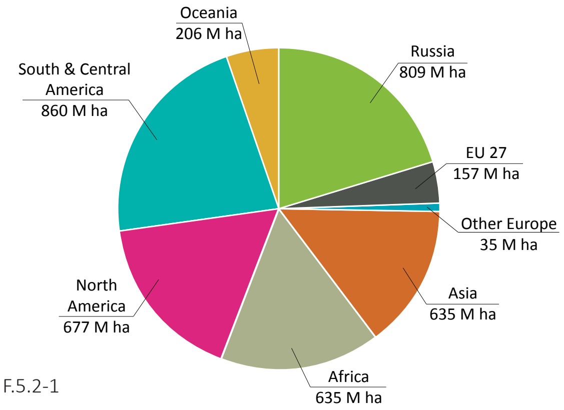
# 5. Environmental aspects of raw material supply and manufacturing

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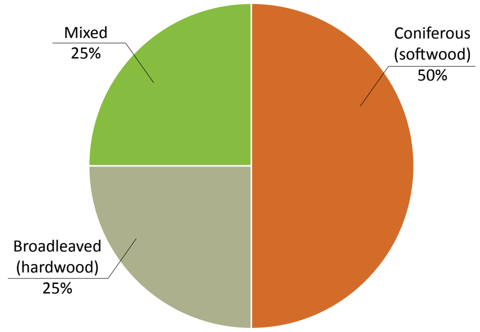



F.5.2-2

# 5 ENVIRONMENTAL ASPECTS OF RAW MATERIAL SUPPLY AND MANUFACTURING

## 5.1 Introduction

T. Häkkinen

The objective of this chapter is to discuss the aspects of life cycle assessment on product level, considering the extraction of raw materials, transportation and manufacturing. Instead of dealing with the issue from the general point of view, the chapter focuses on the environmental assessment of sawn timber and some other wood-based product.

The section gives information about the raw material supply, environmental impacts of harvesting and manufacture, and discusses the impact of different factors on the carbon footprint of sawn timber and the possibilities to improve.

The target of the section is to provide an example of product-level LCIs in order to cover the full value chain in this book instead of focusing only on building-level assessments.

This chapter also points out that the principal purpose of the LCA methodology is to provide a tool for eco-design and life cycle management. The LCA method is most powerful when the product developers and designers use it as a tool that supports– not just a comparison of available products or buildings – but the development of new and improved eco-efficient solutions.

## 5.2 Raw material supply

F. Dolezal, H. Mötzl

### The global context of European forests

Globally, forests are an immense resource, accounting for 29.6% of the Earth's total land base. Although European forests, excluding Russia, account for just 5% of that area, they are the most intensively managed in the world, providing 12% of current global round wood fellings and 23% of industrial round wood [1]. The global forest cover is shown in Figure F.5.2-1.

The European forest sector's output is about 25% of current world industrial production of forest products, accounting for almost 30% of wood-based panels, paper and paperboard [2].

### Forest types, coverage and felling

85% of Europe's forest cover is semi-natural (some human intervention, but generally natural characteristics), while only

F.5.2-3

F.5.2-1 Global forest cover by continent [2]
F.5.2-2 The composition of EU 27 forests [3]
F.5.2-3 Wood harvest, Austria

8% is plantation forest, mainly to be found in northwest Europe. In addition, about 5% of the forest area is undisturbed forests, untouched by man, which can be found in East Europe and the Nordic/Baltic areas [3]. Figure F.5.2-2 shows the composition of European forests.

Considering felling per capita, with a 2.0 bank meter, Austria is ranking high above EU-27 amounts and the world (0.8 and 0.6, respectively), but far below Scandinavia with a 6.7 bank meter. In absolute figures, Austria's wood harvest accounted for approximately 4% of EU-27 felling and approximately 0.5% of the world's felling in the year 2005. The share of softwood, with 84%, is comparatively high in Austria compared to EU-27 with 74% and the world with 37% [4].

**Different circumstances in European forests – north-middle-south**

Beside climatic differences between Northern, Central and Southern Europe with an effect on forest species, even topographic differences are important. Not only forest species are affected by topography, but also logging and forwarding methods with regard to the achieved return.

Since swathes of Central Europe are covered with mountains, harvesting is more complicated, and therefore manual labour still covers a huge part, not just in logging, but also in bringing. For example, in Austria, only 20% of logging is carried out by harvesters [5], 80% is done by using chain saws and in this case bringing methods are mainly cable winch or cable pulls.

*North – Sweden*

Sweden is a forest country. Two-thirds of the total land area is covered with forests, and half of its net national income comes from the export of forest products. Everyone has common access to the forest; forests are important for recreation and they are dominant in the Swedish landscape. The forests are fairly uniform in composition. The main species are Norway spruce (Picea abies) (46%), Scots pine (Pinus silvestris) (37%), and various deciduous species (15%). [6]

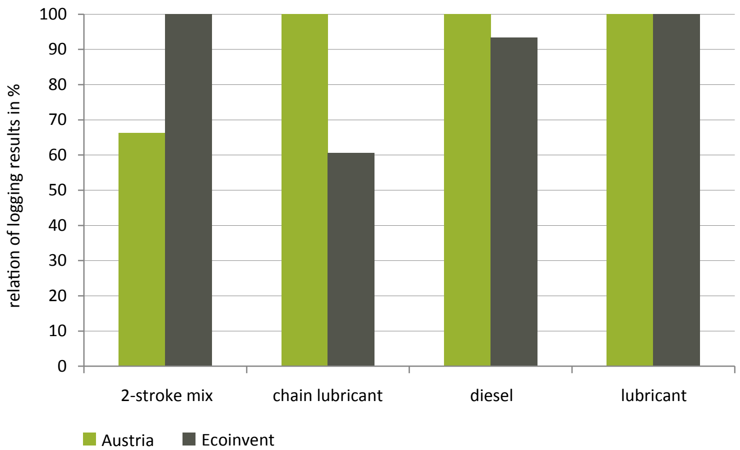
*Middle – Austria*

Forests cover about 47% of Austria's territory (3.9 million hectares). They provide important economic, environmental and socio-cultural benefits, from timber production to protective and recreational functions, which directly or indirectly benefit the whole population. In the mountainous areas (the western two-thirds of the country is alpine), forests have an important role in protection against landslides and avalanches. The forest area has shown a slightly increasing trend in recent decades as a result of natural extension onto agricultural land and afforestation in protected areas. Virtually all forest is considered semi-natural; there are small areas of undisturbed forest. Coniferous species (primarily Norway spruce, Scots pine, European larch and silver fir) make up more than four-fifths of the growing stock. Beech is the main broadleaf species. [6]

*South – Spain*

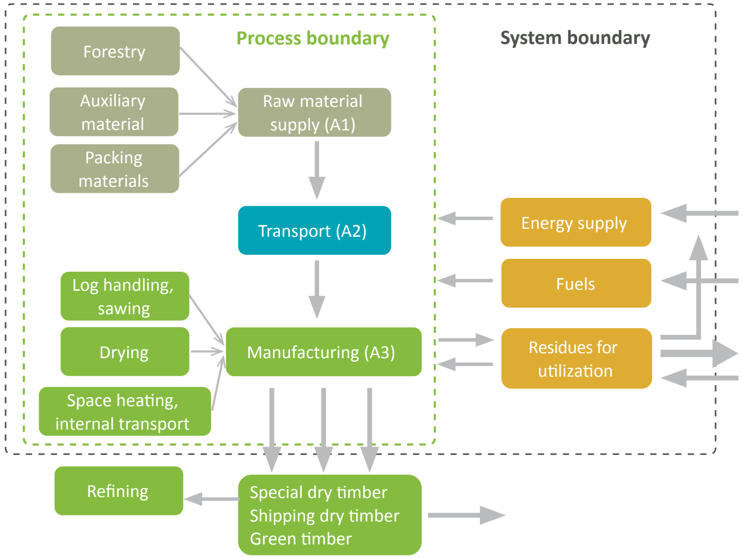
With 14.4 million hectares of forest cover, Spain is the fourth country in Europe in terms of forest resources (following Sweden, Finland and France, but excluding the Russian Federation). Forests, which occupy almost 29% of the country's total land area, are increasing by about 86,000 ha per year, both through natural expansion and through the forest plantation programme that has been under way for more than 50 years, with soil protection and erosion prevention as its main aims. The most productive forests are found in the Atlantic coastal zone and are composed mostly of pines (Pinus pinaster and P. radiata) and eucalyptus (Eucalyptus globulus), although some mixed natural forests of oak (Quercus robur and Q. patraea) and beech (Fagus sylvatica) are still found.

F.5.2-4




F.5.2-5

F.5.2-4 Timber planks on the sawmill machinery, Sweden
F.5.2-5 Wood harvest comparison of data HFA-Ecoinvent in percent




F.5.3-1
F.5.3-2

F.5.3-1 Timber planks are naturally air-dried, Austria
F.5.3-2 System boundary of studied system

In the Pyrenees, there are forests of silver fir (Abies alba), beech and pine, depending on altitude. [6]

**Austrian investigation to logging data**

Since data for wood harvesting seemed to have a relevant impact on LCA results, an investigation into logging in Austria was carried out and results were compared to data of the widely used database Ecoinvent data v2.2 [7]. Therefore, energy consumption measurements were carried out in the forest during harvesting procedure and results, referred to the quantity of harvested wood, compared to Ecoinvent data in Figure F.5.2-3.

Measurements were carried out in lower Austria in a gently inclined (15%) terrain with an estimated harvest of 40 bank meters per hectare. The felled species was Scots pine with a length from 15 to 18 m and a diameter between 18 and 25 cm planned as raw material for the pulp industry. Since it was the second harvest (the third would be the last), no clear cutting was carried out.

Felling devices:

1. Harvester type Valmet 901,2
2. Chain saw type Husqvarna 365 SP 3,40 kW/4.60 HP

Time, energy consumption and quantity of wood were measured when 30 trees were felled in parallel by each device. Quantity was measured automatically by the harvester and manually if a chain saw was used.

Results of the comparison show similar dimensions. Differences can be found in the consumption of the 2-stroke mix and diesel. Whilst Ecoinvent only calculates with chain-saw felling, in Austria approximately 20% of the stems are cut by harvesters. This leads to lower 2-stroke mix results, but higher chain lubricant and diesel consumption for felling and forwarding.

## 5.3 Sawn timber manufacturing and carbon footprint

S. Vares

**General [8, 9]**

Sawn timber is a product for various construction applications. Timber can be graded and further processed into I-beams and Scaffold boards, finger-jointed solid construction timber (KVH), and various lamellas for glue-laminated products. Timber production is the largest industry branch within the wood product industry, and because of that, it is extremely important how accurately and comprehensively the inventory of the timber production processes is done for a good quality environmental impact assessment. Overlooking some processes and generalizations between mills and by products might lead to an inaccuracy in timber calculations, which would also have an effect on the results of the refined products.

**LCA and carbon footprint**

LCA addresses the environmental aspects and potential environmental impacts throughout a product's life cycle (i.e. cradle-to-grave [10]). Carbon footprint is the overall amount of fossil-based carbon dioxide ($CO_2$) and other greenhouse gas (GHG) emissions (e.g. methane, laughing gas, etc.) associated with a product along its supply chain.

Wooden products have to be dealt with by specific methodological approaches, which also affect the results. Important issues that have a significant effect on the final result include consideration of carbon sequestration, allocation of impacts to product and by-products, consideration of release of GHGs in final disposal and recycling, and consideration of consequential effects. Because of those complicated issues, the assessment can give very different results, which is also seen in the literature. One issue is emphasized here: the product level assessment should be based on an attributional analysis to avoid double counting.

The methodology and assessment results presented here cover the timber process from the 'cradle-to-gate' phase (A1, A2, A3) [11] and aspects related to the carbon footprint assessment (Figure F.5.3-2).

**Material efficiency and by-products**

Timber production generates not only timber but also valuable raw materials for the chipboard, energy and pulp industry (Figure F.5.3-3). The wooden material waste could be minimum or very small because all parts from wood can be utilized efficiently.

The timber yield is approximately a half from log-m$^3$ (approximately 2 m$^3$ logs are needed for 1 m$^3$ of timber produced and all the rest (~1 m$^3$) is a by-product in respect to timber). Different mills have slightly different timber yields, depending on log characteristics such as diameter, length and position in sawing, but it is crucial for timber assessment if double the amount of wood material is counted as raw material for one unit of timber produced or if only one unit is needed for one unit of timber and the impacts are correspondingly allocated to timber and by-products.

The main rule is to avoid allocation by dividing the unit processes into different sub-processes, but in the cases where the process cannot be subdivided into two, allocation shall respect the main purpose of the processes studied, allocating relevant products and functions appropriately.

When the study is for sawn timber, the raw materials come from the forest. One question is how the forestry management should be dealt with, because it also serves other products, which are raw materials for other industries. A reasonable allocation method for forestry is mass allocation. But in saw mills, where the main purpose of the process is to produce sawn goods, it is reasonable to allocate all impacts to the main product.

In general, the allocation procedure that should be selected depends on material and market characteristics and the purpose of the study. Several by-product allocation procedures (value allocation, mass allocation, etc.) are possible and described in ISO 14044 [10]. Regardless of which allocation method is chosen, according to the prEN 16485 [12], the inherent properties like biogenic carbon and energy content should be allocated according to the material physical flows.

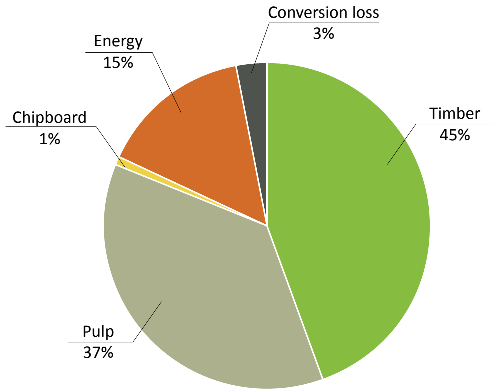
**Energy consumption**

Sawmill activities include log handling, processing, sawing, drying, refining, space heating, lighting, internal transportation, and packing. The operation needs energy, and the amount and type has an influence on the environment. The main energy type in operation is heat, which is mainly used for timber drying. The mills have many alternative ways to generate and use energy, and they all bring about their own methodological questions for LCA. (The methodological choices here are given in parenthesis).

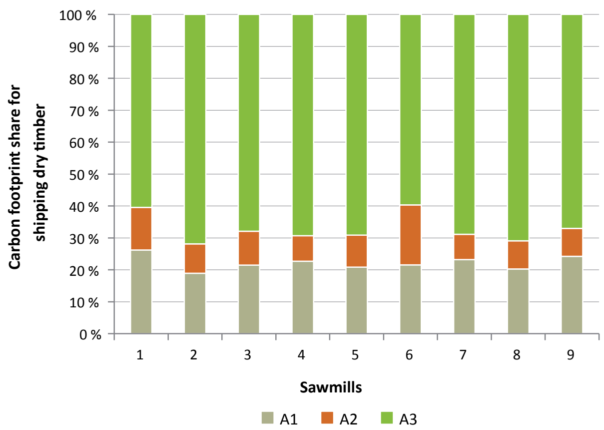
- Own by-product incineration (used by-products have an impact from forestry );
- Bought by-product incineration (used by-products have an impact from forestry);
- Own energy use ($CO_2$ emission from biomass incineration is considered as 0);
- Sold power (power is considered as the by-product);
- Sold heat (heat is considered the by-product);
- Bought power (country average, electricity production calculated for CHP plants according to the benefit share allocation method, but also energy, exergy and other methods are in use);
- Bought heat (environmental impact based preferably on the specific heat producer data if not known, then the average country specific district heat data could also be used).

Timber products are special dry timber for carpentry needs (dried till ~12%), shipping dry timber (dried till ~18%) and unseasoned, green timber (not dried). Annual production of the types depends on market needs, and because of the different amount of energy

F.5.3-3

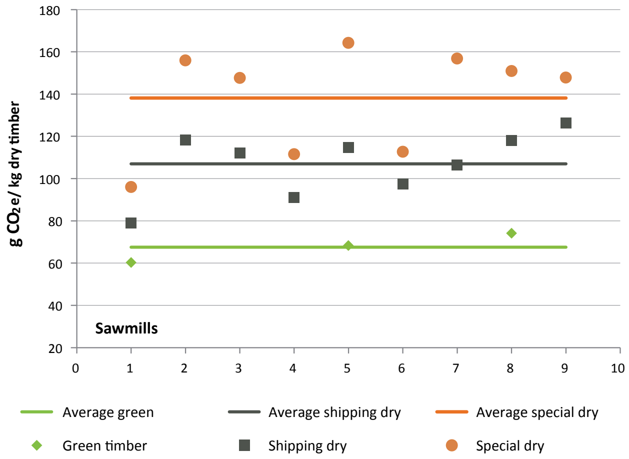



F.5.3-4




F.5.3-4 Use of lofs in Finnish sawmills

F.5.3-5 Carbon footprint and share of life cycle stages (A1, A2, A3) for shipping dry timber, Finland




F.5.3-6

F.5.4-1

| | Heat | Electricity |
|---|---|---|
| Log handling | 0 % | 2–10 % |
| Sawing and post-treatment | 0–5 % | 15–30 % |
| Drying | 80–90 % | 30–50 % |
| Trimming and processing of sawn goods | 0–5 % | 2–10 % |
| Further processing | 0–20 % | 20–35 % |
| Other premises: spaces, maintenance etc. | 1–10 % | 1–5 % |

F.5.3-6 Carbon footprint for timber produced in Finland (as a dry product)

F.5.4-1 Distribution of heat & electricity between different processes in sawmills

needed for unequally dried products, it is important to assess the product types separately, not as the mill's average timber.

Assessment results also depend on the electricity consumption and the production type. Supplied electricity is a mix of different fuels, energy types and technologies. In Europe, there are countries where a majority of electricity is produced by utilizing renewable hydro energy, but also countries where the main fuel type is fossil coal. The mills located in different countries and having the same electricity consumption may still cause a very different carbon footprint result only because of the unfavourable electricity supply mix.

### Carbon footprint and product stage

The product stages are A1 (raw material), A2 (transportation) and A3 (manufacturing) [10]. According to the survey, raw material acquisition may cause 20–30%, transportation ~10%, and manufacturing 60–70% of the total carbon footprint emissions in the case of shipping dry timber. The survey results are shown in Figure F.5.3-5.

The shares between mills and product stages are quite similar, but the total amount varied a lot depending on the energy consumption in the mill, the utilization of by-products for drying, and the timber types produced.

As the timber is produced for different applications, a different amount of seasoning is needed. Special dry, shipping dry and unseasoned timber consume different amounts of energy for drying, but the energy type for drying could also vary from renewable to non-renewable source. When heat is created from the wood-based co-products, then $CO_2$ emissions comes from renewable sources, and it is taken as a net zero value in the carbon footprint assessment. But when this co-product is sold out and heat is bought from a non-renewable source, then heat used for timber drying causes $CO_2$ emissions. For example, 1 kWh energy from natural gas, consumed in the drying process, causes ~220 g of fossil-based $CO_2$ emissions, but when the bark or dust is used, then the fossil-based $CO_2$ emission is ~0.

Because of that, it is desirable that country-specific assessments always exist, the result covers as many mills as possible, and the result is presented separately by timber types produced.

The carbon footprint result for special dry, shipping dry and unseasoned timber for Finland mills and the average are shown in Figure F.5.3-6.

## 5.4 Optimization and development aspects of current manufacturing processes

L.Linkosalmi

### Energy saving potential

The energy-saving potential in the woodworking industry can be divided into heat and electricity. Many woodworking industry processes need heat and electricity. Electricity is needed in all phases of production, whereas heat is needed mainly in the drying phase. Potential energy saving aspects are always mill-specific and need to be identified case by case. Table F.5.4-1 shows the ration of heat and electricity use in the different process phases in sawmilling.

Some general coherence can be identified in energy saving potential. There is no need to reduce the use of heat because heat for manufacturing processes is normally gotten from residues of the process. A heat plant is normally located next to a production mill, and fuel is coming from the process (bark and wood particles). Mills are self-sufficient according to fuels and can often produce even more heat.

Improvement potential:

- Renewable energy sources should be introduced
- Heat and electricity, in case of a CHP plant, could be distributed and sold out.
- Different drying systems in the woodworking industry could be developed to increase the heat efficient of dryers.
- Use of Best Available Technologies (BAT)
- Transportation efficiency of raw materials

### Carbon efficient potential

In the case of carbon efficiency, the main focus should be to reduce fossil greenhouse gas emissions, although biogenic GHG emissions can also be reduced from an energy saving perspective.

As presented in the previous section (5.3), the carbon footprint of sawn timber will come mainly from the manufacturing phase and less from the forestry and transportation phases. Table F.5.4-2 shows more specifically how the carbon footprint is divided between different phases in sawn timber production.

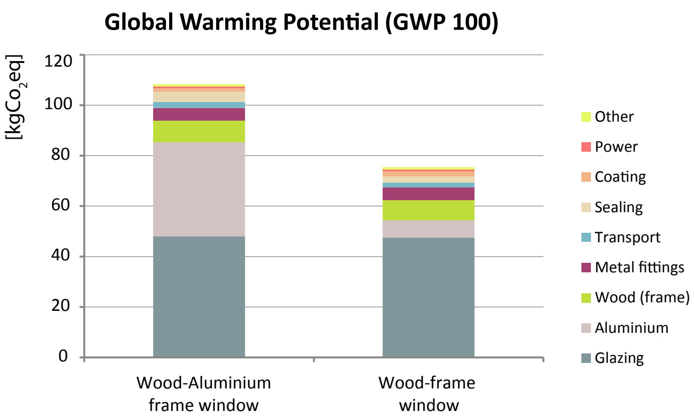
In plywood manufacturing, GHG emissions are distributed differently then saw timber manufacturing. In plywood manufacturing, adhesive and other raw materials have a big effect on the raw materials GHG emissions (approximately 50% of all GHG emissions). Table F.5.4-3 shows more specifically how the carbon footprint is divided between different phases

The general ratio for different products or phases cannot be stated because of differences in the manufacturing process. Forest types and forestry varies within Europe, and transportation distances and transportation methods also vary. Techniques used in production and drying methods also have an influence. Main effects to the greenhouse gas emissions have in used electricity and heat sources. Countries have different kinds of electricity mixes, and those can also be varied year by year according the availability of different electricity sources such as hydro power. Heat for the process is often produced from residue, but can also be produced from fossil fuels (e.g. natural gas).

When the production of upgraded products is studied, manufacturing and transportation have a smaller effect on the carbon footprint. A case study made in Austria shows differences in window manufacturing for two frame types. The main effect on the carbon footprint have materials production; the actual manufacturing of windows and the transport of materials have a minor role in the carbon footprint.

Glazing has a major effect on the carbon footprint of windows. Aluminium also has a big effect on wood-aluminium-frame windows. (Figures F.5.4-4 and F.5.4-5)

F.5.4-5




## 5.5 Conclusions

T.Häkkinen

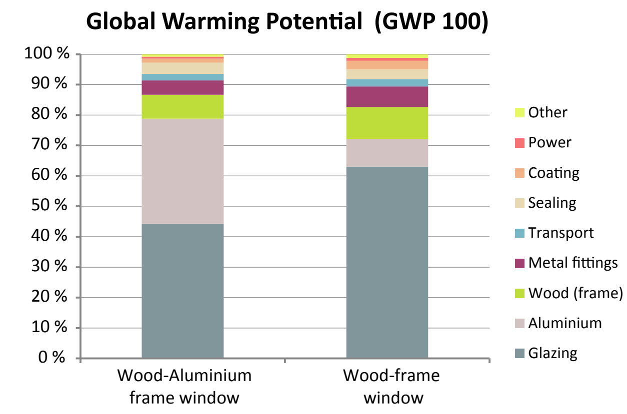
As discussed in this section, geographical and country-specific differences have an effect on the carbon footprint of wood-based products. Climatic differences between Northern, Central and Southern Europe have an effect on forest species and how logging is done. Country-specific energy mixes impact greenhouse gas emissions.

Greenhouse gases from the production of sawn timber vary a lot, depending on the energy consumption in the mill, the utilization of by-products for drying, and the timber types produced.

The most important stage of the production process with regard to energy consumption is the drying process. For example, for shipping dry timer the drying phase may be responsible for 80–90% of heat energy and for 30–50% of electricity. Thus, the average results should not be used in LCI calculations of wood products, but the data should represent relevant wood materials in terms of their required moisture content and quality.

In order to correctly assess the environmental impacts of sawn timber, detailed information about the production processes is

F.5.4-4




| | Share of GHG emissions % |
|---|---|
| Raw material | ~70 |
| Transportation | 10-15 |
| Production | 10-15 |
| Drying | 5 |

F.5.4-3

| | Share of GHG emissions % |
|---|---|
| Raw material | 15–30 |
| Transportation | 5–20 |
| Sawing process | 30–50 |
| Drying | 0–40 |

F.5.4-2

F.5.4-2 Distribution of GHG emissions between different processes in sawn timber production.

F.5.4-3 Distribution of GHG emissions between different processes in plywood production [13]

F.5.4-4 Share of different phases in the carbon footprint of the windows.

F.5.4-5 Carbon footprint of different phases of window manufacturing.

needed. The most important information includes accurate data about the division of the original log to different product flows and moisture content. It is also important to pay attention to the fact that the moisture content varies along the production chain.

The potential to improve the carbon efficiency of a process is to control the manufacturing and drying processes to reduce energy use and at the some time decrease greenhouse gas emissions. Renewable energy sources should also be introduced while not forgetting the energy saving potential.

The environmental profile of sawn timber and its correct calculation is of utmost importance for the assessment of all other products including the final end product – a wooden building. If mistakes are made, it affects the whole value chain.

F.5.5-1 Drying chamber at the sawmill, Sweden

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[12] prEN 16485 Round and sawn timber – Environmental Product Declarations – PCR for wood and wood-based products for use in construction.

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