Interreg Sudoe

EUROPEAN UNION

IMIP_

Innovative Eco-Construction System Based on Interlocking Modular Insulation Wood & Cork-Based Panels

European Regional Development Fund

D1.3.1 ANALYSIS OF CURRENT USES OF WOOD AND CORK IN THE SUDOE SPACE

IMIP-SOE3/P3/E0963

Project funded by the Interreg Sudoe programme through the European Regional Development Funds (ERDF)

PROJECT CONTEXT

Project acronym	IMIP
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Deliverable	D1.3.1 Analysis of current uses of wood and cork in the Sudoe space
Summary	The deliverable is designed to demonstrate the main uses and features of pinewood and cork in the SUDOE space, highlighting mainly the use of these materials in construction. The main wood products used are saw wood, glued laminated timber, Laminated Veneer Lumber, Cross-Laminated Timber, Parallel-Strand Lumber and Laminated Strand Lumber, Natural wood veneer, Wood I-BEAMS Joists, Particle Board or Chipboard, Oriented Strand Board, Fibreboard, Medium Density Fibreboard, Plywood, Wood-wool and wood-fibre insulation panels, Stressed-Skin Panels and Expanded agglomerated cork.
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CONTENT

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INTRODUCTION

The most significant sub-sectors of the forest-based industries in Europe are the woodworking and furniture industries, which in 2011 had a total turnover of over 200 billion € and 2 million employees in 314,000 mostly small and medium sized companies. The woodworking sector consists of sawmilling (15%), wood construction products (37%) and furniture manufacture (48%). Some 102.9 million m^3 of sawn wood were produced in the EU in 2015, close to two thirds of which came from the five largest-producing EU Member States: Germany (20.9%), Sweden (17.7%), Finland (10.3%), Austria (8.6%) and France (7.3%) (Forest-based Sector, 2020).

Wood is our most important renewable raw material for construction and furniture. First, wood and wood products sequester carbon and reduce CO_2 in the atmosphere, helping to mitigate climate change. Secondly, wood products are made in an established, low energy production system, with minimal emissions. By-products from sawmills such as chips and sawdust are transformed into wood-based panels. In addition, wood products can be reused and recycled. At the end of their useful life they can be used for bio-energy (Forest-based Sector, 2020).

The production of roundwood in the EU-27 continues to increase - in 2018 it was 21% higher than in 2000, 23% of the EU-27's roundwood production in 2018 was used as fuelwood; the rest was used for sawnwood and veneers, pulp and paper production. In 2018, about 401,000 enterprises were active in wood-based industries across the EU, representing 20% of EU manufacturing enterprises.

Making Europe the world's first climate-neutral continent is within reach but requires more innovative initiatives and research-based actions. Examples of research and innovation activities needed to tackle the challenge, how this: sustainable forest management, biodiversity and resilience to climate change; increased, sustainable wood production and mobilization; more added value from noon-wood ecosystem services; Towards a zero-waste, circular society; efficient use of natural resources; Diversification of production technologies and logistics; Purposeful, safe jobs and links between rural and urban region; Renewable building materials for healthier living;

New fibre-based products and 80 per cent lower CO_2 emissions; Renewable energy for society.

The EU woodworking industries include the production of sawn wood, wood-based panels, and wooden construction materials and products. About 70% of the wood in the EU is used in construction and furnishings.

OBJECTIVE

The forest-based sector value chains produce a wide range of products ranging from wood construction products, packaging, furniture, paper and pulp products, and hygiene articles to biomass fuels, bioplastics, biocomposites, carbon fibres, textile fibres and biochemicals. The aim of this task intent to analyse the different current uses of wood (*P. pinaster, P. halepensis, P. nigra*) and cork (*Q. suber*) in the Sudoe regions, specifically France, Portugal and Spain.

METHODOLOGY

This research is the result of effort and collaboration of different institutions, organisms, delegations, and individual consultants, as CSA, AITIM and, AAE.

RESULTS

Woodworking industries

The political interest in using wood products to achieve climate change mitigation targets, as well as the recent technological and institutional changes, have resulted in new investments and improved cost competition for new wood-based construction solutions. In general, the positive prospects for the wood products industry are related to the expectations for a shift towards low-carbon economy favouring renewable resources. From the available data (Eurostat 2020), France roundwood production in 2018 was approx. 48.2 million m^3 of which approx. 53% were for industrial purposes. In Portugal, with 14.0 million m^3 produced and Spain, with 17.4 million m^3, more than 90% of their total round wood production was for industrial purposes. With the exception of France Portugal and Spain recorded a gradual increased in roundwood production since 2000 (Figure 1). The output of roundwood in EU is dominated by conifers trees accounted for 68% of all roundwood harvested.

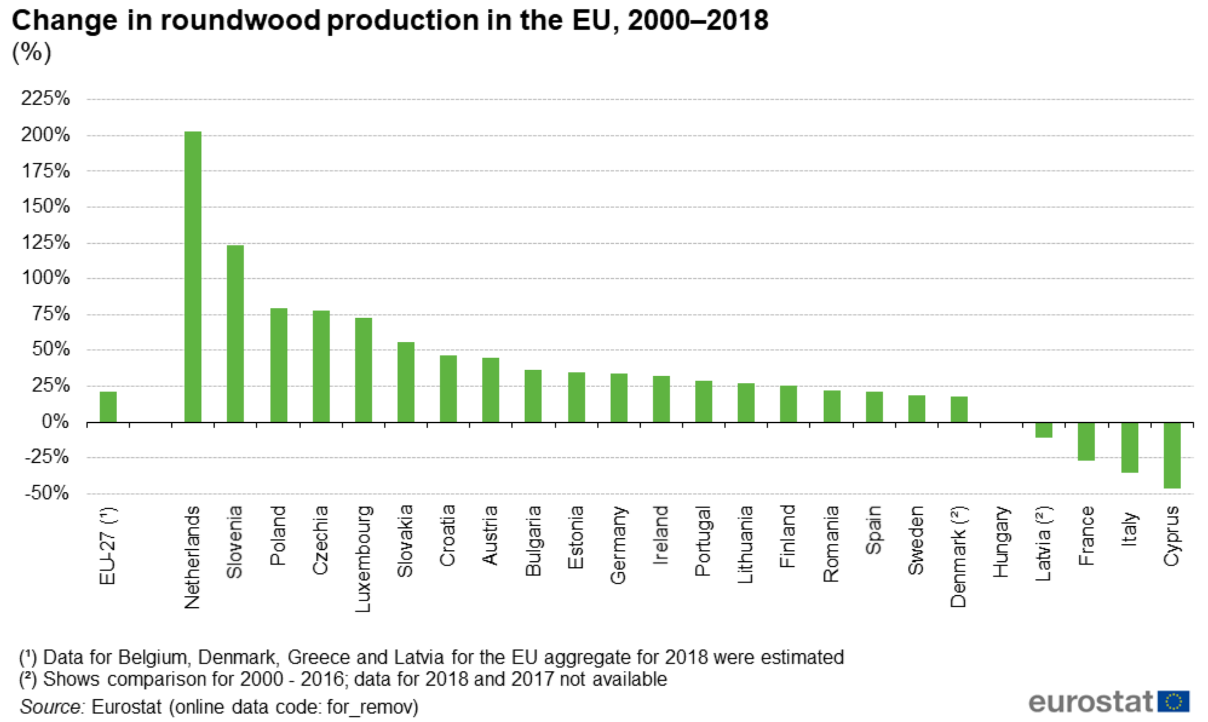

Figure 1. Change in roundwood production in the EU-27, 2000-2018 (%). Source: Eurostat.

The wood products industry can be divided into three subsectors, sawnwood, wood-based panels and engineered wood products (e.g., for construction, furniture and packaging). From the available data, in 2019, France sawn wood production totalled approx. 13.0 million m^3, Portugal 5.0 million m^3, and Spain approx. 3.0 million m^3 (Figure 1a).

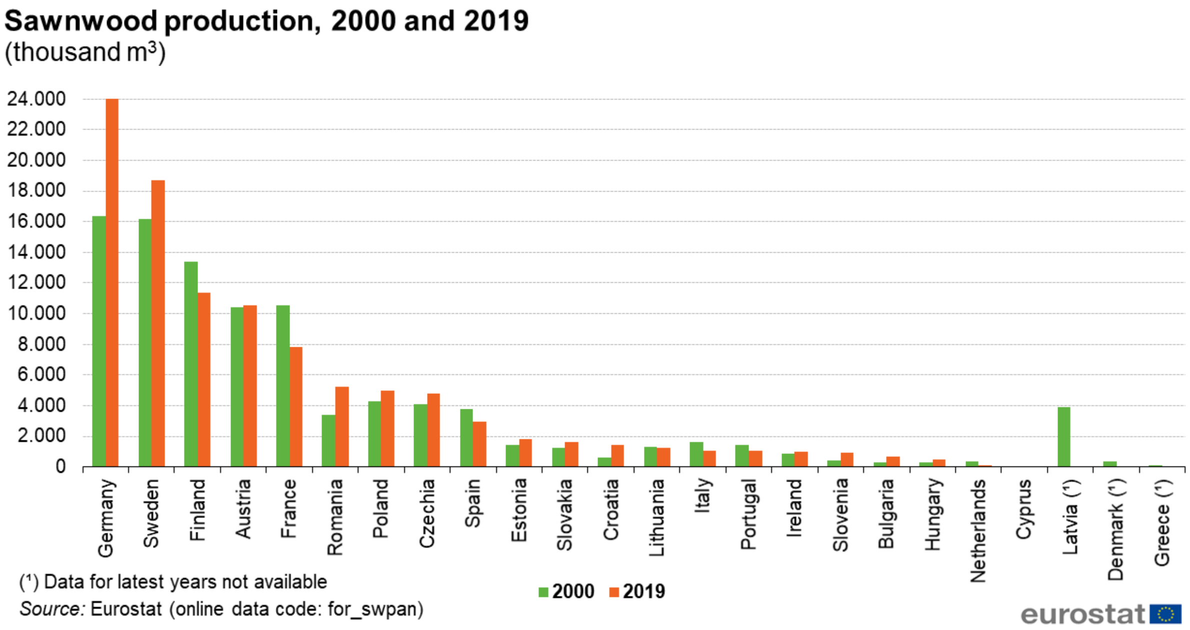

Figure 1a. Change in sawnwood production in the EU-27, 2000 and 2019. Source: Eurostat, 2020.

Figures 2, 3 and 4 show the production engineered wood products in Spain, France and Portugal (Eurostat 2020). In Spain the production engineered wood products, such as total fibreboards (MDF/HDF) is growing (Figure 2). In 2018, it reached an estimated 1.7 million m^3, i.e. almost 0.7 million m^3 (41 %) more than the peak output recorded in 2009, indicating that the forest industry is adapting to changes and has great potential to become a key player in emerging bio economies. In 2018 the total production of total particleboards (particleboard, and OSB) in Spain reached 1.9 million m^3 after a decrease in production observed between 2011 and 2013 (reflecting the recent European economic crisis), improving from 2014 and after remaining constant (Figure 2). The plywood panels industry is growing. In 2018, it reached an estimated 1.0 million m^3, i.e. almost 0.610 million m^3 (62 %) more than the peak output recorded in 2016.

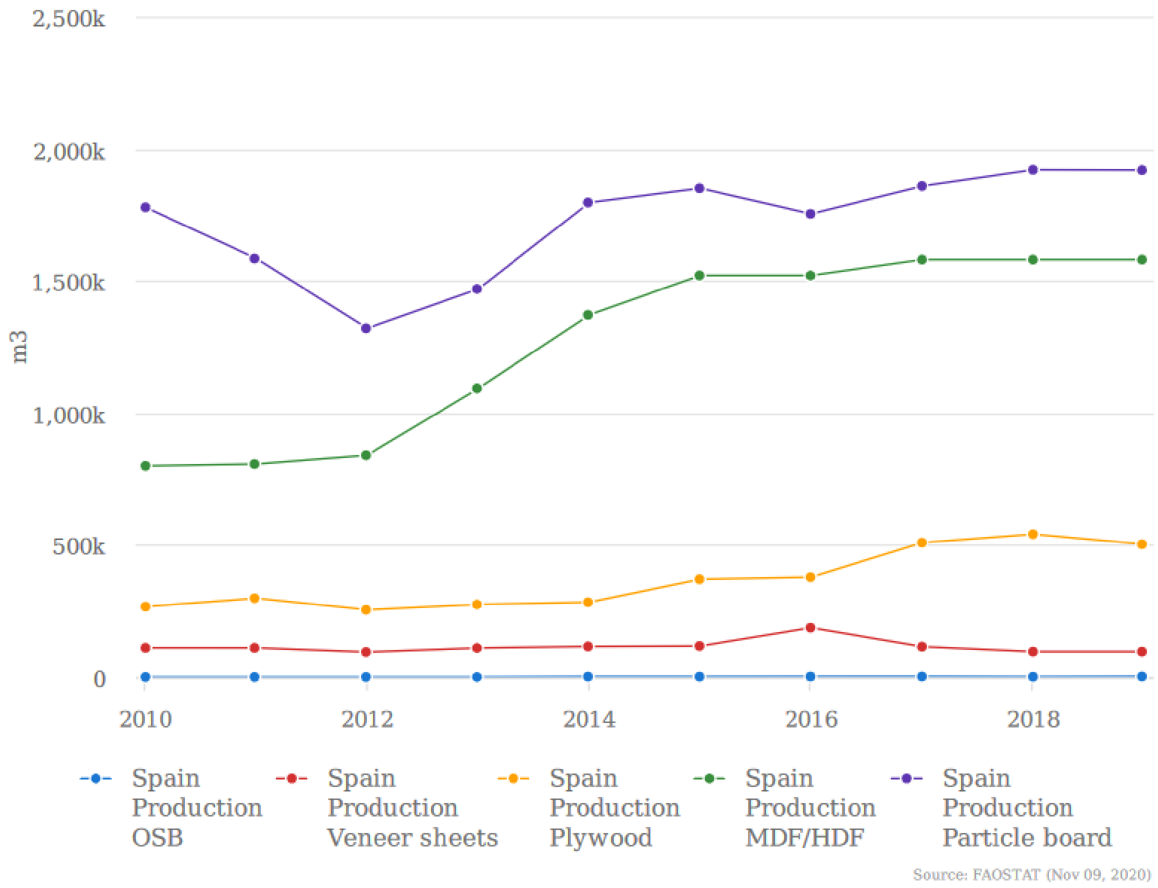

Figure 2. Engineered wood panel's production in Spain 2009-2018. Source: Eurostat.

In France, engineered wood panel production is dominated by the particleboard industry compared to fibreboard production, with a steady decline in production since 2011 (Figure 3). In 2018 the total production of particleboards was 3.4 million m^3, almost 1.0 million m^3 less than the peak output recorded in 2011 (4.4 million m3). Regarding the total fibreboards production it showed an increasing trend. In 2018 it reached an estimated 1.3 million m^3, i.e. almost 0.3 million m^3 (25 %) more than the peak output recorded in 2009 (Figure 3). Also as in Spain the plywood panels industry in France production is small when compared with the particle and fiber panels industries. Regarding the production of plywood panels in France, it remained constant over the years. In 2018 reached 0.260 million m^3.

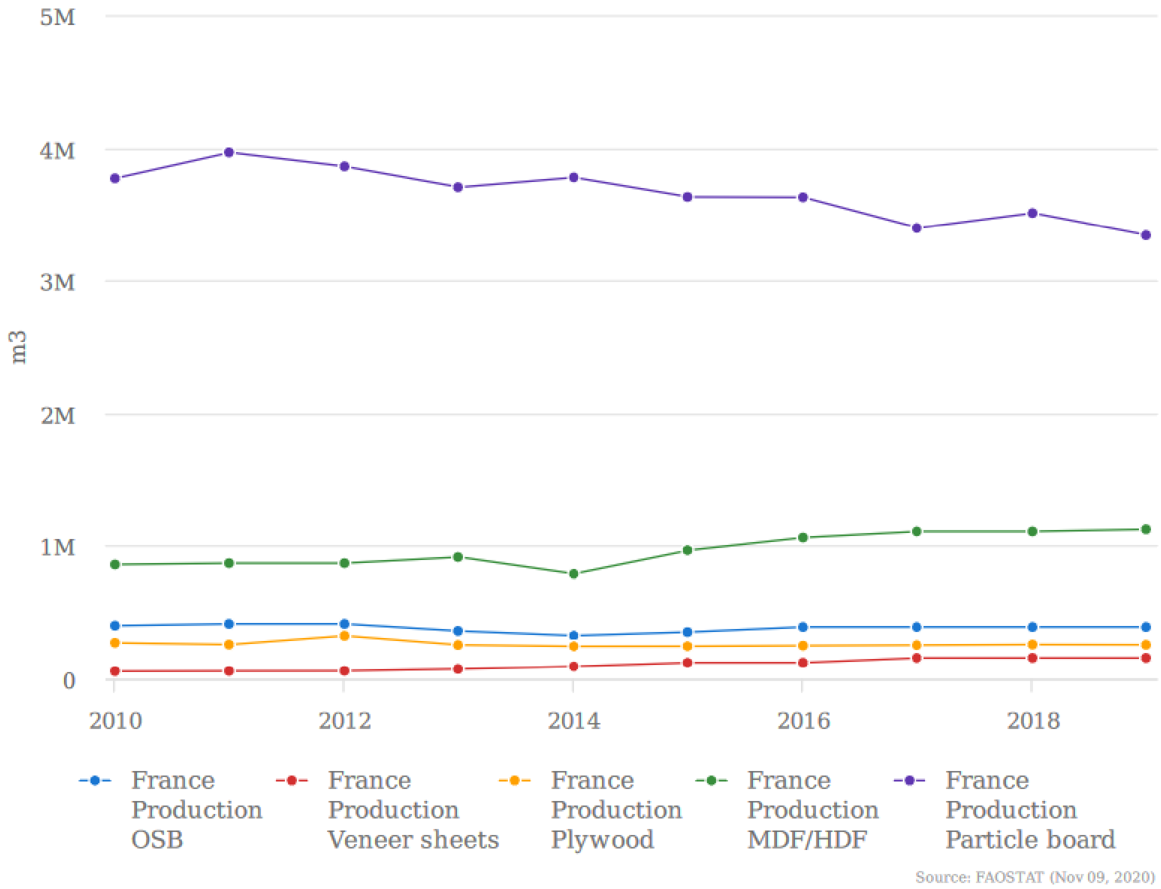

Figure 3. Engineered wood panels production in France 2009-2018. Source: Eurostat.

In Portugal, the production of engineered wood panels (fibreboard and particleboard) not presented a clear trend (Figure 4). There were, in the last 3 years, for both types of panels a clear reduction. In 2018 the particleboard and fibreboard in Portugal were, respectively, 0.63 million m^3 and 0.41 million m^3. In Portugal, the plywood industry decreased.

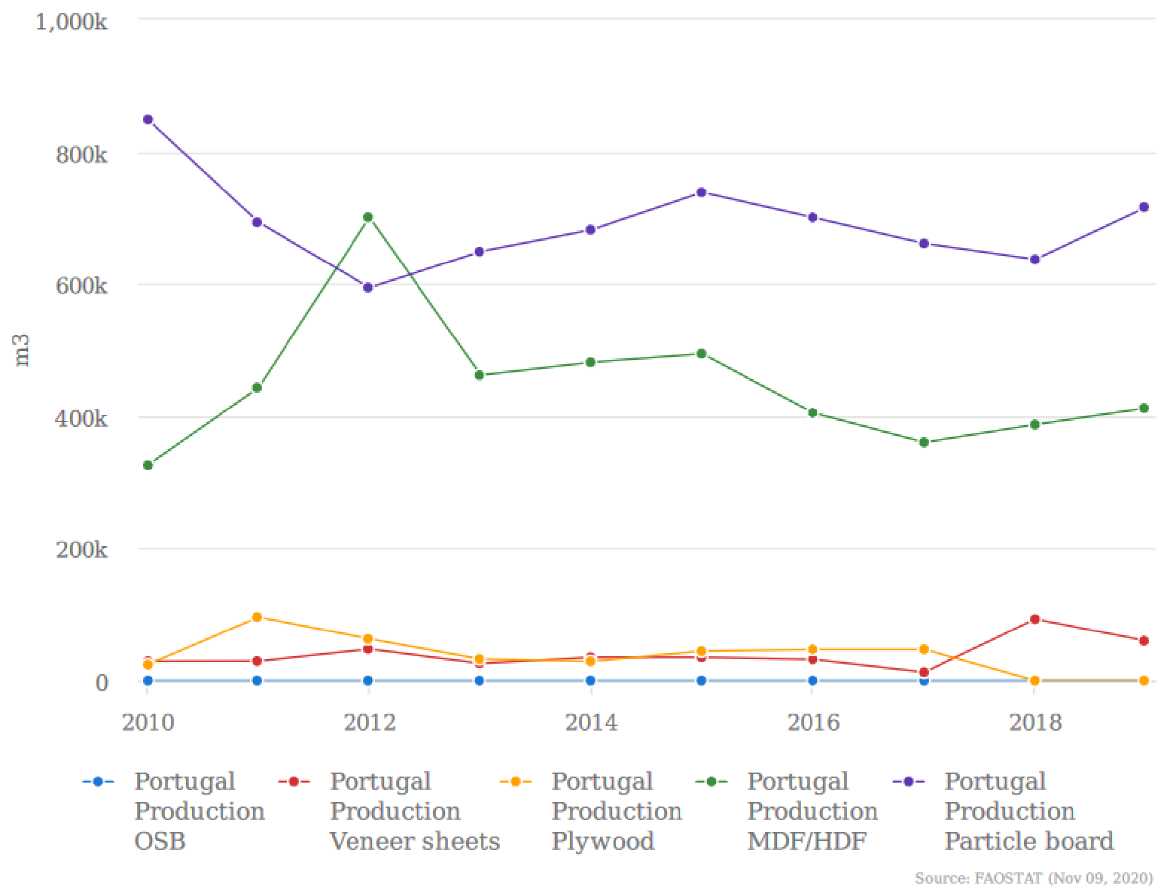

Figure 4. Engineered wood panels production in Portugal 2009-2018. Source: Eurostat.

Cork sector

Figures 5, 6 and 7 show the main cork products import and export in 2018 in Portugal, France and Spain (Thousand euros) (Eurostat 2020). Portugal is the world leader in the cork sector in terms of exports. In 2018, its share was 62.5 % followed by Spain with 18.4 % and France with 5.2% (APCOR, 2020). In the cork stopper segment, natural stoppers come in first place, at 224.3 million euros followed by other types of stoppers, including technical stoppers such as agglomerates and champagne stoppers. The export of cork as a building material, reach 78.5 million euros in 2018. However, in exports by volume, building materials lead with 68.3 % and 137.3 thousand tonnes, followed by cork stoppers, with 25.4 percent and 51.1 thousand tonnes (APCOR).

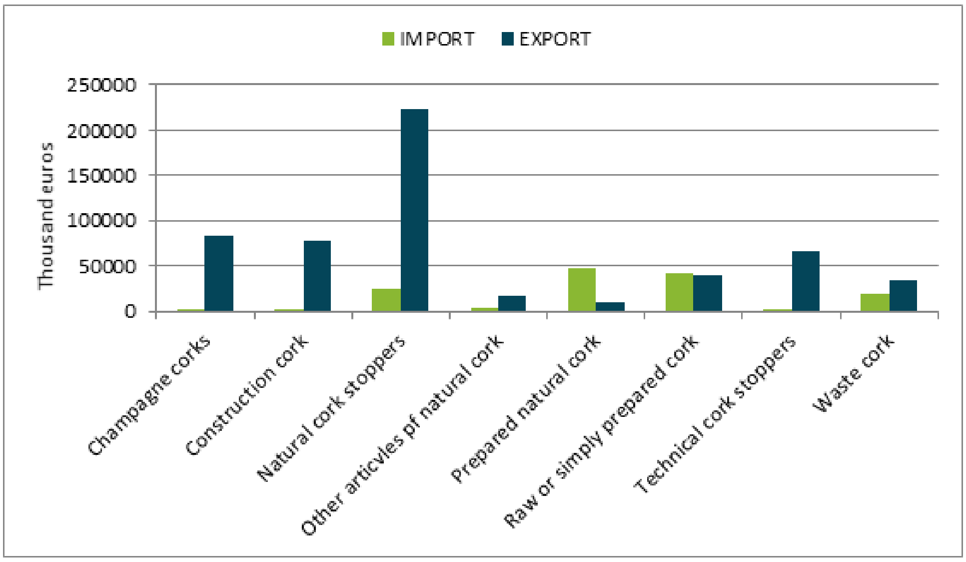

Figure 5. Main cork products import and export in 2018 in Portugal.

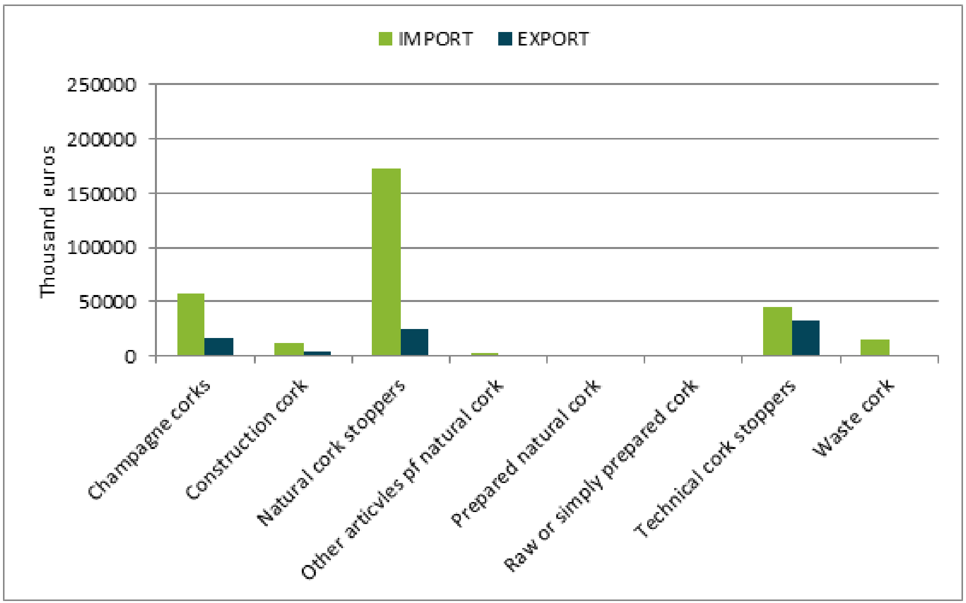

Figure 6. Main cork products import and export in 2018 in France.

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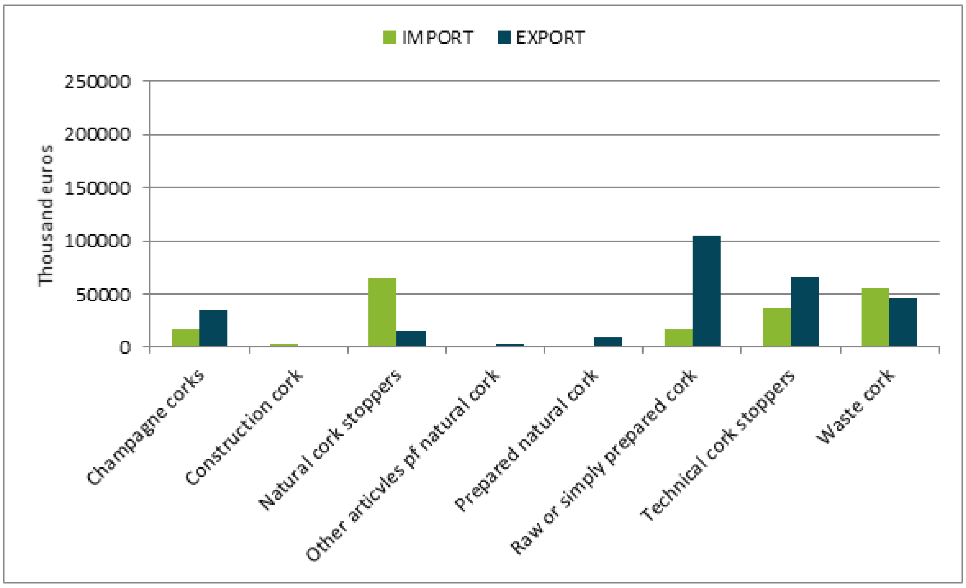

Figure 7. Main cork products import and export in 2018 in Spain.

In 2018, France continued to be an important importer of cork products in terms of value. France was the leader in the consumption of champagne corks and natural cork, with 229.0 million euros. Regarding construction materials, imports amounted to 12.4 million euros.

Spain is an important exporter of cork as a raw or simply prepared cork representing 104.0 million euros, technical stoppers (at 66.4 million euros) and waste cork 46.1 million euros.

Wood Products

When we talk about wood products, we talk about the wood transformation processes from the forest to the end user. In this transformation process, we can separate what is generically called the 1st transformation, which included the work of sawmills, the wood panel industry and the pulp industry, and the 2nd transformation that includes sawn wood transformation operations, more or less traditional, ranging from the production of pallets and packaging to furniture and carpentry, or the manufacture of structural components for construction, like glued-laminated panels and scantlings, solid wood panels, 3-ply panels, door frames, cladding, decking are available in variety of species (pine oak, ash, beech, poplar, walnut, etc.).

Sawn wood

The total output of sawnwood across the EU-27 was approximately 100 million m³ per year from 2010 to 2018, reaching 109 million m³ in 2018. Germany and Sweden were the EU's leading sawnwood producers in 2018, accounting for approximately 21 % and 17 % of the EU-27 total sawnwood output, respectively.

Sawn wood (planks, beams, boards, rafters ...) is wood from processing of tree trunk segments in pieces of square or rectangular section, of dimensions variables according to the desired final product or by profile-chipping process and, with few exceptions, is greater than 6 millimetres (mm) in thickness Depending on how the trunk is cut, the parts obtained can take on aspects and different features.

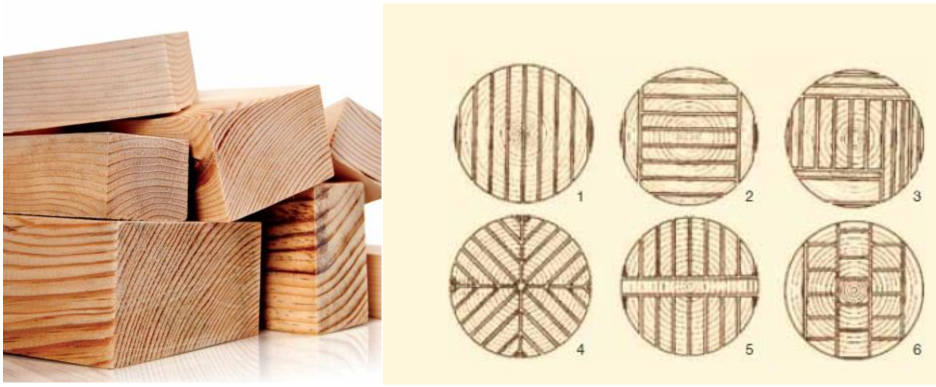

Figure 5. Different sawing patterns for a trunk.

Sawn wood, after being produced, it undergoes a process drying process (natural or oven) in order to acquire the humidity indicated for the use it will have. Inappropriate moisture content is at the root serious defects of the wood in service. If the use of the produced parts is outdoors or in ground-contact ~~abroad~~, then they must go through a more or less deep treatment process that protects it from termite attacks, insects and decay fungi.

Despite most of the sawn wood of pine in Portugal and Spain to be used for packaging and pallets, it is also consumed in carpentry, furniture and civil construction.

Glued laminated timber (Glulam)

Glued laminated timber (GLT), also abbreviated glulam, and glued solid timber (GST) are structural wood products made up of several ~~layers~~ lamellas of structural timber that have been bonded together using structural adhesives. GLT is used to form pieces with important cross-sections and lengths and maximum 45 mm thick, while GST, also known also as Duo and Trio elements are formed with lamellas between 45 and 85 mm thick. Lamellas are used for moderate cross-sections and length elements. Lamellas are composed by finger-jointed boards with the grain direction running along the length of the laminated timber product obtaining more homogeneous and isotropic large pieces, with less tendency for cracking, since the stresses generated by one lamella are limited to it, and counteracted and absorbed by the others.

Glulam wood is recommended for any type of construction from residential projects to industrial buildings. It can even be applied to buildings located in areas with specific climatic demands, if a moisture protection treatment is applied.

A variety of structural components can be formed using glulam including parallel beams, pre-cambered beams, sloped beams, curved beams, flight beams and trusses.

Laminated timber is usually planed and is available in various finishes and pressure impregnated. The most common cross-section dimensions are shown in the accompanying table, but laminated timber is also available to special dimensions. Most common cross-section dimensions for laminated timber Maximum height of laminated timber is approx. 2 meters and maximum length approx. 30 meters. Maximum dimensions vary according to manufacturer. The lamellas ~~strips or sheets~~ from which GLT is made are ~~n~~ 45 mm maximum thickness for straight beams ~~and 33 mm maximum~~ but smaller thickness can be necessary for curved or exterior structures.

The manufacture of Glulam brings together two very old techniques: 1) the gluing technique and 2) the lamination technique. Therefore, when talking about "glued laminated wood", we talk about a wood composed of pieces glued and bonded together with parallel fibers (Figure 6). To generate efficient structural elements, the pieces must be joined with adhesives of such high resistance.

Laminated timber beams have good fire resistance behaviour if the cross-section has the proper dimension for the case and do not bend under the effect of heat. Charring ~~speed~~ rate for laminated timber is approx. 0.65-0.7 mm/min.

Varieties of wood species are appropriate for manufacturing glulam. Some of the most common types include, spruce, Scots pine, SPF (Spruce-Pine-Fir), Douglas Fir, Larch. Strength-graded and ready finished glued timber products, etc. are available in EN14080 for softwood. Less commonly, hardwoods such as Oak and Sweet Chestnut are also used, generally under special technical assessments such as ETA (European Technical Assessment) procedures.

Figure 6. Glued laminated wood left, and Glued solid wood, right.

Laminated Veneer Lumber (LVL)

Laminated Veneer Lumber (LVL) is a high strength engineered wood product used primarily for structural applications. LVL employs thin, veneer layers to form larger beams. It is manufactured by bonding together rotary peeled or sliced thin wood veneers under heat and pressure. It is a structural wood product made by gluing together lathe-turned veneers (Figure 7).

Prior to lamination, the veneers are dried and the grains of each veneer are oriented in the same direction. This makes LVL stronger, straighter and more uniform than solid timber and overcomes some of timber's natural limitations such as strength-reducing knots. This gives orthotropic properties (different mechanical properties against different axes) in a similar way to the properties of sawn timber, rather than the isotropic properties (the same mechanical properties in each direction) in the plane of plywood. The added ~~durability~~ feature of being an engineered wood product means LVL is less prone to shrinking or warping. LVL can also support heavier loads and span longer distances than normal timber.

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On the other hand the fact that all veneers are oriented in the same direction means that its shrinking and swelling behaviour is orthotropic and similar to glulam or solid wood, not being compensated or improved by transversal veneers, as it happens in other wood products such as CLT or Plywood. For that reason in order to improve this behaviour, some variants, mainly used as horizontal panels, are available with a percentage of the veneers transversally oriented.

Normally the veneers are not sanded or filled, but LVL can be made to order with the surface veneers sanded. Laminated veneer lumber is available in various finishes and also pressure-impregnated to class AB. Laminated veneer lumber is specified according to Standard -EN 14374.

Maximum width of LVL is 2.5 meters. Maximum length is 24 to 25 meters depending on the manufacturer. Transport problems usually limit the length to approx. 25 meters. The thickness of the beams varies from 27 to 75 mm. Standard heights vary by manufacturer.

In horizontal construction, typical centres for LVL are from 5 to 12 meters. As well as floor and roof construction, LVL can be used for trimming and supporting beams and for stiffening. In fire, the charring speed is 0.6 mm/min.

Finnish laminated veneer lumber is made by gluing 3 mm thick spruce veneers together. Depending on the veneer product, all the veneers are in the longitudinal direction or some of the veneers are glued crosswise.

Figure 7. Laminated veneer lumber (LVL)

Cross-Laminated Timber (CLT)

Cross-laminated timber (CLT) is a solid wood board formed by stacking and gluing together successive perpendicular layers of wood. The layered stacks are then pressed in large hydraulic or vacuum presses to form an interlocked panel. The number of layers in a panel typically range from three to seven, though they can ~~vastly~~ exceed this number. Typically, the thickness varies between ~~51~~ 60 and 280 ~~400~~ mm with the width being no more than 4.8 m and the length 20 m, although generally their dimensions are limited due to transport to 2.5 width and 12.5 m long (Figure 8) This cost-competitive wood building system can be used in a wide range of applications, including mid-rise urban infill, industrial, educational and civic structures.

The most typical uses of CLT are as load-bearing parts for building frames, such as walls, floors and roofs. The boards are also used in facade cladding and interior lining. They are usually machined into the desired shape in a factory using a CNC (computer numerically controlled) machine. Because of this, it is easy and precise to prepare a board for conversion into a window or door, for example. Usually, the board surface is polished and the material in the surface layers selected so that, if desired, it can be fitted into an interior space unlined.

Figure 8. Cross-laminated timber (CLT)

Since CLT panels resist high racking and compressive forces, they are particularly cost effective for multi-story and long-span diaphragm applications. They weigh less than concrete or steel, so can also reduce foundation costs. In addition, CLT elements can be combined with other building materials such as glulam beams, enabling flexibility in design, style and finish architecture.

Parallel-Strand Lumber (PSL) and Laminated Strand Lumber (LSL)

PSL are engineered wood elements made using parallel oriented long strands, with a length-to-thickness ratio of approximately 300, bonded together with adhesives and pressed to form elements to be used as beams, columns, headers, stringers and other lineal load-bearing members. LSL are similar elements manufactured with shorter strands that have a length-to-thickness ratio of approximately 150.

This results in a dense and homogeneous material in which knots and other imperfections are randomly dispersed throughout the product. In Europe is not a very common product, and therefore is not included in the design standards such as Eurocode 5, EN 1995-1-1, while in EEUU and Canada is one of the possible structural products in use for building.

Figure 8. PSL load-bearing element. ©2020 Weyerhaeuser NR Company. All rights reserved.

Natural wood veneer

Wood veneers in the simples of terms are thin slices of natural wood generally less than 1/40" thick. These veneers are typically pressed onto or laminated to thicker core materials such as plywood, particleboard and MDF to create structural panels to be used in place of thicker hardwood lumber. This is still real wood but machinery and technology allow the material to be sliced thin without waste instead of sawing it into thick boards. Just like thick boards, it can be plain sawn, quarter sawn, rift cut, or rotary cut and produce the many different grain patterns associated with each cut (Figure 10).

Along with natural hard and soft wood veneers, there are reconstituted or engineered wood veneers, which are fabricated but still natural wood cellulose fibre. These are made from renewable and highly sustainable forests and are often made to replicate exotic woods that are either endangered, limited, or very expensive to acquire.

Producing veneer faces of a standard dimensional size such as 4'x8' or 4'x10' is the next step in the process. It takes multiple leaves of veneer to create a face or sheet that is 4' wide. To accomplish this, the veneer leaves are knife cut lengthwise to create a true parallel edge. The leaves are glued edge to edge in the splicing operation to make faces in widths of 4' and larger. These faces then will be backed with other materials such as paper, wood cross band, poly/resin back or phenolic. Almost complete at this point, the veneer sheets will go through a flexing operation and on to a final sanding operation. They are now ready to use for a multitude of manufacturing, woodworking, crafting and DIY purposes (Wise Wood Veneer, 2020).

While commonly used in building and construction for doors, wood cabinets, furniture, etc., the versatility of flexible wood veneers goes well beyond the traditional aspect. Architects and designers incorporate wood veneer into their plans as complete interiors or as accent to other mediums. Many upscale retailers incorporate wood veneers into their display fixtures. Lighting companies, signage companies, audiophile speaker manufacturers, musical instrument makers, RV, aircraft, and custom yacht manufacturers have all found ways to work this versatile material into their products.

More recently, there is a trend to use wood veneer in all types of DIY and craft focused businesses. Of these, some of the unique uses are cell phone and mobile device cases, wooden invitations and greeting cards, jewellery, wall art and custom framing, and even eyewear.

Figure 9. Pine wood veneer

Wood I-BEAMS Joists

An I-beam is a light beam support assembled by gluing together wooden flanges and fibreboard and plywood webs. Applications of use include the base floor-, intermediate floor and roof structures of buildings and external wall frames Each joist features an enhanced OSB web with high-grade solid sawn lumber or GP Lam® LVL flanges (Figure 10). The centre of the section serves to transmit shear stresses, so a material with good shear properties is required.

I-beams are best suited in structures that require rigidity, heat insulation capacity, dimensional precision and economy. The beams are easy to work using normal carpentry tools, and holes can be made in the web plates for electrical and HVAC installations. When altering the beams, however, the manufacturer’s or structural designer’s instructions must be observed. With a flanged beam, you can achieve the same load-bearing capacity with a smaller amount of material than with glued laminated timber or sawn timber, so the price is also competitive (wood Produtcts, 2020).

Figure 10. Wood I-BEAMS Joists.

Particle Board or Chipboard

Particleboard, or chipboard, is used as a generic term for any wood-based panel product that is made of wood particles (wood flakes, chips, shavings, saw-dust and similar) and/or other lignocellulose materials in particle form (flax shives, hemp shives, bagasse fragments and similar), with the addition of an adhesive, bonded together with an adhesive system under pressure and heat (EN 309) ensuring internationally required quality levels and meeting the requirements of European standards EN 312 and EN 13986.

Wood chips comprise the bulk of particleboard and are prepared in a mechanical chipper generally from coniferous softwoods and hardwoods, such as birch, are sometimes used. The chips in the surface layer are thinner than those in the middle layer, so the surface of the particleboard is denser and more compact than the middle. Particleboard density typically in the region of 650-750 kg/m^3.

Figure 11. Cross section of particleboard

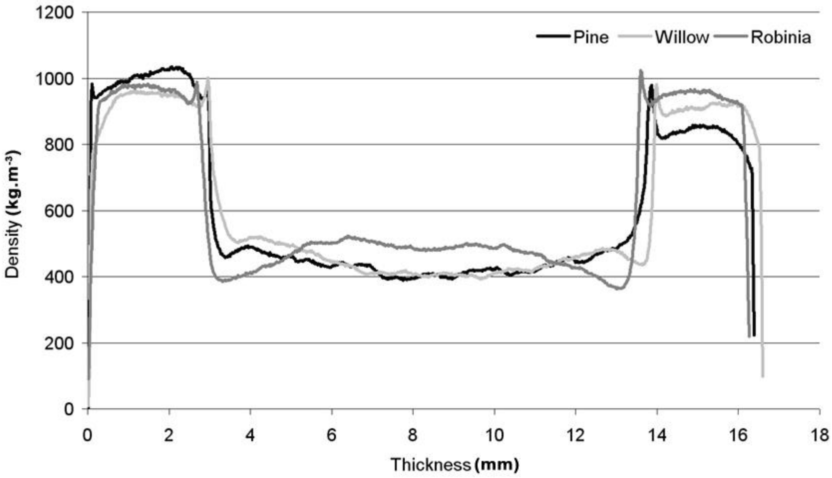

Figure 12. Density profile developed during manufacture for improved properties in bending and a harder surface.

Characteristics of Particle Boards:

- Particle boards are affordable compared to other solid timber products as these are cheaper.
- The boards are denser and uniform than other conventional wood and plywood is available.
- Particle board can be painted or veneer can be applied onto the surface to make it attractive.

Although the board is denser, it is known to be the lightest and weakest amongst the other fibreboard such as hardboard (high-density fibreboard) and medium-density fibreboard. Higher the density of the particle board, higher is the strength and resistance if screw fasteners have to be unfastened. The furniture, which requires large pieces of wood are, made using particleboards such as tabletops, TV cabinets, desks, etc. A lot of time is saved to simply bond two pieces of wood together to achieve the desired size.

Specifications:

Wood-based panels used for construction purposes are covered by a harmonised European standard (EN 312), which contains the requirements for the following seven grades (technical classes):

- P1: general purpose boards for use in dry conditions
- P2: boards for interior fitments (including furniture) for use in dry conditions
- P3: non load-bearing boards for use in humid conditions
- P4: load-bearing boards for use in dry conditions
- P5: load-bearing boards for use in humid conditions
- P6: heavy duty load-bearing boards for use in dry conditions
- P7: heavy duty load-bearing boards for use in humid conditions.

Panel sizes commonly available are:

- 1830mm × 1200mm
- 2440mm × 1220mm
- 2750mm × 1220mm
- 3050mm × 1220mm

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- 3660mm × 1220mm

in thicknesses of: 2.5mm, 3.2mm, 6mm, 9mm, 12mm, 15mm, 18mm, 19mm, 22mm, 25mm, 30mm and 38mm

Standard particleboards are uncoated particleboards meant for furniture manufacture and construction. The resistance to moisture of particleboards belonging to classes P3, P5 and P7 is significantly improved by using melamine-reinforced adhesive in the manufacture of the board.

Physical properties:
Particleboard is hygroscopic and its dimensions change in response to a change in humidity. Dimensional change for a 1% change in particleboard moisture content:

P4 and P6 - length 0.05%; width 0.05%; thickness 0.7%.

P5 and P7 - length 0.03%; width 0.04%; thickness 0.5%

OSB (oriented strand board)

OSB is an engineered wood-based panel material. Oriented Strand Boards are multi-layered panels made from strands of wood of a predetermined shape bonded together with a binder (often water resistant) under pressure and heat. Wood strands are cut tangentially from debarked logs which are held longitudinally against rotating knives. The ribbon of flakes produced is usually about 75mm wide and this breaks up on handling to produce individual flakes which are 75mm along the grain and from 5mm to 50mm across the grain, these strands are grouped into big sheets and pressurized at a high temperature OSB is usually composed of three layers, with the strands of the outer two layers orientated in a particular direction, more often than not in the long direction of the panel. The European specification for OSB is EN300.

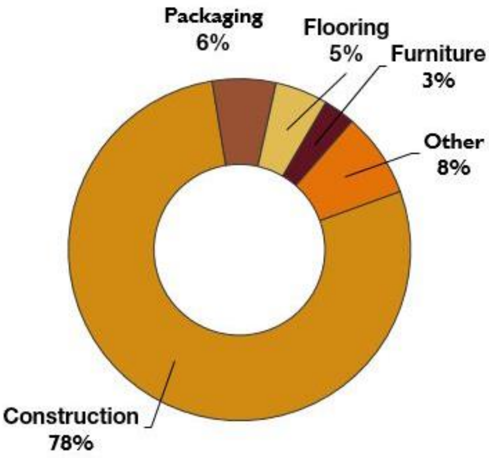

Figure 13. Oriented Strand Board (OSB) end-uses, 2019

The three main adhesives used in the production of OSB are phenol-formaldehyde (PF), isocyanates (MDI or PMDI) and melamine-urea-formaldehyde (MUF).

OSB is readily identified by its larger and longer wood strands, compared to particleboard. The orientation of the surface strands is not always visually apparent, especially in small pieces of panel. The panel tends to have a number of holes on the surface due to the overlap of strands. OSB has come into fashion as a product with the same purpose and function as plywood -- so OSB and plywood compete in the marketplace.

As to water vapour permeability, the value of the water vapour resistance factor (m) for OSB having a density of 650 kg/m, can be taken as 30 using the ‘wet cup’ method and 50 when the ‘dry cup’ procedure is employed (EN 12524).

When it comes to thermal conductivity, the thermal conductivity (l) of OSB is 0.13 W/m.K for a mean density of 650 kg/m.

In reaction to fire, under the new Euroclass system for the reaction to fire of materials, untreated OSB with a density >600 kg/m_ and a thickness >10 mm will typically achieve a Euroclass D rating except when used as a laminate floor covering, or a Euroclass DFL rating when it constitutes a laminate floor covering and tested as a separately marketed product whether or not it is subsequently fixed to a flooring substrate.

Figure 14. Oriented Strand Board (OSB)

Panel density (and therefore panel mass) varies depending upon the product, being affected by the timber species and the process used in manufacture. Typical densities are 600 kg/m3 to 680 kg/m^3.

Panel sizes commonly available are:

- 2440mm × 1200mm
- 3660mm × 1220mm

in thicknesses of 6mm, 8mm, 9mm, 11mm, 15mm, 18mm, 22mm, 25mm and 38mm.

Specification: OSB manufactured in Europe for construction purposes must now be specified in accordance with *BS EN 300 Oriented strand boards (OSB). Definitions, classification and specifications*2. As explained in PanelGuide *Section 2*, OSB that is used in construction must comply (by law) with the Construction Products Regulation (CPR) by compliance with the harmonised European standard (hEN) for wood-based panels (*EN 13986*, implemented in the UK as *BS EN 13986 Wood-based panels for use in construction. Characteristics, evaluation of conformity and marking*); this standard calls up *BS EN 300* which contains the requirements for the following four grades (technical classes):

- OSB/1 – General purpose boards, and boards for interior fitments (including furniture) for use in dry conditions
- OSB/2 – Load-bearing boards for use in dry conditions
- OSB/3 – Load-bearing boards for use in humid conditions
- OSB/4 – Heavy-duty load-bearing boards for use in humid conditions.

Table 1. Dimensional change for a 1% change in OSB panel moisture content.

Panel type	Length %	width %	Thickness %
OSB/2	0.03	0.04	0.7
OSB/3	0.02	0.03	0.5
OSB/4	0.02	0.03	0.5

Biological attack: Typically OSB will not be attacked by wood-boring insects common in temperate climates. It can be used in hazard classes 1, 2 and 3 as defined in EN 335-1 "Durability of wood and wood-based products - Part 1: Definition of hazard classes of biological attack". For these three hazard classes, the respective moisture content of OSB and the organisms that may attack OSB under the specified conditions are given in EN 335-3 "Durability of wood and wood-based products — Part 3: Application to wood-based panels".

Formaldehyde: Free formaldehyde in the workplace atmosphere has a WEL of 2 parts per million (ppm). However, studies indicate that anyone machining OSB in mechanically ventilated situations is exposed to levels of free formaldehyde significantly below this.

Finishing: Where smooth surfaces are required, pre-sanded panels should be specified.

Applications: Due to its high mechanical properties and the orientation of the strands within panels, OSB is particularly suitable for load-bearing applications in construction and is widely used for flooring, roof decking and wall sheathing, but there is also a wide field of other applications where OSB as a wood-based panel product can be utilised. Different grades of the product are available for different levels of loading and different environmental conditions. Guidance on the use of OSB in these load-bearing applications is given in ENV 12872 and EN 13986. OSB is a quality, precision-engineered product that can satisfy the same applications and loading conditions as plywood and in some cases a thinner OSB panel may be used thereby reducing costs.

Large quantities of OSB are also used for sarking and industrial packaging and in site hoardings and pallet tops.

Fibreboard

Medium density fibreboard (MDF) is an engineered wood product composed of fine lignocellulosic fibers, combined with a synthetic resin and joined together under heat and pressure to form panels. The most commonly used lignocellulosic fibers are wood, but others plant fibers can be used.

The constituents of a typical standard MDF manufactured in the United Kingdom or Ireland are 82 virgin wood fibre (wholly or mainly softwood), 10% synthetic resin binder, 7% water, less than 1% paraffin wax solids and less than 0.05% silicon. The most common binder is urea-formaldehyde, although, other binders may be used, such as melamine- urea-formaldehyde, phenolic resins and polymeric methylene di-isocyonate (PMDI).

MDF fibres are normally made by using a thermomechanical pulping (TMP) process. These are then mixed with a synthetic resin binder. The resinated fibres are dried and then formed into a mattress ready for pressing. The mattress is pressed between heated polished press plates to the desired thickness.

MDF has smooth sanded surfaces; it has a homogeneous construction and is typically pale straw in colour. For identification, purposes the whole panel, i.e. individual layers of the panel may be dyed according to industry practices (e.g. green for panels with enhanced moisture resistance, or red for panels integrally treated with flame-retardant chemicals).

Integral colouring is distinct from the voluntary-coloured stripe system that may be applied on the outside edge of panels in a pack, at opposite corners to identify particular grades in accordance with EN standards.

Standard forms of MDF typically have densities as follows:

- Average density: 700 kg/m3 to 800 kg/m^3

- Core density: 600 kg/m3 to 700 kg/m^3
- Face density: 1000 kg/m3 to 1100 kg/m^3

MDFs can have densities that range from below 550 kg/m3 up to 800 kg/m3 and above. Due to variation between brands, the weight of MDF is not constantly proportional to thickness.

Figure 15. Medium Density Fibreboard (MDF)

Plywood

Plywood is an engineered wood from multiple layers of thin veneer that are glued together (Figure 15). Each adjacent layer is rotated ~~bu~~ up to 90 degrees to reduce the risk of splitting when nailed in the edges. The thickness of an individual sheet is 0.2 – 3.2 mm.

Plywood is produced on a worldwide basis using a wide range of timber species including softwoods and temperate or tropical hardwoods. Many different species can be used for plywood manufacture with the principal qualification criteria that the log can be reliably peeled or sliced into veneer. Softwood species commonly used include spruce, pine and fir. Hardwood species used include birch, beech, poplar and eucalyptus. The quality of the finished plywood depends on both the quality, species and lay-up of the veneers, as well as on the resin type and bonding quality.

Maritime pine has been used for the manufacture of plywood since the 1970's.

The high mechanical characteristics of this species make this type of plywood particularly suitable for structural applications in building (racking in timber-framed houses, load-bearing floors, I-beams...) but also for industrial packing and boxes. Grooved, it is used in the interior covering of walls and its good resistance to fungi enables its use for cladding.

Figure 16. Plywood

Plywood is commonly used in construction, for transportation, for packaging, for furniture and for decorative applications. Completely versatile, it is also suitable for the extreme uses, amongst others for ship and boat building.

Plywood is produced with resin bonds, which range from those suitable only for interior use to those which will withstand elevated levels of humidity in external exposure. Bonding classes: EN 314-2 defines the tests to be carried out to check the bonding class of a panel. These classes correspond to the following conditions of use:

- Class 1: Dry conditions: for interior applications with no risk of wetting, with a moisture content corresponding to environmental conditions of 20°C and 65% relative humidity.
- Class 2: Humid conditions: for use in protected exterior applications with a moisture content corresponding to environmental conditions of 20°C and 85% relative humidity.
- Class 3: Exterior conditions: for use in unprotected external applications, where the moisture content will frequently be above 20%.

Usually, urea-formaldehyde resins are used for class 1, melamine-urea-formaldehyde for class 2, melamine-urea-formaldehyde or phenol-formaldehyde for class 3.

Classes of formaldehyde release

According to the reference standard, EN 636, a panel is classified according to formaldehyde release test results:

- Class E1: less than 0.1 ppm according to EN 717-1
- Class E2: more than 0.1 ppm according to EN 717-1

The surface appearance of plywood depends upon the species and grade of veneer used for the surface layers. The classification of surface appearance is covered in the five parts of BS EN 635 Plywood – Classification by surface appearance, as follows:

The density of plywood is not normally controlled as part of the product specification but is a function of the species of timber used. Most construction plywood will have a density in the range of 400 kg/m3 to 700kg/m 3. However, as most plywood is manufactured from a single species or a limited range of species, the production from a particular manufacturer will fall within a defined density range and therefore reference should be made to the manufacturer's documentation or packaging for further information and handling data.

Common panel sizes are:

- 2440mm × 1220mm
- 2440mm × 610mm (normally T&G)
- 2500mm × 1220mm
- 3050mm × 1525mm
- 3050mm × 1220mm

Moisture resistance: The type of adhesive used to bind the veneers makes the plywood resistant to moisture and humidity. A layer of paint or varnish can also increase resistance to water damage. These types of veneers are suitable for exterior use Moisture resistance is important in interior applications as well, including on floors. The cross lamination ensures the veneers do not warp, shrink, or expand when exposed to water and extreme temperature.

Impact resistance: Plywood has high tensile strength, derived from the cross lamination of panels. This distributes force over a larger area, reducing tensile stress. Plywood is therefore able to withstand overloading by up to twice its designated load.

Fire resistance: Plywood can be treated with a fire resistant chemical coating.

Insulation: Plywood has high thermal and sound insulation. This makes it a useful insulating material for flooring, ceilings, roofing, and wall cladding.

Types of plywood:

Structural plywood: Used in permanent structures where high strength is needed. This includes flooring, beams, formwork, and bracing panels. It can be made from softwood or hardwood.

External plywood: Used on exterior surfaces where a decorative or aesthetic finish is important. It is not used to bear loads or stress, such as on exterior door surfaces, and wall cladding.

Internal plywood: This has a beautiful finish, for non-structural applications like wall panelling, ceilings, and furniture.

Marine plywood: It is specially treated using preservatives, paint, or varnish, to resist water damage. It is used in shipbuilding, resists fungal attacks and does not delaminate.

Wood-wool and wood-fibre insulation panels

Compact but low-density materials that include wood wool or wood fibbers are considered interesting and renewable products for some construction applications such as sheathing or thermal insulation.

Wood-wool (WW) cement binded panels are commonly used for insulation and covering purposes (non load-bearing ceilings), generally with dimensions ranging from 600 width to 600, 1200, 2000 or 2400 mm length, and thicknesses between 15 and 35 mm. Of lower density than other wood-based panels (400-500 kg/m3) are a well-established product with interesting features regarding fire reaction, acoustic absorption and even appreciated by its distinctive surface appearance. In Europe they are regulated by EN 13168 standard.

Wood-fiber insulating boards (WF) are composed by wood fibers binded and pressed up to certain levels providing elements for insulation purposes with common sizes of 600 x 1200 mm, and thicknesses from 10 to 300 mm, with densities between 110 y 230 kg/m^3 .They are regulated by EN 13171 standard. Among its main advantages are its renewability and favourable environmental features. Its technical characteristics depends on several factors such as its density.

Figure 17. Left, wood-fibber insulation panels (source: Gutex); Right, Wood-wool panel (Source: Knauf insulation. Herakith.es).

Cork

Cork is a biological closed-cell material with a set of specific properties that result from its chemical composition and cellular structure, i.e. very low permeability, hydrophobic behaviour, biological inertia, large elastic compression and dimensional recovery.

The basis of many of the cork physical properties lies to a large extent in the features of its cellular structure: the structure is compact with a very regular arrangement of small and thin-walled cells and without intercellular spaces. The individual cells are small hexagonal prisms that are stacked base to base forming cell rows, with rows aligned parallel to each other in a compact and regular arrangement (Pereira 2007). When observed in the transverse section (the plane perpendicular to the plant axis), the structure is a brick-wall type with the cells cut parallel to their prism axis and appearing with a rectangular form; the radial section is very similar. In the tangential section (the plane perpendicular to a stem radius), the cork cells appear polygonal, mostly as hexagons with a honeycomb structure (Pereira et al., 1987).

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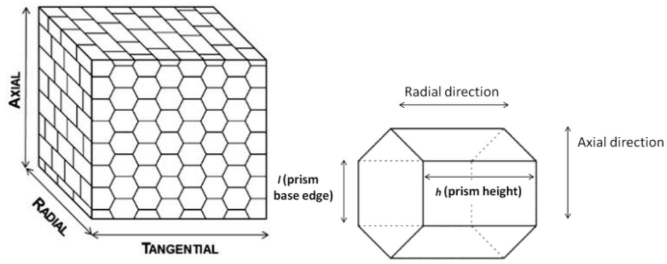

Figure 20. Schematic representation of the cellular structure of cork and of an average cork cell as an hexagonal prism and showing the prism base edge (*l*) and prism height (*h*) as well as the radial and axial direction.

The chemical composition of the cork cell walls as well as the specific chemical features of the main components are also determining factors for establishing the materials's properties (Pereira 2015). Cork is chemically characterized by the presence of suberin as a major cell wall structural component (33% to 50% of cork). Suberin is a macromolecule of ester coupled fatty alcohols, fatty acids and diacids, hydroxy fatty acids and glycerol, including also ferulic acid and eventually other phenolic components (Pereira 2007, Graça and Pereira 2000). The cork cell wall further includes lignin and the polysaccharides cellulose and hemicelluloses, while polar and non-polar extractives are present with a considerable content (Pereira 2007).

Cork-based materials

Besides the use of cork as a so-called "natural solid" material, as for the natural cork stoppers, other cork-based materials are produced, namely cork agglomerates and expanded cork boards. It should be stressed that the major economic target of cork production is the manufacture of wine natural cork stoppers (and to a lesser extent of cork discs) and only the process residues from this production as well as the non-suitable cork planks are directed to other uses that go through trituration and agglomeration in most of the cases (Pereira 2007).

Cork agglomerates are classified into two types: composite agglomerates (also called white agglomerates or just cork agglomerates) and pure or expanded agglomerates (also called black agglomerates). Cork agglomerates are used in several products, but the main applications are as surfacing material for wall and floor coverings, and as bottle sealants for agglomerated cork stoppers. The expanded cork agglomerates are used as insulation materials mainly for thermal, acoustic and vibrational applications.

Cork agglomerates are produced using the large amount of residual by-products from the manufacture of cork stoppers and discs, and also from the refuse raw-cork planks and other types of cork raw materials such as virgin cork (Pereira 2007). Cork agglomerates are made of cork granules mixed with a binder and/or other additives. Their properties depend on the density and granulometric of the cork granules (from >1 cm to 1 mm), on the type of binding resin, and on the production conditions. The aim is to obtain a product similar to natural cork, but allowing more complex shapes and larger dimensions (Fortes et al., 2004). The process is carried out under a moderate pressure and heating as adequate for the specific polymer curing and bonding. The adhesives include thermosetting polymers, such as urea–formaldehyde, melamine or phenolic adhesives (e.g. for flooring agglomerates), or thermoplastic polymers such as polyurethanes (e.g. for softer surfacing materials). The cork agglomerates may be produced with different densities: 200–300 kg/m^3 for surfacing, partitioning and insulation applications and higher densities up to 500 kg/m^3 for flooring (Pereira, 2007).

The compression of the cork particles during the agglomeration process causes partial densification of the cells with collapse and corrugation originating higher density values of the materials in comparison to the natural cork. The cork agglomerate can be described by a reference Young's modulus of 7.4 MPa in compression and 17.4 MPa in tension (Moreira et al. 2010). The thermal conductivity coefficient of flooring cork tiles with thickness between 3.2 and 8 mm is 0.06–0.10 W/m K (Gil 2007, Knapic et al., 2016)

Expanded cork agglomerates use undervalued corks e.g. virgin cork, or low quality reproduction cork. The granules have dimensions in the range of 4 mm to over 22 mm and the agglomerates are self-bonded i.e. produced without an external binder. They are produced in blocks by heating the cork granules in autoclaves with superheated steam at 300-350°C and 40 kPa, during 17 to 30 minutes, depending on the initial moisture content. Under these process conditions expansion of the cork cells occur and thermo-chemical degradation of the extractives and structural components of cork (Pereira 1992), with the release of by-products that act as natural adhesives between the granules to form the agglomerate (Pereira 1992; Rosa and Fortes 1988). These agglomerates are also called black agglomerates due to their dark colour induced by the high temperatures associated with this process. There is a substantial structural and chemical alteration of cork (Pereira, 2007): the cork cells expand, the cell walls stretch and decrease in thickness, and the cell shape changes from prismatic to a more balloon type; the arrangement in rows also becomes faded, and the material becomes more isotropic; the cell volume increase is over 100%, and hence the name of expanded cork agglomerates (Pereira, 2007). Cork is thermally stable below 200 ◦C and after that degradation depended on temperature and heating time with increasing mass loss, i.e. 3% at 200 ◦C 10 min and 46% at 350 ◦C 60 min (Figura 18). The cell wall components have different thermal stabilities, with lignin and suberin being the most resistant while extractives and hemicelluloses are more heat sensitive. Hemicelluloses disappear and cellulose is degraded to a considerable extent. Suberin is more resistant and degradation starts at approx. 250◦C. 300◦C samples only contain 7% suberin.

The cork agglomerated blocks are cooled, stabilized and cut to the targeted product, usually boards of different size and thickness.

Figure 21. The Expanded Cork Board is made by expanding cork grains through the action of steam. It is agglutinated from resins in the cork itself, without the use of any synthetic agents.

The usual manufacturing process allows for the production of boards with densities of 80 to 300 $kg.m^{-3}$, depending on the range of applications.

The granulometry that is finally obtained is dependent on the job function of the agglomerate. For example, it can vary from 3 to 10 mm for acoustic agglomerated cork and from 5 to 22 mm for thermal agglomerated cork

Figure 22. Agglomerated Cork

An advantage of this agglomerate is that it is a wholly natural material. These materials are applied mainly in thermal insulation, acoustical absorption, and vibration damping. The cork board maintains its physical properties to lower temperatures than other insulator materials, and under fire conditions does not release toxic substances, as may occur with alternative materials (Silva et al., 2005). Expanded agglomerates are also considered as a material of retarded combustion (Gil, 1998)

Expanded agglomerated cork for thermal and acoustic insulation - mechanical and physical characteristics

Based on information of APCOR (Cork as a Building Material, Technical Manual) and ISOCOR (Perfect Insulation In any environment, ISOCOR – catalog) the thermal and acoustic insulation characteristics of expanded agglomerated cork s are described and mean characteristics summarized in Tables 1 and 2.

Table 1. Mean characteristics of expanded agglomerated cork (thermal)

(*Source: Cork as a Building Material Technical Manual, APCOR*)

Density	100-140 kg/m³
Thermal Conductivity Coefficient (θm = 23°C)	0.039-0.045 W/m.°C
Specific heat (to 20°C)	1.7-1.8 kJ/kg.°C
Thermal Expansion Coefficient (20°C)	25-50 X 10^{-6}
Maximum pressure in elastic conditions	50 kPa
Modulus of Elasticity (compression)	19-28 daN/cm²
Thermal Diffusion	0.18-0.20 X 10^{-6} m² /s
Poisson Coefficient	0-0.02
Water Vapour Permeability	0.002-0.006 g/m.h.mmHg
Modulus of Rupture (Bend Strength)	1.4-2.0 daN/cm²
Tensile Strength, Transversal	0.6-0.9 daN/cm²
Tensile Strength, Longitudinal	0.5-0.8 daN/cm²
Dimensional Variation 23-32°C, 50-90 % HR	0.3%
Oxygen Index	26 %
Tension Deformation at 10 % (compression)	1.5-1.8 daN/cm²
Temperature Deformation (80°C)	1.4 a 2.4 % (thickness)

Table 2. Mean characteristics of expanded agglomerated cork (acoustic)

(source*: Cork as a Building Material Technical Manual, APCOR*)

Density	≤ 100 kg/m3
Sound Absorption Coefficient (500-1500 c/s)	0.33-0.8
Thermal Conductivity Coefficient (θm = 23)	0.037-0.042 W/m.°C
Modulus of Rupture (Bend Strength)	1.4-1.6 daN/cm²
Water Vapour Permeability	0.004-0.010 g/m.h.mmHg
Tensile Strength, Longitudinal	0.3 daN/cm²
Water Absorption (immersion) **(capillarity)**	9.2 % 1.9 %
Dimensional Variation 32-66°C, 90-0 % HR	0.4 %

In terms of percussion, expanded agglomerated cork can be applied as a layer placed between the lining and the flooring system (floating floors). Covering both ceilings and walls, expanded agglomerated cork absorbs a part of the total incident sound energy thus reducing the intensity of the reflected sound. In this respect its irregular surface is a contributing factor, being full of cavities it increases the reflection of the sound waves, resulting in a loss of energy for each wave (Cork as a Building Material Technical Manual, APCOR)

Regarding the acoustic absorption of expanded agglomerated cork, the thicker the material, the greater the sound absorption. With a reduction in thickness, maximum absorption moves to higher frequencies (Fernandez, 1974). Thus, depending on the type of sounds that need to be insulated it is possible to choose the most appropriate material. Studies carried out regarding the transmission of B-bass, M-moderate and S-sharp percussion noises on various sound insulation flooring types, comprising of expanded agglomerated cork panels, obtained the following results (Cork as a Building Material Technical Manual, APCOR)

Table 3. Insulation values (Provided by ISOCOR)

Thickness (mm)	R (m^2 k/W)	K (W/m^2 K)
40	1.000	1.000
50	1.250	0.800
60	1.500	0.667
80	2.000	0.500

NP 603:1967 Expanded pure agglomerated cork boards - Determination of the modulus of rupture by bending.

NP 1042:1985 Expanded pure agglomerated cork boards – Determination of moisture content.

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