Changing wood use to improve carbon storage: which products should be the short-term focus?

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ACRONYMS AND ABBREVIATIONS

ADEME	French Agency for Ecological Transition *(Agence de la transition écologique)*
BAU	Business-as-usual
BBC	French reference for low energy buildings *(Bâtiment Basse Consommation)*
BIPE	Economic Information and Forecasting Office *(Bureau d'informations et de prévisions économiques)*
Citepa	Technical Reference Center for Air Pollution and Climate Change *(Centre interprofessionnel technique d'études de la pollution atmosphérique)*
CLT	Cross laminated timber
CSTB	Scientific and Technical Center for Building, *(Centre scientifique et technique du bâtiment)*
EWP	Engineered wood product
FCBA	Technological Institute for Forestry, Cellulose, Wood and Furniture *(Institut technologique Forêt Cellulose Bois-construction Ameublement)*
HWPs	Harvested wood products
IPCC	Intergovernmental Panel on Climate Change
LTS	Long-term strategy
LWP	Lightweight wooden packaging
MFH	Multi-family housing
MDF	Medium-Density Fibreboard
SFH	Single-family houses
MTE / MTES	French Ministry of Ecological Transition (since 2020) / and Solidarity (2017-2020)
OSB	Oriented Strand Board
R&D	Research and development
SNBC	*Stratégie nationale bas-carbone* (National Low Carbon Strategy)
VEM-FB	*Veille économique mutualisée de la filière forêt-bois* (Joint economic monitoring of the forestry and wood sector)

UNITS

Mha	Million hectares
Mm^3	Million cubic metres
Mt	Million tonnes
Mt CO_2	Million tonnes of CO_2
Mm^2	Million square metres
Mm^3 swe	Million cubic metres of solid wood equivalent
Mt swe	Million tonnes of solid wood equivalent

EXECUTIVE SUMMARY

To achieve carbon neutrality, France must develop production chains for "long-life" wood products

Is it possible to harvest more timber to feed the bioeconomy, while preserving the carbon storage capacities needed to achieve carbon neutrality? For years this has been the subject of fierce debate among NGOs, experts, and stakeholders in the forestry and wood sectors, all of whom clash over how much timber France should harvest. While this issue is undoubtedly important, another matter is similarly important but receives less attention: what is the best way to use the harvested wood?

There is a consensus that France needs to develop the production and consumption of "long-life" wood products, *i.e.* products such as structural beams or wood-based insulation that can store carbon for long periods. The development of these wood uses is indeed a no-regrets solution in terms of the climate: whether we increase the timber harvest a little, a lot, or not at all, these uses are necessary to maximize France's carbon sink and to enable the country to become carbon neutral. This development is therefore crucial, and occupies the heart of France's long-term strategy (LTS), the *Stratégie nationale bas-carbone* (*SNBC*), which has set very ambitious targets for these sectors – targets that may be unrealistic, according to our latest study. The problem is that the strategy currently says nothing about the policies that need to be implemented to achieve these targets. To become carbon neutral, France must enact a significant policy to foster the development of long-life wood products. The next *SNBC*, which is currently being drawn up, and the future *loi de programmation énergie-climat* (LPEC, energy and climate planning law), which will be adopted by summer 2023, are opportunities that should not be missed.

Drawing up a real policy to develop these production chains requires the identification of which ones are the most promising

This study reviews the long-life wood products that could be obtained from the resources currently dedicated to the paper and energy industries, the technical constraints on their production, and possible outlets on the French market.

Two promising levers have been identified to better use the harvested wood:

1. Optimizing the material recovery of timber, *i.e.* sawing as much timber as possible, even if it means using new technologies to utilize small-diameter timber or wood with defects.
2. Redirecting a proportion of the resources currently used by the paper and energy production sector, such as small-diameter wood and wood processing by-products, to long-life uses such as construction panels and insulation.

These different options imply the development of processing industries and new outlets, in proportions that vary in terms of feasibility and short-term promise.

Better usage of timber: limited immediate potential but promising in the longer term

Timber is wood of the highest quality that is already mostly used as a long-lasting material. However, some wood of this quality does not fulfil its technical potential and is used for short-lived purposes, such as household heating. This mainly relates to hardwoods, and to wood of small diameter or low quality.

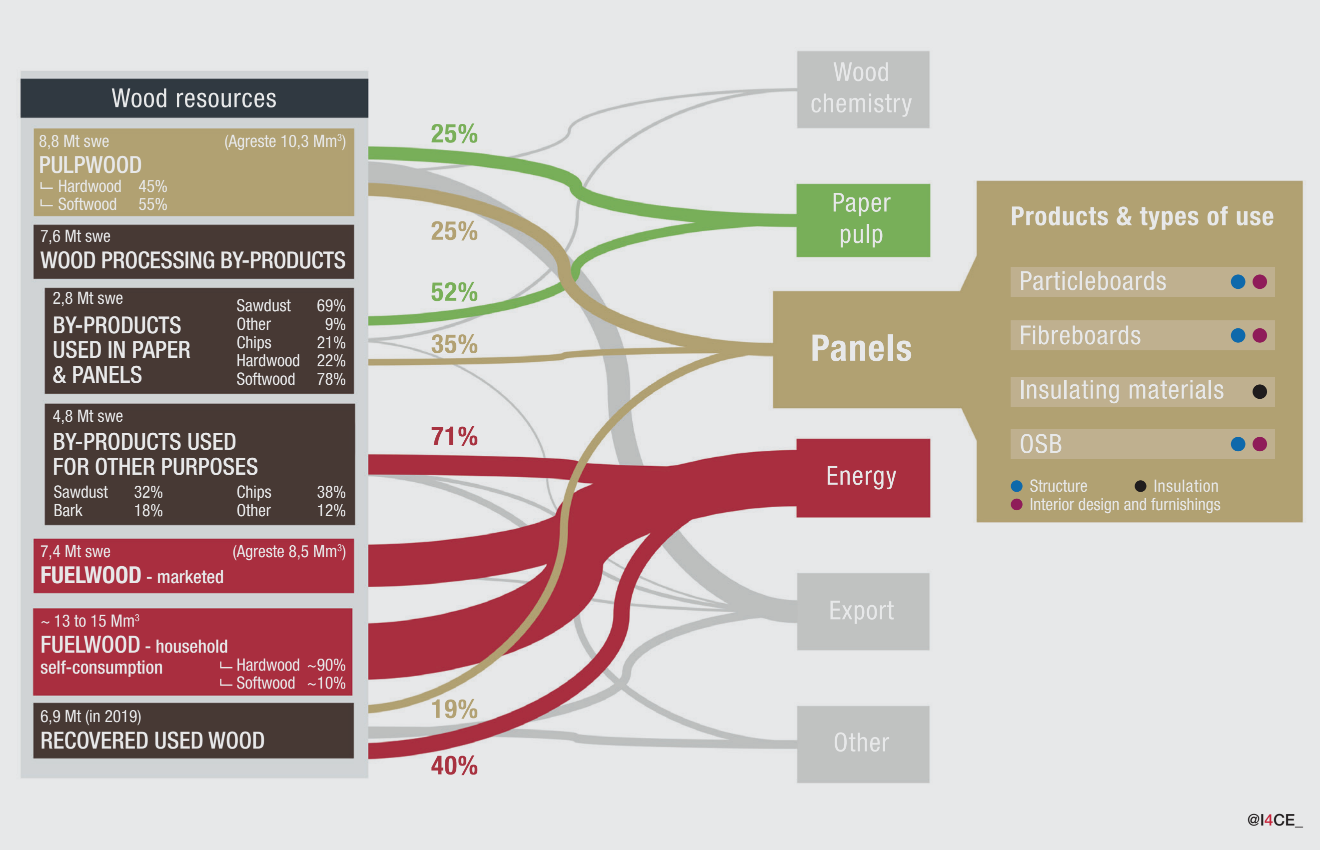
Developing outlets for these wood types could increase the proportion of timber in the harvest, particularly that dedicated to long-lasting products. The use of products that are less restrictive in terms of resources used, such as engineered wood products, could enable these woods to be better used. However, these developments still require R&D and major changes in the industry, which reduces their short-term potential. In the longer term, the potential for improving the use of what is qualified today as timber, could be as much as 8 Mm^3 annually, without counting the potential associated with future developments such as engineered wood products.

See Diagram

Promising short-term sectors: panels and insulation

Timber processing by-products and wood of lower quality and smaller diameter are used extensively in the paper and energy industries (**Diagram**), but can also be used for longer-lasting purposes: in the construction sector with wood-based insulation and panels for walls and floors, for example, and in the furniture industry to make desks, kitchens, etc.

FLOWCHART OF FRENCH WOOD RESOURCES MAINLY DEDICATED TO THE PAPER, PANELS AND ENERGY SECTORS, 2018



NB: Percentages express the share of each type of resource currently destined to these sectors. Example: 25% of the pulpwood is consumed by the pulp and paper industry.

The panels and insulation industries are considered particularly promising for changing wood usage, because they share the same resources as the paper and energy sectors. It is therefore technically possible to redirect some of these resources towards these industries. Indeed, the production processes of these products present few technical issues that would prevent the redirection of these resources. While some technical challenges have been identified – mainly in diversifying the types of raw materials used – there are, however, innovative solutions that already exist in France and abroad, indicating that, with the right investments, these constraints could be quickly overcome.

Let's take advantage of the favorable political context to guarantee sufficient outlets for these markets

The development of these sectors requires the implementation of an industrial policy to develop production capacity, as well as the identification of the right economic and regulatory incentives to expand outlets for the most promising products. The potential development of these products is vast, and justify the inclusion of a strong reorientation objective in France's long-term strategy: we estimate the maximum technical potential for additional wood-based panels and insulation consumption to be between 15 Mm³ and 30 Mm³ per year, according to 'trending' and 'ambitious' construction and renovation scenarios respectively.

However, our calculations confirm that the quantitative targets for the consumption of long-life wood products are unreasonable. In particular, the 22 Mm³ target for "panel usage" in the *SNBC* could only be achieved under a number of very ambitious conditions that are far from the current reality:

- that wood panels and especially wood insulation become more popular than other materials in the construction industry;
- that the annual renovated surface area increases as sharply as set out in the *SNBC*, which corresponds to a total renovation of the housing stock to a very high level of energy efficiency in less than 30 years;
- that the export of these products develops to compensate for the otherwise desirable development of panels made from recovered used wood.

New support measures are already creating a favorable environment for such a development: the *Assises de la Forêt et du Bois*[1] led to a reinforcement of existing measures and to the creation of new ones to support the development of the wood industry and its outlets, the entry into force of the environmental regulation for new buildings (*RE2020*) could soon promote bio-based materials consumption, and energy renovation objectives could be an ideal springboard for securing major outlets for wood-based insulation if they are supported by specific incentives.

This study therefore leads to three main recommendations for changing wood use:

- to make wood-based panels and insulation more competitive than alternatives (plaster, concrete, glass wool, etc.): these products are the two most promising in terms of redirecting wood use;
- to make the use of wood as material more competitive than the use for energy: in addition to studies that cast doubt on the benefits of fuel wood for the climate, fuelwood is the main resource that can be redirected from short to long–term usages;
- to conduct a more detailed study of the potential for increasing the proportion of timber in the harvest, particularly through the development of engineered wood.

Finally, emissions linked to the manufacture of wood products do not seem to call into question the importance of this reorientation[2], even though the issue merits further examination, particularly regarding insulation materials.

1 A series of working groups launched by the French government in 2021, and which reunited many stakeholders of the French forest-wood sector to discuss the sector's issues.
2 (Kunič 2017, Myllyviita, *et al.* 2021)

INTRODUCTION

As they grow, forest trees absorb CO_2 from the atmosphere and store it in their biomass. The harvesting of wood has two effects on this carbon sink:

- The forest ecosystem carbon sink (in situ carbon storage) suffers from logging, leading to a loss of stored carbon (wood removed from forests, decomposition of branches and roots) which reduces the short-term carbon storage capacity as the canopy recovers;
- However, some of the wood removed from the forest continues to store carbon for long periods of time, as it used in the manufacture of long-life harvested wood products (HWPs). This stock of wood products constitutes a storage pool of wood-based carbon (ex-situ carbon storage).

Optimizing the uses of harvested wood is therefore essential to ensure that the negative effect on in situ carbon storage in the short to medium term is at least partially offset by the carbon storage in HWPs. Thus, increasing the proportion of harvested wood used for long-life products without changing the amount of wood harvested, would increase ex situ carbon storage without having an impact on in situ storage, therefore making it a "no-regrets" strategy, regardless of the final decision on the right level of harvest.

The French long-term strategy (LTS) – the roadmap for transitioning the society and economy of France to carbon neutrality by 2050 – thus aims to "prioritize uses of wood with a longer lifespan" with a view to massively increasing carbon storage in wood products by 2050 (a tenfold increase in this stock compared to its level of 1.9 $MtCO_2$ in 2015). To achieve this aim, the strategy points to a significant increase of at least 70% in the wood harvest[3] over the period 2015-2050 while, above all, relying on a reorientation towards long-life harvested-wood products to increase the share of the harvest dedicated to these materials (from 25% in 2015 to 50% in 2050). The two main ways to increase the share of harvested wood used for long-life products are: developing sawn timber usage, and developing long-life products that can be made from low-quality resources, such as panels.

However, it is not clear how such a reorientation of HWPs will be implemented in practice: which final products are more likely to be consumed or exported? Can these products actually be manufactured with the type of wood currently used for other purposes? What is the maximum demand for these products? To clarify the "wood products" component of the LTS, this study identifies the products concerned by a reorientation, as well as the associated production constraints that could limit these usage changes. It also assesses whether potential outlets are sufficient to absorb the volumes of HWPs predicted by the French LTS. The study is divided into the following sections:

1. **Resource inventory** of the forest-based sector and today's final uses;

2. **Proposal for a practical interpretation** of the objective introduced by the *SNBC* to bring about changes to wood use, through the identification of long-life products, the production of which can be increased by reorientation, and their consumption can also be increased;

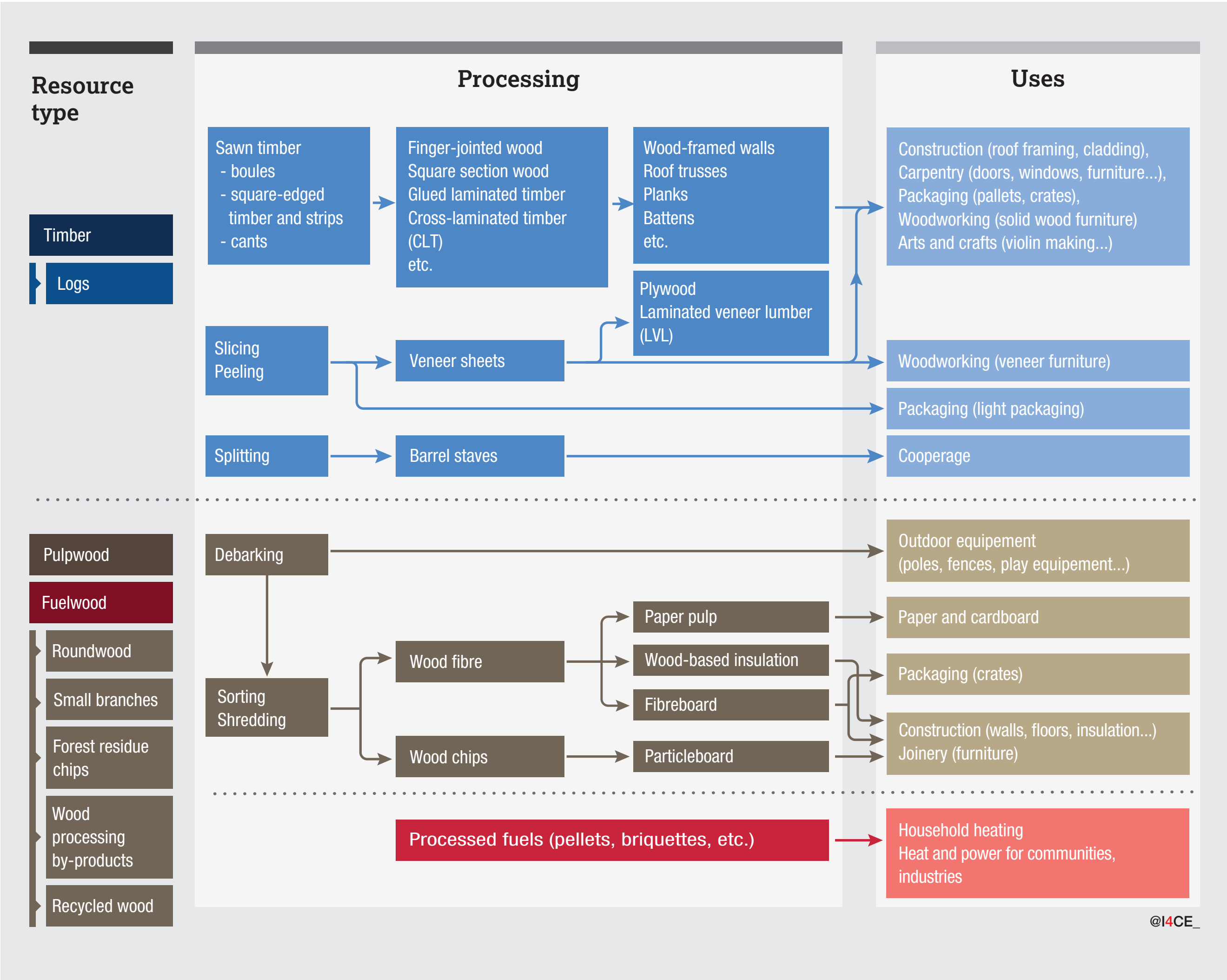
3. **Estimation of the theoretical maximum potential** use of the most promising products for the reorientation of wood uses.

3 Wood harvest estimated at 49 Mm³ (IGN; FCBA 2016), including self-supply of fuelwood to households.

1. THE PRODUCTION CHAIN: A RESOURCE PATHWAY FROM FORESTS TO WOOD PRODUCTS

To determine what the wood production chain would look like if it produced three times the volume of long-life products, we drew up an inventory of the available French resources (**1.1**, **1.2**) and their current usages (**1.3**). **Figure 1** shows the key stages of the journey from forest resource to the main final uses, which are explored in detail in the following sections.

FIGURE 1. DIAGRAM OF THE RESOURCE PATHWAY, FROM FORESTS TO WOOD PRODUCTS



1.1. Forest resources

The forests of mainland France supply the market with wood of different qualities and species.

1.1.1. Wood qualities: timber, pulpwood, fuelwood

Timber

Timber is defined as wood of sufficiently high quality to be processed by sawing, slicing, peeling or splitting. Qualification is based on measurements of tree diameter and bole length[4], as well as intrinsic quality (sound wood, without defects that hinder processing) according to current timber market expectations (**Table 1**).

TABLE 1. CURRENT TIMBER QUALIFICATION CRITERIA (IGN; FCBA 2019)

	Deciduous	Coniferous
Tree diameter at 1.3 m	≥ 35-40 cm	≥ 15-25 cm
Small-end diameter	≥ 25-30 cm	≥ 14-20 cm
Bole length	3 m	4 m (except maritime pine: 2 m)

Based on these criteria and census data from the national forest inventory from 2014 to 2018, the French National Institute of Geographic and Forest Information (*Institut national de l'information géographique et forestière, IGN*) has estimated the potential volume of timber harvested annually at around 24 Mm³, almost 80% of which is coniferous (*i.e.* 18.6 Mm³) and 20% is deciduous (*i.e.* 5.2 Mm³) (IGN; FCBA 2019). However, there is a total difference of +18%[5] between the harvest of potential deciduous timber as measured by the IGN and the marketed harvest over the period 2005-2017 as reported in the annual industry surveys, *i.e.* the harvest of quality timber would exceed actual timber use. The reasons for this are explained and discussed in **section 1.4** which addresses the possible forms of wood use change.

In 2019, 19.6 Mm³ of timber was harvested and marketed in mainland France, excluding wood harvested following an event that affected its health or technical quality (**Table 2**).

Pulpwood and fuelwood

In forestry, pulpwood and fuelwood refer to a similar type of resource, *i.e.* wood that is not timber grade, but that can be used as a raw material or for its calorific value when burned. Pulpwood and fuelwood come from forests in the form of roundwood including small-diameter branches and forest residue chips[6], and can be assimilated to wood processing by-products and recovered used wood as well, as discussed in **section 1.2** below.

To be precise, roundwood can be used as pulpwood when it has a sufficient minimum diameter to be exploited as such (from 7 cm). Below this diameter, it is generally left in the forest, but it can also be used as fuelwood, possibly after being chipped or in the form of logs when it is intended for household heating.

In 2019, 10.5 Mm³ of pulpwood and 8.1 Mm³ of fuelwood were harvested (**Table 2**), to which must be added the household self-consumption[7] of firewood taken from forests, estimated at around 13 to 15 Mm³ annually (ADEME 2021, ADEME, Solagro, Biomasse Normandie, BVA 2018)[8]. Most pulpwood harvested (94% or 9.9 Mm³) is dedicated to paper pulp and panel production, while some is used in pole manufacture, for which the roundwood shape is preserved (see **section 1.3.2**).

TABLE 2. TYPES OF WOOD HARVESTED IN 2019 ACCORDING TO THE ANNUAL FORESTRY SURVEY AND AN ESTIMATE OF HOUSEHOLD FIREWOOD SELF-CONSUMPTION. FIGURES in Mm³

MARKETED HARVESTED WOOD	**38.15**
▶ Timber	**19.56**
▶ Pulpwood	**10.53**
Roundwood for pulp and panel production	9.85
Other industrial wood (including poles)	0.68
▶ Fuelwood (excluding self-consumption)	**8.06**
Roundwood > 2 m, in logs < 2 m	5.36
Forest residue chips	2.70
Fuelwood used by households	~ 13-15
TOTAL	**~ 51-53**

4 Part of the tree trunk without branches.
5 Variation by species: Oak 9%, Beech 18%, Chestnut 44%, Valuable deciduous 78%, Other deciduous species 75% (IGN; FCBA 2019).
6 Forestry slash or small-diameter wood chips.
7 Self-consumption refers to the situation where the user does not pay for the wood and harvests it on their own property or that of an acquaintance (friend/neighbour) or of the local authority. (ADEME, Solagro, Biomasse Normandie, BVA 2018).
8 Self-consumption was calculated by the French Agency for Ecological Transition (*ADEME*) with the assistance of the French Ministry of Ecology (*MTES*) on the basis of household firewood consumption based on the Housing and Population Census surveys.

Sub-standard logs

These logs may be of adequate size to qualify as timber, but are of insufficient quality to be harvested for this purpose. They are therefore downgraded and used by the pulping industry or for energy production. This may include diseased trees or those affected by wood-eating insects, as well as trees with natural defects or defects related to silvicultural management (knots, growth anomalies, resin pockets, etc.), or trees that are unsuitably shaped (particularly regarding insufficient straightness) for the intended usage or the necessary processing methods and equipment.

1.1.2. Harvested species

Timber

Deciduous and coniferous species represent respectively 27% (5.3 Mm^3) and 73% (14.2 Mm^3) of the timber harvested in 2019 in mainland France; and 32% (9.7 Mm^3) and 68% (20.4 Mm^3) of the combined timber and pulpwood harvest (Agreste 2020). The proportions and volumes of the main species harvested are shown in **Annex 1**.

Pulpwood

Roundwood excluding poles comprises 60% coniferous and 40% deciduous species (**Annex 1**). According to data from the Joint economic monitoring of the forestry and wood sector[9] (*VEM-FB*) for the year 2018, the use of pulpwood is divided equally between paper pulp (25%) and panels (25%); while 45% is exported and the remainder is allocated to wood chemistry (VEM-FB 2021).

Fuelwood

Fuelwood for collective and industrial heating

The distribution of the wood species used for collective and industrial heating has not been quantified. Regarding the wood processing by-products, it can be assumed that they are mainly coniferous species, since the amount of coniferous sawn timber is much higher than that of deciduous sawn timber.

Fuelwood for domestic heating in households

Households heating with wood use mostly logs. Of the annual household consumption of 23 Mm^3 logs, taking all sources into account (forests, non-forest areas, recovered and waste wood), the use of deciduous trees predominates (**Annex 1**). Between 13 and 15 Mm^3 of this 23 Mm^3 is estimated to come from forests (ADEME, Solagro, Biomasse Normandie, BVA 2018).

9 *Veille économique mutualisée de la filière forêt-bois* in French.

1.2. Other resources

1.2.1. Primary and secondary processing by-products

This term covers sawmill by-products and by-products from all other wood processing industries. These products, which are particularly derived from timber processing, can be used by re-entering the production chain for the paper and panel industries that use these products, or as fuel or for wood chemistry. There are several by-product types, including: bark, sawdust, first cut slabs[10] and edgings[11] which are transformed into chips, veneer offcuts, etc.[12]. The amount of by-products generated is directly related to the processing yield. This varies according to the type of products processed, but also according to the species processed. **Table 3** presents average percentages of by-products calculated by the FCBA for the production of boules[13] and square-edged timber[14] according to their respective proportions in French sawn timber production.

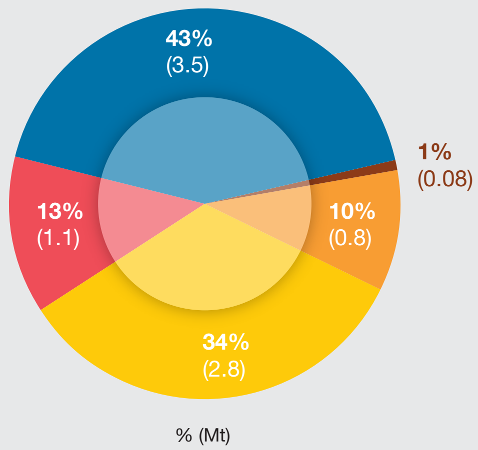
TABLE 3. AVERAGE PERCENTAGE OF BY-PRODUCTS PER M³ OF BARKED LOGS (FCBA 2019)

	Oak	Beech	Fir & Spruce	Maritime pine
Bark	14%	8%	10%	20%
Sawdust	9-11%	10-11%	11-13%	10-13%
Other off-cuts	32-34%	24-30%	20-23%	18-24%

Only by-products generated in the production of sawn timber, wooden sleepers, barrel staves and some secondary processing products (profiled timber, laminated floor panels, fibre, wood wool, flour and impregnated wood) are subject to an annual survey (Agreste 2020). In 2019, 34% of these resources (2.8 Mt out of a total of by-products of 8.2 Mt) were destined for pulping (**Figure 2**), while 22%[15] were used for energy production. The remaining 43% is used as mulch, animal bedding, etc. There is no data available to identify the exact final destination of these by-products. Part of them are exported: in 2018, this relates to 8% of the by-products meant for paper- and panel-making, and to the 12% of marketed by-products that were not used for pulp (VEM-FB 2021).

The options for using and processing the by-products depend on their form (chippings, bark, sawdust of varying grades, etc.) and the specifications of each product (pulp, panels, insulation). The latter are presented in **section 3**.

FIGURE 2. DISTRIBUTION OF WOOD PROCESSING BY-PRODUCTS, IN % OF TOTAL AND (MT) (AGRESTE, 2020)



1.2.2. Recovered used wood

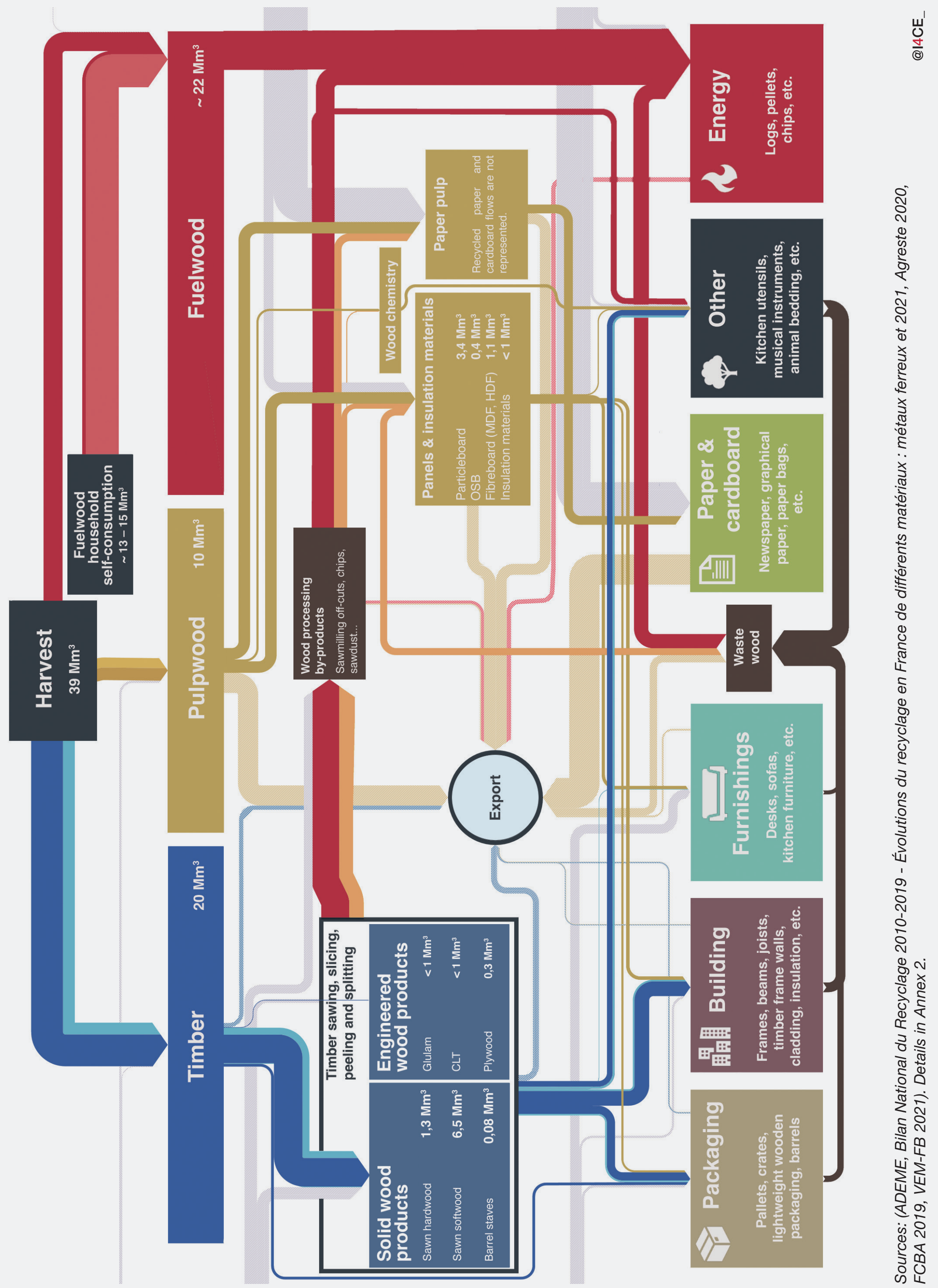
Wood recycling concerns all wood product types, from pallet-type packaging to construction products, excluding hazardous products, and its material recovery makes it possible to extend the life of the wood harvested. According to the latest national recycling report for France, 6.9 Mt of wood waste was collected in 2019 (ADEME 2021). The raw materials from the recycling of this waste can be used to produce wood panels (currently mainly particleboard),

10 Sawmill waste corresponding to the first and last boards of sawn logs.
11 Sawmill waste from the production of square-edged timber to level the edges.
12 Long sheets of wood obtained by peeling the log, with a thickness of less than 6 mm.
13 Boules are stacks of logs sawn lengthwise, so as to reconstitute the log after sawing.
14 Wooden planks.
15 13% if we consider only the by-products not intended for pulp- and panel-making, which is marketed and explicitly identified as a supply for energy production. 22% if we add the by-products not intended for pulp- and panel-making, not marketed but identified as having been used for energy production or other purposes.

the production of which accounted for 40% of the waste collected in France in 2019 (including exports to foreign factories).

This proportion is likely to increase in the coming years. At present, conflicts of use exist for this collected waste, particularly with energetic valorization, which accounted for 40% of the waste collected in 2019, but the implementation of the extended producer responsibility principle[16] in the furniture components and building products and materials sectors[17] should guarantee an increase in available waste and thus reduce conflicts of use.

FIGURE 3. RESOURCE FLOW DIAGRAM FOR THE FRENCH FOREST-BASED SECTOR IN 2018



Sources: (ADEME, Bilan National du Recyclage 2010-2019 - Évolutions du recyclage en France de différents matériaux : métaux ferreux et 2021, Agreste 2020, FCBA 2019, VEM-FB 2021). Details in Annex 2.

Legend: Species: Softwood, Hardwood; Export: Timber, Pulpwood, Fuelwood; Import

16 Extract from a fact sheet published by the French Ministry of Ecology: “The principle is simple: whoever manufactures, distributes or imports a product must take responsibility for its end-of-life. The producer and distributor must therefore finance, organize and implement the appropriate collection, reuse or recycling solutions for their product” (Ministère de la Transition écologique 2020).

17 Entry into force on 1 January 2022.

1.3. Main uses of wood harvested in France

The French LTS plans to prioritize wood uses with longer lifespans, particularly by increasing the use of wood in construction. The greater the proportion of the harvest dedicated to such uses, the more sustainable the carbon storage and the greater the carbon sink. To assess carbon storage in products, the LTS uses default half-life durations[18]: 35 years for sawn timber and 25 years for panels. These are the default values recommended by the Intergovernmental Panel on Climate Change (IPCC, 2019) in the absence of more specific data.

This section provides an inventory of wood usage in France. Products are classified according to their indicative lifespan: short (**1.3.1**) and long (**1.3.2**). A third category includes uses that do not easily fit into one of the first two categories, either due to the relativity of what is considered long or short, or because of the innovative nature of the uses concerned (**1.3.3**).

LIFETIMES AND HALF-LIVES

A product's lifetime is the time during which it can fulfil its function.

The half-life is defined as "the number of years it takes for the quantity of carbon stored in a category of harvested wood products to decrease to one half of its initial value" according to Article 3 of EU Regulation 2018/841 on the inclusion of greenhouse gas emissions and removals from LULUCF.

The two values are linked and difficult to measure accurately in practice. In this study we have used both concepts to highlight the gap between them where appropriate, and thus to support a new way of considering long-life uses that goes beyond the current idea of sawmills/panels (long-life) at one end of the scale, and paper/energy (short-life) at the other, which is found in the French LTS. Indeed, in some cases, a product's reference half-life value (*e.g.* 35 years for sawn timber) may be far from the lifespan of some of these uses (*e.g.* wooden concrete moulds, which have a very short lifespan).

1.3.1. Short lifespan uses

Paper and cardboard

In 2018, 7.9 Mt of paper and cardboard (all types) were produced in France (newspaper, tissues, packaging cardboard, etc.), (Copacel 2021).

Most paper is produced from recycled paper and cardboard (57%). The rest of the supply is made up of paper pulp (34%) and other non-wood materials (talc, kaolin, etc.). This pulp is imported in high proportions (nearly 60% of the paper pulp consumed in France), and is therefore not accounted for in national carbon flows.

French pulp production mainly utilizes French wood (95% of the supply, *i.e.* 5.9 Mt), 73% of which is coniferous (more than 80% pine) and 27% deciduous (mainly hornbeam, chestnut and other secondary species). Deciduous wood mainly comprises roundwood (85%), while coniferous wood has a higher proportion of by-products (33%). Taking all species together, 68% of wood supplied to the pulp industry is roundwood harvested in France (*i.e.* 4.2 Mt), while French-produced by-products represents 27% (*i.e.* 1.7 Mt, more than 85% of which is coniferous wood).

In total, in 2018, the pulp industry consumed 25% of the pulpwood harvested in France and half of the by-products intended for pulp and panels (VEM-FB 2021).

The half-life of these products is estimated at 2 years by default, but can be extended to 7 years when recycling is taken into account (Citepa 2021).

Packaging: lightweight wooden packaging and crates

The packaging sector is divided into three sub-sectors: lightweight wooden packaging, industrial packaging (or crates) and pallets. The values and volumes provided here are taken from a report commissioned by the wood packaging division of the *France Bois Forêt interprofession* (Gallileo Business Consulting 2020).

18 The national inventory of greenhouse gas emissions (GHG) carried out by Citepa applies more precise half-lives for different uses (panels, packaging, furniture, carpentry, etc.) ranging from 3 years (packaging) to 50 years. (Citepa 2021).

Lightweight wooden packaging

Lightweight wooden packaging (LWP) is mainly intended for the food industry (which accounted for 94% of LWP production by volume in France in 2019), in the form of crates for fruit and vegetables, oyster boxes, cheese boxes, etc. LWP is mainly produced from poplar logs of French origin: in 2019, LWP production used 0.7 Mm³ of rough timber, of which 73% were logs (0.5 Mm³), all from either peeled (91%) or sawn French poplar.

Industrial packaging (crates)

Crates are made from sawn timber (79%, mainly coniferous species), plywood (14%) and OSB and particleboard (7%), accounting for a total of 0.2 Mm³ of wood.

The benchmark half-life used for the calculation of packaging carbon flows is 3 years (Citepa 2021), although the materials used (sawn timber, panels) have higher half-lives (35 and 25 years respectively). The practical lifespan of these crates is around one month, especially if they are not reused (FCBA 2008).

Clothing

Cellulose is the raw material of several synthetic textiles: viscose, lyocell and modal. This cellulose can come from wood (especially eucalyptus or beech), but also from soya, corn, etc. (ADEME 2019).

The wood is processed in a similar way to that used to produce paper. There is limited information available on the quantities of French wood used by this sector, or on the quantities produced in France or from French resources, or on the lifespans of this product type. We therefore made the assumption that lifespans would be in line with those of other textile types used for clothing, which for Europe has been estimated at between 3 and 5 years on average by a study under the European LIFE programme (WRAP 2017).

Concrete formwork

Formwork is the wooden, metal or plastic structures used for concrete moulds on construction sites. Wooden formwork is the most common, which is made of plywood, OSB or solid wood planks. Although detailed information on the input and output flows of national production and consumption are not available, solid wood formwork consumes no more than 0.02 Mm³ swe of sawn timber, all of it from national resources.

Depending on the semi-finished wood product used, the national inventory assigns formwork with a half-life of 35 years (sawn timber) or 25 years (plywood, OSB). However, in practice, the life of the finished product (formwork) is less, as the wood can be subject to deformation resulting from the initial usage on site. However, plywood formwork can be wrapped in a phenolic film to protect it from wear and tear, which extends its lifespan.

Fuelwood

Wood for energy production takes many forms: logs, pellets, chipped forest residues, primary and secondary by-products (sawdust, bark, etc.), recovered used wood (*e.g.* pallet shredding), etc.

The national inventory applies a half-life of zero to such products, even though fuelwood can in practice be stored for between 1 month and 2 years by its users (FCBA 2008).

1.3.2. Long lifespan uses

Long lifespan uses are concentrated in the building sector. The section below presents these uses (**Figure 4** and **Figure 5**) by detailing the type of resources typically used for the associated wood products (subject to the availability of information).

FIGURE 4. TIMBER – USES AND ASSOCIATED WOOD PRODUCTS IN THE BUILDING SECTOR

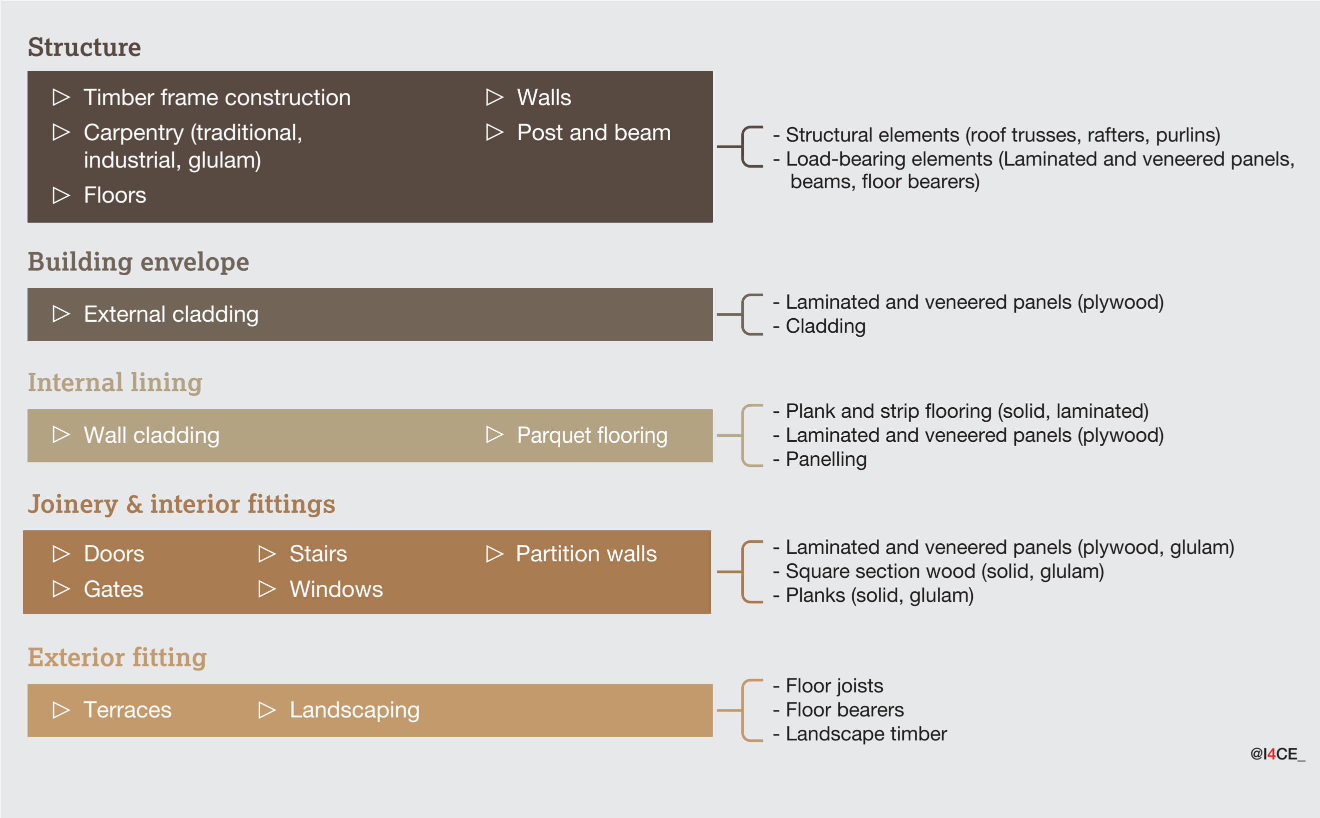
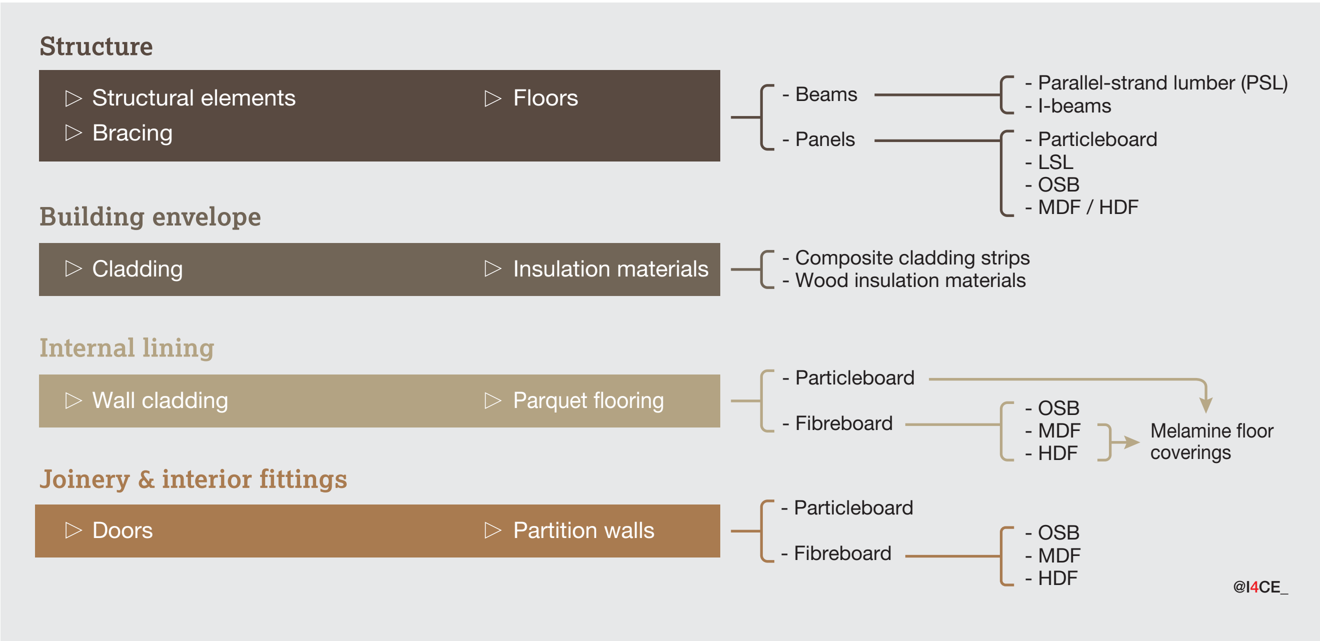


FIGURE 5. PULPWOOD – USES AND ASSOCIATED WOOD PRODUCTS IN THE BUILDING SECTOR



Timber

There exists an extensive array of timber products and to provide an exhaustive list here would be purely for interest only. Indeed, the dimensions and desired uses are determining factors of a product's classification, while the processing methods do not differ, which is why these products are grouped under the general term "sawn timber".

However, it is worth distinguishing solid timber products from so-called "engineered wood" (or reconstituted wood, composite wood). Solid timber is defined as logs that are sawn, sliced, peeled or split without significant additional processing of the wood structure, unlike engineered wood, which is a composite material made by the breakdown of logs. Unlike solid timber products, engineered wood products

(EWPs) are composed of several sections of the same log or several logs glued together.

Sawn timber products are made from a variety of species, both deciduous and coniferous, although the majority is coniferous sawn timber (**Annex 1**).

Engineered wood products

The term “engineered wood products” covers all wood-based products, from those made with timber to the panels made from pulpwood. This section only covers EWPs with timber as their raw material.

Apart from finger-jointed solid timber, which is very similar to solid timber, EWPs are all quite similar in definition, all involving the binding together of plies (laminates or veneers). The variation between products mainly relates to the orientation and thickness of the plies and the shape of the product (beam, panel, etc.). **Table 4** summarizes the characteristics of the main product types.

Illustration 1. CLT

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Illustration 2. Plywood

© Stock image/Shutterstock.com

TABLE 4. OVERVIEW OF THE MAIN ENGINEERED WOOD PRODUCTS

<table>
<tr><th>Product</th><th>Description</th><th>Most commonly used species</th><th>Material yield
(% product / m³ of log over bark)</th></tr>
<tr><td>Finger-jointed solid timber</td><td>Solid timber pieces assembled lengthwise, interlocked and glued end to end.</td><td>Coniferous trees
(fir, spruce, Douglas fir, pine)</td><td>Corresponding to those of sawn timber, varying according to the species. For example: 52 to 58% for spruce, 42 to 48% for maritime pine (FCBA 2019).</td></tr>
<tr><td>Plywood</td><td>Solid panel made of veneer sheets obtained by peeling or slicing. It can be used for a variety of applications: for wall and floor panels used in construction, as panels for partition walling or cladding), or as I-beam cores (central part). It is also used in the industrial packaging sector and in the furniture industry.</td><td>Coniferous, deciduous (poplar, birch, beech)</td><td>50% for coniferous, 40% for deciduous species (FCBA 2019).</td></tr>
<tr><td>Laminated veneer lumber</td><td>A solid panel[19] similar to plywood, of large dimensions (length: 18 m or above, max. width: 2.5 m) and used for panels, beams with a rectangular cross-section and I-beams.</td><td rowspan="3">Coniferous trees</td><td>50% (Finnish Woodworking Industries 2019)</td></tr>
<tr><td>CLT</td><td>Cross-laminated timber (CLT) is a solid panel product made up of layers of sawn wood planks, crossed at 90° to each other.
It is a large product (max. length: 18 m, max. width: 4.8 m) for structural use, and its performance makes it particularly suiTable for the construction of medium to high-rise buildings.</td><td rowspan="2">36 to 38% (Finnish Woodworking Industries 2019)</td></tr>
<tr><td>Glued laminated timber</td><td>Also known as Glulam, this product is made from sawn timber strips.
It is produced as beams, the performance and dimensions of which (especially the length, which can reach up to 40 m) are again particularly suiTable for the construction of large buildings.</td></tr>
</table>

19 Laminated veneer lumber (LVL) is rarely identified as a panel. However, it is subject to French standards specific to panels, and is explicitly considered as a veneer panel by the World Customs Organization’s Harmonized System from 1 January 2022 (FAO 2020).

Pulpwood

Long-life products from pulpwood processing can be grouped into four categories:

- panels derived from pulpwood and secondary resources: particleboard and fibreboard,
- insulation,
- structural roundwood (poles),
- other products and finished products incorporating processed panels.

Panels derived from pulpwood and secondary resources: particleboard and fibreboard

In 2018, approximately 5 Mm³ of panels were produced in France (FCBA 2019). These panels are either finished products intended to be used as they are (*e.g.* panels for construction) or semi-finished where secondary processing is necessary for their final use (*e.g.* particleboards which are integrated into furniture production).

Roundwood is the raw material for half of the wood-based panel sector (mostly from the domestic French harvest), 30% is by-products (of which 34% is imported), and the remaining 20% is recovered used wood (almost exclusively French) (FCBA 2019, VEM-FB 2021).

Shared characteristics of these products include being mainly produced from coniferous species, their availability in a variety of forms (thicknesses, dimensions, with or without grooves) and suitability for many applications. They are generally substituTable for one another as shown in **Figure 5**, however their composition differs and therefore they are presented separately here.

Pulpwood-based panels can be divided into two categories: particleboard and fibreboard. The different raw materials used for these two product types are not always interchangeable and both panel types have a specific manufacturing process. Average proportions of raw materials in the production of the main products are presented below, calculated from the information provided in the Environmental Product Declaration (EPD). The list of EPDs used is published in **Annex 3**.

Particleboard: Also commonly known as chipboard, it is composed of several layers of particles glued together. It is produced from primary and secondary wood processing by-products (42%) and shredded recovered used wood (50%). National French production in 2018 was approximately 3.5 Mm³ (FCBA 2019).

Illustration 3. Particleboard

baitong333/Shutterstock.com

Fibreboard: These products meet different standards depending on density; for example, there is medium-density fibreboard (MDF) and high-density fibreboard (HDF). They are made up of several layers of fibres glued together. MDF is produced from shredded roundwood (79%) and primary and secondary processing by-products (21%). More than 1 Mm³ of MDF and 0.07 Mm³ of HDF were produced in 2018 in France (FCBA 2019).

Illustration 4. Fibreboard

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OSB: OSB (oriented strand board) is made up of several layers of thin wood strips of different sizes and orientations. In France, OSB is made from 100% roundwood and is produced by a single factory. Although recent, they are the most popular panels for structural uses in construction, for example in the bracing of wood-framed walls. French production in 2018 is estimated at 0.4 Mm³ (FAO 2021).

Illustration 5. OSB

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Insulation materials

Wooden insulation materials are mainly produced from wood fibres, although some insulation boards are made from cork (bark from cork oak). There are two types of wood fibre insulation: wood wool and wood fibre. Wood wool is produced in the form of flexible to semi-rigid boards, and wood fibre in the form of rigid boards. Production methods differ considerably: wood wool is only produced from roundwood, whereas wood fibre can be produced from roundwood, by-products and recovered used wood.

Like mineral (*e.g.* rock wool) or petrochemical (*e.g.* expanded polystyrene or EPS) insulation, wood-based insulation can be used for both internal and external insulation. It can be mixed with other insulating materials or additives (*e.g.* cement) to increase resistance properties (against fire, wood-eating insects, etc.) and versatility, thus reducing the proportion of wood in the product's composition.

Illustration 6. Wood fibre insulation board

Figures for the exact volume produced are not publicly available, but an amount of less than 0.4 Mm³ can be inferred (FCBA 2019).

The half-life of insulating materials is not specified by any standards, but experts estimate it to be similar to non-structural panels, which have a half-life of around 20 years (IPCC, 2006, 2019).

Structural roundwood (poles)

Structural roundwood is pulpwood that has undergone very little processing: after the usual stages of wood preparation (debarking, topping, etc.), bucking and possible preventive treatment (depending on the species and the desired use), it is ready for use as telephone poles, fences, outdoor recreation or as part of a construction project (*e.g.* stacked log wall). The volume harvested for this use is low: in 2018 it was 0.05 Mm³, which included only coniferous species (Agreste 2020).

Other products and finished products incorporating panels derived from pulpwood and secondary resources

Floor supports, wood-framed walls, wood partitioning: All the panel types presented above can be used for these applications, provided they are adapted for the purpose in accordance to the standards in force (*i.e.* particleboard used for furniture does not have the same technical characteristics as that used for a timber frame wall).

Melamine parquet: This is composed of MDF and HDF particle board or fibreboard as a support, and a decorative sheet glued to the board.

I-beam: Taking its name from its I-shape, an I-beam is a composite beam: its flange (*i.e.* beam top and bottom edges) is made from solid or engineered wood (*e.g.* LVL) from coniferous species, and its web (*i.e.* central part) is made from metal, HDF, OSB or plywood. French I-beam production is 0.02 Mm³ annually[20].

Composite decking, cladding: Wooden decking and cladding are traditionally made from solid wood planks or even plywood (for cladding only). However, it is possible to produce them with by-products (wood flour in particular) and recovered used wood.

1.3.3. Other uses

Medium lifespan uses

Packaging: pallets

In 2019, the pallet sector mobilized 1.5 Mm³ of new sawn wood, 97% of which was used for the production of new pallets, the rest for the reconditioning of used pallets; 1 Mm³ of this sawn wood is of French origin, mainly comprising coniferous species. A small volume (0.02 Mm³) of sawn wood from the recovery of old pallets is also used for pallet reconditioning (Gallileo Business Consulting 2020).

Their estimated average lifespan is 5 (FCBA 2008) to 8 years (SYPAL 2012).

Furniture

Many types of furniture can be designed from panels: storage furniture, kitchen furniture, bathroom furniture, office furniture, etc. This is one of the main markets for panels (VEM-FB 2021).

We classify these products as “medium lifespan” because according to the French Technical Reference Center for Air Pollution and Climate Change (*Citepa*), they have a half-life of 10 years (Citepa 2021). This is a longer lifespan than paper and fuel, but below the potential of panels. Thus, regarding the *SNBC* objectives, they are among the long-life uses, but the French Agency for Ecological Transition (*ADEME*) is sceptical of the accuracy of including furniture when carrying out carbon balances (ADEME 2014).

Other uses

Green chemistry

Wood-based green chemistry can transform pulpwood into a wide variety of products: cosmetics, food, textiles (see below), industrial products... All wood resources can be exploited (bark, foliage, wood... (Deglise et Brosse 2014)).

It is difficult to assign a lifespan to these products due to the diversity of forms.

20 According to the French Union of Wood Construction Industry (*UICB*) and the French Union of Wood I-Beam Manufacturers (*APIBOIS*), their members produce 1.2 million linear metres of I-beam per year, which represents 90% of national production (UICB 2021). The total national production should therefore be 1.3 million ml. According to the three collective I-beam EPDs, 0.018 m³ of wood on average is needed for 1 ml of I-beam.

TABLE 5. SUMMARY OF THE MAIN WOOD PRODUCTS AND ASSOCIATED USES

Products	Uses	Indicative lifespan (FCBA 2008)*
SOLID TIMBER		**Short to long depending on use**
SAWN TIMBER		
Various sawn timber products (beams, solid tiles, etc.)	Construction: structure, interior and exterior fittings (partitions, parquet flooring, terraces, etc.), joinery (windows, staircases, etc.), building envelope (cladding)	15 to 75 years
Boards, rafters, pallet blocks	Packaging: pallets	5 to 8 years (SYPAL 2012)
Boards	Packaging: crates	1 month
Various sawn timber	Furniture	5 to 25 years
SAWN TIMBER AND VENEER		
Lightweight wooden packaging components	Packaging: lightweight wooden packaging	1 month
BARREL STAVES	Packaging: barrels	8 years
POLES	Construction: structural	75 years
	Outdoor facilities (outdoor recreation, utility poles, etc.)	Long
ENGINEERED WOOD		**Short to long depending on use**
SAWN TIMBER LONG		
Finger-jointed solid timber	Construction: structural	75 years
Cross laminated timber (CLT)		
Glued laminated timber		
VENEERS		
Laminated veneer lumber (LVL)	Construction: structural	75 years
Plywood	Construction: structural, interior design	15 to 75 years
	Furniture	5 to 25 years
	Packaging: crates	1 month
PANELS		**Short to long**
Oriented strand board (OSB)	Construction: structural, interior design	15 to 75 years
	Packaging: crates	1 month
Medium or high-density fibreboard (MDF, HDF)	Construction: structural, interior design	15 to 75 years
	Furniture	5 to 25 years
Particleboard (chipboard)	Construction: structural, interior design	15 to 75 years
	Furniture	5 to 25 years
WOOD-BASED INSULATION MATERIALS	**Construction: building envelope**	**Long**
Wood wool		
Wood fibre		
Cork		
OTHER PRODUCTS		
Paper and cardboard		1 to 16 months
Clothing		3 to 5 years (WRAP 2017)
Green chemistry		N/A
FUELWOOD	Energy	1 month to 2 years

*Except for maximum lifespan of pallet, poles, insulation and "Other products" category.

Timber · Pulpwood · Fuelwood

1.4. Changing the uses of wood: three main avenues

Changing the uses of harvested wood involves dedicating a larger share of the harvest to certain uses ahead of others. The French LTS calls for an increasing share of the harvest to be dedicated to so-called “long-life” uses, to the detriment of shorter lifespan uses such as packaging, paper and fuel. In scenarios where the harvest increases, as is the case in the strategy, the volumes dedicated to “short-life uses” do not decrease in absolute terms: the quantities of paper remain stable, and the volume of fuelwood increases slightly. Whereas, in a context where the harvest increases by only a little, or not at all, the volumes of wood dedicated to certain uses would decrease in favour of others.

As shown in **Table 5**, there is not necessarily a strict relationship between roundwood and long-life uses, or with by-products and short lifespan uses. The reorientation potential will thus concern roundwood, as well as by-products or recovered used wood. This potential can take the following forms:

Increasing the proportion of timber used for long-term purposes. With a view to optimizing the harvest use, this lever could target the share of harvested wood that is directed towards short-life uses (mainly packaging, see **section 1.3.1**) and potential timber that is currently used as pulpwood or fuelwood (**section 1.1**) although having sufficient quality to be used as timber. Increasing the proportion of timber used for long-life purposes can also be done by investing in processing tools to improve the material yield of timber processing. Finally, promoting the use of engineered wood can also be a way of using a lower quality (structurally or visually) resource or wood with a diameter that is smaller than that usually used for equivalent solid timber products.

Using a larger share of the pulpwood and fuelwood harvest for long-life products such as panels, to the detriment of short-life uses, particularly fuel. To favour the use of wood as a material, the French LTS plans to reduce the proportion of wood harvested for energy production, without actually decreasing the absolute volumes dedicated to the energy sector as result of an increasing harvest. As 75% of wood resources in 2015 went into energy use according to the LTS, the target pathway aims at a 50:50 ratio between industrial wood and fuelwood usages in 2050. Regarding pulpwood, 25% of the 2018 harvest was used by the paper and cardboard industry (**Figure 7**, **section 3.2**). Thus, there is a potential to increase the share of pulpwood and fuelwood harvest dedicated to long-life uses such as panels, by reorienting the harvest towards material use as a priority.

- **Favouring long lifespan uses for recovered used wood and processing by-products.** Recovered used wood and by-products have several uses, with lifetimes ranging from less than two years (fuelwood) to a longer storage of biogenic carbon of up to several decades (panels). However, the strategy’s target of producing 25 Mm³ of panels by 2050 is calculated on the basis of forecasts of available forest resources over this time horizon. The share of panels produced from by-products and recovered used wood is therefore additional to the production volume targeted by the LTS.

To determine what changing the uses of harvested wood could mean in practical terms, we show here that increasing the use of timber is technically difficult in the short-term, but concerns volumes that could be significant (**section 2**) while there are no major technical obstacles to the reorientation of pulpwood and fuelwood, which could generate large volumes of panels and insulation materials (**section 3**).

2. LIMITED SHORT-TERM POTENTIAL FOR CHANGING TIMBER USE, BUT LONG-TERM PROMISE

2.1. The gap between the potential amount of timber harvested and actual timber usage: a limited issue in the short-term

As mentioned in **section 1.1**, there is a mismatch between the potential amount of wood harvested as timber, according to forestry statistics, and timber actually processed by the sawmilling, slicing, peeling and splitting industries according to public data (**Table 6**). One of the several reasons that may underlie this discrepancy is that potential timber is used as pulpwood or fuelwood, which on average has a shorter lifespan. The criteria by which potential timber is classified by the inventories are the result of discussions between the IGN and representatives of the timber industry to establish the diameters and qualities that the sector is currently processing. They do not only depend on the processing capacities of technologies, but also on the state of the market: if demand for certain species is high or their supply is insufficient, then wood with smaller diameters and lower quality will be considered as timber quality, and vice versa in a situation of low demand/abundant supply. An increase in the price of finished products or technological innovations could also widen the range of diameters that qualify as potential timber, *i.e.* diameters that are currently classified as pulpwood could be used as timber.

For deciduous species, the gap between harvested potential timber and the timber declared in the annual forest exploitation survey is 18%, although it can be as high as 44% for chestnut and 78% for valuable deciduous species due to a lack of demand for such species (IGN; FCBA 2019). The gap is only 4% for coniferous species. However, it is worth noting that the latest definition of potential timber was established on the basis of current market conditions; to qualify as timber, the *IGN* states that small-end diameters for most coniferous species must be at least 20 cm, notably because the supply is sufficiently abundant for the industries not to seek out smaller diameters. If this small-end diameter is reduced to 14 cm, the difference between potential and actual timber for coniferous species is 16%. Similarly for deciduous species, the *IGN* estimated the gap to be around 50% in a study which did not take market specificities into account (IGN; FCBA 2016).

No market for certain species and diameters

This substantial gap reveals the lack of market interest in these species. This mainly concerns deciduous species: depending on the species, the diameter and log quality, domestic outlets are becoming scarce (Alexandre 2017, Forestry Club de France; Conseil & Stratégie Durables; CYME Innovations; FIVE Conseil 2019, Cattelot 2020, Cour des comptes 2020, Hermeline et Lavarde 2020) and represented less than 20% of sawn wood production in 2019 (Agreste 2020). These types of wood suffer from competition with conifers, which are more competitive and adapted to market expectations because processing is simpler (their wood being generally less dense and softer) and they are compliant with international standards.

Furthermore, sawn wood must be assessed for its mechanical performance if it is to be used for structural applications in the construction sector. It cannot be sold for this purpose without such evaluation: and since some secondary deciduous species have not been characterized[21], their possible outlets as timber are limited.

The market may also be lacking due to local phenomena: if local demand is insufficient, the costs of transporting wood from a place of harvest to a distant sawmill may render the operation unprofiTable (Forestry Club de France; Conseil & Stratégie Durables; CYME Innovations; FIVE Conseil 2019).

Finally, the material use of the smallest and largest diameter coniferous species could be improved. Finding buyers for the largest trees, especially firs, can be difficult because they are either too big for cant saws ("modern" saws) or, if they are of a size that can be sawn, then the diameter does not enable such machinery to operate at maximum productivity (Hermeline et Lavarde 2020). In both cases, band saws ("traditional" saws) are used instead, which experts say incur higher costs than for medium diameter wood processed with canter saws. As canter saws have become more common in coniferous sawmills in recent years (Chalayer 2014, Hermeline et Lavarde 2020), this difference in the sawing

21 According to experts, six deciduous species have been characterized for structural use in buildings: Sessile and Common Oak, Beech, Chestnut, Poplar and Aspen.

costs of various diameters may explain why the demand for the largest diameters is lower than the supply. Regarding the smallest diameters, the difference between the two estimates of harvested coniferous potential timber of different small-end diameters (14 and 20 cm) shows the lack of market interest in diameters of less than 20 cm, despite the fact that it is technically possible to process such wood as timber.

Without current market constraints, and looking only at the technical classification of wood, one could therefore consider that the reorientation potential would be close to 50% for deciduous and 16% for coniferous species. In absolute terms, this difference would be 6 Mm^3 for deciduous species and almost 3 Mm^3 for conifers, which corresponds to 36% of harvested wood of potential timber quality. However, this figure is a maximum potential, as the discrepancies between potential timber and declared timber may also be due to defects that the *IGN* cannot detect, particularly regarding deciduous and large coniferous species.

TABLE 6. COMPARISON OF HARVESTED TIMBER GRADE QUANTITIES MEASURED BY THE IGN AND TIMBER VOLUMES DECLARED IN THE ANNUAL FOREST EXPLOITATION SURVEY, FOR THE PERIODS 2011-2015 (IGN; FCBA 2016) AND 2005-2017 (IGN; FCBA 2019), IN Mm^3 AND %

	Annual survey	IGN & FCBA (2019)	Gap	Gap in %	IGN & FCBA (2016)	Gap in %
CONIFERS (14 cm small end cut)	**13**	**15.6**	**2.6**	**+ 16 %**	**NA**	**NA**
Fir	6	7.7	1.7	+ 22 %	NA	NA
Spruce						
Douglas fir	1.7	2.5	0.7	+ 30 %	NA	NA
Maritime pine	5.3	5.4	0.2	+ 3 %	NA	NA
CONIFERS (20 cm small end cut, except maritime pine)	**13**	**14.4**	**0.6**	**+ 4 %**	**14**	**- 4 %**
Fir	6	6.3	0.3	+ 5 %	6.1	- 8 %
Spruce						
Douglas fir	1.7	1.7	-0.05	- 3 %	1.8	- 11 %
Maritime pine	5.3	5.4	0.2	+ 4 %	3.7	- 21 %
Scots pine	0.8	0.9	0.1	+ 13 %	1.1	+ 28 %
DECIDUOUS	**4.3**	**5.2**	**0.9**	**+ 18 %**	**10.9**	**+ 53 %**
Oak	2.4	2.6	0.2	+ 9 %	4.9	+ 55 %
Beech	1.2	1.5	0.2	+ 15 %	2.3	+ 47 %
Chestnut, valuable hardwood and others	0.6	1.1	0.5	+ 43 %	3.8	+ 55 %

Inconsistent quality

The quality of harvested potential timber can be inappropriate for sawing due to defects that are undetecTable prior to cutting; this is particularly true for very large[22] fir trees (Hermeline et Lavarde 2020) where the annual potential timber harvest amounts to at least 0.5 Mm^3 (IGN; FCBA 2019). It can also be due to the pedoclimatic context of the stands, such as beech harvested in mountainous areas, which tend to have more knots (Hermeline et Lavarde 2020), and are therefore less suiTable for sawing, despite its dimensions which enable it to be classified as potential timber.

If technology remains unchanged, it therefore seems difficult to massively increase the proportion of timber in the harvest by influencing market conditions. In the longer term, however, the modernization of processing industries and the development of outlets for deciduous species, possibly aided by technological advances (*e.g.*, engineered wood), are likely to activate this lever.

22 With a diameter greater than 67.5 cm as defined by the national forest inventory.

2.2. Optimization options to increase long-term carbon storage in timber

Development of engineered wood products

The performance of these products is comparable or even superior to that of solid timber, and they may even be preferred due to their ease of use (*e.g.*, CLT building systems which are prefabricated to the required size in the factory, prior to transport and on-site installation), or they enable new uses (*e.g.*, long span Glulam beams, the construction of buildings of more than five storeys in CLT). When the mechanical performance is superior to that of solid timber, it is possible to use a smaller volume of product than would have been necessary with solid timber for the same purpose. Regarding production, while their material yield (volume of logs needed to produce 1 m^3) is not significantly different to that of solid timber (Table 4), its production is however more flexible because thinner or lower-quality logs can be processed. In addition, it is possible to produce long sections from small sections, where the solid wood equivalent would have required a single log of sufficient quality and size.

The growth of EWPs has made it a dynamic sector where innovations abound. While most of these products are generally only made from coniferous timber, private initiatives are emerging such as Glulam and CLT made from beech, or from coniferous species of a diameter similar to that of pulpwood.

Engineered wood can therefore increase the proportion of the harvest allocated to long-life uses by:

- increasing the use of timber from resources previously neglected by the sawmill industry (deciduous species, small-diameter timber, or timber of lower visual or mechanical quality);
- improving the material efficiency of construction, by enabling less material to be used for the same purpose, thus freeing up resources for other long-life uses.

However, it remains to be seen exactly how much of the reorientation potential this represents. Nevertheless, it seems promising: estimates of potential timber show that for coniferous species alone, using sections with diameters between 20 cm and 14 cm adds about 2 Mm^3 of timber, *i.e.*, 15% of the volume currently harvested. Regarding the possibility of using less material for the same purpose, additional expertise would be needed to precisely estimate the volumes of wood that could be saved by favouring engineered wood over solid timber.

Diversification of resources used for packaging production

As discussed in **Section 1.3**, about 1 Mm^3 of mainly coniferous sawn wood harvested in France (*i.e.*, about 2 Mm^3 of roundwood) is dedicated to the production of crates and pallets. According to experts, it would be technically feasible to increase the proportion produced from deciduous sawn wood and to utilize timber of a diameter that would presently classify it as pulpwood rather than timber.

Changing the uses of deciduous timber could have two positive consequences:

- A possible increase in the material use of deciduous timber due to the packaging market becoming a more significant outlet;
- An increase in the lifespan of coniferous sawn wood: increasing the proportion of deciduous sawn wood in packaging production would enable a “freeing up” of coniferous sawn wood for longer lifespan uses, particularly in construction. It should be noted that although the quality of sawn wood intended for packaging is in principle inferior to that of sawn wood for construction, its use in construction is not impossible, particularly if it incorporates EWPs.

The benefit of allocating smaller diameter deciduous resources to packaging production is less clear, however, as such usage will replace longer life outlets for the same material, such as panels. However, this would reduce the proportion of timber (according to current qualification criteria) dedicated to packaging, which could be redirected to longer lasting uses.

Modernization of processing tools and the improvement of material yield

Improving the efficiency of processing logs into sawn wood could increase the proportion of the harvest used for long-life products. However, it is not easy to make more sawn wood from the same volume of roundwood. The material yield of sawmills depends on multiple parameters relating to the machines and transformation processes (*e.g.*, saw type, blade thickness, expertise, flow optimization), the intended products (*e.g.*, dimensions, appearance) and the type of wood used (*e.g.*, species, diameters, tapering). Thus, the improvement of the material yield can be achieved at several levels without expecting to see massive overall gains (*i.e.*, for the whole national sector) as, according to experts, investments are costly to achieve small improvements on this scale. However, investments in digital equipment to detect defects and adapt processing (sawing, peeling) according to species would be beneficial both to increase the material yield of processing in general, but also to make deciduous and large coniferous species a more attractive option, despite their propensity for defects that reduces their profitability.

Developing the re-use of timber products

According to experts, implementing extended producer responsibility[23] for construction products could lead to the re-use of large volumes of timber products (structural and finishing work) and the recycling of others, thereby extending the life of these products.

Mechanical grading

In France, the grading of sawn wood for construction is mainly based on visual criteria (Hermeline et Lavarde 2020), whereas the correlation between the presence of knots and mechanical strength is not confirmed. Experiments have shown that more sawn wood is rejected by visual grading than by machine grading (Viguier 2015). This limit does not, however, help to justify the discrepancy between potential timber and timber declared to the annual forest exploitation survey, because downgraded sawn wood is declared as timber before being sawn, but it does reveal that an unquantified proportion of sawn wood may not be exploited to its full technical potential.

Forestry changes

It is possible, however, that silvicultural changes (*e.g.*, different species, selective thinning, regular thinning) may increase the proportion of timber in the harvested volume. However, the expected benefits from such silvicultural changes are only likely to materialize in the very long-term (>50 years).

In conclusion, while it seems that potential timber is not currently being "wasted" to a significant degree by being used as pulpwood or fuelwood, the potential of technical developments such as engineered wood, or the development of processing and outlets for deciduous species, would make it possible to improve material recovery and to redirect short-life uses to longer ones. This potential is promising: it could reach 8 Mm^3, *i.e.*, 36% of the total potential timber harvested (including the timber used as such), without taking into account the part of this difference that is due to defects that cannot be detected by the *IGN*. Reducing the diameters that can be qualified as timber, along with the increase in the material use of low-quality wood, could also achieve gains in terms of long-life uses of several million cubic metres. A more detailed quantification of this potential according to the products and innovations to be developed would be an important contribution to the French LTS's "forest-wood" component.

However, realizing this potential requires R&D, innovations and significant investments in the industrial fabric to transform the processing sectors, which will take time. The need to support the sector in these areas has already been identified by its stakeholders, albeit from the perspective of the better use of the entire national resource, and not specifically of resources that can be redirected towards long-life uses. Support measures already exist, or will soon emerge following the *Assises de la Forêt et du Bois*[24] (2021-2022), such as the calls for projects on the "industrialization of wood and bio-sourced construction products and systems" (development of innovative EWPs, possibly made from deciduous species), on "biomass heat for the wood industry" (contributing to the development of the EWPs industry by supporting the installation of drying kilns, which experts say is essential to increase national production of these products) or the launch of a research and development programme aimed at developing new outlets for deciduous and secondary species (Ministères de l'Agriculture et de l'Alimentation, de la Transition écologique, de l'Industrie 2022).

23 As a reminder, this principle requires producers and distributors to finance, organize and implement appropriate collection, reuse or recycling solutions for its product.
24 A series of working groups launched by the French government in 2021, and which reunited many stakeholders of the French forest-wood sector to discuss the sector's issues.

3. CHANGING THE USES OF PULPWOOD AND FUELWOOD-TYPE RESOURCES

To implement a reorientation of the wood use strategy, a significant proportion of wood processing by-products and recovered used wood can be mobilized that is currently used for short-term uses (paper, energy), which could be redirected towards longer term uses (panels and insulation) (**Figure 6**). The objective is to quantify the maximum potential outlets for the different long-life uses of pulpwood. The methodology follows the following steps:

1. Identifying the types of long-life products derived from pulpwood, fuelwood and secondary resources, and assess the associated production constraints.
2. Assessing the volumes of such products that could be consumed domestically if wood was used wherever technically feasible, both now and in future as part of a climate-compatible scenario.
3. Comparing these current and future volumes to those in the LTS to assess its ambition.

3.1. No major technical constraints

3.1.1. Production constraints related to wood species and types

A common feature of today's numerous types of pulpwood-based panels is that they are mainly made from coniferous species, with a small proportion of deciduous species. Deciduous species are not recommended for use with the glues required to manufacture these products. Furthermore, factories produce continuously and require a constant supply in terms of both quality and quantity to avoid any break in supply. As coniferous species are more widely harvested, favouring these species is a way of ensuring a constant supply.

Production constraints according to each product are as follows:

▶ *Particleboard*

This production seems the most flexible as particleboards can be produced from any resource type, including by-products and recovered used wood. However, there are three limitations:

- fine sawdust[25] is excluded from the by-products used;
- production must include a minimum proportion of virgin material in the raw material mix, so it is not possible to produce panels entirely from sawdust and recovered used wood;
- processing recovered used wood requires investment in specific production facilities.

▶ *Fibreboard*

OSB

In France, OSB is only produced from roundwood because the lamellas that make it up are of dimensions that require sufficiently long wood.

MDF and HDF

Halfway between particleboard and OSB, MDF and HDF can be produced from by-products, but only those that can produce similar fibres to those obtained by chipping roundwood, *i.e.*, with particles that are not too fine.

▶ *Insulation*

Wood wool

Sufficiently long wood is required to obtain the long fibres needed for this product, so it can only be produced from roundwood.

Wood fibre

Production is more flexible than that of wood wool: it can incorporate by-products and recovered used wood.

Among by-products, bark and fine sawdust are generally destined for fuel wood and can be used by in-plant combustion facilities. As for panel offcuts, they can be shredded and returned to production, although the use of fibreboard to produce particleboard is not recommended, as this can damage parts of the industrial machinery and affect product quality.

25 Wood processing by-products in the form of very thin particles.

This is also true for panels that are recycled. Ease of recycling depends to a large extent on the type of board: there are no particular difficulties associated with recycling OSB, but particleboard and other fibreboards are sometimes used to make furniture or as parquet flooring, where the finished product does not only contain wood but also plastics, metals, etc. The difficulty then lies in separating the different materials before being able to consider the recovery of the wood used in these panels.

The technical obstacles to increasing the proportion of the harvest used for products from pulpwood processing are therefore essentially limited to:

- constraints regarding the species processed: most products are made from conifers, particularly because they are easier to process and have a higher concentration of lignin[26] than deciduous species, which therefore enables less use of synthetic glue[27];
- restrictions on the form of the raw material: some products are made exclusively from roundwood and/or cannot be made from by-products and/or recovered used wood.

In addition to these constraints relating to industrial processing techniques we can include the economic barrier relating to the production capacity of the panel industry which, according to experts, is close to its limits.

The evolution of these constraints and the issues associated with them in relation to the objective of redirecting the harvest are discussed in the next section.

3.1.2. Promising developments in production systems

The issues raised by the two technical barriers outlined above are of equal importance as both can derail the process of changing wood use.

Several reasons underlie the constraint related to conifers, some of which are economic (resource availability, market trends) and others are technical (lack of processing options, exclusive need for conifers). This constraint may limit the potential of resources that could be reoriented: roundwood-type fuelwood is one of the main targets of usage reorientation, but a majority of fuelwood resources leaving the forest are deciduous species (see **section 1.1**). Given the requirement for wood panel plants to have a constant supply of coniferous wood, adjustments to current manufacturing processes would be required to maximize reorientation potential. Interesting developments have already taken place which suggest that there is scope for change that would be compatible with the objective of changing wood uses:

- Increasing the proportion of deciduous species used for panels can be achieved by adjusting the adhesive mixes, while some companies have already diversified their product range, for example 100% poplar OSB and 100% deciduous MDF are now available.
- The use of deciduous timber has been the subject of particular attention for several years[28] and could increase sawn wood production, which would in turn increase the deciduous by-products generated. A more abundant supply of deciduous by-products would help stabilize the supply to panel producers and would increase the chances of a larger proportion being used and would make the supply more reliable for producers.

Constraints on the form of the raw material, especially the predominance of roundwood, seem more difficult to overcome. Increasing the manufacture of products currently made only from roundwood can be achieved either without changing the amount currently harvested by using roundwood from the paper industry or the energy sector, or instead by increasing the harvest. Potential ways of addressing this constraint merit in-depth specialized research to assess the feasibility of a relaxation of product specifications. Some companies are already marketing innovative solutions:

- Some OSB is produced abroad from recovered used wood by investing in a specific production line.
- Veneer offcuts, a by-product of the peeling industry that does not have a use, can be used in the production of certain engineered products for the construction sector, which are currently only produced in North America. LSL (Laminated Strand Lumber) and PSL (Parallel Strand Lumber) are intended for structural use and are produced from short and long strands, respectively.
- It is also possible to produce MDF with recovered used wood fibres. A lot of research has been published on this subject to determine the optimal mix with virgin fibres and to limit any impacts on the board quality.
- Wood flour can be an outlet for particles that are too fine to be used in panel production. It is possible to use this material to produce composite products such as cladding and decking boards.

Finally, the national panel industry will need to massively increase its production capacity if it is to meet the ambitious production growth target set by the French LTS. The economic feasibility of such growth must therefore be assessed, as equally massive investments would be required.

26 Lignin is a component of wood, and acts as a natural glue.
27 Often based on formaldehyde, these glues generate toxic formaldehyde emissions which are subject to regulations concerning their measurement, labelling and a maximum acceptable level in construction products to preserve indoor air quality.
28 These include the characterization of hardwoods by the FCBA and their report on the prospects for the development of deciduous resources in France (FCBA 2011), the EU Hardwoods project on the development of deciduous species in the construction industry from 2013 to 2017, and the study commissioned by the French Ministry of Agriculture on the future strategic choices to support the deciduous trees processing industry (Forestry Club de France; Conseil & Stratégie Durables; CYME Innovations; FIVE Conseil 2019).

In summary, the type of species does not seem to be an insurmounTable obstacle. This factor is therefore not considered in the assessment of potential opportunities in **section 4**. On the other hand, some products (OSB and wood wool in particular) cannot easily be based on anything other than roundwood (**Table 7**). As there are close substitutes (particleboard and fibreboard) that can use by-products or recovered used wood, and large volumes of roundwood can be oriented towards a different use, this is also not considered to be a substantial barrier to the opportunities assessed in **section 4**.

3.2. Panels and insulation materials: the main drivers for pulpwood and fuelwood reorientation

With the resources currently available and their distribution within the various processing sectors, the panels and insulation sectors seem to be the most promising at short-term. Indeed, we already know how to manufacture these products on a massive scale and that they can be made from a large pool of reusable resources (represented in red and blue on **Figures 6** and **7**). Moreover, these are products that can benefit from significant outlets in the construction sector. We therefore believe that these are the key products for the reorientation of wood uses policy.

Particleboard and wood fibre insulation have the greatest potential: their specifications are sufficiently flexible to enable the use of all resource types, and are not limited to roundwood as is the case for OSB produced in France and wood wool (see **section 3.1** and **Table 7**). The exclusive use of roundwood is not incompatible with the reorientation objective since roundwood constitutes some of the supply to the pulp and energy industry, but the type of available resources is consequently more limited. Thus, despite the need to develop production capacities and to imagine potential outlets to envisage large-scale changes of use, a proportion of pulpwood and fuelwood resources currently dedicated to short-life uses can already be reoriented without adjusting manufacturing processes since they are identical to those transformed by this industry (roundwood and coniferous by-products, recovered used wood, etc.).

Ultimately, for a specific use to have a strong impact in terms of better material recovery, it must have a long lifespan and be linked with resources currently used to make short-life products. The products listed in **Table 8** meet these two criteria, with priority given to outlets in the construction sector. We have prioritized the longest life uses, and at this stage we have not developed the analysis for shorter life sectors or those already saturated by wood material (packaging, furniture), and outlets representing small volumes (poles, cork insulation).

FIGURE 6. FLOW CHART OF FRENCH PULPWOOD AND FUELWOOD RESOURCES IN 2018

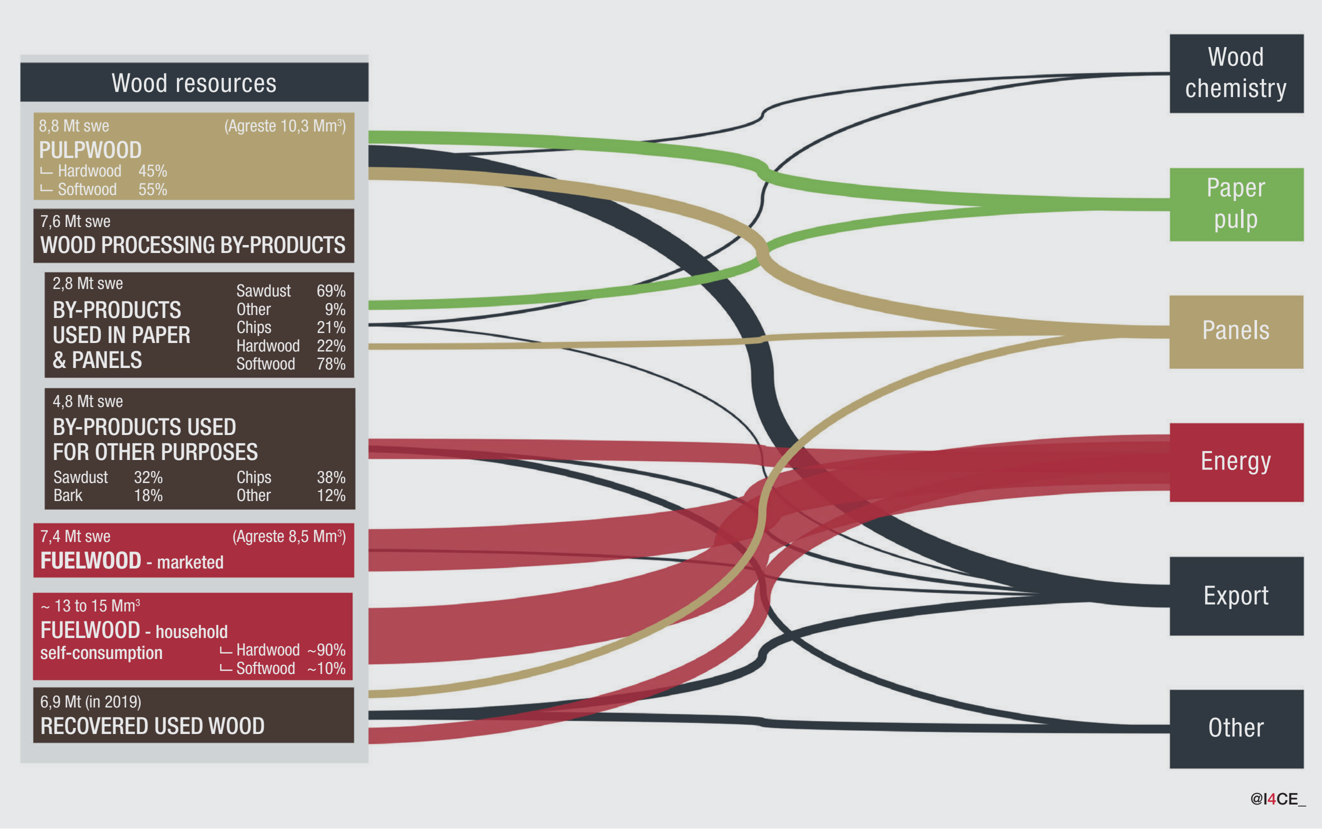

FIGURE 7. FLOW CHART OF FRENCH PULPWOOD AND FUELWOOD RESOURCES AFFECTED BY CHANGING WOOD USE

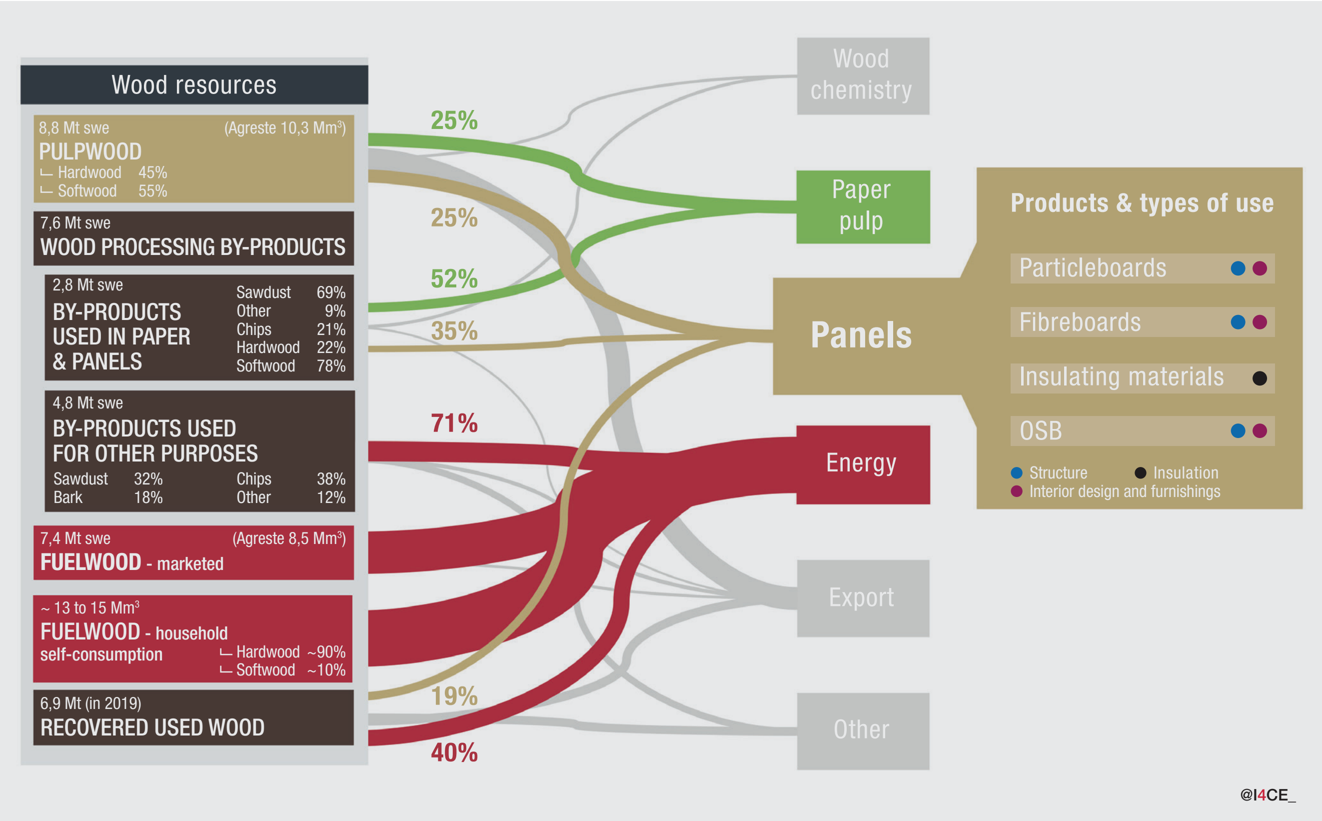

TABLE 7. SUMMARY OF THE MAIN TECHNICAL CONSTRAINTS IDENTIFIED THAT ARE LIMITING TO CHANGE THE USES OF PULPWOOD AND SECONDARY RESOURCES TOWARDS THE PRODUCTION OF PANELS AND INSULATION MATERIALS

	Particleboard	Fibreboard	OSB	Wood wool insulation	Wood fibre insulation
Hardwood	Yellow	Yellow	Yellow	Red	Yellow
Pulpwood - paper	Green	Green	Green	Green	Green
Paper	Green	Green	Red	Red	Green
Fuel (excluding bark, fine sawdust)	Green	Green	Red	Red	Green
Fuelwood	Green	Green	Green	Green	Green
Recycled wood	Green	Yellow	Yellow	Red	Green

- (Green) Resource is commonly used for the manufacture of this product.
  - ▶ No technical reasons why this resource should not be used for this product.
- (Yellow) Resource not commonly used to manufacture this product, but it is already used for alternative products.
  - ▶ A technical barrier exists that may prevent the redirection of the resource to this product, but it may be overcome in the near future.
- (Red) Resource is not used for this product and, to date and to our knowledge, there is no alternative solution to enable its use.
  - ▶ There is a major technical obstacle that would prevent the short-term reorientation of the resource towards this product, with no prospect of development at present.

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TABLE 8. MAIN USES OF WOOD THAT MOBILIZE RESOURCES THAT ARE CURRENTLY MAINLY DEDICATED TO SHORT-LIFE PRODUCTS

Products	Uses	Resource types	Lifespan (FCBA 2008)*
SOLID TIMBER			**Short to long depending on use**
Poles		**Pulpwood (roundwood)**	
	Construction: structural		75 years
	Outdoor equipment (outdoor recreation, telephone poles, etc.)		Long
ENGINEERED WOOD - PROCESSED PANELS AND INSULATION MATERIALS		**Pulpwood and secondary resources (by-products, recovered used wood)**	**Short to long**
Oriented strand board (OSB)			
	Construction: structure, interior design	Roundwood, mainly coniferous	15 to 75 years
	Packaging: crates	Roundwood, mainly coniferous	1 month
Medium or high-density fibreboard (MDF or HDF)			
	Construction: structure, interior design	Roundwood and by-products (excluding fine sawdust and bark), mainly coniferous	15 to 75 years
	Furniture	Roundwood and by-products (excluding fine sawdust and bark), mainly coniferous	5 to 25 years
Particleboard (chipboard)			
	Construction: structure, interior design	By-products (excluding fine sawdust and bark) and recovered used wood, mainly coniferous	15 to 75 years
	Furniture	By-products (excluding fine sawdust and bark) and recovered used wood, mainly coniferous	5 to 25 years
Wood-based insulation materials	**Construction: building/thermal envelope**	**Pulpwood and secondary resources**	**Long**
Wood wool		Roundwood, coniferous	
Wood fibre		By-products, mainly coniferous	
Others		**Pulpwood and secondary resources**	
Paper and cardboard			1 to 16 months
Clothing			3 to 5 years (WRAP 2017)
Green chemistry			N/A

** Except for the maximum lifespan of poles (exterior fittings), insulation materials and the «Other» category*

- (green) Products can be made from resources currently used for short-life purposes and are part of a market with potential for growth.
- (yellow) Products can be made from resources currently used for both short and long-life purposes, and their increased production may be at the expense of another long-life product.
- (orange) Products are in an already saturated market with no potential for growth.
- (red) Short-life products or uses.

4. ASSESSMENT OF THE WOOD USE CHANGE POTENTIAL FOR THE MOST PROMISING PRODUCTS

Wood-based panels and insulation are the HWPs that could benefit greatly from a change in wood usage (**section 3.2**). This reorientation involves assessing the maximum potential outlets for these products, but also determining an order of magnitude of the maximum theoretical demand in 2035 and 2050, given the dynamics created by the French LTS's objectives for the building sector (new construction, energy renovation), assuming that wood use is maximized as far as possible regardless of economic considerations. This is equivalent to considering that the market share of the products under consideration is 100% for construction works where it is possible to use them; for example, plasterboard is normally used for partitions in houses, but it is possible to make these walls from wood frames and wood-based panels, and we assumed that consumers would always choose the latter option.

The literature on the evolution of the demand regarding building materials has already provided rigorous prospective work regarding both the scenarios constructed and the technical assumptions made. For wood products, we used the reference prospective study: *Évolution de la demande finale du bois dans la construction, la rénovation et l›aménagement des bâtiments* (Development of final demand for wood in construction, renovation and fitting of buildings), carried out by BIPE and FCBA[29] in 2019, for the evolution of the global demand.

4.1. Method

Technical assumptions

The method for estimating the maximum demand for panels and insulation is based on the one used in the BIPE and FCBA study: we used the trend and "Carbon Neutrality Objective" (CNO) scenarios for the development of built and renovated surfaces designed by the authors, as well as the technical coefficients of each structure for which it is possible to use panels or insulation materials.

However, we did not apply the assumptions made by the authors on market shares and their evolution, so that we could obtain a maximum technical potential for wood use. Details of the assumptions and information taken from the BIPE and FCBA study and which we have used are given in **Annex 4**.

As the different board types are relatively interchangeable and the supply of reusable roundwood is considerable compared to the current demand for OSB (the only board type that exclusively requires roundwood), no distinction is made between the different boards.

Prospective scenarios for the number of constructed and renovated buildings

For new construction, the trending scenario identifies annual averages for the number of dwellings and non-residential buildings[30] built from 2016 to 2050 according to the assumptions of the business-as-usual (BAU) scenario of the French LTS for primary residences, and is completed by the projections carried out by the BIPE for secondary residences and vacant dwellings. The CNO scenario cross references the target pathway of the LTS for the forestry and wood sector with its counterpart dedicated to the building sector.

For renovation, BIPE and FCBA provide projections of renovated areas for energy and non-energy purposes. The CNO scenario is particularly ambitious in terms of the areas targeted for energy renovation, in line with the national objectives of renovating the entire housing stock to a low energy consumption level by 2050. Since the estimate we have proposed is intended to illustrate the extent to which the volumes envisaged by the LTS for "panel usage" could be in demand from the domestic construction and renovation market, choosing this scenario enables us to exaggerate these potential outlets by calculating the highest range of volumes that this would represent.

29 Respectively a French strategy consultancy firm and the national technical institute for forestry, cellulose, wood and furniture.
30 Offices, shops, educational and medical buildings, etc.

4.2. Results by product type

The total volumes of panels and wood wool that could be used in new construction were obtained by multiplying the total areas built by the technical coefficients calculated by the FCBA[31] (**Table 9**). The underlying assumption is that all needs are covered by these products to the detriment of other materials (plaster panels, glass wool insulation, concrete...).

TABLE 9. MAXIMUM USABLE VOLUMES OF PANELS (PAN.) AND INSULATION MATERIALS (INS.) FOR NEW CONSTRUCTION AND RENOVATION ACCORDING TO THE TREND AND CNO SCENARIOS ON THE DEVELOPMENT FOR BUILT AND RENOVATED AREAS IN THE BIPE AND FCBA STUDY

	Current		Trend (French LTS BAU)						CNO (French LTS pathway)					
	2015*		2019		2035		2050		2019		2035		2050	
	Pan.	Ins.	Pan.	Ins.	Pan.	Ins.	Pan.	Ins.	Pan.	Ins.	Pan.	Ins.	Pan.	Ins.
New construction	No data	0.05	**6.8**	**5.1**	**5.4**	**4.3**	**4.7**	**3.4**	**6.6**	**5.1**	**5.2**	**4.2**	**4.3**	**3.2**
Residential			4.0	3.8	3.2	3.1	2.4	2.2	3.8	3.8	3.2	3.1	2.4	2.0
Non-residential			2.8	1.4	2.2	1.2	2.3	1.2	2.8	1.4	2.0	1.1	1.9	1.2
Energy retrofit	No data	0.3	N/A	**8.6**	N/A	**10.2**	N/A	**7.7**	N/A	**8.9**	N/A	**22.2**	N/A	**22.6**
Residential				7.7		9.1		6.3		7.9		20.7		20.7
Non-residential				0.9		1.1		1.4		1.0		1.5		1.9
Non-energy retrofit	No data	N/A	**3.0**	N/A	**3.2**	N/A	**2.7**	N/A	**3.1**	N/A	**4.7**	N/A	**4.6**	N/A
Residential			1.6		1.6		1.6		1.6		1.6		1.6	
Non-residential			1.5		1.6		1.1		1.5		3.1		3.0	
TOTAL	**1.1**	**0.4**	**9.8**	**13.8**	**8.6**	**14.4**	**7.4**	**11.1**	**9.7**	**14.1**	**9.9**	**26.4**	**8.9**	**25.8**
TOTAL PAN. + INS.	1.5		23.6		23		18.5		23.8		36.3		34.7	

**Source: (BIPE and FCBA 2019).*

Wood-based panels

In 2019, assuming that national demand for construction materials favours wood-based panels over their competitors, 9.8 Mm³ could be consumed according to the trend scenario. This is more than six times higher than the 1.6 Mm³ projected for the year 2020 by the BIPE and FCBA study, which limits the market shares of wood-based panels to those observed over the period 2010-2015 for the various uses of panels.

According to the CNO scenario, the main potential for panels lies in the renovation of residential and non-residential buildings. Renovation for energy efficiency purposes does not present a particular challenge in terms of panels as they are not used in the building work modelled in the BIPE and FCBA study. However, some energy renovation works can use panels, for example in the case of replacement of energy-intensive office facades with timber frame walls, and the use of panels as rain screens for outside thermal insulation or as

31 These coefficients “take into account the characteristics of the typical building (average floor numbers, average area, for different typical scopes).” (BIPE and FCBA 2019).

cladding for internal thermal insulation. The amount of panels useable for energy renovations could therefore be significant.

For non-energy renovation, the estimated demand is higher, especially in the non-residential sector, and thus exceeds the demand for new construction in 2050 as projected by the CNO scenario.

Indeed, for new construction, the trend scenario sees a decrease in panel demand of about 25% over the period 2019-2050, and 8% in the CNO scenario. This trend is mainly due to the residential sector. The dynamics of the residential sector are based on national public statistics and on the developments of the LTS scenarios, which predict a slowdown in demographic growth, which reduces the amount of new surface area built (BIPE and FCBA 2019). Demand from the non-residential sector is relatively low throughout the period, partly due to the limited opportunities for panels in this sector.

Wood-based insulation materials

The demand for insulation in new construction is in the same order of magnitude as for panels and decreases in the same proportions for the same reasons. However, insulation has a very large development potential in energy renovation, more than 600% higher than the maximum potential demand from new construction in 2050 in the CNO scenario. There is also a significant and positive difference between the demand for panels and insulation (+235% in 2050 for the CNO scenario), as well as between the trend scenario and the CNO scenario, which aims at renovating almost the entire building stock built before 2012 to BBC (French low-energy building standard) level (+130% in 2050). Wood-based insulation materials have a key role to play in future energy renovations, and the "climate-friendly" scenario (CNO) forecasts very significant volumes.

4.3. Comparison with the French long-term strategy

Looking specifically at panels in the CNO scenario, the LTS target for future panel supply from French harvested wood is much higher (+150%) than could be absorbed by the construction and renovation market, given the maximum technical panel usage potential. Indeed, the LTS calls for major growth in carbon storage by panels by 2050 (**Table 10**), which translates into an expected production of 22 Mm³ in 2050[32] (**Table 11**).

TABLE 10. CARBON STORAGE TARGETS IN WOOD-BASED PANELS (INTERMEDIATES) OF THE "AMS 3" SCENARIO (LTS TARGET PATHWAY) OF THE SNBC (CURRENT FRENCH LTS), IN MTCO$_2$

	2015	2030	2050	2080
Panel usage	7	11	22	31

TABLE 11. ANNUAL INPUT FLOWS OF WOOD-BASED PANELS (FINISHED PRODUCTS) ACCORDING TO THE "AMS 3" SCENARIO OF THE SNBC (CURRENT FRENCH LTS), IN Mm^3

	2015	2030	2050	2080
Panel usage	6	10	22	30

Conversely, if we imagine that "panel usage" according to the LTS includes both panels and wood-based insulation materials, the results are more encouraging: if the LTS panel-usage target includes wood-based insulation materials, which have major development potential due to growth in the energy renovation of buildings, it is possible to come close to the 2050 target of 22 Mm³ for the Trend scenario, and even to exceed it for the CNO scenario.

It should be noted, however, that these calculations assume that wood-based insulation completely displaces all other types of insulation, which is not at all the case at present. Wood-based insulation currently only accounts for a small share of the insulation market and is often prohibitively expensive. Over the period 2010 - 2015, the BIPE and FCBA study measured the market share of wood fibre insulation at 4% for single-family houses and 1% for the non-residential buildings; the maximum potential market share is estimated at 11% and 6% respectively, far from our 100% market share assumption. Producing and consuming such quantities of wood-based insulation materials would probably require a profound market transformation, but it may offer a potential option for increasing carbon storage in "panel usage".

With more realistic market shares, panel demand projections in 2050 presented by the BIPE and FCBA study are much lower in all of the study's scenarios (**Table 12**). Even in the CNO scenario, which is considered to be very ambitious for the building sector, the LTS volumes are far higher than the national panel demand (I4CE 2022).

32 The LTS's targets relate to intermediate products (*i.e.* which will undergo further processing before being used), whereas here we estimate volumes of finished products. The installation of panels in buildings generates an average of only 24% of losses (BIPE and FCBA 2019), which we deduct from the annual wood product input flows reported in the calculations of the LTS.

TABLE 12. PANEL DEMAND IN 2050 ACCORDING TO PROJECTIONS OF THE FOUR BIPE AND FCBA STUDY SCENARIOS (2019), IN Mm³

Trend	1,5
Alternative	2,0
Volontary	2,4
Carbon neutrality objective	2,7

Thus, it would probably be necessary to rely on exporting some of these panels and insulation materials to achieve the LTS objectives in terms of carbon storage in wood products. This represents a twofold challenge: an economic challenge, as the French wood sector currently runs a large trade deficit, despite annual net panel exports of 0.8 Mm³ (I4CE 2019); and an ecological challenge, insofar as the transport of wood reduces the expected climate change mitigation benefits by around 20% (I4CE 2019).

However, it should be noted that the volumes foreseen by the *SNBC* are also based on a very ambitious increase in the wood harvest, which is also considered economically unrealistic by the literature (I4CE 2022).

Finally, the term “panel usage” is used in the *SNBC* to refer to all long-life wood products made from pulpwood. The target volume is simulated on the basis of the valuation of the national forest resources, and does not take the incoming flows of recovered used wood into account. However, this recovered used wood is increasingly supplying the production of certain panels and insulating wood fibres. This recycling is undeniably good news for the climate, as it extends product lifespans and meets the same global usage without increasing the harvest. Nevertheless, by fulfilling a proportion of the demand for panels and insulation, it increases the risk that the panel supply projected by the LTS for 2050 will not find sufficient outlets.

5. CONCLUSION

Changing wood uses to boost the increase of long-life products thus involves two major pathways: 1) optimizing the use of timber, and 2) prioritizing the allocation of pulpwood/fuelwood resources towards long-life uses.

Regarding timber, the reorientation potential mainly concerns the better use of deciduous timber quality wood and small diameter and lower quality wood. The maximum growth for a better use of potential timber is evaluated at 8 Mm^3 per year, some of which includes defects that cannot be detected by the IGN during forest inventory and prohibit a material use. Moreover, this potential seems difficult to exploit on a large scale in the short-term due to the presence of both technical and economic challenges (research and development of engineered products, massive investment in processing capacities, changes to practices, etc.).

The most promising pathway from a short-term technical perspective is the development of the panels and wood-based insulation sector. Indeed, sectors linked to these products already exist and there are few major technical barriers that could hinder the reorientation of wood towards this area by restricting the resource types that can be processed. Many of the existing constraints have already been addressed by innovative products that diversify the type of raw materials used (*e.g.*, increased use of deciduous species, recovered used wood), which suggests that these constraints could change relatively quickly through investment in the processing industries. Thus, all resource types supplying the paper and energy sectors (industrial and energy quality roundwood, by-products, etc.) could, from a strictly technical perspective, be redirected in the relatively short-term towards the panel and insulation sectors. In 2018, the usage flows of these resources represented nearly 30 tonnes of solid wood equivalent (excluding recovered used wood).

We estimate the maximum technical potential for the use of panels and insulation to be between 20 Mm^3 and 35 Mm^3 annually, according to the trending and ambitious renovation scenarios respectively, *i.e.*, between 15 Mm^3 and 30 Mm^3 more than the 4.6 Mm^3 of panels produced in France in 2019. However, this figure confirms that the *SNBC* targets for the consumption of long-life wood products are unreasonable. The 22 Mm^3 “panel usage” objective in particular could only be achieved under certain conditions, which are very ambitious and far removed from the current situation, namely:

- that wood panels, and above all wood-based insulation materials, predominantly replace other materials in the construction industry;
- that the increase in annual renovated surface area is as steep as the *SNBC* would like, which equates to a complete renovation of the housing stock to a very high level of energy efficiency in less than 30 years;
- that there is an increase in the exports of these products to compensate for the surplus of panels derived from the otherwise desirable development of panels from recovered used wood.

While reaching such levels of housing renovations or of wood market shares may seem unrealistic at present, in view of the current market situation, it does not discredit the reorientation strategy. The ecological transition will indeed require drastic transformations to our production and consumption patterns and massive housing stock renovation, as well as the development of bio-based products, which are all drivers towards carbon neutrality.

Thus, beyond a revision of the LTS’s ambitions in terms of changing the uses of wood, this study makes three main recommendations:

- make the material uses of pulpwood, fuelwood and secondary resources more competitive than energy uses: in addition to studies that question the climate value of fuelwood, this type of wood constitutes the main resource that can be redirected from short to long-term uses;
- make wood more competitive than its substitutes in the construction panel sector (plaster, concrete, etc.) and in the insulation sector (glass wool, rock wool, etc.), which are the two most promising sectors in terms of changing wood uses;
- conduct a more detailed study of the potential to increase the proportion of timber in the harvest, particularly through the development of engineered wood.

Finally, emissions linked to the manufacture of wood products do not seem to call into question the importance of this reorientation[33], even though the issue merits further examination, particularly regarding insulation materials.

33 (Kunič 2017, Myllyviita, *et al.*, 2021)

REFERENCES

ADEME, 2014. Bois et articles en bois – Documentation des facteurs d'émissions de la Base carbone ® – v11.0.0.

ADEME, Solagro, Biomasse Normandie, BVA, 2018. Étude sur le chauffage domestique au bois : marchés et approvisionnement.

ADEME, 2019. Le revers de mon look – Quels impacts ont mes vêtements et mes chaussures sur la planète.

ADEME, 2021. Forêts et usages du bois dans l'atténuation du changement climatique.

ADEME, Devauze, C., Koite, A., Chrétien, A., Monier, V., 2021. Bilan National du Recyclage 2010-2019 – Évolutions du recyclage en France de différents matériaux : métaux ferreux et non ferreux, papiers-cartons, verre, plastiques, inertes du BTP et bois.

Agreste, 2020. Récolte de bois et production de sciages.

BIPE & FCBA, 2019. Étude prospective : évolution de la demande finale du bois dans la construction, la rénovation et l'aménagement des bâtiments.

Birdsey, R., Duffy, P., Smyth, C., Kurz, W.A., Dugan, A.J., Houghton, R., 2018. Climate, economic, and environmental impacts of producing wood for bioenergy. Environ. Res. Lett. 13, 050201. doi.org/10.1088/1748-9326/aab9d5

Cattelot, A.-L., 2020. La forêt et la filière bois à la croisée des chemins : l'arbre des possibles.

CGAAER, Hermeline, M., Lavarde, F., 2020. La valorisation des gros bois.

CGEDD, Alexandre, S., 2017. Rapport de mission de la déléguée interministérielle à la forêt et au bois.

Chalayer, M., 2014. La cantérisation du bois ouvre de nouveaux horizons. Le Bois International.

Citepa, 2021. Rapport OMINEA – 18ème édition.

Copacel, 2021. Rapport statistique 2020 de l'industrie papetière française.

Cour des comptes, 2020. La structuration de la filière forêt-bois, ses performances économiques et environnentales.

Deglise, X., Brosse, N., n.d. Quelle place pour le bois dans la chimie verte ? (version révisée 2019). Encyclopédie de l'Académie d'agriculture de France, La forêt et le bois en 100 questions.

FAO, 2020. Changes in agricultural and forest product codes in the Harmonized System (HS) nomenclature maintained by the World Customs Organizations (WCO).

FAO, 2021. FAOSTAT statistical database.

FCBA, 2008. Étude Carbostock – Conception d'une méthodologie de quantification des variations de stock dans les produit sdu bois répondant aux exigences du GIEC et application à l'année 2005 pour un rapportage volontaire dans le cadre de la CNUCC.

FCBA, 2011. Perspectives de valorisation de la ressource de bois d'œuvre feuillus en France.

FCBA, 2019. Memento pour l'année 2018.

Finnish Woodworking Industries, 2019. LVL Handbook Europe.

Forestry Club de France, Conseil & Stratégie Durables, CYME Innovations, FIVE Conseil, 2019. La scierie de feuillus du futur : quels choix stratégiques pour demain ? Quelles entreprises, pour fabriquer quels produits, destinés à quels marchés ?

Gallileo Business Consulting, 2020. Étude structurelle sur l'emballage bois. Oct. 2019 – Nov. 2020.

I4CE, Cevallos, G., Grimault, J., Bellassen, V., 2019. Relocaliser la filière bois française : une bonne idée pour le climat.

IGN, FCBA, Colin, A., Thivolle-Cazat, A., 2016. Disponibilités forestières pour l'énergie et les matériaux à l'horizon 2035.

IGN, 2018. Un inventaire forestier annuel sur l'ensemble de la France métropolitaine.

IGN, FCBA, Colin, A., Cuny, H., Monchaux, P., Thivolle-Cazat, A., 2019. Réévaluation de la ressource et de la disponibilité en bois d'œuvre des essences feuillues et conifères en France.

IPCC, 2006. 2006 IPCC guidelines for national greenhouse gas inventories. Institute for Global Environmental Strategies, Hayama, Japan.

IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC, Switzerland.

Kunič, R., 2017. Carbon footprint of thermal insulation materials in building envelopes. Energy Efficiency 10, 1511–1528. doi.org/10.1007/s12053-017-9536-1

Ministère de la Transition écologique et solidaire, 2020. Stratégie nationale bas-carbone (SNBC).

Ministère de la Transition écologique et solidaire (MTES), 2020. Fiche d'information "Les filières REP, qu'est-ce que c'est ?"

Ministère de la Transition écologique, 2021. Inventaire national des émissions de gaz à effet de serre [WWW Document]. URL www.ecologie.gouv.fr/inventaire-national-des-emissions-gaz-effet-serre/ (accessed 7.30.21).

Ministères de l'Agriculture et de l'Alimentation, de la Transtion écologique, de l'Industrie, 2022. Fiche des actions des Assises de la Forêt et du Bois.

Myllyviita, T., Soimakallio, S., Judl, J., Seppälä, J., 2021. Wood substitution potential in greenhouse gas emission reduction–review on current state and application of displacement factors. For. Ecosyst. 8, 42. doi.org/10.1186/s40663-021-00326-8

SYPAL, 2012. La palette bois enfonce le clou.

UICB, n.d. Poutre en I [WWW Document]. URL www.uicb.pro/nos-metiers/poutre-en-i/

Viguier, J., 2015. Classement mécanique des bois de structure – Prise en compte des singularités dans la modélisation du comportement mécanique.

WRAP, 2017. Mapping clothing impacts in Europe: the environemental cost; prepared by Sarah Gray.

ANNEXES

Annex 1 – Harvested wood species

Timber

FIGURE 8. TIMBER HARVEST OF DECIDUOUS SPECIES MARKETED IN 2019, IN % AND Mm³
(AGRESTE, 2020)

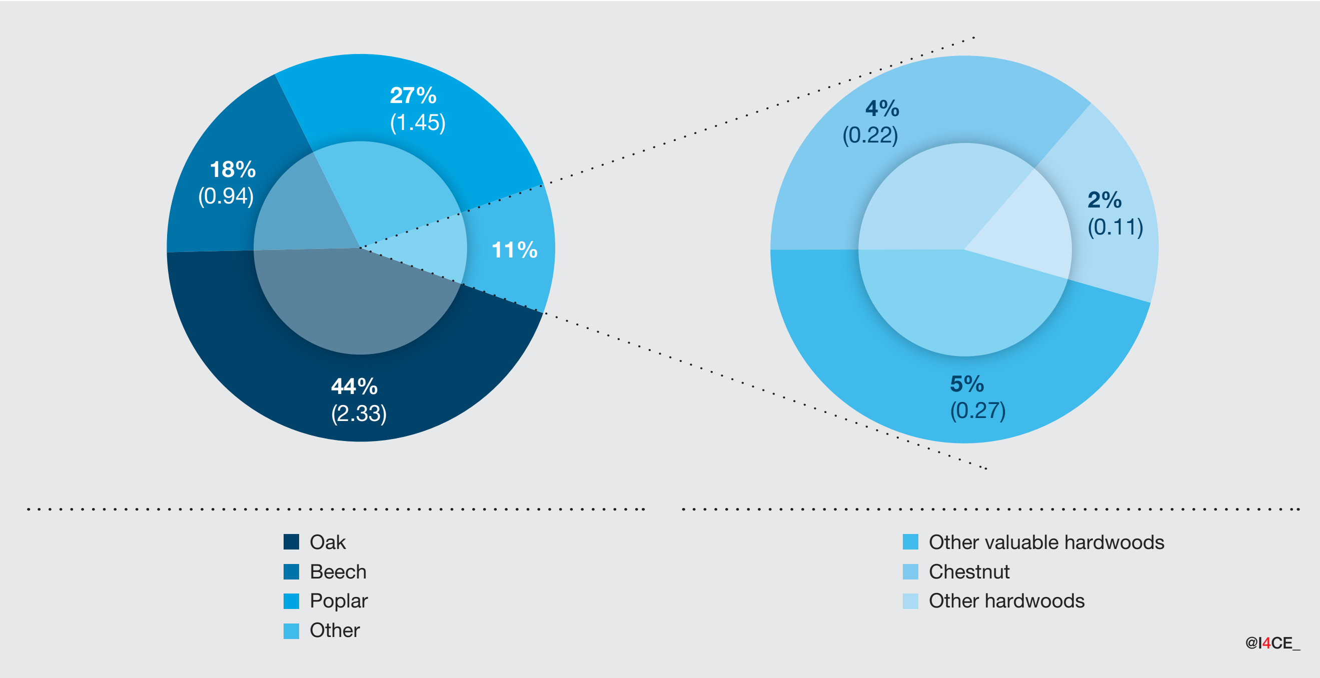
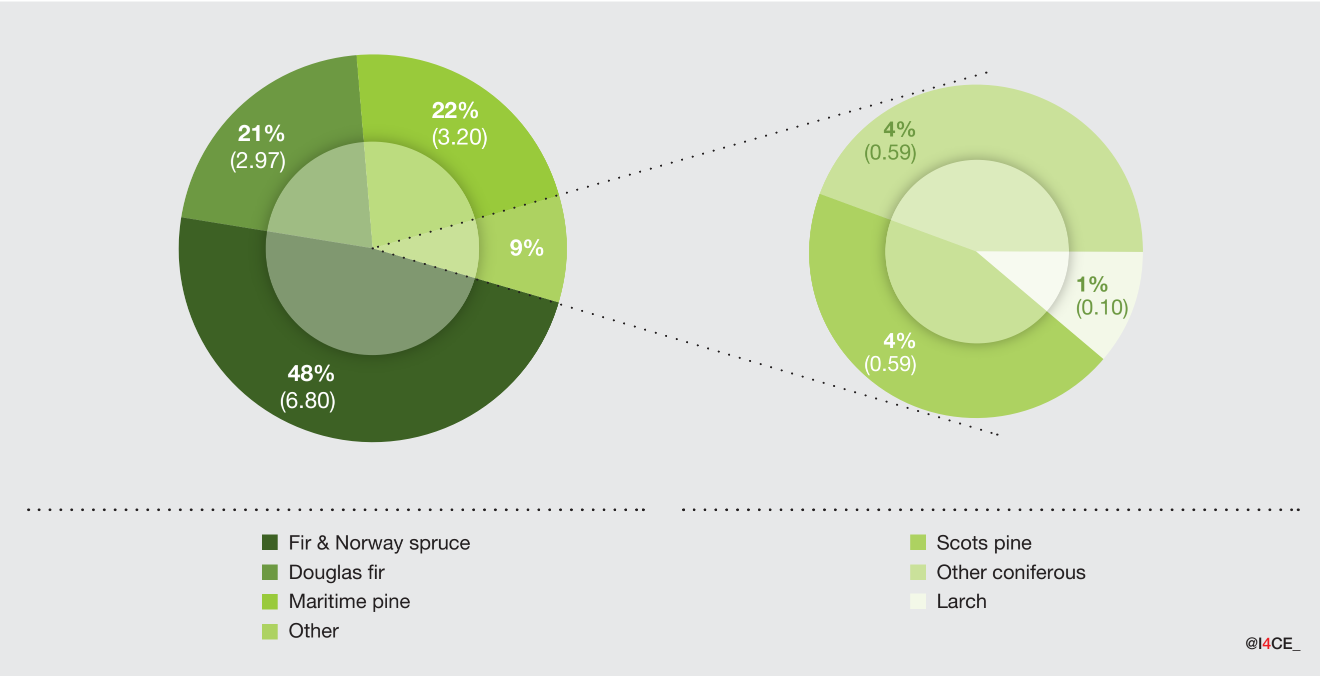


FIGURE 9. FIGURE 9 TIMBER HARVEST OF CONIFEROUS SPECIES MARKETED IN 2019, IN % AND Mm³
(AGRESTE, 2020)



Pulpwood and Fuelwood

FIGURE 10. PULPWOOD HARVEST (EXCLUDING POLES) MARKETED IN 2019, IN % AND Mm³
(AGRESTE, 2020)

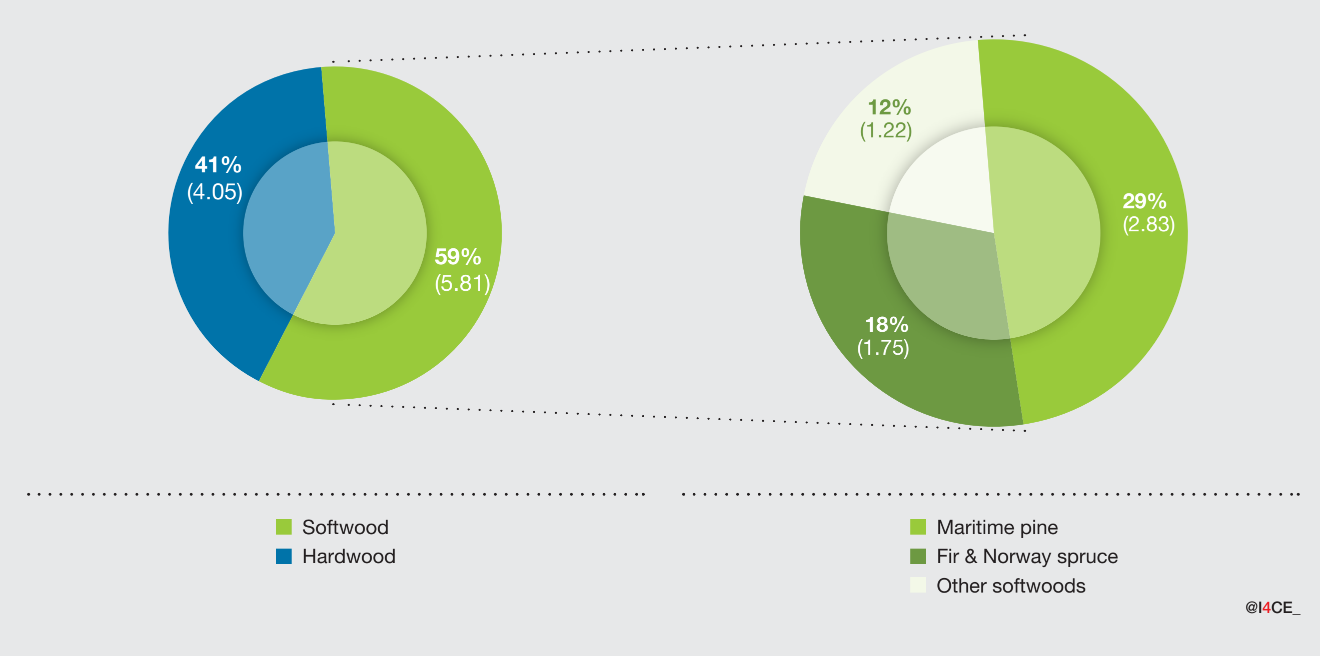
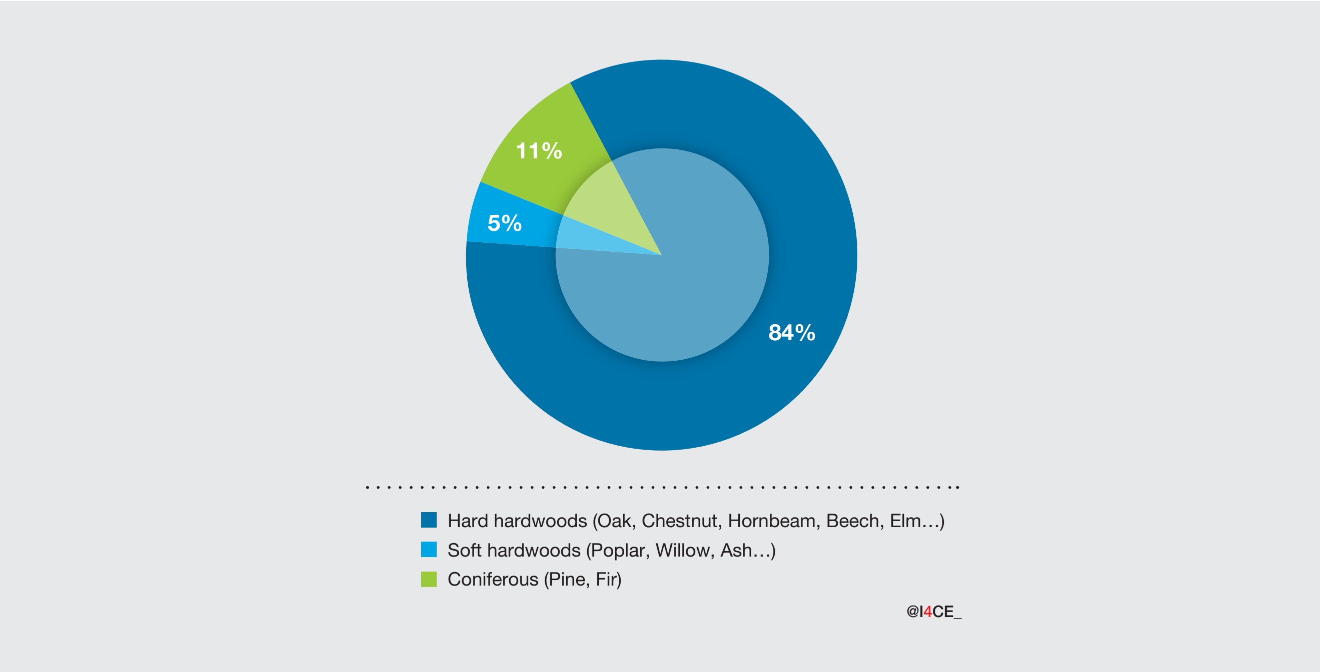
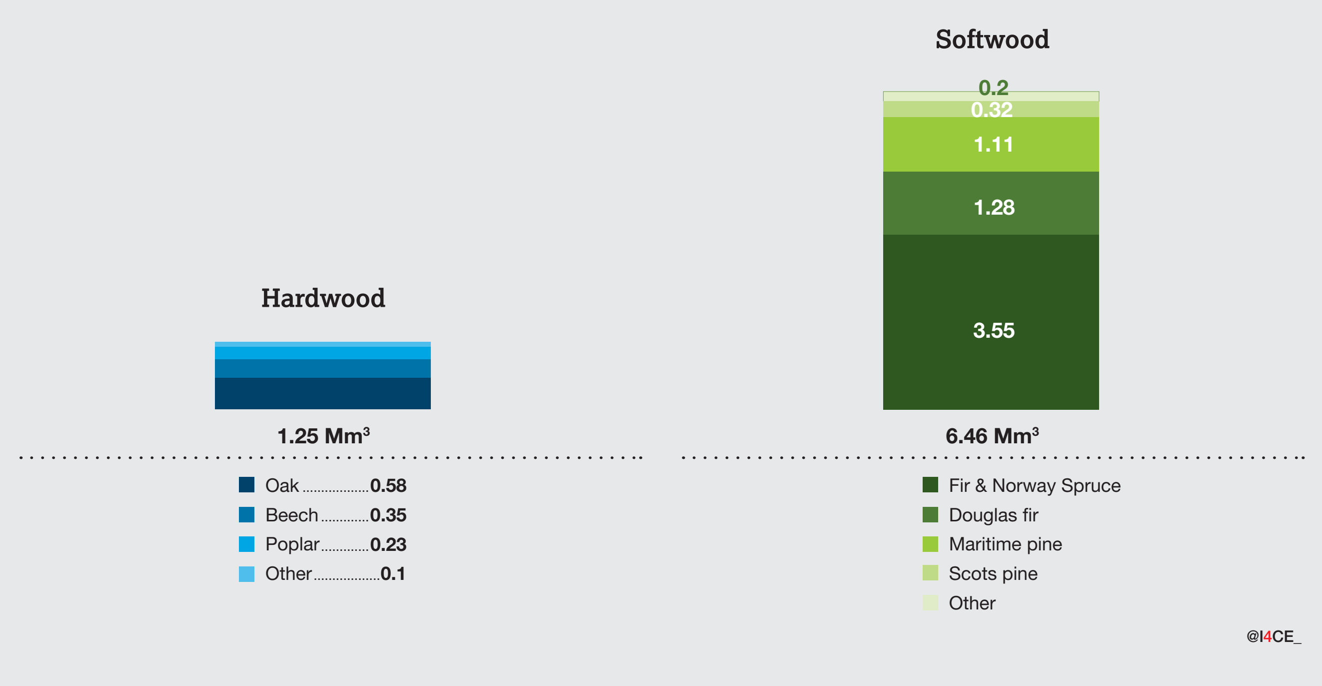


FIGURE 11. SPECIES USED AS LOGS FOR DOMESTIC HEATING
(ADEME, SOLAGRO, BIOMASSE NORMANDIE, BVA, 2018)



Sawn wood

FIGURE 12. SAWN WOOD PRODUCED IN FRANCE IN 2019, EXCLUDING WOODEN SLEEPERS AND BARREL STAVES, IN Mm³ (AGRESTE, 2020)



Annex 2 – Sankey diagrams

The Sankey diagrams were produced using mainly data from the *Veille économique mutualisée de la filière Forêt-Bois* (VEM-FB or VEM) for the year 2018. These data, integrated into a use-supply (or inputs-outputs) table, aim to reconstruct the complete value chain between the harvest of the forest resource and the final consumer. The VEM website provides a methodological guide and frequently asked questions page, which give more details about the project.

We provide details below on the composition of each category in the diagrams, based on the VEM-FB nomenclature and by indicating other data sources where appropriate.

The reference year is 2018 unless otherwise stated.

The units of measurement used are: million cubic metres (Mm^3), million cubic metres solid wood equivalent (Mm^3 swe), million tonnes (Mt) and million tonnes solid wood equivalent (Mt swe). The VEM uses only Mm^3 solid wood equivalent and Mt swe. It provides volumes resulting from a conversion of monetary flows rather than observed volumes. However, monetary flows do not give a reliable picture of the volumes exchanged; for example, a tonne of paper does not cost the same as a tonne of panels. The tonne of solid wood equivalent overcomes this difficulty by unifying the unit prices of the various outlets in the industry and energy sectors. The same logic applies to timber, for which the unit used by the VEM is the cubic metre of solid wood equivalent. The VEM provides the following explanation on this matter: "*The value-volume conversion process of the monetary input-output table enables the expression in physical flows of the relations between the sector's activity branches as well as the importance of international trade. This translation is carried out per usage sector, where the products at the origin of the uses are identified. Thus, all monetary flows have been converted into equivalent tonnes of wood for this "industrial wood" sector.*"

First supply chain level - uses and supplies

Category	Source	Detail
Harvest	(Agreste 2020)	
Self-consumption	(ADEME 2021, ADEME, Solagro, Biomasse Normandie, BVA 2018)	Total volume of wood energy consumed in 2018, in Mm^3 (ADEME 2021). The study (ADEME, Solagro, Biomasse Normandie, BVA 2018) gives a breakdown of the types of wood consumed by households according to a 2017 survey (**Figure 12**). We assumed that this distribution did not change in 2018 and have applied it to the total amount of wood logs consumed. This estimate is superficial but sufficient for a general idea of the main species consumed.
Wood processing by-products	(Agreste 2020, VEM-FB 2021)	Incoming flows ("timber processing" → "Related sawmill products"), in Mt (Agreste 2020). Outgoing flows ("Related sawmill products" → X), in Mt swe (VEM-FB 2021).
Recovered used wood	(ADEME, Bilan National du Recyclage 2010-2019 - Évolutions du recyclage en France de différents matériaux: métaux ferreux et 2021)	Waste flows for 2019, taken from the national recycling balance sheet (Bilan national du recyclage) 2010 - 2019.

Second value chain level - resource processing

All timber flows are in million cubic metres of roundwood equivalent (Mm³ swe). All pulpwood and fuelwood flows are in million tonnes of wood equivalent (Mt swe).

The volumes of intermediate products shown in the graph are taken from the Memento produced by the FCBA. The units are million cubic metres (Mm³) for sawn wood, barrel staves, engineered wood and panels; and million tonnes (Mt) for paper pulp.

Category	Source	Details
TIMBER PROCESSING		
Sawn wood	(Agreste 2020, FCBA 2019, VEM-FB 2021)	**Aggregate of:** 08 Oak rough sawn wood 09 Beech rough sawn wood 10 Other temperate deciduous rough sawn wood 11 Tropical deciduous rough sawn wood 12 Spruce-fir rough sawn wood 13 Douglas fir rough sawn wood 14 Other coniferous rough sawn wood 15 Maritime pine rough sawn wood **Other sawn wood, aggregate of:** 17 Other types of sawn wood 20 Planed products 29 Impregnated products (rough, sawn or planed)
Barrel staves	(Agreste 2020, FCBA 2019, VEM-FB 2021)	16 Barrel staves
Veneers and plywood	(Agreste 2020, FCBA 2019, VEM-FB 2021)	31 Veneers and wood-based panels This category also includes pulpwood-based panels. We select here only the part produced from timber.
Glued laminated timber, CLT…	(FCBA 2019, VEM-FB 2021)	20b Glued products
PROCESSING OF PULPWOOD, FUELWOOD AND SECONDARY RESOURCES		
Paper sector	(FCBA 2019, VEM-FB 2021)	43 Paper pulp
Panel sector	(FCBA 2019, VEM-FB 2021)	31 Veneers and wood-based panels This category also includes panels made from pulpwood. We select here only the proportion produced from pulpwood.
Energy sector	(FCBA 2019, VEM-FB 2021)	30 Industrial wood fuels 19 Electricity and heat from wood combustion
Wood chemistry	(VEM-FB 2021)	46 Chemical wood products

Third value chain level - consumption

The different sectors of final consumption are: Packaging, Construction, Furniture, Paper and Board, and Energy. All are supplied by flows from the resource processing industries: sawing, peeling, slicing and splitting, processed panel industry, pulp industry, and wood chemistry. The only outflows are due to exports. The accounting unit is then that of the incoming flow. For example: "Sawmills" → "Packaging" in Mm^3 swe, "Process board industry" → "Packaging" in Mt swe.

Category	Source	Detail
Packaging	(VEM-FB 2021)	37 Wood-based packaging (pallets, etc.) 38 Casks
Construction		**Building products, aggregate of:** 33 Engineered wood floors 34 Carpentry 35 External joinery 36 Interior joinery 39 Wood concrete moulds, wood shingles 40 Wood products for outdoor use
Furniture		47 Wood-based furniture
Energy		04 Fuelwood 19 Sawmill by-products not for pulping 30 Industrial wood-based fuels 49 Electricity and heat from wood combustion
Other		19 Sawmill by-products not for pulping **Other products, aggregate of:** 41 Miscellaneous wood products 42 Cork products 48 Other manufactured products (musical instruments, games and toys...) Any other flow that does not go through a transformation stage (wood processing by-products not destined for pulping, recovered used wood...) or that is not destined for one of the major consumption sectors (Packaging, Construction...).
Paper and cardboard		44 Paper and cardboard 45 Paper and paperboard articles

Annex 3 – List of environmental product declarations (EPD) used

Products	EPD
OSB	• Panneaux de lamelles de bois minces orientées OSB (oriented strand board) de type 3 (panneaux travaillants utilisés en milieu humide) bruts (v.1.2) • Panneaux de lamelles de bois minces orientées OSB (oriented strand board) de type 4 (panneaux travaillants sous contraintes élevées utilisés en milieu humide) bruts (v.1.2),
MDF	• Panneaux de fibres MDF (medium-density fibreboard) de type light bruts (v.1.3) • Panneaux de fibres MDF (medium-density fibreboard) utilisés en milieu humide bruts (v.1.2) • Panneaux de fibres MDF (medium-density fibreboard) utilisés en milieu sec ignifuges bruts (v.1.2) • Panneaux de fibres MDF (medium-density fibreboard) utilisés en milieu sec bruts (v.1.4) • Panneaux de fibres MDF (medium-density fibreboard) de type ultralight bruts (v.1.2)
HDF	• Panneaux de fibres MDF-HDF (high-density fibreboard) bruts (v.1.3) • Panneaux de fibres MDF-HDF (high-density fibreboard) de type mince bruts (v.1.2)
Particleboard	• Panneaux de particules de type P2 (panneaux pour agencements intérieurs utilisés en milieu sec) bruts (v.1.2) • Panneaux de particules de type P2 (panneaux pour agencements intérieurs utilisés en milieu sec) surfacés mélaminés (v.1.2) • Panneaux de particules de type P3 (panneaux non travaillants utilisés en milieu humide) bruts (v.1.2) • Panneaux de particules de type P4 (panneaux travaillants utilisés en milieu sec) bruts (v.1.2) • Panneaux de particules de type P5 (panneaux travaillants utilisés en milieu humide) bruts (v.1.2)
Wood insulation materials	• Isonat FLEX 40 100 mm (v.1.3) • FLEX 40 145 mm (v.1.1) • FLEX 40 40 mm (v.1.1) • FLEX 55 100 mm (v.1.4) • FLEX 55 145 mm (v.1.1) • FLEX 55 200 mm (v.1.3) • STEICO flex F (v.1.2) • Knauf FIBRA ULTRA FC Clarté 100mm (v.1.3) • Fibraroc 35 200mm & Fibraroc 35 FC/Typ3 200mm (v.1.4)
Composite cladding	• Lame de bardage en bois composite SILVADEC - Claire-voie Atmosphère (v.1.2)

Annex 4 – Method for estimating maximum domestic demand for wood-based panels and insulation materials

The average technical coefficients of the volumes of panels and insulation consumed for each structure, and each of these building categories used in the present study are shown in **Table 13**.

TABLE 13. TECHNICAL COEFFICIENTS – AVERAGE PANEL AND INSULATION VOLUMES PER STRUCTURE IN DM³/M² (UNLESS OTHERWISE STATED)) (BIPE AND FCBA 2019)

Type of use of wood products	Product family	Use	SFH	MFH	Service sector	Industry and Storage	Agricultural
Structural elements	Building systems	Timber frame	30	39	49	0	0
	Carpentry	Load-bearing structure of the flat roof	22	22	N/A	N/A	N/A
Wood for insulation	Insulating wood fibre *		140	140	140	140	140
Interior design	Flooring	Laminates	8	8	8	8	0
	Partitions	Non-supporting partitions*	3	3	2,5	2,5	0
		Building partitioning (fixed or removable)*	N/A	N/A	125	0	0
		Partitioning of wet rooms*	N/A	N/A	25,2	25,2	0
		Firewalls *	N/A	30	30	0	0
	Panelling	Wooden ceilings	14	14	16	0	0
		Interior wood lining of walls	14	14	16	16	16
	Furniture	Kitchen	89	No data	89	N/A	N/A
		Bathroom	No data	No data	No data	No data	No data
		Cupboards	200	No data	200	N/A	N/A
External vertical cladding	Wooden facade cladding*		0	3	3	3	3

NB: SFH stands for single-family houses, and MFH for multi-family houses.

When a choice is possible between different construction solutions, the solution that uses the most panels is selected. For example, for the construction system of service sector buildings, the timber frame (49 dm³/m² of floor) was chosen rather than the post and beam system (46 dm³/m²) or the mixed wood and concrete system (34 dm³/m²).

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Products and structures marked with an asterisk are not expressed in dm³/m² and their flow coefficients are shown in the following Table (**Table 14**).

TABLE 14. TRANSFER COEFFICIENTS FOR TECHNICAL COEFFICIENTS NOT EXPRESSED IN DM³/M²

Use	Nature of coefficient	SFH	MFH	Service sector	Industry and storage	Agricultural
Wood fibre insulation	m² wall or facade / m² floor	0.71	0.91	0.63	0.63	No data
Non load-bearing partitions (wood)	Im partitions / m² of equipped floor	0.49	0.43	No data		N/A
Building partitioning (fixed or removeable)		N/A	N/A	0.1	0.05	
Partitioning of wet rooms		N/A	N/A	0.02		
Fireproof partitions		N/A	No data	0.1	0.05	
Kitchen	m² kitchen / m² floor	0.15	0.1	No data	N/A	
Cupboards	m² cupboard / m² floor (except for service sector: m² cupboard / hotel room)	0.02	0.01	0.9	N/A	
Wood facade cladding / wood cladding	m² facade / m² floor	0.71	1.51	0.65	0.63	No data

The BIPE and FCBA study provides average built and renovated areas over periods of several years for each building category. From this we derived unit values for the 2019, 2035 and 2050, which are shown in **Table 15** and **Table 16**. The values for the base year 2019 may differ between the trend and CNO scenarios as they are not observed values but are calculated according to the assumptions of both scenarios (the base year in the study being 2015 and not 2019).

TABLE 15. BUILT-UP AREAS UNDER THE TREND AND CNO SCENARIOS, ACCORDING TO BUILDING CATEGORY, IN MILLIONS OF SQUARE METRES (MM²) (BIPE AND FCBA 2019)

Building category	Trend (French LTS BAU)			CNO (French LTS pathway)		
	2019	2035	2050	2019	2035	2050
Service sector	8.8	6.7	7.1	8.8	5.9	6.2
Industry	3.3	3.3	3.3	3.6	3.6	3.5
Storage	3.3	3.2	3.2	3.3	3.2	3.2
Agricultural	5.8	4.6	3.4	5.5	3.3	1.6

For the renovation of the non-residential sector, only the surface area of service sector buildings are forecast.

TABLE 16. RENOVATED AREAS UNDER THE TREND AND CNO SCENARIOS, ACCORDING TO BUILDING CATEGORY, IN MILLIONS OF SQUARE METRES (MM²) (BIPE AND FCBA 2019)

Type of renovation	Building category	Trend (French LTS BAU)			CNO (French LTS pathway)		
		2019	2035	2050	2019	2035	2050
Energy	Residential	68.1	80.6	55.3	70.1	183.3	182.9
	Service sector	10.6	12.2	16	11.2	16.7	22
Non-energy	Residential	41.6					
	Service sector	55.2	61	42	55.9	118.2	112.6

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