from regional forests to maintain the heritage that characterise gondolas and the other traditional lagoon boats.

Friuli Venezia Giulia

- **Alto Adriatico Custom S.r.l. Via Consiglio d'Europa 42, 34074 Monfalcone (Gorizia).**
  The Alto Adriatico Custom shipyard was founded in 2006 by two craftsmen, Odilo Simonit and Paolo Skabar, and deals with the construction of new custom boats, especially in wood, refitting, maintenance

and the production of interior fittings. The two founding partners come from the experience as collaborators of Hannibal and subsequently together with other partners of the Alto Adriatico shipyard, which was founded nearby Muggia in 1991 and still nowadays represents one of the reference shipyards in woodworking.
The partners had the opportunity to work on numerous historic boats, including Moya (1910), awarded as the best restoration, Sorella from 1858, Bat from 1889, Dyarchy (1934), Delfino (1941) or the gaff ketch Javelin from 1897. In collaboration with the Trieste native Carlo Sciarrelli, they worked on famous wooden sailing boats such as Tiziana IV from 2002 or the 18-metre Chandra from 2004, designed by the Argentine architect German Frers.
In 2006, Simonit and Skabar opened the new Alto Adriatico Custom Srl shipyard.
Alto Adriatico Custom deals with the construction of new custom boats, refitting and maintenance, especially in wood, and finally the production of interior fittings for both the nautical sector and for custom residential and commercial furniture, coordinated by the architects activated by the clients. Since the start of the activities, some important interventions have been carried out: remarkable is the restoration of the sailing vessel Galeb for the Sergej Mašera Maritime Museum in Piran (Slovenia).

- **Cantiere Nautico Planais S.r.l.** Viale Enrico Fermi 49, 33058 San Giorgio di Nogaro (Udine).
  Cantiere Nautico Planais is specialized in the refitting and maintenance of classic and vintage boats made of wood, with interventions on both the internal and external structures and hull's parts.
- **Cantieri Marina San Giorgio S.p.A. Via E. Fermi, 21 - 33058 - San Giorgio di Nogaro (Udine).**
  Cantiere Marina San Giorgio is specialised in refitting interventions on wooden boats operated by expert craftsmen.
- **Cantiere Nautico di Porto San Vito S.r.l. Riva G. da Verrazzano 1, 34073 Grado (Gorizia).**
  The Cantiere Nautico di Porto San Vito is specialised in the construction of teak decks and platforms, the repairing and caulking of teak decks, and the construction and repair of internal and external wooden components.
- **Shipyard Marina Sant'Andrea. Via Enrico Fermi 53, 33058 San Giorgio di Nogaro (Udine).**
  The carpentry is capable of carrying out all the restoration and refitting work executed by the master carpenters, able to always use the most suitable wood types required in order to ensure the care and attention to every detail of very high quality.

Croatia

- **Shipyard Punat, Obala 5, 51521 Punat.**
  The tradition of the Punat Shipyard dates all the way back to 1922, when Nikola Zoric, founder and first owner, started the business. On just two slipways, mainly wooden vessels up to 350 tons were built. Those included many types of vessels: sailing ships (*trageti, leuti*), cargo ships, fishing boats and yachts - all made of wood, for which this shipyard became famous. In 1980s, the Shipyard Punat was the biggest shipyard for constructing wooden vessels in Croatia. In time past mainly oriented to wood as a

constructive material for shipbuilding, today the shipyard on its facilities, with employees and various subcontractors offers a refit and repair for all kind of working boats and large yachts up to 50 m length. The impact of Punat Shipyard on the local community is immense. Besides providing employment for over 1300 employees and living for their families, this business has directly impacted the life and development of the town for a century. Today, employees are skilled in contemporary crafts required for maintenance of modern boats, but also in traditional skills like rope splicing and sailmaking. Today, the Punat shipyard mainly maintains and refits boats up to 50 m in length and 600 tons of freight. Local excursion boats are regular customers, while the large yachts from other marinas, including the largest of the increasingly popular catamarans, rely on the shipyard for the major repairs and refit.

- **Betina shipyards.**
  Betina is a village located on the Croatian island of Murter, seven kilometres from Tisno, where a drawbridge connects the island and the mainland. Its importance for the Croatian wooden shipbuilding sector is witnessed by the existence of the Betina Museum of Wooden Shipbuilding (https://www.mbdb.hr/en/betina-shipyards-today/).
  Both Betina and the whole island of Murter are interested by numerous new wooden vessel constructions, along with repairs of formerly disintegrated ones. The introduction of plastic to the shipbuilding industry resulted in less shipbuilders employed in wooden constructions, so from the 1970s the construction of these boats has been decreasing. Nevertheless, Betina remained one of the main centres of small wooden shipbuilding on the Adriatic Sea. Today, there are shipbuilders in Betina who are capable of constructing all types of small wooden boats: traditional *gajeta*, *leut* or *bracera*, but also modern yachts. The existing shipyards in Betina are specialised in repairings on bigger wooden boats and construction of new units. Several smaller shipyards are active, where small and medium-sized boats are built and renovated. There are also several freelance shipbuilders performing boat repairs outside the shipyards.
  In accordance with the data given by the Betina Museum, the following list reports the shipbuilders that are still active today: Jadranko Bosna, Milan Burtina, Željko Burtina Šare, Nikola Balin, Đenko Filipi, Ljubomir Ante Fržop, Milan Jadrešić, Denis Jakovčev, Marko Kapov, Neven Kukin, Siniša Mikin, Krešimir Papeša, Nikola Papeša, Tomislav Pavić, Boris Sladić, Valter Sladić i Petromir Uroda.
  Great incentive for new shipbuilding are represented by the numerous Lateen sail regattas that are performed periodically nearby. Specifically, close to Betina, 8 traditional regattas are being held. Regattas are certainly the main reason why ships are built and refurbished today. In addition to this, wooden ships today are mostly used for sailing and enjoyment. An example of a wooden vessel whose construction was mostly based on the use of local trees is the *Leut Kvarneriol*, an 8 metre-long and 3 metre-wide sailing vessel registered for the transport of 12 people. The frames of vessel are made of a mixture of oak and elm, while the deck is in larch. The cabin is made of mahogany, and the *sohe* (the traditional oarlocks) are made of black elm. In addition both black and white elm were used in shipbuilding.

In addition, several of the active shipyards are involved in prestigious restoration projects based on last-century wooden sailing vessels such as the *Gajeta Marija, Gajeta Cicibela and Gajeta Baba Tone*, which are typical *Betina gajeta* vessels.

3. Mapping of Schools and Training Institutes

The Master shipwright figure is more related to art than a real job. For millennia, Master shipwrights have modelled wood, shaped it and transformed it into hulls capable of ploughing the waters. Initially, the work of the Master shipwrights was aimed mainly at the creation and repair of vessels used for fishing or, in any case, for work. With the birth of nautical pleasure crafting and the consequent demand for wooden boats for more recreational uses, these experts have evolved into true artists capable of designing new models and creating vessels following lines and styles in step with the times.

This profession, contemplated by article 117 of the Italian Navigation Code [25], is unfortunately disappearing, leading to the progressive loss of specific professional knowledge and the contents of tradition. The growing shortage of these professional skills represents an element of difficulty in production.

The profession of Master Shipwright, however, has a future: to protect an important fleet of vintage boats in need of frequent restoration, to respond to the growing number of enthusiasts of wooden boats, and to contribute to the evolution of interior design for yachts. In this regards, the several schools and training institutes, as well as specific professional courses that are active towards the survival of the figure of the Master shipwright are mapped below.

3.3.1 Active courses

- **Polo Tecnico Professionale di Venezia "I.I.S. VENDRAMINI CORNER" - Istituto Professionale per il Made in Italy "Giorgio Cini", Castello 787/A, Venezia.**
  For many years hosted on the island of San Giorgio Maggiore, in the early 2000s the institute moved together with the Convitto near the Giardini della Biennale, in the same area as the nautical institute with which it shares laboratories and special highly technological classrooms.
  After some transformations, since 2018 the institute has been included among the Professionals for Made in Italy, and is the only one in the country to offer training in shipbuilding. Master shipwrights, carpenters of squeri and shipyards and other shipbuilding experts support the teachers by making all their experience and love for their profession available to the students. In fact, thanks to the attention to teaching combined with professional training, the students of the IPIAMI "Giorgio Cini", at the end of their studies will have developed the skills of builders and repairers of typical lagoon boats and pleasure boats, both in wood and fiberglass.
  At the end of the studies, the professional figure will have developed skills in the ship technical field with knowledge of the typical processes of maritime and port shipyards and in-depth knowledge of the materials, traditional and innovative in compliance with the environment and safety, mainly used in pleasure craft and in the maritime world. Knowledge of new production and assembly

technologies in pleasure boats and coastal navigation will focus on a strong competence in the knowledge of the most innovative materials with a push towards knowledge and respect for the environment and pollution.
The experimental study path lasts four years and aims a providing the following competenceso:

- Define and plan the sequence of operations for the construction of a hull - or part of it - based on the project and instructions received and/or supporting documentation (diagrams, drawings, procedures, bills of materials, etc.) and the system of reports;
- Prepare tools, utensils, equipment and machinery needed for the various processing phases based on the type of materials to be used, the project and the procedures envisaged;
- Monitor the operation of tools, utensils, equipment and machinery, taking care of ordinary maintenance activities;
- Carry out the assembly of the components of a hull and any adjustments and corrections on pre-assembled products;
- Carry out finishing and completion operations on the hull, in compliance with the design specifications;
- Carry out ordinary and extraordinary maintenance of a pleasure boat, in compliance with specific sector regulations.
- Carry out ordinary and extraordinary maintenance on mechanical and electrical systems and engines of boats and install small electrical systems.

- **Polo Tecnico Professionale di Venezia "I.I.S. VENDRAMINI CORNER" - IPIAMI SERALE CANTIERISTICA NAVALE.**
The course is based on technical-practical skills in ship and lagoon constructions that will be acquired and practiced thanks to the numerous hours of laboratory. In this regard, noteworthy is the collaboration with the Metropolitan City of Venice and the implementation of the school shipyard that has been strengthened with the acquisition and setting up of a second shipyard in the Arsenale area. In particular, in addition to traditional woodworking, the processing of composite and innovative materials such as fiberglass, aluminium, carbon fibre and Kevlar is implemented, which allows technological innovation and lagoon tradition to be supported and combined on both historic and innovative boats.

3.3.2 Past courses

- **Advanced training for shipwrights ancient tradition and new technologies** [26], organised within the Interreg Italy-Croatia FRAMESPORT project and implemented by the Municipality of Monfalcone, Alto Adriatico Custom shipyard and Polo Tecnologico Alto Adriatico Andrea Galvani.
The training course aims to raise awareness and expertise on this ancient craftsmanship to all those people who wanted to increase their skills on the subject of building and working wooden boats, potential future shipwrights and enthusiasts in the field. The formative plan of the course is reported in Figure 36 and wanted to address all the most crucial topics necessary to professionals.

Course module	Topic
Introduction	Introduction to the training course: vision and mission, presentation of project stakeholders Teaching methodology and individual practice
1) Historical and economic background of the boats	History and tradition of boating in the Adriatic areas Types of wooden sailing and motor boats Boating plans
2) The construction materials	Types of wood for boating Traditional and historical woodwork New materials with high ecological sustainability (and the European strategic sustainability goals)
3) From technique to practice with the wooden boat restoration part	Insights of wooden boat design. The merits of choosing wood construction. The design of the boat - reading and understanding boating plans Restoration of wooden boats (conservative vs. philological restoration) Wooden boat repairs Bonding systems Inspection and determination of damaged and critical parts Evaluation of restoration interventions
4)New technologies (technical & tecnological skills)	New software for refit design Use of augmented and virtual reality visors - the case of the Galeb The enabling technologies and the European strategic goals of digitization and sustainability Product innovation: from idea to prototype to product and process engineering Eco-design: design for disassembling and design for dismantling Innovative materials: technology transfer and sustainability Additive manufacturing: what it is and the main advantages in adopting this technology in the product innovation journey
5) Communicating and living the tradition	Events and sport marketing of ancient boats

Figure 36 - Formative plan of the shipwright course offered within the FRAMESPORT project [26].

- **Consorzio Cantieristica Minore Veneziana – Master shipwright course.**
  The consortium was born from the will of a group of professionals, whose goal is to relaunch one of the major assets of the lagoon city: shipbuilding. In particular that related to the construction of wooden boats [27].
  The basic training course for "apprentice shipwrights" was born from the need to train specialized personnel by small businesses operating in the sector of the production of gondolas and other

wooden boats according to the Venetian lagoon tradition, and is the first condition for the relaunch of the smaller local shipbuilding industry in the face of the risks of asphyxiation, due to a lack of qualified workers and the loss of the tradition of shipwrights and the lack of the necessary generational turnover on the entrepreneurial front.
The course has the fundamental objective of training qualified workers for a rapid entry into the world of minor shipbuilding work by offering real opportunities for stable employment. To achieve the objective of introducing students to training and acquiring skills as a Master shipwright, the course intends to pursue a training method that allows:

- the training necessary to introduce young people to employment as "apprentice master shipwright" at shipbuilding yards for wooden boats;
- training to obtain the title of Master shipwright with an exam at the Port Authority.

The course is structured as shown in Table 1.

- **Confartigianato Venezia and Con-Ser Srl course for "Higher technician for the design and construction of wooden boats".**
  The course was funded by the Veneto Region and the European Social Fund to learn the art of building traditional wooden boats (from design to construction). The course aimed at qualifying young unemployed/unemployed graduates as well as personnel expelled from the world of work interested in working in traditional shipyards. Excellent results were obtained in the past by analysing the data from old editions: more than 60% of participants are still employed in shipyards or as employees or have even set up their own business. The course lasted a total of 900 hours (580 classroom/construction site + 320 internship within the various assigned construction sites).

Table 1 - Structure of the course for apprentice Master shipwright [27].

1	Elements of technical drawing and mathematics	30
2	Wood technology	25
3	History and theory of ships	31
4	Geometry of ships	15
5	Wooden shipbuilding technologies	25
6	Marine outfitting	15
7	Engine propulsion systems	20
8	Safety in shipyards	16
9	Practical exercises in laboratory	151
10	Traineeship	150
	TOTAL	**478**

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List of figures

Figure 1 - Most-used materials in boatbuilding [3]. 3
Figure 2 - Three principal axes of wood [1]. 5
Figure 3 - Clinker-built sailing vessel (https://www.denmanmarine.com.au/gartside-10-traditional-clinker-dinghy-c28/). 10
Figure 4 - Carvel-built vessel (http://bertan.gipuzkoakultura.net/23/ing/11.php). 11
Figure 5 - Comparison between clinker planking and carvel planking.. 12
Figure 6 - Combined strip-planking and cold-moulding and strips preparation.. 13
Figure 7 - Strip-planked hull [5]. 14
Figure 8 - Gondola's construction drawing (https://www.veniceboats.com/images/progetto%20Gondola%20serie%20completa%201.jpg). 15
Figure 9 - Gondola's construction process (https://cjalzumit.wordpress.com/2022/08/24/costruzione-della-gondola/). 16
Figure 10 - Macroscopic subdivision in coppice and high forests of areas and planned areas in Veneto region [6]. 17
Figure 11 - Forest area (ha) classified by forest categories and by province, excluding Sappada municipality [6]. 18
Figure 12 - Evolution of forest area in Veneto region from 1936 to 2015 [6]. 18
Figure 13 – Subdivision of the forest area in Veneto region [7]. 19
Figure 14 - Veneto state-owned forests [6]. 22
Figure 15 - Mussin boat (courtesy of Consorzio Legno Veneto and Società Mutuo Soccorso Carpentieri e Calafati). 22
Figure 16 - Mussin boat after recovery (courtesy of Consorzio Legno Veneto and Società Mutuo Soccorso Carpentieri e Calafati). 23
Figure 17 - RASO raft still present in the Somadida forest (https://auronzomisurina.it/ambiente/foresta-di-somadida/). 24
Figure 18 - Forest areas in Friuli Venezia Giulia (IRDAT, 2022). 26
Figure 19 - Regional forest of Friuli Venezia Giulia [11]. 27
Figure 20 - Summary of regional forests of Friuli Venezia Giulia [11]. 28
Figure 21 - Croatian forested areas (https://www.eea.europa.eu/data-and-maps/figures/land-cover-2006-and-changes/croatia). 29
Figure 22 - Active enterprises in 2017 subdivided in terms of ATECO code [14]. 36
Figure 23 - Origin of wood employed in the Veneto region [18]. 42
Figure 24 - Enterprises that use local wood (among the 127 interviewed in [18]. 42
Figure 25 - Destination market with reference to 2019 annual turnover [18]. 42
Figure 26 - Tree species in the timber supply chain of Belluno province [18]. 43
Figure 27 – 2013-2018 price trends for the various species [19]. 45
Figure 28 - Trend of price and demanded quantities of fir from Trentino region [21]. 46

Figure 29 – Trend of price and demanded quantities of fir in form of logs and timber framing [21]. 47
Figure 30 - Trend of price and demanded quantities of larch [21]. 47
Figure 31 - Trend of price and demanded quantities of Swiss pine [21]. 48
Figure 32 - Life cycle assessment (unknown source). 53
Figure 33 - LCA approaches (unknown source). 53
Figure 34 - Life cycle boat hull phases/boundary system [23]. 55
Figure 35 - Comparison of the complete hull life cycle in the four scenarios excluding fuel [23]. 56
Figure 36 - Formative plan of the shipwright course offered within the FRAMESPORT project [26]. 74

List of Tables

Table 1 - Structure of the course for apprentice Master shipwright [27]. 75