

University of Sarajevo
Mechanical Engineering Faculty
Department Wood Technology



Three forest countries,

but also three different cultures, identities, mentalities, languages, religions, people, and collaboration between architecture, engineering and timber craftsmanship

Bosnia and Herzegovina is the most forested country in the Balkan area, and **Sweden** and **Slovenia** are two of the most densely forested countries in the European Union. Living habits differ considerably between these three countries, but the use of wood is very similar.

This book grew out of the collaboration of three wood scientists with totally different backgrounds who met and discussed their common interest – wood. Based on the different experiences in each country, the idea was to try to find ways to increase the common knowledge base for the use of wood, achieving excellence in timber design research and education; the architect with a deep knowledge of culture based needs, the engineer with experience and knowledge of technological needs, and the practitioner who always has to find the final solution.

Use of Sustainable Wood Building Materials
in Bosnia and Herzegovina, Slovenia and Sweden

Murčo Obućina Manja K. Kuzman Dick Sandberg

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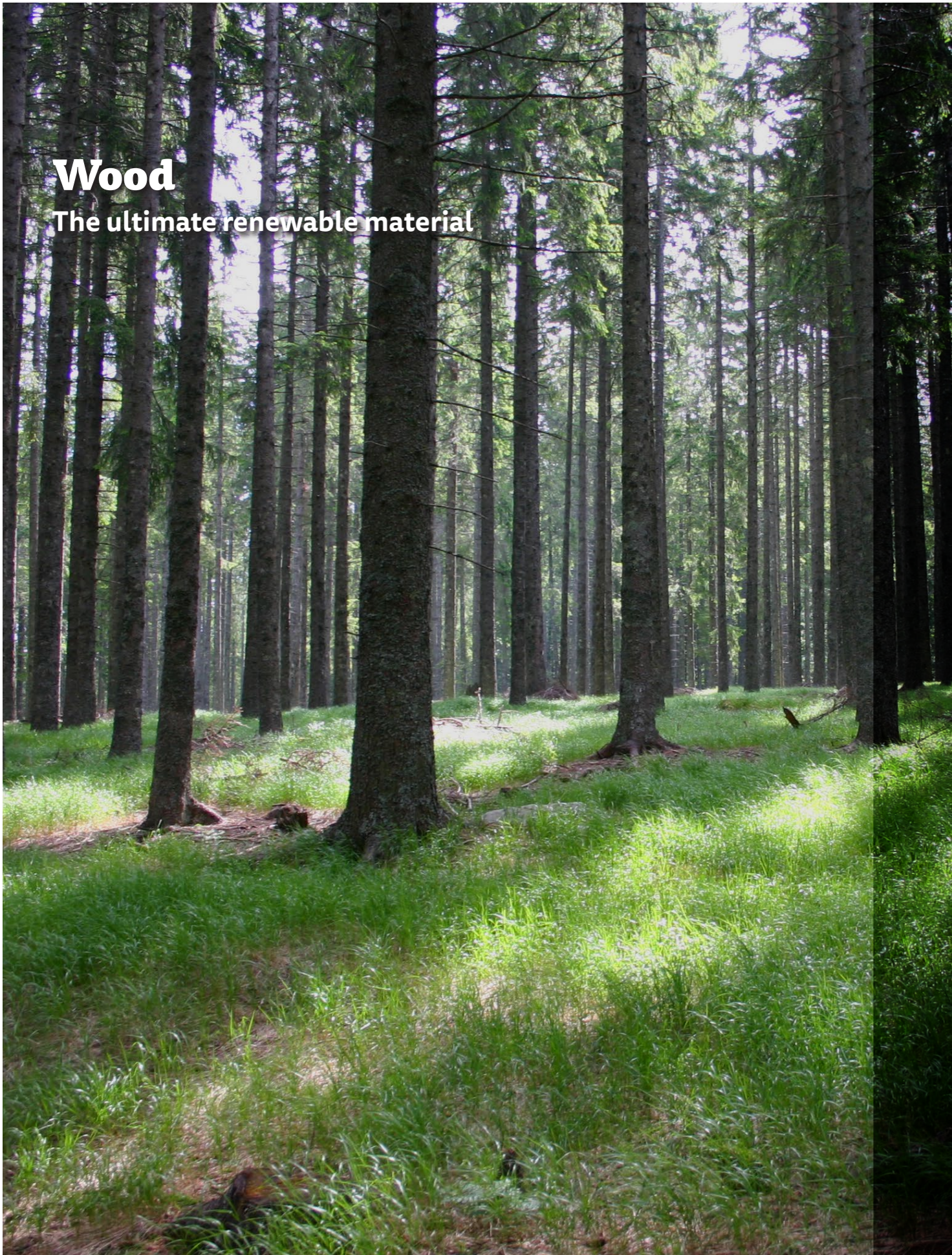
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Living with wood

Slovenia



Project by Jana Hladnik Tratnik, Tina Grzej Photo: Miha Bratina

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but also three different cultures, identities, mentalities, languages, religions, people, and collaboration between architecture, engineering and timber craftsmanship

Bosnia and Herzegovina is the most forested country in the Balkan area, and Sweden and Slovenia are two of the most densely forested countries in the European Union. Living habits differ considerably between these three countries, but the use of wood is very similar.

Wood is the ultimate renewable material. It possesses qualities that have made it a material of choice for millennia, and these qualities are further enhanced by its recognized ability to sequester carbon, while the polymeric components of wood and its porous structure confer on it a noble, versatile and general-purpose character and a faculty for transformation exceeding that of all other materials. The unique advantages of this material, its widespread availability, sustainable renewal, favourable ecological assessment and flexibility of implementation grant it letters patent of nobility in the eyes of scientists and engineers. In the eyes of architects, however, the simplicity and beauty of wood as a new aesthetic are not only a visual experience - architects try to get its smell, texture and tangibility and integrate them into the architectural built environment. Forest and timber are a unique ecological value chain that is a great potential for these three countries.

This natural, sustainable material produced from the local forest will be the basis for new approaches in modern products which can be adapted to suit individual building types in balance with the regional building culture. Basic architectural traditional principles, linked with the economical frame of each country, influence the development of sustainable contemporary architecture and new methodologies. These are the ideas that shape this book, and aim to bring knowledge from selected northern and southern European countries to a scientific and broader public.

Forest products are special. For a deep understanding of the quality of a specific product, one also has to have a knowledge of the origin of the raw material, i.e. the forest and its prerequisites. Therefore, the first chapter presents the forest, forest industry and primary wood products in Bosnia and Herzegovina, Slovenia and Sweden.

In chapter 2, the properties and uses of some common engineered wood products are described. The fact that wood is a natural product originating from individual trees imposes limits on its use. Wood may need to be transformed in order to acquire the desired functionality. Besides greatly improving the understanding of basic properties, chemistry and physics of the product as well as giving rise to advances in materials and wood science, modelling techniques provided the means for engineers and researchers to engineer wood as a material and produce new materials under controlled processing conditions to meet evolving demands and increasing competition. With a multidisciplinary approach, featuring technical disciplines as well as architecture as an art, it is possible to transform new engineered wood products into poetic living-spaces for human beings.

In the subsequent three chapters, different aspects and prerequisite of timber engineering and architecture in Bosnia and Herzegovina, Slovenia and Sweden are presented. In particular, the use of wood in the industrial manufacture of single-family timber houses is presented and discussed. It is evident that the collaboration in interdisciplinary teams leads to impressive timber structures pushing the boundaries of innovation in timber design. The development of timber engineering in the three countries has reached different levels, as can be seen when the use of wood in the industrial manufacture of timber houses is described. In addition, the reader will find in chapter 5, a presentation of contemporary timber building technologies in Slovenia and Sweden, the advantages of prefabrication in a standard building process, and the future role of multi-storey timber buildings. Legislation supporting timber constructions in both countries is also presented. Innovative timber technologies mean that designers and architects are faced with new tasks and new challenges, as well as opportunities for creating a new, low-energy and sustainable environment and buildings.

For those who wish to go further and study wood science, timber engineering and architecture in the three countries, the appendix provides a selection of links to wood companies in Bosnia and Herzegovina, Slovenia, and Sweden, as well as a list of faculties, research institutes and industry associations.

For the benefit of researchers, engineers, timber constructors, architects, designers in wood and others with an interest in this fascinating wood industry, we hope that this scientific monograph can offer an overview of the use sustainable wood building materials from selected southern to northern European countries and will lead to a deeper understanding of methods of processing of wood, using wood and living with wood in different regions. There is a large field of 'timber best solutions' - allowing plenty design freedom for individual expression - awaiting research and development that can be dealt with successfully only by close interdisciplinary collaboration (between architects, engineers and business).

This book grew out of the interdisciplinary collaboration of three wood scientists with totally different backgrounds who met and discussed their common interest - wood. Based on the different experiences in each country, the idea was to try to find ways to increase the common knowledge base for the use of wood, achieving excellence in timber design research and education; the architect with a deep knowledge of culture-based needs, the engineer with experience and knowledge of technological needs, and the practitioner who always has to find the final solution. We hope that this book will be a real inspiration to future design in wood!

Finally, we wish to thank the wood firms involved for their help in lending material and supporting the publication of the book. The reviewers of the book - Azra Korjenic at Research Centre of Building Physics and Sound Protection, Vienna University of Technology and Milan Šernek at Department of Wood Science and Technology, University of Ljubljana - are also gratefully acknowledged.

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Closer ties between countries

About the countries



Bosnia and Herzegovina

is a country in south-eastern Europe located on the Balkan Peninsula. The total land area is 51,200 km² from which 51,197 km² belongs to land, and 12.2 km² belongs to the surface of the sea. The total territory of Bosnia and Herzegovina with its neighbouring countries is 1,538 km, with land border of 774 km, river border of 751 km, and sea border of 13 km. The borders of Bosnia and Herzegovina are mainly delineated by natural markers such as rivers like Drina, Sava and Una, and mountains like Dinara, located in the south-western part of the country. According to the census reports of Bosnian Census 2013, the population of Bosnia and Herzegovina is 3,531,159. Forests and forest land cover more than 56% of the country. From ancient times, forests have kept a reputation of the largest and the most important natural resources of Bosnia and Herzegovina. For a long period of time their economic value was nowhere to be seen. The history of the Bosnian forestry, as an individual industry, begins in the first half of the nineteenth century.



Slovenia

is situated in southern Central Europe and covers 20,151 km² of land. The population of Slovenia is 1,996,617 and the nation has a density of 99 people per square kilometre. Slovenia borders are Italy to the west, Austria to the north, Croatia to the south and southeast, and Hungary to the northeast and has a coastline of 47 km by the Adriatic sea between Italy and Croatia. The north part of the country is dominated by the Alps, while in the southwest, the Karst Plateau is a region filled with limestone caves and gorges. Slovenia is the only country in Europe that combines the Alps, the Mediterranean, the Pannonian Plain and the Karst. Slovenia is one of the newest countries in Europe, having declared independence from the former Yugoslavia in 1991. It joined the European Union in 2004 and adopted the Euro in 1997. Despite this, the country is rich in history and tradition, with many delightful medieval towns and castles dotted across the landscape reflecting the many different conquering armies that have claimed the land down the centuries.



Sweden

is a sparsely populated country, characterised by its long coastline, extensive forests and numerous lakes. It is one of the world's northernmost countries. In terms of surface area it is comparable to Spain. Sweden's borders have been unchanged since 1905 and the country has not been at war since 1814. Less than 3% of Sweden's land area is built up and forests cover 70% of the country. Sweden is long – some 1,574 kilometres from top to bottom. There are 10 million people in Sweden, of whom about 2 million are under the age of 18. 85% of them live in cities where the capital Stockholm has about 1 million residents. Sweden is a very multicultural country: 15% of Swedes were born in another country, while about one in five children has a family with roots in another country. Swedes study and work hard but they also take their rest and relaxation seriously. So the *fika* – a coffee break that normally consists of coffee, cookies or sweet buns – is a social institution and an important part of the national culture.



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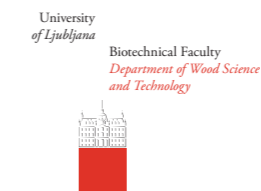
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Jahorina

Bosnia and Herzegovina





1 Forest, forest products industry and primary wood products

Bosnia and Herzegovina

Bosnia and Herzegovina (B&H) is a country in southeastern Europe located on the Balkan Peninsula. The total area is 51,209 km² of which about 12 km² is a sea. The border of B&H with its neighbouring countries is 1,538 km, and are mainly delineated by natural features such as rivers like the Drina, Sava and Una, and mountains like Dinara, located in the south-western part of the country. B&H is divided into two entities nearly equal in size of land area: Republika Srpska and the Federation of B&H. The population of B&H is about 3.5 million [1].

Forests and forest land cover more than 56% of the country, Figure 1.1. From ancient times, forests have been the most important natural resources of B&H with a high economic value. The wood industry is trying after the post-war economic recovery to develop from simple commodity and subsistence production to a modern wood processing industry.

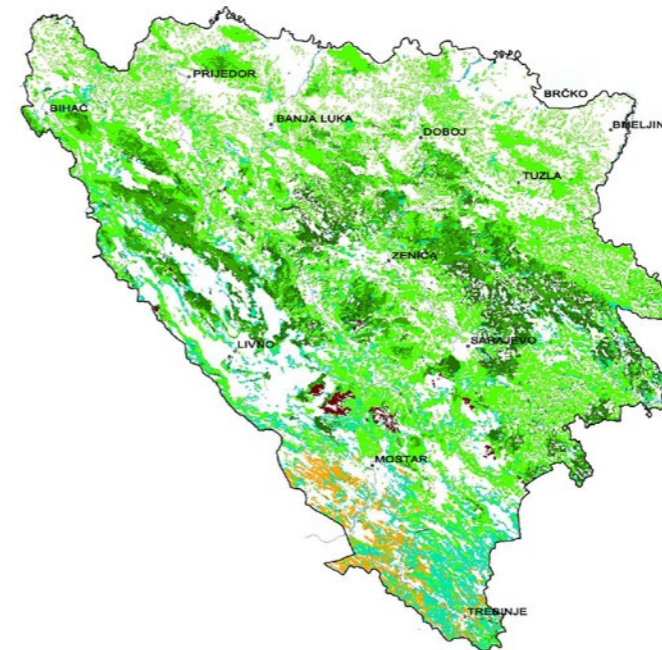


Figure 1.1 Bosnia and Herzegovina with forest land shown in green [2].

The state institutions of B&H have over time set the conditions for using the forest land in B&H and how to use it for further processing. Under the Ottoman Empire, forest ownership relations were established on the foundations of Sharia law and canon law, whereby forests were treated as public goods in order to avoid them becoming the subject of private property and possession.

Under the Austro-Hungarian administration (1878-1918), a regulation of forest ownership was implemented. The rights of private forests were established and state forests were made available to foreign industry through long-term contracts, and the use of the forests resource for various purposes increased.

Logging operations in large scale continued in Yugoslavia, but also diseases and other sorts of devastation in forest reduced the stock. In the 1930s, regulations were established that provided re-establishing the forest by planting or seeding the areas from which forest was logged. In socialist Yugoslavia, favorable conditions were established, which led to a positive development of forestry. After World War II, it took a relatively short time to develop seedbeds and wide afforestation, and this established a long-term basis for forest regeneration that could be a base for the forest products industry. The Forest Law adopted in 1978 regulated many issues of forest management.

After the Dayton Agreement in 1995, the responsibility for the forest management has been taken over by different associations. The last federal Forest Law was enacted in 2002. The federal and cantonal governments that manage and preserve both public and private forests, transfer forest management to forest associations located in each canton, and the forest products industry is completely separated from forestry. The link between wood processing and forestry can be found only in the sale and acquisition of roundwood for the industry [2].

Forest resources and potential future logging

The area of available forest with a productive character in B&H is currently 2,172,700 ha or 42% of the total land area. Of this, the coppice forests represent about 843,000 ha, Table 1.1.

Table 1.1 The forest and forest land area by vegetation form in B&H [3].

Forest type	Accessible area				Inaccessible area	Total area
	Economic forests	Non-economic forests	Protective forests	Special purposes		
	(ha)	(ha)	(ha)	(ha)		
High forest	1,329,500	46,300	5,200	8,800	262,600	1,652,400
Coppice forest	843,200	158,700	1,600	2,400	246,300	1,252,200
Shrubberies	52,700	41,100	0	100	36,700	130,600
Barren forest	55,700	88,400	800	3,400	38,900	187,200
Other forest areas	3,300	3,100	0	100	2,600	9,100
Total	2,284,400	337,600	7,600	14,800	587,100	3,231,500

The area of forest land classified as inaccessible because of the suspected presence of landmines is nearly 600,000 ha, but most of this area, according to the characteristics of the terrain and vegetation, would in the future devolve to forest land with a productive character. These areas represent of course a security problem and create a great economic loss.

Areas of available production forest, i.e. forest that can be used for logging roundwood for industrial purposes are shown in Table 1.2 for both Federation B&H and Republic Srpska.

Table 1.2 Production forest in Federation B&H (FB&H) and Republic Srpska (RS) [3].

Forest type	FB&H		RS	
	(ha)	(%)	(ha)	(%)
High forest	673,300	± 3.1	647,300	± 3.2
Coppice forest	355,400	± 6.0	485,300	± 5.0
Total	1,028,700	± 2.7	1,132,600	± 2.6

Opportunities for intensive planning are greateast in the state forests because the state as the owner can easily arrange for intensive and sustainable forest management, through the imposition of cutting plans to be followed by the companies that manage the state forests. In the private sector, it is much harder to introduce effectively forest management because of a large number of small forest owners and their lack of organization. Therefore it is currently unrealistic to forecast the volume of roundwood from private forests which could be logged for the use in the forest products industry. There are nevertheless data for cutting in private forests that can be taken as a guide in assessing the future roundwood supplies from private forests. There is however a considerable potential to increase the volume of roundwood from private forests.

Data of available forest resources in B&H and their use can be found in the second forest inventory 2006-2009, Table 1.3. A comparison between the annual increment and the annual harvested volumes show that about 56% of the increment is cut in the state-owned forests compared to 37% in private forest, which show a high potential for increased harvesting of biomass from B&H forests.

Table 1.3 Forest data according to ownership [3].

Forest type:		High forests			Coppice forests			High and Coppice forests		
		State	Private	Total/mean	State	Private	Total	State	Private	Total/mean
Areas	(ha)	1,063,400	266,100	1,329,500	408,700	434,500	843,200	1,472,100	700,600	2,172,700
	(%)	72	38	100	48	62	100	68	32	100
Volume	(1,000 m³)	299,630	53,968	353,598	35,710	46,412	82,122	335,340	100,380	435,720
	(m³/ha)	282	202	266	87	107	97	228	143	201
Annual increment	(1,000 m³)	7,481	1,622	9,103	907	1,192	2,095	8,388	2,814	11,202
	(m³/ha)	7.03	6.10	6.83	2.22	2.75	2.48	5.67	4.09	5.16
Annual harvest	(1,000 m³)	4,416	446	4,862	307	598	906	4,723	1,044	5,767
	(m³/ha)	4.15	1.68	3.62	0.75	1.38	1.07	3.21	1.50	2.63

High forests in Bosnia and Herzegovina

Tables 1.4 to 1.7 present an overview of the stock, annual increment, and the estimated volume of harvest in the state-owned productive high forests in B&H as a whole, and for the Federation B&H and Republic Srpska separately.

Table 1.4 Accessible area of state-owned productive high forest in B&H [3]. FB&H - Federation B&H, RS - Republic Srpska.

Data of high forest	Accessible state productive high forest			
		FB&H	RS	B&H
Area	(ha)	544,100	518,000	1,063,400
Volume	(1,000 m³)	152,261	147,078	299,630
Annual increment	(1,000 m³)	3,846	3,635	7,481
Annual logging according to inventory (m³/year)	(1,000 m³)	2,407	2,011	4,418
- share of annual increment	(%)	62.6	55.3	59.0
Annual logging according to management plans 2006-2010	(1,000 m³)	2,684	2,485	5,169
- share of annual increment	(%)	69.8	68.4	69.1
Actual outcome of management plans 2006-2010	(1,000 m³)	2,060	2,234	4,294
- share of annual volumes in the management plans	(%)	77	90	83

Data taken from second state forest inventory in B&H 2006-2009, Federal Ministry for Agriculture, Water management and Forestry 2011, and from Public Enterprise Forests of Republic of Srpska, 2011

The total state-owned forestland covers an area of about 98,100 ha, with an annual increment of about 7.5 million m³, Figure 1.2. Registered logging in these forests is about 60% of the annual growth. The logging in even-aged stands is only 1.2%, although their area is about 9.2% of all the state high forests. The reason is the small share of valuable assortments in the plantation forests.

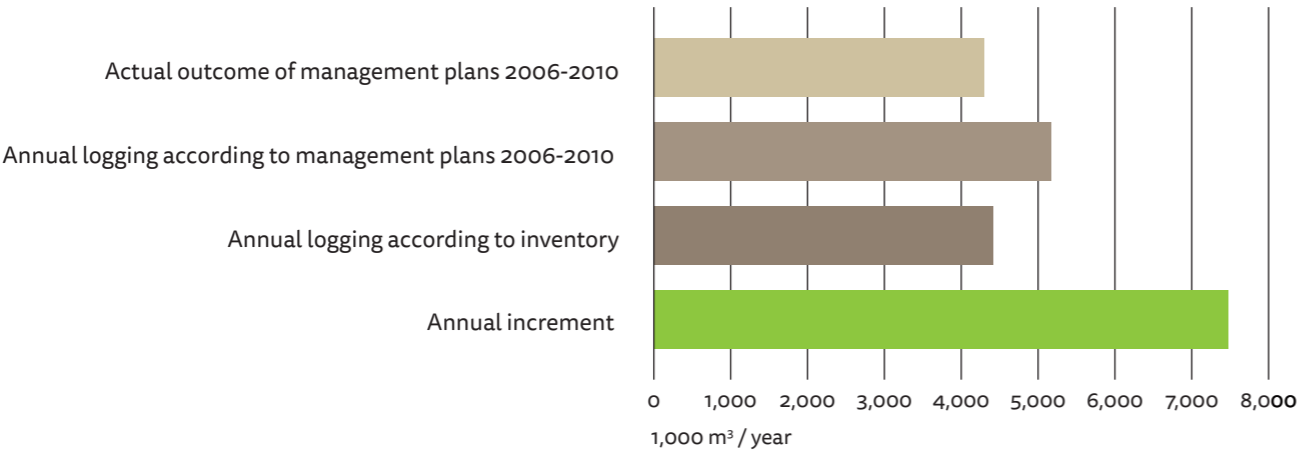


Figure 1.2 The annual volume increment, registered felling, planed felling and realized felling within state-owned productive high forests [3].

Table 1.5 shows the stock and annual increment in state high forests in B&H, based on data from the second state forest inventory. These forests generate the major revenue for B&H’s forestry, and they are regularly managed on the basis of management plans. Data on planned and executed annual allowable logging are related to the recent period (2010 and 2011). Planned felling is a 10-year average based on the currently valid management plans.

It is evident that the planned logging, which is significantly lower than the increment in the forests, is not fully implemented. The completed logging is regularly analyzed, and it shows that the annual logging is not implemented in the low-quality forests, in forest plantations, in degraded forests, and within the high forest with natural regeneration. Although this is legally unacceptable because the annual logging must be met by tree species, diameter and quality classes.

Table 1.5 Estimated size of the stock and annual increment of roundwood in the state-owned productive high forests in B&H, in Federation B&H and Republic Srpska [3].

Species	Stock (m³/ha)	Annual increment (m³/ha)	Total stock (1,000 m³)	Annual increment (1,000 m³)	Annual logging plan (1,000 m³)	Realized (%)	Available (1,000 m³)
B&H							
Conifers	125	3.4	133,424	3,621	2,309	88	273
Broadleaves	156	3.6	166,206	3,860	2,532	76	602
Total	281	7.0	299,630	7,481	4,841	83	875
Federation B&H							
Conifers	128	3.5	69,482	1,893	1,283	81	206
Broadleaves	152	3.6	82,779	1,953	1,072	77	328
Total	280	7.1	152,261	3,846	2,355	70	534
Republic Srpska							
Conifers	123	3.3	63,911	1,730	1,026	96	39
Broadleaves	161	3.7	83,165	1,906	1,459	85	212
Total	284	7.0	147,076	3,636	2,485	90	251

Possible logging and assortment structure of high forests

In the Second state forest inventory, the basis of assessments of logging in all the high forests in B&H is presented. It assesses the volume, size, and vitality of forests if thinning necessary and how it would alter the breeding character. Such a way of thinning means that all the diseased and low-grade trees are removed, i.e. the thinning lead to a large proportion of inferior wood because of low quality or small diameter of the trunks.

Sample plots have been used to estimate the volume and assortments of roundwood from the most important species, i.e. fir, spruce, and beech, possible to cut in a 10-year period, and which could

be achieved if the forests should be well managed, Table 1.6. The numbers are roundwood volume which account for 85% of the logged volume of trees, the remaining 15% is bark and logging residues.

The relationship between different roundwood assortments is almost the same in all the analyzed territorial units in B&H, which in practical terms means that the forests have a similar structure by diameter and by quality. The conifer to a broadleaf relationship may also affect the assortment. The logging volumes are dominated by broadleaves, with about 68% in the Federation B&H and about 74% in Republic Srpska. Figure 1.3 present the percentage share of assortments in the forest of conifers and broadleaves in B&H.

Table 1.6 The structure of expected annual logging volumes and assortments in Federation B&H (FB&H) and Republic Srpska (RS), for both state and private high forests [3].

Product category	FB&H			RS			B&H			
	Conifers	Broadleaves	Total	Conifers	Broadleaves	Total	Conifers	Broadleaves	Total	
Veneer logs	1,000 m³	13	112	125	5	55	60	18	159	177
Saw logs	1,000 m³	1,056	1,128	2,184	727	930	1,657	1,811	2,046	3,857
Small-diameter roundwood	1,000 m³	330	-	330	225	-	225	564	-	564
Pulpwood	1,000 m³	183	856	1,039	151	824	975	339	1,701	2,040
Firewood	1,000 m³	11	1,556	1,567	11	1,559	1,570	22	3,158	3,180
Total	1,000 m³	1,593	3,652	5,245	1,119	3,368	4,487	2,754	7,064	9,818

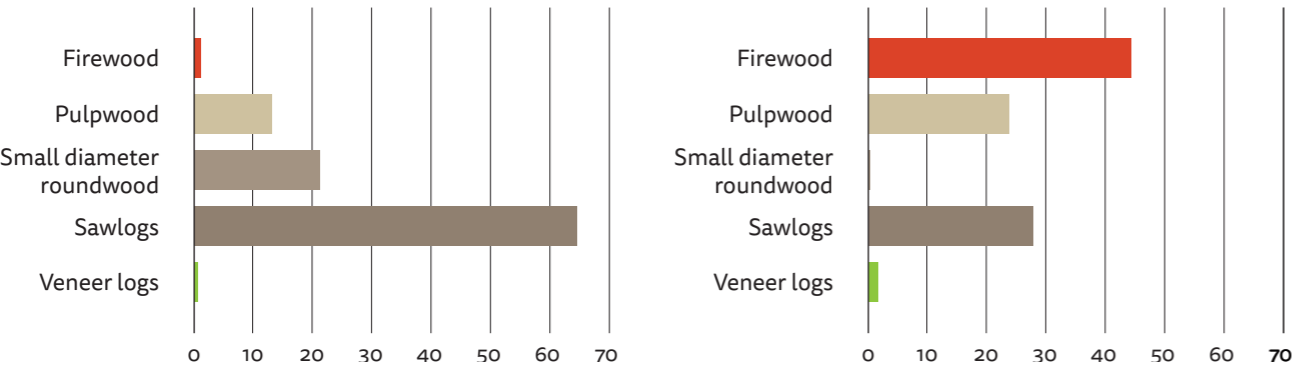


Figure 1.3 Percentage share in assortment of (left) conifers and (right) broadleaves [3].

Coppice forest

Coppice forests in B&H are heterogeneous in terms of structure, the size of the trees, and species. The quality of roundwood is generally poor and is mainly used as firewood. A clear-felling in coppice national forests is usually followed by reforestation and the conversion of coppice forests into more well-manage forest types.

In private forests, logging is performed by individual owners mainly for the supply of firewood, and the logging volumes of roundwood are hard to estimate. Previous legislation only allowed selective felling (cutting individual trees) in private forests in the amount of increment, and at the request of individual forest owners. Clear-felling has not been permitted in private forests, and this hinders their economic utilization [3].

The logging volume of coppice forests is about 40% of the logging volume stated in the management plans 2006-2010 and only 20% of the annual increment, Table 1.7 and Figure 1.4. The planned annual logging volume of roundwood is not at the level of which it could be, based on the area of coppice forests which are planned to be converted into a high forest, or the stocks that should be cut in these areas. The volume of roundwood harvest from coppice forests indicates the degree of planned conversion of coppice forests to high forest.

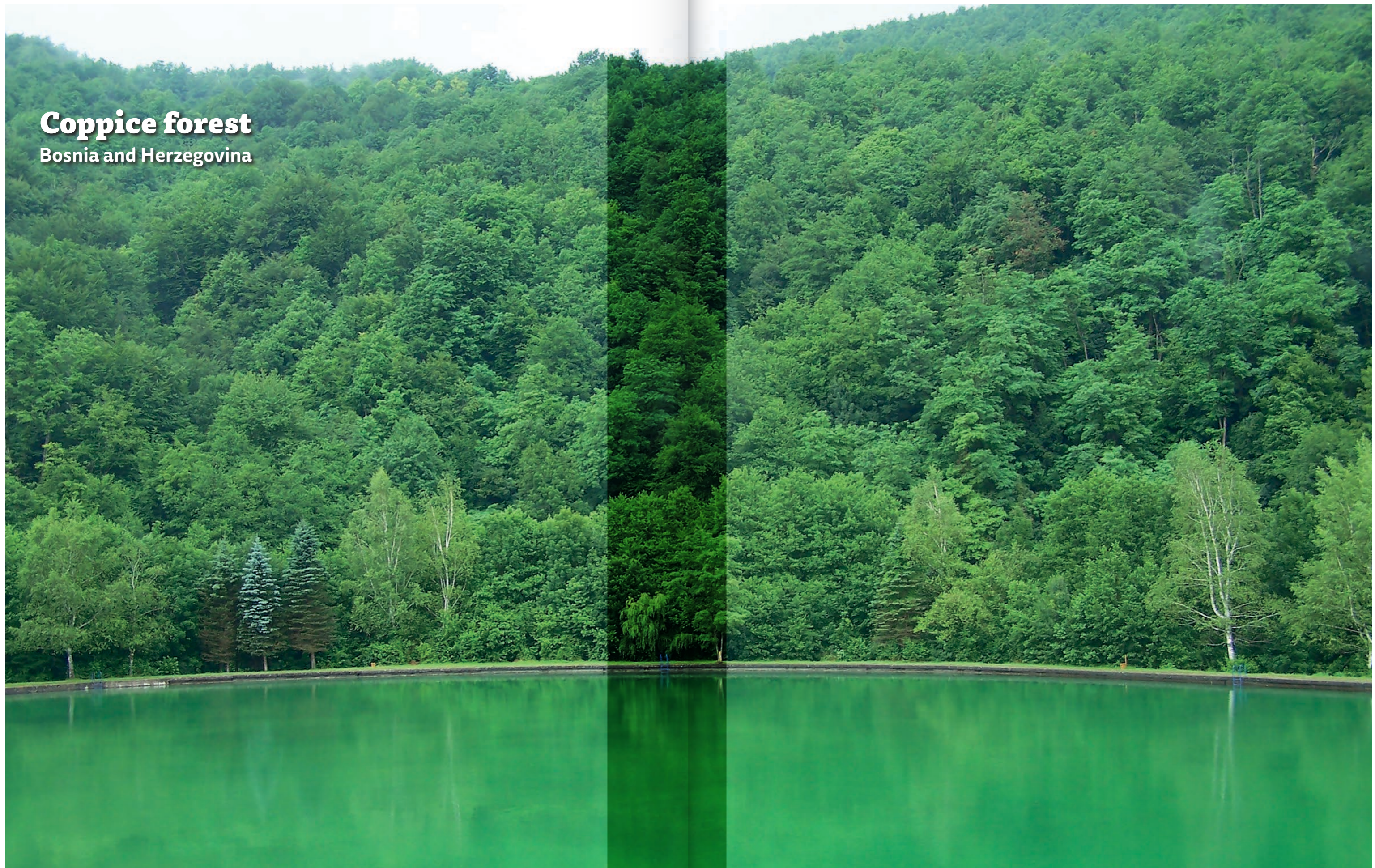
Table 1.7 State owned productive coppice forests in numbers [3]. FB&H - Federation B&H, RS - Republic Srpska.

Accessible state productive coppice forest		FB&H	RS	B&H
		(ha)	(1,000 m³)	(1,000 m³)
Area of coppice forests	(ha)	195,800	212,800	408,700
Volume	(1,000 m³)	16,987	18,721	35,708
Annual increment	(1,000 m³)	451	455	906
Annual logging according to inventory	(1,000 m³)	97	209	306
- share of annual increment	(%)	22%	46%	34%
Annual logging according to management plans 2006-2010	(1,000 m³)	233	179	412
- share of annual increment	(%)	52%	39%	45%
Actual outcome of management plans 2006-2010	(1,000 m³)	58,000	114,997	173
- share of annual volumes in the management plans	(%)	25%	64%	42%

Data from Second state forest inventory in B&H 2006-2009, Federal Ministry for Agriculture, Water Management and Forestry 2011, and Public Enterprise Forests in Republic of Srpska, 2011

Coppice forest

Bosnia and Herzegovina



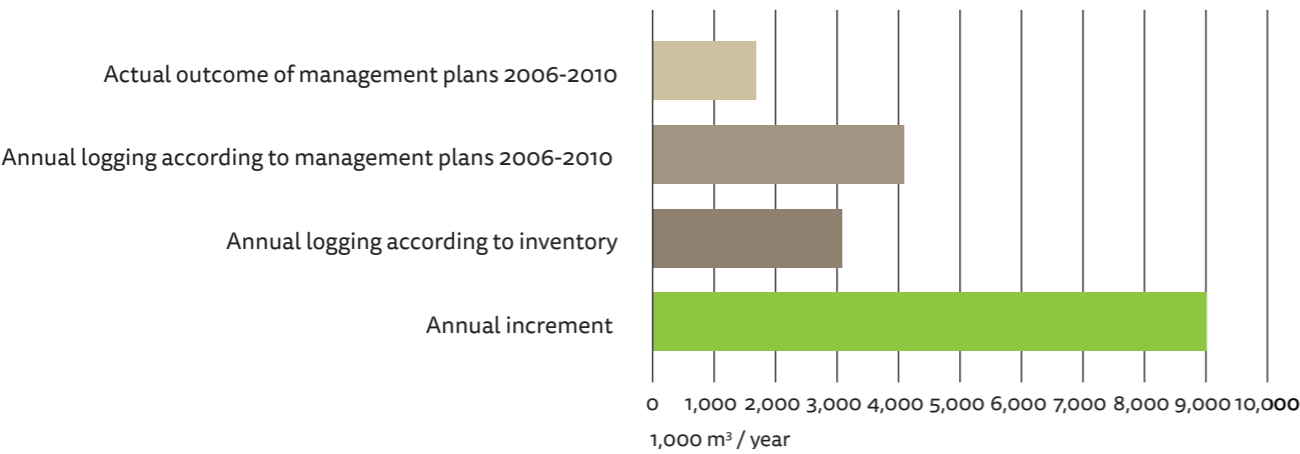


Figure 1.4 The annual volume increment, registered felling, planed felling and realized felling within state-owned productive coppice forests [3].

Based on the extensive work of Besim Balić and colleagues, it was possible to estimate the roundwood assortment in beech coppice forests in the Canton of Sarajevo [3].

Six different assortments of beech wood were defined and the volumes were estimated, Figure 1.5. There is only a small variation in the mix of roundwood assortments of beech coppice forests, so these figures can be used for B&H as a whole. The roundwood assortments that could be acquired by rational use of these forests were also analyzed separately by trial felling. It is clear that firewood is the main assortment in beech coppice forests and sawlogs of mainly poor quality count for about 10% of the forest volume.

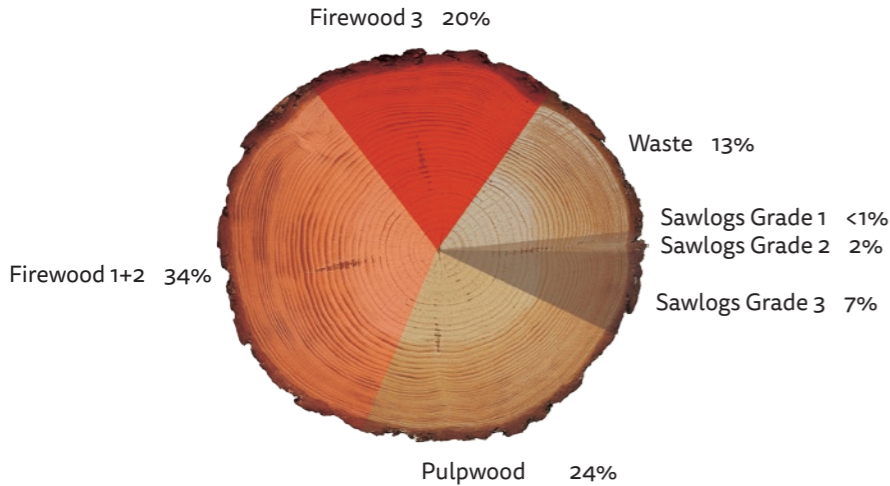


Figure 1.5 Average percentage share of wood assortments in beech coppice forests [3].

Primary wood products

The forest products industry is the oldest industrial sector in B&H and is very important for the economy. It is located all over B&H but mainly organized within Šipad, Konjuh, and Krivaja regions. The part of the industry that processes primary wood products consist of about 200 medium and large size companies and is an important employer in small communities.

Before the war during the 1990s, the wood industry accounted for 10% of the gross national income (around € 3 billion) and 11% of the total exports. The capacity of the wood industry has exceeded the state’s needs, and this has resulted in large amounts of wood products for export to the international market, especially to the European market, and a strong business network of private companies and their worldwide representative offices were developed [4].

There is no doubt that the wood industry in B&H has had advantages of good access to large volumes of a domestic forest, low investment and salary costs, but former advantages are not a guarantee for the successful future development of the industry. The general assessment is that the use of forest resources and the functionality and availability of wood processing capacity is not satisfactory. It is also evident that there is no strategic sectorial and cross-sectorial approach to the development of the wood industry.

In order to raise production capacity, strategic goals should be set to provide the necessary conditions for the development of the wood industry. Some important areas of improvement are closer business relations between forestry and companies involved in wood processing, defined target products and support for the export of more value-added products, company promotion and joint market representation as export strategy, quality control, human resources, and education.

The largest economic growth in B&H since 2008 was recorded in 2013. The gross domestic production (GDP) increased by 1.9% per annum, and the wood industry contributed strongly to this increase. According to available data published by the State Agency for Statistics and Economic Chamber, the wood industry achieved outstanding results in 2013 in relation to the total domestic industry production and exports. In 2013, the wood and wood products category became the largest foreign trade surplus for the first time (base metals were in the lead until 2013). The foreign trade surplus for sawn timber and wood products was a total of € 207 million, with an export-import ratio of 350%. Another encouraging fact is that the wood products category recorded an annual growth of 14% with the fourth year of consecutive growth. The value of exported wood products was € 411 million, which represents the highest value since the beginning of conducting foreign trade statistics in 2000 [5].

The production of wood products (excluding furniture), has reached an annual increase of 12.5% in 2013, which surpassed the increase recorded in the total manufacturing sector (9.5%) and in total industrial production (6.7%). Furthermore, after a decrease from 2011 to 2012, production in the furniture industry increased by 5.3% in 2013. In 2013, the production of wood products accounted for 3.2% and furniture production accounted for 2.6% of the total industrial production, and now represent the fourth largest product category in B&H, following the production of food, base metals, and fabricated metal products. Figure 1.6 shows the relationship between the wood industry and the overall production in B&H.

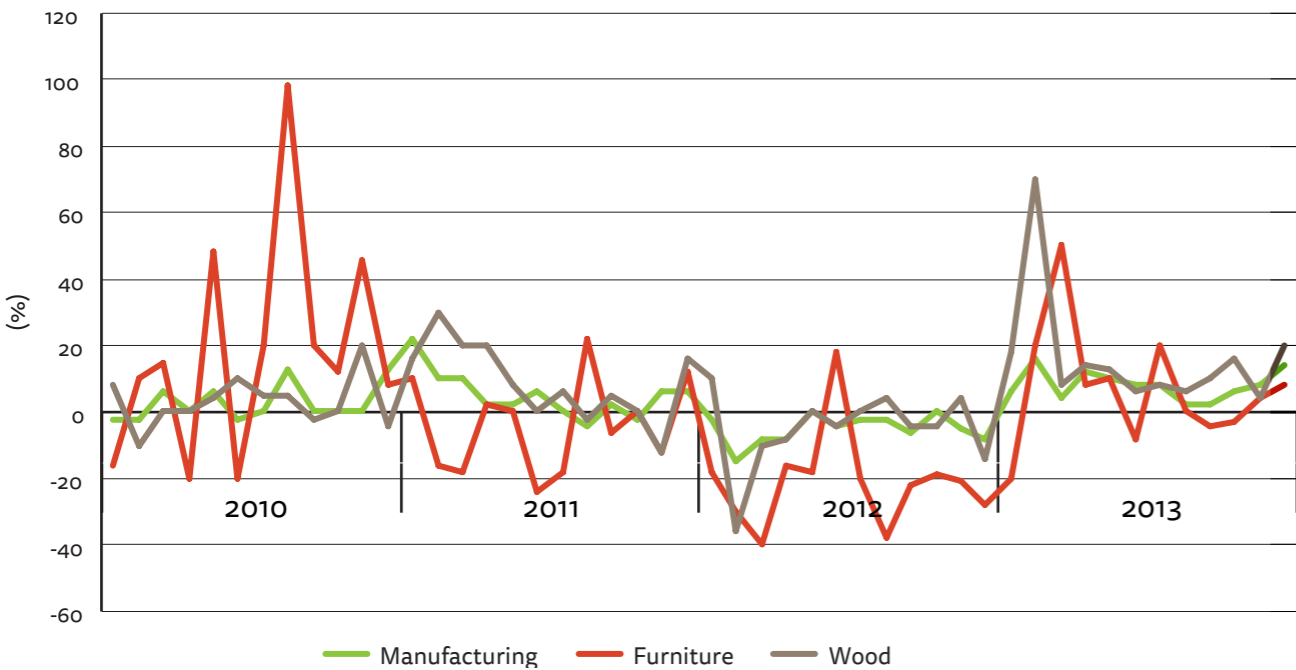


Figure 1.6 Relationship between the production value in the wood, furniture and total manufacturing industry [6].

The wood industry has managed to keep the number of employees as in 2012. This is a positive sign, considering that the number of persons employed in B&H is continuously decreasing. The wood industry employed 17,050 people in 2013, of whom 10,973 were engaged in the production of wood products, while 6,077 were employed in the manufacture of furniture. The number of employee in the wood and furniture industries account for 2.5% of the total official employment in the B&H and 13.5% of employment in the manufacturing industry.

The export structure of the wood industry

A growing demand for wood products among major trading partners in the European Union was the dominant factors that increased the production volume in the wood industry during recent years. The wood industry in B&H is traditionally export-oriented, with the majority of its revenues coming from the European Union market, mainly from Germany, Croatia, Slovenia, Italy, and Austria. A part of the European Union, the largest export markets are the countries in southeastern Europe such as Serbia, Montenegro and the Republic of Macedonia.

Table 1.8 shows the export of wood products. It has been an increase in export for most types of wood products since 2010, and after a moderate growth decrease in 2012, when the recession not only slowed down the wood industry but also other key export industries, the manufacture and export of wood products had a strong expansion in 2013.

Table 1.8 Exports of forest products from B&H [1].

Product category	2010	2011	2012	2013	Increase 2010-2013	
	(million €)				(%)	(%)
Sawn timber	118	139	139	146	36	24
Veneer	11	12	12.5	13.5	3	23
Joinery products	20	24.5	25	27	7	35
Other wood products	5.5	7.5	9	10	2	82
Furniture	156	174	185	199	48	28
Prefabricated houses	13	14.5	15.5	15.5	4	19
Total	324	372	386	411	100	(mean) 27%

The exports are dominated of sawn timber and furniture which constitutes nearly 85% of the total exports in the wood industry sector. The production of prefabricated houses and furniture is competitive and is also expected to get a stable growth in future.

The largest export of sawn timber is to Serbia and Germany (15%), Croatia (13%), Slovenia (11%) and Italy (9%), which together account for 63% of the total exports of sawn timber, Table 1.9. However, it should be noted that the total share of the five largest export markets is constantly decreasing (from 71% in 2010 to 63% in 2013). Despite the fall of these five major markets, the exported volume of sawn timber continues to grow, Table 1.8.

Table 1.9 The five leading export markets for sawn timber (% of total export of sawn timber) [7].

Country	2010	2011	2012	2013
Serbia	20.7	17.9	17.8	15.3
Germany	18.1	18.2	17.6	14.9
Croatia	16.3	15.0	14.1	13.2
Slovenia	6.8	7.9	6.7	10.5
Italy	8.9	10.8	10.2	8.8
Total	70.8	69.8	66.4	62.7

Regarding the export of veneer, the key export markets are very similar to those for sawn timber; the five major export markets for veneer products include Germany, Italy, Slovenia, Croatia and Austria, representing about 80% of the total export of veneer. A different structure is found for the joinery sub-segment, where the Netherlands is the main export market (14%), followed by Italy, Croatia, Germany and Serbia, accounted for 72% of the total joinery exports in 2010, but at the end of 2013 their share had dropped to 55%.

For furniture, Germany, is the most important export market with 37% of total exports. The furniture industry has conducted an aggressive marketing campaigns and participated in several furniture fairs in Germany in the past years. These activities have improved visibility of furniture from B&H and established business partnerships with companies on the German market. The strong German economy over the last years has been further supported and has encouraged this uptrend. The export of furniture to the German market increased by 15% in 2013.



KEY FIGURES 2015

B&H forest products industry

Number of companies: 1,425

Number of employees: 30,000

Revenue (€): 3% of GDP

Export (€): 608,000,000

Key export markets: Germany, Croatia, Austria, Italy, Slovenia, The Netherlands

Source: Foreign trade Chamber of Bosnia and Herzegovina (www.komorabih.ba)

Beech forest

Loški potok, Slovenia



Slovenia

Wood has always been an important product for Slovenia – it is the third most densely forested country in the European Union, after Finland and Sweden. Approximately 4 million m³ of roundwood are produced each year from 1,186,104 ha of forest. In addition, the forested land has expanded from 35% to almost 60% in a matter of decades.

Forests are an important natural resource in Slovenia protecting biodiversity and playing an important role in the conservation of the Slovenian natural heritage. Almost 50% of all Slovenian forests are parts of Natura 2000 sites. These protected forests cover 35% of Slovenia’s total surface area. The most typical feature of the Slovenian landscape is its forests (Figure 1.7), which cover as much as 58% of the national territory [8]. The most important tree species as reported by the Slovenia Forest Service are beech (*Fagus silvatica*) and spruce (*Picea abies*), each of which account for 32% of the Slovenian forests [9]. Oak (*Quercus* spp.) and fir (*Abies alba*), each with a 7% share are the third and fourth most important tree species in Slovenian forests. Other important tree species with considerably lower populations are Scots pine (*Pinus sylvestris*); ash (*Fraxinus excelsior*), Manna ash (*Fraxinus ornus*), birch (*Betula* spp.), cherry (*Prunus avium*), black alder (*Alnus glutinosa*), hornbeam (*Carpinus betulus*), mountain elm (*Ulmus* spp.), mountain maple (*Acer spicatum*), maple (*Acer* spp.), mountain ash (*Sorbus aucuparia*), chestnut (*Castanea sativa*), lime-tree (*Tilia* spp.), larch (*Larix decidua*); whitebeam (*Sorbus aria*), black locust (*Robinia pseudoacacia*), and aspen (*Populus tremula*).

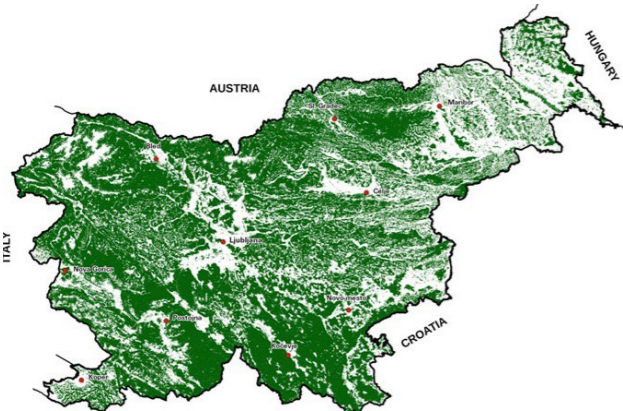


Figure 1.7 Forest coverage in Slovenia. The principal forest regions in Slovenia stretch into the afforested areas in the western Balkans [9].

In Slovenia, the forest ownership is very fragmented. Private forest ownership accounts for 75% of Slovenian forests and the area owned is usually quite small, on average 3 ha. Most of these estates are not of economic interest to the owners, and this is a serious obstacle to optimal timber production and utilization of the forest potential. The state owns 22% of the forest and municipalities own the remaining 3% [9].



Forest, forest products industry and primary wood products

The total forest area in Slovenia is expanding, largely through natural expansion into abandoned farmland, primarily meadows and pastures in more remote parts of the countryside. In many parts of the urban landscape, however, forests must yield to the infrastructure and expanding cities. However, forests remain a valuable natural resource for Slovenia, contains close to 300 million m³ of wood. Figure 1.8 shows the Slovenian growing stock in 2011 [9].



Figure 1.8 Growing stock of forest in Slovenia - dark areas mean a high annual increment [9].

For 2014/15, the Slovenian Forest Service reports 346,100,000 m³ of growing stock, Table 1.10. The annual increase in growing stock was 8,590,000 m³ in the same time period, with a potential annual harvest of 3.3 million m³. However, in recent years, the average harvest has been between 3.4 and 3.9 million m³ and has comprised approximately 55% softwood and 45% hardwood.

Table 1.10 Slovenia’s forest in numbers [8].

	Amount per year	
	2012/13	2014/15
Surface area of forested land (ha)	1.12 · 10 ⁶	1.18 · 10 ⁶
Of total land area (%)	58.4	58.3
Number of naturally occurring tree species	71	71
Growing stock (m ³)	337.8 · 10 ⁶	346.1 · 10 ⁶
Annual increment of growing stock (m ³)	8.42 · 10 ⁶	8.59 · 10 ⁶
Potential annual harvest, i.e. forest management plans (m ³)	5.75 · 10 ⁶	6.18 · 10 ⁶
Hardwood (m ³)	3.07 · 10 ⁶	3.35 · 10 ⁶
Softwood (m ³)	2.68 · 10 ⁶	2.84 · 10 ⁶

In addition to forests for roundwood production, Slovenia has two other type of forest: protected forests and forests with a special purpose, Figure 1.9. These forest types are defined in law by the “Regulation on protection forests and forests with a special purpose” [10].

Protection forests cover around 8% of the total forest area. In 2010, the area of protected forest covered 99,200 ha, which is 60% more than in 2000, Table 1.11.



Figure 1.9 Protected forests in Slovenia (in red) [9].

Table 1.11 Area of protected forests and natural reserves in Slovenia [9].

	Protected forest (1000 ha)	Forest reserves (1000 ha)
2000	62.2	10.5
2005	99.9	9.8
2007	9.6	9.6
2008	100.1	9.6
2009	99.7	9.6
2010	99.2	9.6

Managing the forests for sustainability (certified forest)

The first forest management plan in the territory that is now Slovenia was established by the Habsburgs in 1770 and the first measurement of the growing stock in all the Slovenian forests was made in 1953–1954. Since then, 10-year forest management plans have been regularly made for all Slovenian forests, regardless of ownership. Forest management plans in the region recognized selective management as early as 100 years ago, and in some cases avoided clear cutting as a harvesting method. In 1950, the law prohibited clear-cutting completely [11]. All trees to be cut in public forests are marked by professional staff of the Slovenian Forest Service, and in private forests this is done in cooperation with forest owners.

In December 2007, the General Assembly of the United Nations adopted the most widely used intergovernmental definition of Sustainable Forest Management (SFM): “SFM as a dynamic and evolving concept aims to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations”.

To promote the responsible management of forests and to prove that forests are well managed in accordance with strict environmental, social, and economic criteria, forests have been certified to the Forest Stewardship Council (FSC) and other certification schemes worldwide.

In Slovenia, 260,000 ha of forests are certified by the FSC system, which is at least one fifth of the complete forest area in Slovenia, where these are predominantly national forests (235,000 ha). The area according to the national certification scheme PEFC* for forests is gradually increasing and now encompasses 42,000 ha of privately owned forests.

Companies with Chain of Custody (CoC) certificates are dispersed over the whole wood supply chain, from forests to final products. Companies use the FSC and PEFC certificates for tracking wood predominantly as a marketing mechanism for export markets and compliance with green public procurement policies. The number of companies with the FSC or PEFC certificate for tracking certified wood (CoC) continues to increase and already exceeds 300 companies. Among these, over 90% have the FSC CoC certificates. Marketing channels for the PEFC certified products are also gaining strength (41 companies), and this has led to an increased interest in the PEFC CoC certificate [12, 13].

*PEFC = Programme for the Endorsement of Forest Certification

Cascade use of wood for sustainability

Cascading use is a strategy to use raw materials such as wood or other bio-based materials, in chronologically sequential steps, efficiently as possible for new materials and only to recover energy from them when it no longer is economical or technical possible for renewable use, Figure 1.10. The use of the same unit of wood for multiple successive applications will result in a gradual reduction of quality and particle size [14].

In the forest products industry, the waste hierarchy is presently underdeveloped and largely ignores the EU’s preferred option of maximizing the carbon storage potential of wooden materials by their reuse in solid form with subsequent down cycling of reclaimed wood in as many steps of a material cascade as possible [15].

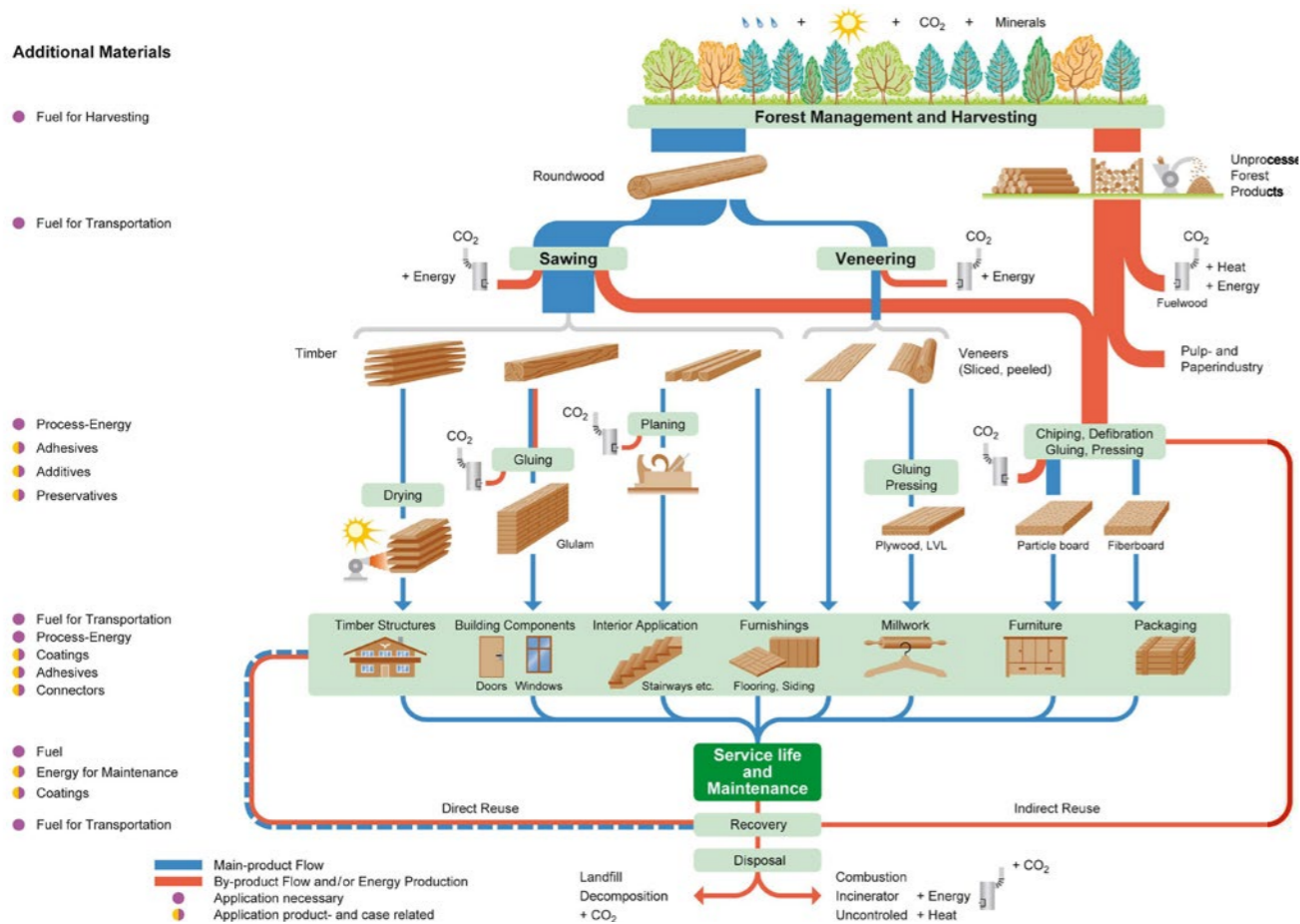


Figure 1.10 Cascade use of wood [14].

Slovenian primary wood products

25 years ago, the wood products industry employed 37,000 people, and together with the forestry sector this number was as large as 45,000 people. However, until the global economic crisis in 2008, the number of employees dropped to 20,000 and by 2010, the number has fallen below 14,000. Part of the reason for this decline was that, with independence, Slovenia lost a large part of the market to the states of former Yugoslavia, and for a few years this was the main reason for the contraction in the industry.

Despite its promising past, the downward trends in recent decades turned the wood sector into a non-profitable and low-added value sector where there was apparently no future. Consequently, the interest in occupations related to the industry waned, schools teaching sector-related subjects were closed and inevitably, a stagnation of nearly 20 years followed. However, this is now changing.

Forest products industry is considered to be the only Slovenian economic sector and product chain that has a sufficient quality of raw material; it is geographically dispersed; it has technologically

well-equipped manufacturing facilities; and a highly diversified market for its products. The companies that operate within the sector are diverse, i.e. Slovenia produces a full product range from mechanical and chemical processing to energy production, Figure 1.11. The mechanical branch comprises sawn timber, plywood and particleboard manufacture, and the fabrication of furniture and timber components for the construction industry. Pulp and paper, cardboard, and packaging materials are produced by the chemical branch. The production of biofuel from biomass uses waste and residues from the forestry and related industries [16].

The production of primary wood products in Slovenia from 2008 to 2014 is shown in Table 1.12. Production values include products that may immediately be consumed in the production of another product. This includes production from all sources within the country including public, private, and informal sources. It excludes the production of veneer that are used for plywood production. The production of primary wood products in Slovenia has not significantly changed in the past years. Despite this mild recovery after the economic crisis in 2008, production of particleboard and veneer decreased considerably. Significant decreases in production can also be identified in sawn timber of hardwood.

Table 1.12 Production of primary wood products in Slovenia in the years from 2008 to 2014 [17].

Product category	Production volume (m³)						
	2008	2009	2010	2011	2012	2013	2014
Chips and particles	150,000	118,473	82,000	82,000	105,000	170,000	310,000
Hardboard	0	0	0	0	0	0	0
Insulating board	15,057	1,679	0	0	0	0	0
MDF	177,000	150,000	110,000	120,000	130,000	125,000	130,000
Industrial roundwood (softwood)	26,202	44,178	52,492	63,060	41,294	41,970	113,627
Industrial roundwood (hardwood)	33,936	19,113	20,970	26,846	21,917	74,333	99,484
Particleboard	147,218	117,489	130,000	130,000	90,000	40,000	75,000
Plywood	70,000	103,222	100,000	81,000	67,000	66,000	70,000
Sawlogs + veneer logs (softwood)	1,385,903	1,213,078	1,179,884	1,297,112	1,389,607	1,428,923	1,814,659
Sawlogs + veneer logs (hardwood)	299,759	301,252	272,205	284,436	251,681	265,798	303,128
Sawn timber (softwood)	376,000	449,000	625,000	610,000	580,000	580,000	610,000
Sawn timber (hardwood)	108,000	76,000	135,000	93,000	80,000	80,000	90,000
Veneer	65,000	37,000	20,000	30,000	25,000	25,000	25,000

Table 1.13 shows the import of primary wood products from 2008 to 2014. Data for imports include products shipped into a country for domestic consumption or processing. They include imports for re-export, but exclude “in transit” shipments. It is evident that the import of softwood sawn timber increased considerably. Chips and wood particle imports have also increased in the past six years. Particleboard imports have decreased in recent years due to the downsizing of furniture production in Slovenia after 2008.

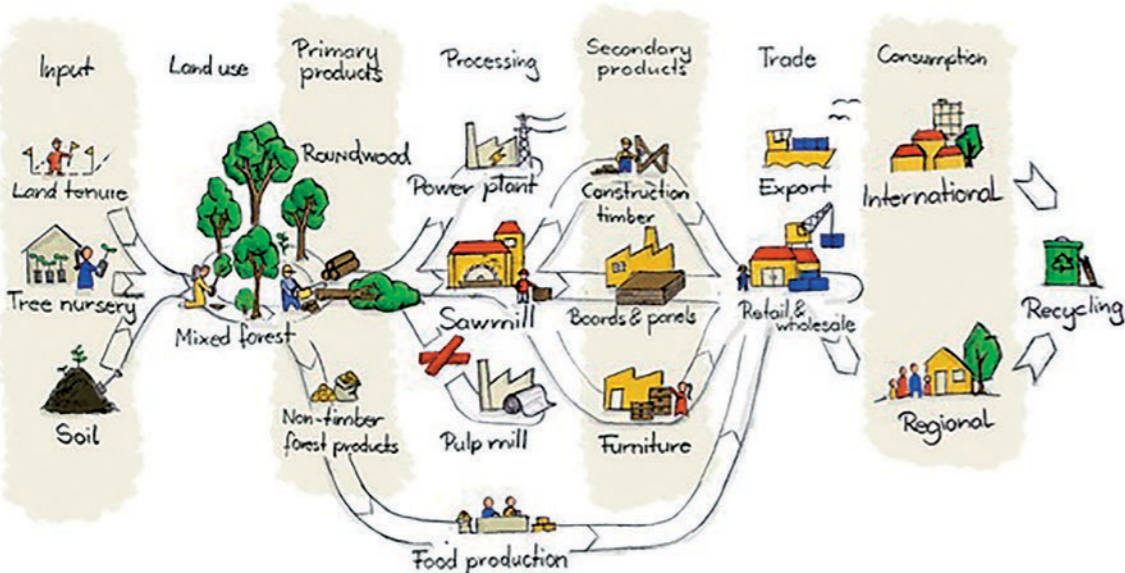


Figure 1.11 The forest products value chain of wood raw material from forestry, over land use, primary products, processing, secondary products, trade to consumption and recycling.

Table 1.13 Import of primary wood products to Slovenia from 2008 to 2014 [17].

Product category	Production volume (m³)						
	2008	2009	2010	2011	2012	2013	2014
Chips and particles	46,132	124,644	170,454	194,269	198,792	261,424	216,374
Hardboard	19,758	15,066	13,423	11,216	9,575	10,064	8,936
Industrial roundwood (softwood)	48,359	58,697	59,244	103,776	119,297	198,358	151,958
Industrial roundwood (hardwood)	108,838	102,050	132,714	140,552	84,007	127,743	138,485
Industrial roundwood (tropical hardwood)	3,084	2,723	1,556	1,301	1,206	1,147	1,206
Insulating board	4,064	3,711	3,752	4,802	4,141	3,959	4,250
MDF	39,081	30,457	36,666	37,093	37,006	41,121	32,134
Particle board	179,556	152,712	163,610	152,177	143,532	148,550	146,583
Plywood	22,796	18,036	22,898	22,250	21,228	20,827	30,006
Sawn timber (softwood)	810,823	940,648	873,639	726,957	922,066	997,619	813,615
Sawn timber (hardwood)	128,073	72,519	85,451	94,061	85,496	93,098	88,037
Veneer	13,969	9,550	9,657	9,100	8,514	9,767	9,553

Table 1.14 shows the export of primary wood products. Export data include products of domestic origin or manufacture shipped out of the country, and also includes re-exports and “in-transit” shipments. The export of primary wood products increased in recent years.

Table 1.14 Export of primary wood products from Slovenia from 2008 to 2014 [17].

Product category	Production volume (m³)						
	2008	2009	2010	2011	2012	2013	2014
Chips and particles	196,144	177,533	153,229	200,955	281,238	343,832	341,624
Hardboard	9,252	7,725	4,916	3,679	6,087	7,619	9,067
Industrial roundwood (softwood)	274,149	306,085	337,480	512,887	669,902	743,153	1,372,454
Industrial roundwood (hardwood)	201,375	200,779	228,137	295,400	358,392	404,983	600,742
Industrial roundwood (tropical hardwood)	0	0	0	0	0	0	0
Insulating board	19,421	1,004	157	218	364	478	164
MDF	94,012	94,202	114,048	114,880	104,079	119,672	127,846
Particle board	125,277	92,167	104,107	96,485	71,807	39,551	63,163
Plywood	93,029	78,081	73,293	67,712	52,193	47,946	53,990
Sawn timber (softwood)	944,170	1,002,819	1,012,493	910,967	1,079,148	1,036,080	942,632
Sawn timber (hardwood)	93,562	66,554	70,019	72,086	67,133	69,773	81,866
Veneer	29,317	19,974	18,312	21,326	17,904	18,891	19,631

The data given in Tables 1.12 to 1.14 include the following [16, 17, 18]:

Key wood products:

- Sawn timber
- Fibreboard of wood, but also from other ligneous materials
- Veneer for plywood, veneered panels and similar laminated panel materials
- Particleboard and similar panel materials of wood or other ligneous materials
- Joinery and carpentry
- Tableware and kitchenware of wood
- Wooden furniture for kitchens, living quarters and public institutions
- Wood marquetry and inlaid wood
- Wooden frames for paintings etc.
- Casks, barrels, vats, tubs, etc.
- Packaging materials
- Pre-fabricated timber houses

House Čurile

Slovenia

Photo: Miran Kambič

Industrial roundwood, is roundwood other than sawlogs, veneer logs, and pulpwood for the industrial use. It includes roundwood to be used for poles, piling, posts, fencing, pitprops, tanning, distillation, and match blocks, etc. It is reported in cubic meters of solid volume under bark (m³Sub).

Sawlogs and veneer logs, is roundwood that will be sawn lengthwise (or profiled) for the manufacture of sawn timber or railway sleepers (ties) or used for the production of veneer. It also includes roundwood (whether or not it is roughly squared) that will be used for shingle bolts and stave bolts, match billets and other special types of roundwood (e.g. burls and roots, etc.) used for veneer production. It is reported in cubic meters solid volume under bark (m³Sub).

Sawn timber, is wood that has been produced from both domestic and imported sawlogs, either by sawing lengthwise or by a profile-chipping process and that exceeds 6 mm in thickness. It includes boards, planks, beams, joists, rafters, scantlings, laths, boxboards, etc., and can be unplanned, planed, lenght-wise jointed, etc. It excludes sleepers, wooden flooring, moulding (sawn timber continuously shaped along any of its edges or faces, tongued, grooved, rebated, V-jointed, beaded, moulded, rounded or the like), and sawn timber produced by re-sawing previously sawn pieces. It is reported in cubic meters solid volume (m³).

Plywood, is boards manufactured by bonding together more than two veneer, where the grains of alternate veneer are crossed, generally at right angles. Products are core plywood or blockboard (plywood with a solid wood core, i.e. the central layer, generally thicker than the other plies consists of narrow boards, blocks or strips of wood placed side by side, which may or may not be glued together); cellular board (plywood with a core of cellular construction); and composite plywood (plywood with a core or certain layers made of material other than solid wood or veneers). It excludes laminated construction materials (e.g. LVL), where the grains of the veneer sheets generally run in the same direction. It is reported in cubic meters solid volume (m³).

Chips and particles, is wood that has been reduced to small pieces and is suitable for pulping, for particleboard and fibreboard production, for use as a fuel, or for other purposes. It excludes wood chips made directly in the forest from roundwood mainly used for the use in energy conversion. It is reported in cubic meters solid volume excluding bark (m³).

Particleboard, is an aggregate category that includes oriented strandboard (OSB), waferboard, and flaxboard. It excludes wood wool and other particle boards bonded together with inorganic binders. It is reported in cubic meters solid volume (m³).

Austria is the most important trade partner for Slovenian primary wood product, but Italy, Croatia, and Hungary are also important Slovenian trade partners. The majority of trade with Austria and Italy is export, while trade with Croatia and Hungary is mostly import, especially of roundwood.

The list of other countries, with which Slovenia trades primary wood products is changing every year. In 2014, in addition to trade with neighbouring countries, trading exceeded 10,000 m³ with Algeria, Bosnia and Herzegovina, the Czech Republic, Libya, Morocco, Saudi Arabia, Slovakia, and Tunisia [17]. The Growth of income from export and the share in net income from the sale are presented in Table 1.15.

Table 1.15 Growth of income from export and share in net income from the sale of the wood products 2014 [18].

Product category	Share of export (%)	Index 15/14	Incomes from the export (1,000 €)	Index 15/14
Sawn timber	31.5	91.8	57,765	113.4
Veneer and wood-based panels	70.5	99.3	133,303	108.0
Assembled parquet floors	28.3	96.0	110,284	135.1
Other carpentry and joinery	56.2	104.7	144,423	108.2
Wooden containers	20.2	80.5	5,161	70.9
Other products of wood	85.1	106.8	85,106	139.1
Manufacture of wood and wood products (mean):	56.4	101.4	536,042	113.1
Office and shop furniture	58.0	100.5	53,714	102.1
Kitchen furniture	56.9	105.2	24,319	112.7
Mattresses	7.3	137.7	264	148.5
Other furniture	35.8	95.2	52,480	106.1
Manufacture of furniture (mean):	45.8	98.3	130,237	105.6
Manufacture of wood and wood products and furniture (mean):	53.5	100.8	666,279	111.3

The geographic dispersion of import and export standard classification activities in 2014 is presented in Tables 1.16 and 1.17 [18].

Table 1.16 Geographic dispersion of export standard classification activities in 2014 [18].

Ranking	Manufacture of wood and wood products	Export (1,000€)	Manufacture of furniture	Export (1,000€)	Manufacture of wood and wood products & furniture	Export (1,000€)
1	Germany	110,993	Germany	30,447	Germany	141,440
2	Italy	88,441	Italy	22,021	Italy	110,462
3	Austria	65,157	Austria	18,745	Austria	83,902
4	Croatia	24,817	Croatia	14,868	Croatia	39,685
5	Switzerland	15,850	United Kingdom	5,926	Switzerland	17,621
6	France	12,609	Denmark	2,981	France	16,126
7	Slovakia	4,358	USA	6,837	United Kingdom	10,915
8	Czech Republic	3,427	France	3,517	USA	12,635
9	USA	5,798	Norway	hidden*	Denmark	6,307
10	United Kingdom	4,989	Belarus	hidden*	Slovakia	6,243

*Data is hidden because of data secrecy act.

Table 1.17 Geographic dispersion of import standard classification activities in 2014 [18].

Ranking	Manufacture of wood and wood products	Import (1,000 €)	Manufacture of furniture	Import (1,000€)	Manufacture of wood and wood products & furniture	Import (€1,000)
1	Austria	40,172	Italy	24,660	Italy	55,806
2	Germany	46,849	Germany	11,844	Germany	58,693
3	Italy	31,146	Austria	8,983	Austria	49,155
4	Croatia	24,036	Croatia	5,881	Croatia	29,916
5	China	9,056	Czech Republic	4,131	China	10,840
6	Serbia	6,606	China	1,783	Serbia	7,919
7	Hungary	4,694	Bosnia and Herzegovina	1,885	Czech Republic	9,042
8	Bosnia and Herzegovina	4,520	Slovakia	hidden*	Bosnia and Herzegovina	6,404
9	Czech Republic	4,911	Serbia	1,313	Hungary	5,134
10	Macedonia	hidden*	Estonia	hidden*	Macedonia	hidden*

*Data is hidden because of data secrecy act

Import and export of Slovenian wood processing industry in 2016, are shown in Figure 1.12.

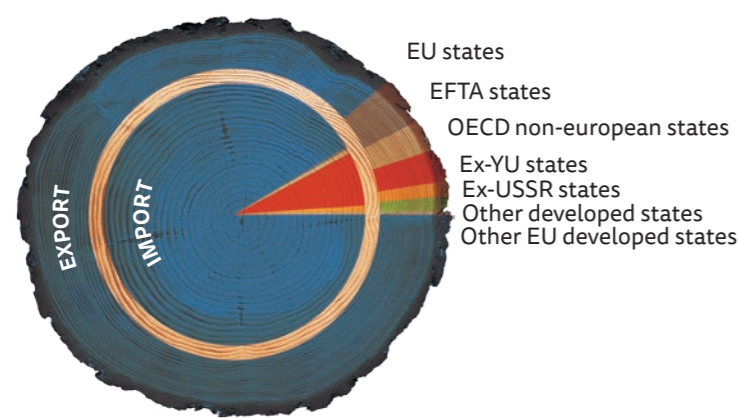


Figure 1.12 The shares of products exchange by economic groups.

Some data of employees, incomes, the processing business and the wood industry in 2015 are presented in Table 1.18 and the net profit/loss in the wood processing sector in 2015 compared with 2014 in Table 1.19 and Figure 1.13.

Table 1.18 Employees, incomes, the processing business and the wood industry in 2015 [18, 19].

Product category	Companies		Employees		Sales income		Assets	
	(No.)	(%) ²⁾	(No.)	(%)	(mill. €) ¹⁾	(%)	(1,000 €)	(%)
All economy	65,214	100	444,839	100	78,693	100	88,706	100
Manufacturing	7,879	12.1	163,597	36.8	24,416	31.0	22,258	25.1
Manufacture of wood and of wood products	561	0.9	6,190	1.39	755	1	666	0.75
Manufacture of furniture	377	0.6	3,622	0.81	285	0.36	280	0.32
Total for the manufacture of wood, wood products & furniture:	938	1.5	9,812	2.2	1,040	1.36	946	1.07

¹⁾ Net sale income (domestic and foregin market together). ²⁾ Shares are calculated for the whole economy

Table 1.19 Net profit/loss in the wood processing sector in 2015 compared with 2014 (in 1,000 €) [19].

Product category	Net profit		Net loss		Net profit/loss ± 15/14
	2014	2015	2014	2015	
Sawn timber	11,306	1,280	6,986	10,026	143.5
Veneer and wood-based panels	8,622	721	4,193	7,901	188.4
Assembled parquet floors	19	5	-34	14,796	-43.2
Other builders' carpentry and joinery	15,337	2,403	9,706	12,934	133.3
Wooden containers	894	129	758	765	100.9
Other products of wood	6,932	231	2,837	6,701	236.2
Manufacture of wood and wood products:	43,110	4,769	24,446	38,342	156.9
Office and shop furniture	3,357	1,159	-467	2,198	-470.9
Kitchen furniture	651	1,807	-1,976	-1,156	58.5
Mattresses	178	8	342	170	49.7
Other furniture	4,481	3,755	-2,662	726	-27.3
Manufacture of furniture:	8,667	6,730	-4,762	1,937	-40.7
Manufacture of wood, wood products and furniture:	51,777	11,499	19,683	40,279	116

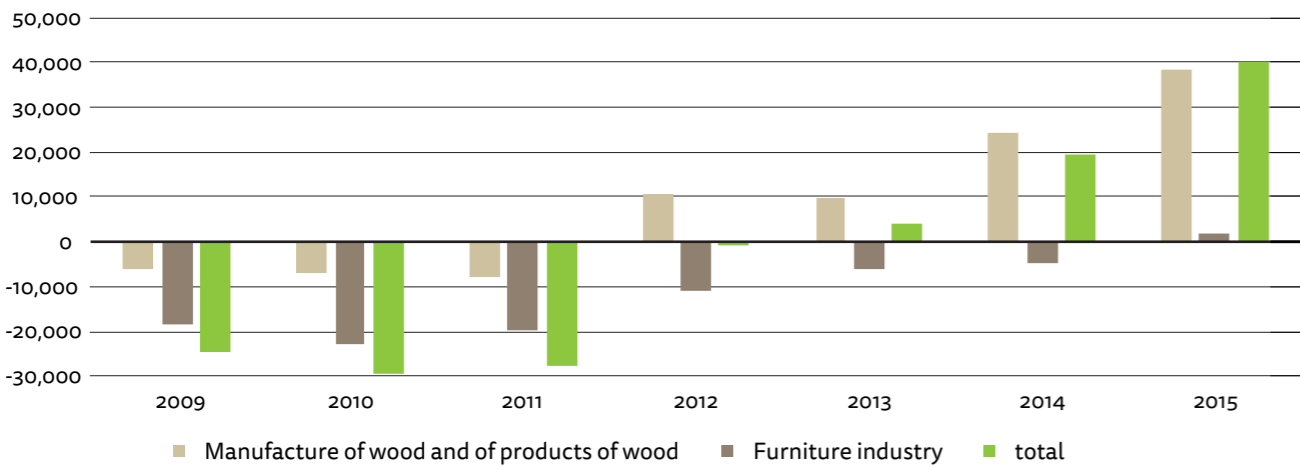


Figure 1.13 Trend of net profit/loss in the wood processing industry.

The cost of products, material and services and the cost of work and added value in the wood processing industry are further analysed in Table 1.20 and Figure 1.14 and the trend of added value per employee in Table 1.21.

Table 1.20 Costs of products, material and services, costs of work and added value in the wood processing industry [12].

Industry sector	Gross value added (GVA) per employee (€)											
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Manufacture of wood and wood products	17,500	18,100	19,900	22,600	22,000	22,200	23,700	26,000	28,000	29,500	32,366	34,804
Furniture industry	17,000	17,400	18,100	19,000	20,000	17,300	18,800	19,700	21,000	22,500	23,139	25,514
Total:	17,300	17,800	19,000	20,700	21,000	19,850	21,100	23,200	25,000	26,700	28,919	31,375

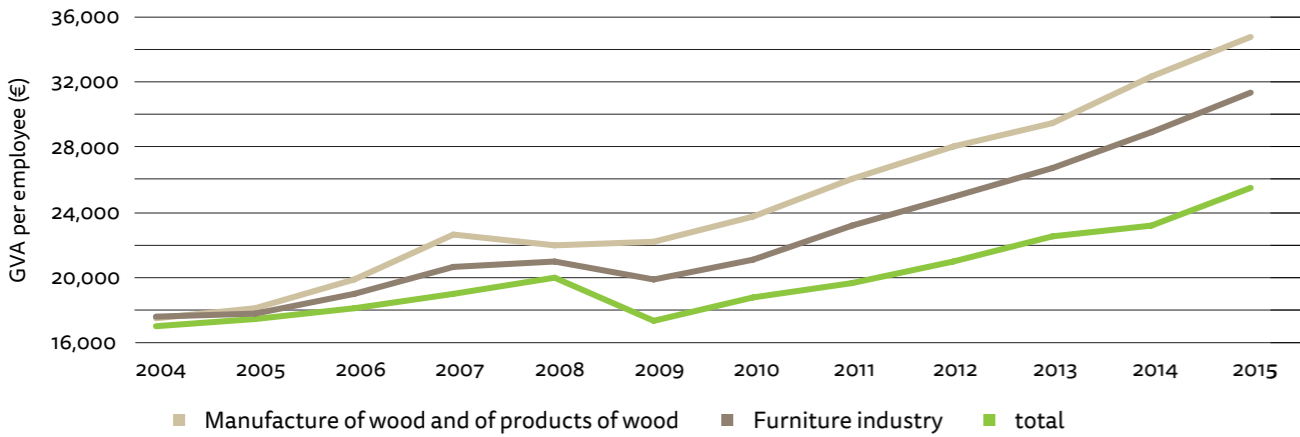


Figure 1.14 Added value per employee.

Table 1.21 Added value per employee (€)[18].

Product category	2013	2014	2015	Added value growth/emp.	Added value growth
Sawn timber	34,167	37,766	39,601	104.9	116.3
Veneer and wood-based panels	29,473	34,953	38,302	108.8	106.1
Assembled parquet floors	13,924	12,357	12,691	102.7	168.3
Other builders' carpentry and joinery	30,657	31,091	33,382	107.4	106.3
Wooden containers	22,789	24,684	23,039	93.3	101.6
Other products of wood	23,238	29,203	33,590	115.0	117.1
Manufacture of wood and of wood products:	29,575	32,366	34,804	107.5	109.4
Office and shop furniture	22,760	23,858	27,774	116.4	113.0
Kitchen furniture	20,108	18,745	20,917	111.6	110.8
Mattresses	34,061	26,950	32,680	88.4	97.3
Other furniture	22,494	23,676	25,469	107.9	109.7
Manufacture of furniture:	22,308	23,139	25,514	110.3	110.1
Manufacture of wood, wood products and furniture	26,797	28,919	31,375	108.5	109.6

Some economical indicators are presented Table 1.22 and production and foreign trade in Table 1.23.



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Table 1.22 Economic indicators for September 2016 [12].

	Autumn forecast of economic trends			
	2015	2016	2017	2018
GROSS DOMESTIC PRODUCT				
GDP real growth (%)	2.3	2.3	2.9	2.6
GDP in EUR m. current prices	38,570	40,004	41,416	42,885
EMPLOYMENT, EARNINGS AND PRODUCTIVITY				
Employment according to the SNA, growth (%)	1.1	1.9	1.4	1.1
Number of registered unemployed. annual average (in 1000)	112,7	103,4	94,5	88,1
Registered unemployment rate (%)	12.3	11.2	10.2	9.5
ILO unemployment rate (%)	9.0	8.2	7.5	6.8
Gross earnings per employee, real growth (%)	1.2	1.8	0.8	0.7
- private sector	1.0	1.4	0.6	0.9
- public sector	1.7	2.6	1.1	0.4
Labour productivity (GDP per employee), real growth (%)	1.2	0.4	1.5	1.5
EXTERNAL TRADE				
Exports of goods and services, real growth (%)	5.6	5.7	5.5	5.0
Exports of goods	5.3	5.9	5.8	5.1
Exports of services	6.5	4.9	4.3	4.4
Imports of goods and services, real growth (%)	4.6	5.3	5.9	5.1
Imports of goods	5.0	5.8	6.2	5.2
Imports of services	2.2	2.8	4.3	4.4
BALANCE OF PAYMENTS STATISTICS				
Current account BALANCE (EUR m)	1,998	2,700	2,326	2,272
- as a % of GDP	5.2	6.7	5.6	5.3
External balance of goods and services (million €)	3,517	4,157	3,980	3,981
- as a % of GDP	9.1	10.4	9.6	9.3
DOMESTIC DEMAND				
Domestic consumption. real growth (%)	1.0	2.3	2.0	1.7
of which:				
Private consumption	0.5	2.3	2.2	2.0
Government consumption	2.5	2.0	1.3	0.7
Gross fixed capital formation	1.0	-4.0	6.0	5.0
Change in inventories, contribution to GDP growth in pps	0.4	0.7	0.1	0.1
EXCHANGE RATES AND PRICES				
USD/EUR exchange rate	1,110	1,116	1,118	1,118
Real effective exchange rate - CPI deflator	-3.8	0.2	-0.3	0.0
Inflation (Dec/Dec)	-0.5	1.1	1.4	1.5
Inflation (annual average)	-0.5	0.1	1.4	1.5
Oil price (Brent crude, USD/barrel)	52.4	42.5	49.0	52.0

Source: IMAD (Institute of Macroeconomic Analysis and Development of the Republic of Slovenia). Autumn Forecast of Economic Trends. September 2016

Table 1.23 Production and foreign trade [12].

Product	Unit	Estimate			Forecast
		2014	2015	2016	2017
SAWLOGS AND VENEER LOGS (Softwood)					
Removals	1,000 m³	1,815	2,210	2,200	2,050
Imports	1,000 m³	14 #	13	10	10
Exports	1,000 m³	923 #	1,293	1,250	1,100
Apparent consumption	1,000 m³	906	930	960	960
SAWLOGS AND VENEER LOGS (Hardwood)					
Removals	1,000 m³	603	321	300	300
Imports	1,000 m³	61 #	47	52	50
Exports	1,000 m³	177 #	199	160	160
Apparent consumption	1,000 m³	187	169	192	190
of which tropical logs					
Imports	1,000 m³	1 #	1	1	1
Exports	1,000 m³	0 #	0	0	0
Net trade	1,000 m³	1	1	1	1
PULPWOOD (Softwood)					
Removals	1,000 m³	634	550	550	500
Imports	1,000 m³	138 #	168	130	140
Exports	1,000 m³	449 #	375	375	320
Apparent consumption	1,000 m³	323	343	305	320
PULPWOOD (Hardwood)					
Removals	1,000 m³	546	559	500	490
Imports	1,000 m³	79 #	65	70	70
Exports	1,000 m³	424 #	439	400	390
Apparent consumption	1,000 m³	201	185	170	170
OTHER INDUSTRIAL ROUNDWOOD (Softwood)					
Removals	1,000 m³	114	100	100	100
OTHER INDUSTRIAL ROUNDWOOD (Hardwood)					
Removals	1,000 m³	99	72	70	70
WOOD FUEL (Softwood)					
Removals	1,000 m³	202	203	200	200
WOOD FUEL (Hardwood)					
Removals	1,000 m³	1.387	1.040	1.000	1.000
WOOD CHIPS, PARTICLES AND RESIDUES					
Domestic supply	1,000 m³	950	1.100	1.100	1.100
Imports	1,000 m³	367	364	395	400
Exports	1,000 m³	647	732	750	740
Apparent consumption	1,000 m³	670	732	745	760

- The historical data are from the most recent Joint Forest Sector Questionnaire (blank) or the Timber Forecast Questionnaire

Product	Unit	Estimate			Forecast
		2014	2015	2016	2017
WOOD PELLETS					
Production	1,000 m.t.	100	110	115	120
Imports	1,000 m.t.	158	152	180	170
Exports	1,000 m.t.	110	122	145	130
Apparent consumption	1,000 m.t.	148	140	150	160
SAWN TIMBER (Softwood)					
Production	1,000 m³	610	625	645	645
Imports	1,000 m³	796	820	740	750
Exports	1,000 m³	967	897	800	800
Apparent consumption	1,000 m³	439	548	585	595
SAWN TIMBER (Hardwood)					
Production	1,000 m³	90	95	105	105
Imports	1,000 m³	92	108	115	115
Exports	1,000 m³	83	98	125	125
Apparent consumption	1,000 m³	99	105	95	95
of which tropical sawn timber					
Production	1,000 m³	0	0	0	0
Imports	1,000 m³	2	3	1	1
Exports	1,000 m³	1	1	0	0
Apparent consumption	1,000 m³	1	2	1	1
VENEER					
Production	1,000 m³	21	20	23	20
Imports	1,000 m³	12	13	12	12
Exports	1,000 m³	18	18	21	18
Apparent consumption	1,000 m³	14	15	14	14
of which. tropical veneer					
Production	1,000 m³	1	1	1	1
Imports	1,000 m³	0	0	0	0
Exports	1,000 m³	1	1	1	1
Apparent consumption	1,000 m³	0	0	0	0
PLYWOOD					
Production	1,000 m³	70	78	90	90
Imports	1,000 m³	30	34	43	45
Exports	1,000 m³	54	59	70	70
Apparent consumption	1,000 m³	46	53	63	65
of which. tropical plywood					
Production	1,000 m³	0	0	0	0
Imports	1,000 m³	7	8	10	10
Exports	1,000 m³	0	0	0	0
Apparent consumption	1,000 m³	7	8	10	10

Product	Unit	Estimate			Forecast
		2014	2015	2016	2017
PARTICLEBOARD (including OSB)					
Production	1,000 m³	75	65	0	0
Imports	1,000 m³	149	159	180	185
Exports	1,000 m³	63	59	9	5
Apparent consumption	1,000 m³	161	166	171	180
of which OSB					
Production	1,000 m³	0	0	0	0
Imports	1,000 m³	14	18	23	25
Exports	1,000 m³	0	1	1	1
Apparent consumption	1,000 m³	14	17	22	24
FIBREBOARD					
Production	1,000 m³	75	65	0	0
Imports	1,000 m³	149	159	180	185
Exports	1,000 m³	63	59	9	5
Apparent consumption	1,000 m³	161	166	171	180
Hardboard					
Production	1,000 m³	0	0	0	0
Imports	1,000 m³	9	9	11	11
Exports	1,000 m³	9	10	11	11
Apparent consumption	1,000 m³	0	-1	0	0
MDF/HDF					
Production	1,000 m³	130	130	130	130
Imports	1,000 m³	32	42	46	47
Exports	1,000 m³	128	131	134	134
Apparent consumption	1,000 m³	34	41	42	43
Other fibreboard					
Production	1,000 m³	0	0	0	0
Imports	1,000 m³	2	0	1	1
Exports	1,000 m³	0	0	0	0
Apparent consumption	1,000 m³	2	0	0	0
PULP					
Production	1,000 m.t.	80	90	80	85
Imports	1,000 m.t.	273	228	240	240
Exports	1,000 m.t.	30	9	3	3
Apparent consumption	1,000 m.t.	286	309	317	322
PAPER & PAPERBOARD					
Production	1,000 m.t.	716	721	730	740
Imports	1,000 m.t.	398	492	520	520
Exports	1,000 m.t.	586	608	635	635
Apparent consumption	1,000 m.t.	528	605	615	625

Wood products in Slovenian timber architecture

Wood has slowly been experiencing a rebirth as a contemporary construction material thanks to the general public's increasing environmental awareness and a greater interest for energy-efficient buildings in Slovenia. Several manufacturers of wood products and prefabricated timber house companies were established in the past decade, and an increasing number of designers and architects are now using this unique resource.

Wood is gaining popularity in the building industry and there are numerous opportunities for growth opening the way for woodworking companies to reduce roundwood or sawn timber exports and increase the added value while using biomass to generate the energy necessary for the woodworking processes. National and international projects in the area of wood material science and engineering in the forest-based value chains provide a platform for networking and integration of research activities, and Slovenian organisations and institutions have been highly pro-active participants.

The dominating methods of timber construction in Slovenia include panel construction, wood frame construction, and mass timber construction. Primary wood products used in these methods range from sawn timber to various Engineered Wood Products (EWPs).

Sawn timber has been losing its historical dominance and is still decreasing in importance, so numerous wood-fibre-based derivative materials such as engineered wood products (EWPs), wood-plastic composites, and other lightweight materials are becoming increasingly used. Buehlmann and Schuler [20] placed selected wood products on a product life cycle based on their global market share. The development phase includes lightweight panels, recycled and reusable wood products and straw boards; the expansion phase includes wood-plastic composites, LVL, and I-joists and the fast growing phase in OSB, MDF, and multi-plywood panels. Solid wood panels, glulam beams, and chipboard are placed in the saturation phase. Plywood is at the border between the saturation and declining phase. Products that are in the declining phase are block panels, hardboard panels (Masonite), and sawn timber. The global trends can be seen also in Slovenia.

In mass timber construction, glulam, CLT, LVL, and laminated strand lumber (LSL) are used for walls, floors, and roofs. In timber-frame structures, timber wall sections are assembled from studs and crossbars of various dimensions. For the exterior and interior faces various panel systems are used. Besides drywall panels and gypsum board, particleboard, wood-cement panels, wood fibreboard, OSB, and plywood are also used, Figure 1.15.



Figure 1.15 For interior faces various wood products are used - some examples of contemporary Slovenian architecture: (a) kindergarten Poljčane (MODULAR arhitekti d.o.o.), (b) house for the best years (Biro Matej Gašperič), (c) mountain view house (SoNo arhitekti), (d-e) wooden house (Studio Pikapulus, Jana Hladnik Tratnik), awarded for the best wood construction 2016.

It is important to raise the level of use of wood per inhabitant of Slovenia, but before architects and their clients “rediscover” wood, foreign markets remain essential for the earnings of local companies with exports accounting for nearly 51% of all revenue. Several regional programmes have been launched to provide support to the neighbouring countries: for the Bosnian wood processing industry to enter the international market, for the clusters within the framework of the *6-Region Strategic Joint Action Plan for Knowledge-based Regional Innovation*, and for the integration of national programmes in the area of wood material science and engineering in the forest-based value chains. Foreign investors can clinch deals with the regional woodworking companies through the channels which the Slovenian companies maintain with the members of the *Southeast and Central European Network of Forest-based Clusters*.

Recovering back the charge - turning the tables: Slovenian policy measures

After more than 20 years of steady decline, the Slovenian government and the forest products industry sector have recognized the country’s huge potential and have adopted concrete measures to improve the faltering situation in the industry.

The *Framework Program for the Transition to a Green Economy* together with the *Action plan for 2015–2016* (www.vlada.si/zeleno) is a document encouraging a structural and systematic process of knowledge integration and a realization of the agreement that a green economy is a long-term strategic guideline for Slovenia [21]. Green economy is an opportunity for the development of new green technologies, for the creation of new green jobs, for the more efficient management of natural resources and for the promotion and development of Slovenian know-how. The goals for the transition to a green economy according to the Ministry of the Environment and Spatial Planning (OPZG) are the following:

- Ensuring economic competitiveness
- Products and services with added value
- Increased self-sufficiency in energy
- Conservation and efficient management of natural resources
- Ensuring quality living and working environments
- Development and marketing of local know-how and services

The action lines for the transition to a green economy are the following:

- Sustainable management of resources
- Green economy growth
- New green jobs
- Encouraging the demand for green products and services
- Green budget reform
- Sustainable urban development
- Public sector green practices
- Education and training for a green economy

- Green practices in agriculture
- Data infrastructure

The Smart Specialization Strategy of Slovenia (S4), adopted in September 2015, is a strategy aiming:

- to strengthen the competitiveness of the economy by enhancing its innovation capacity,
- to diversify existing industries and service activities, and
- to boost the growth of new and fast-growing industries and enterprises.

The priority areas in the S4 strategy, which are directly related to the forest-wood value chains, are the following:

- Natural and traditional resources for the future: the objective pursued here within the field of application “Networks for the transition to a circular economy” is connecting stakeholders (business entities, educational and research system, non-governmental organisations, the state and individuals) into value chains according to the principle “economy of closed material cycles” and the development of new business models for the transition to a circular economy.
- Healthy working and living environment: the objective pursued here within the field of application “Smart buildings and homes, including wood chain” is the inter-sectoral networking and integration of the wood chain in the design of homes and working environment of the future by promoting research and innovation derived from traditional knowledge and skills of the use of wood and wood-compatible natural materials.

The benefits that may be imparted by ones built environment include:

- Reduced psychophysiological stress, the ability to cope better with stressful events and situations, and increased recovery from stress
- Reduced time away from work due to illness
- Increased connection with and care for the natural environment
- Support for increased social cohesion, and
- Support for more activity in typically sedentary lifestyles

A key development document in the field of energetics – the Slovenian Energy Concept (SEC) – is in the process of being drafted. Together with the Energy Act (EZ-1) it shall provide, on the basis of adopted international obligations, long-term goals for a reliable, sustainable and competitive energy supply for the period leading up to 2035 and 2055. The two umbrella goals of the SEC are:

- Reducing greenhouse gas emissions connected with the use of energy by at least 40% by 2035 compared to 1990 levels.
- Reducing greenhouse gas emissions connected with the use of energy for at least 80% until 2055 compared to 1990 levels.

The Eco Fund’s subsidies have had a positive effect on tax revenues, diminishing the grey economy, new green jobs, sustainable development of the construction planning and business, as well as the development of the use of strategic resources, such as wood. The Eco Fund plays a positive role in the development towards green society. The Eco Fund continually implements the following financial programmes:

- Loans to legal entities (municipalities and/or providers of public utility services, enterprises and other legal entities) and sole traders for investments in environmental infrastructure, environmentally sound technologies and products, energy efficiency, energy saving investments, and the use of renewable energy sources.
- Loans to individuals (households) for conversion from fossil fuels to renewable energy sources, energy-saving investments, investments in water-consumption reduction, connections to sewage system, small waste-water treatment plants, replacement of asbestos roofs.
- Grants to individuals (households) for investments in electric cars and for investments in residential buildings (energy efficiency and use of renewable energy sources).
- Grants to legal entities (municipalities and/or providers of public utility services, enterprises and other legal entities) for investments in electric cars and buses for public transport using compressed natural gas or biogas.
- Grants to municipalities for investments in buildings where public education takes place (schools, kindergartens, libraries etc.), newly constructed as low-energy and passive buildings or renovated in passive standard.

The 20-year concessions, awarded to most state-owned forests, expired on 30 June 2016. The Act on the Management of Forests Owned by the Republic of Slovenia was adopted this year. Based on this Act, a new corporate entity, Slovenski državni gozdovi d.o.o. (www.sidg.si), was established under the sole ownership of the Slovenia state, and the entity may not allocate or transfer its share in this company to another entity. The goal of this company is the management of forests owned by the Slovenian state in accordance with the principles of transparency, efficiency and responsibility while managing state-owned assets, and in accordance with the objectives of the National Forest Programme, applicable legislation and forest management plans.

A strategic council for wood, a body coordinating the Ministry of Agriculture, the Ministry for the Economy and the Chamber of Commerce has also been established with a clear responsibility for the steps needed to bring more funds into the sector. An important role is also played by the Slovenian export and development bank (SID bank). The responsibility for promoting Slovenian wood abroad is taken by the Slovenian Public Agency for Entrepreneurship (SPIRIT).

Whether such a highly organized, coordinated approach will bring the desired results will become apparent soon.



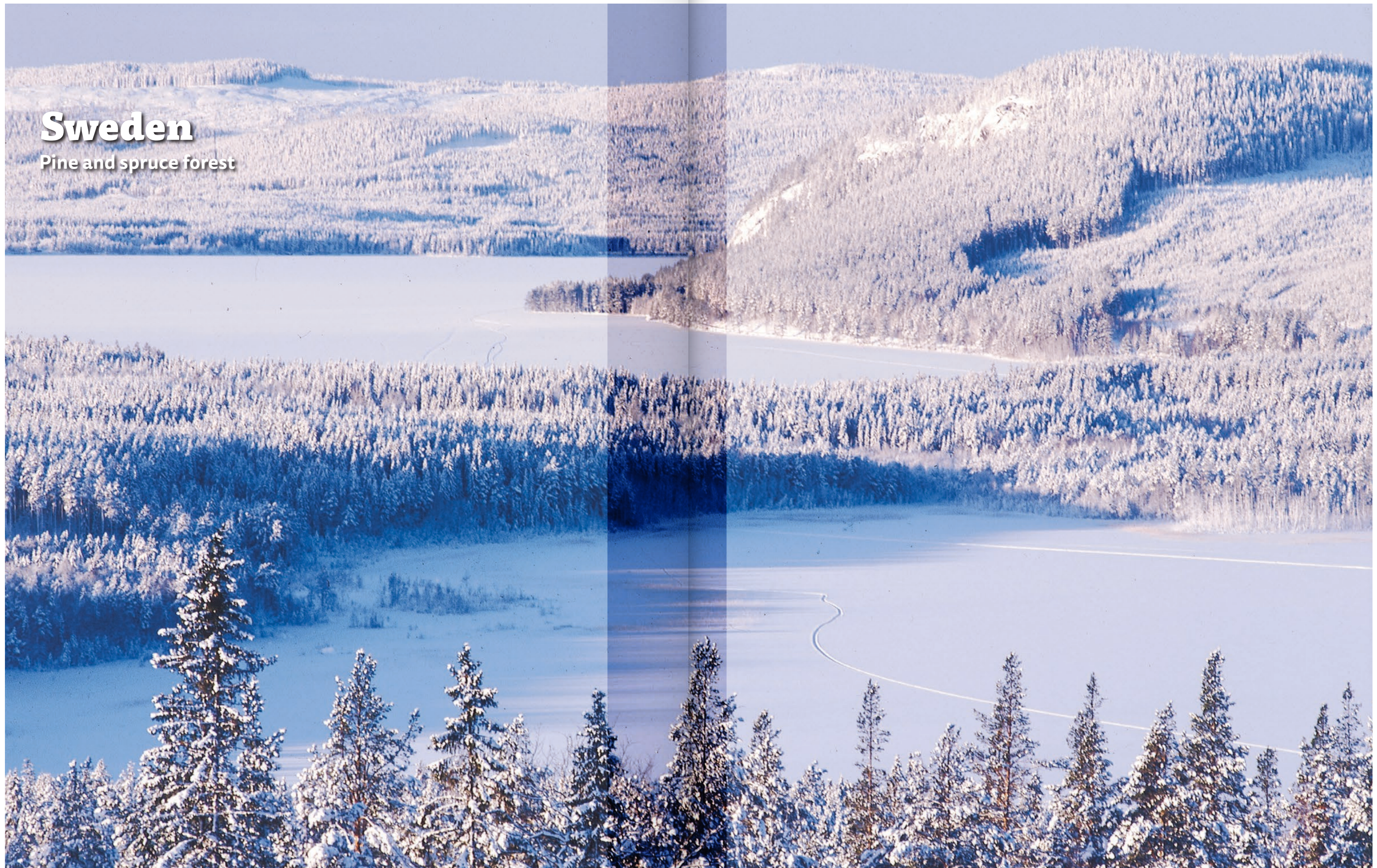
Furniture production

Slovenia



Sweden

Pine and spruce forest



Sweden

Sweden has a long tradition of sustainable forestry and industrial refining of the raw material which forestry can provide. This is also true of other countries, not least our neighbours, Finland and Norway [22].

The Swedish forest industry cluster has developed over a long time. Universities, technical colleges and research institutes play a central role in this cluster, in which the forest products industry collaborates, for example, with suppliers within the engineering, IT, chemical industries, and with the transport sector. Collaboration within the cluster also takes place in the supply chain, with packaging companies, the graphics art industry, construction companies, joiners, furniture makers and others. The bioenergy sector and companies working on bio-refining technology, i.e. the large-scale production of green materials, chemicals and fuels, ideally integrated into the pulp and paper mill for the optimum use of the various components of the raw material, are considered to be an important part of the cluster. Nowadays, the pulp and paper industry and the sawmill industry are the main consumers of the Swedish forest raw material, and they are thus the backbone of the forest products industry cluster.

There is no fundamental analysis of the creation of value in the different parts of the forest products industry cluster and how these cooperate, i.e. how the different parts of the forest products industry interact to create added value for the forest raw material. Such an analysis is complicated to carry out, but it could be a strategic tool for assessing future strategies for the industry. Examples of such an analysis could be to show how different branches of the industry contribute to the total added value of the forest raw material, or to show how the different branches of the industry interact and are dependent upon each other with regard to the availability of raw material, prices etc., and how this relationship may be affected by different future scenarios.

The purpose of this section is to introduce the historical and present-day importance for the Swedish economy of the forest resource, and to discuss in greater detail the specific role of the Swedish wood mechanical industry within the larger forest products industry cluster. Finally, different primary wood products from the Swedish wood mechanical industry are described in more detail.

The wood mechanical industry is here defined as that part of the forest products industry cluster which turns the forest raw material into sawn timber, boards, packaging, structural timber, furniture and interior fittings.

Swedish forest land

Sweden is the third largest country by area in Europe, and about 70% of it is forest, Figure 1.16. Naturally renewable, the forest is one of Sweden's most important resources, playing a central role in a sustainable society. The forest resource must be used to give economic value in a way that maintains productivity and biodiversity – renewal and growth without damaging other ecosystems.

Forest, forest products industry and primary wood products

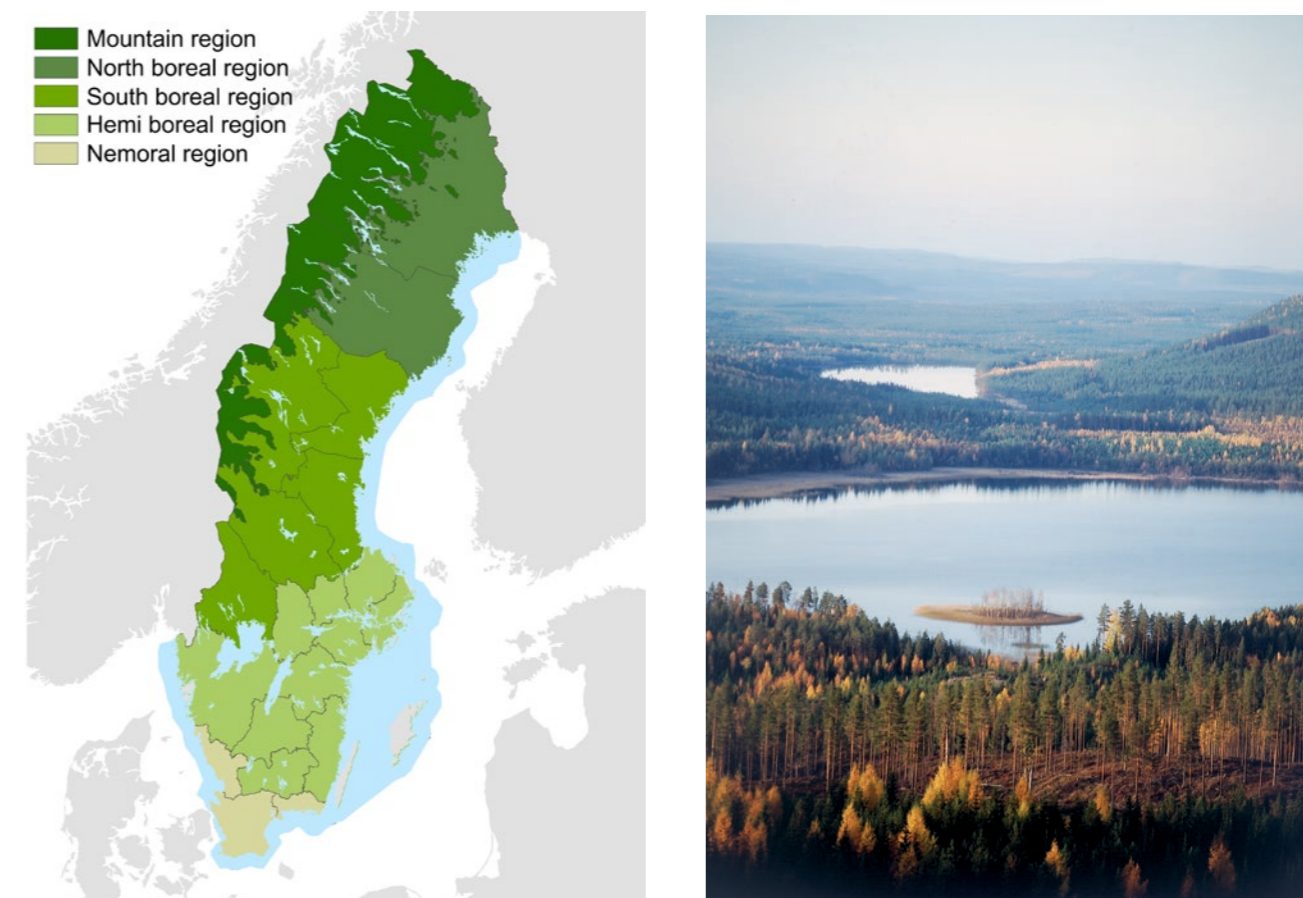


Figure 1.16 Forest land cover about 70% of the area of Sweden and the green regions in the map is land areas covered by 30-100% forest.

The total area of forest land in Sweden is 28.3 million ha but, according to the Swedish Forest Agency [23] and the National Forest Inventory [24], more than 25% of this forest land is exempt from forestry. The forests which are set aside for uses other than forestry can be divided into 4% which is set aside voluntarily by the forest owners, 14% which is subject to formal protection as unproductive forests by the Swedish law, and 7% which is subject to formal protection as e.g. national parks, nature reserves, nature protection areas, habitat protection areas and a 50-year nature conservation agreement [23]. The total area of forest land in Sweden not used for forestry, i.e. land exempted from forestry for some reason, is thus about 21 million ha.

Swedish forests are primarily boreal. The total standing volume is about 3,200 mill. m³, of which 42% is Norway spruce (*Picea abies*), 39% is Scots pine (*Pinus sylvestris*), 12% is birch (*Betula* spp.) and 7% consists of other deciduous trees.

The coniferous forests in Sweden are sometimes referred to as the western taiga. The rotation period of the forest varies from 65–110 years depending on the geographical location. In the southern, hemi-boreal parts of Sweden, a wide belt of mixed forest with coniferous and deciduous trees is found. The southernmost parts are nemoral and were thus originally covered with deciduous forests.

Ownership structure

Half of Sweden’s forests are owned by private individuals, 25% by large forest companies and 25% by the state, the Church of Sweden, and other public organizations, Figure 1.17.

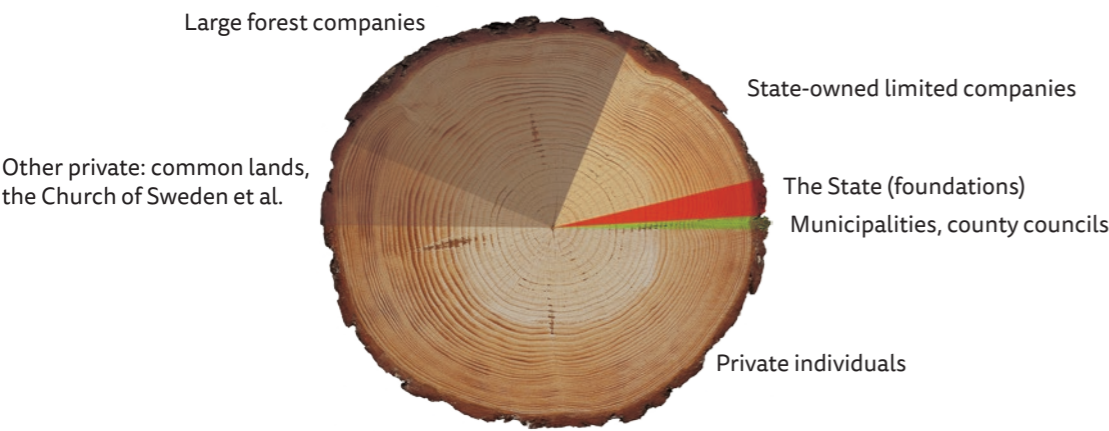


Figure 1.17 The ownership structure of the Swedish land.

Most of the mountain forest is state-owned, and it is to a large extent protected from forestry. The state-owned company *Sveaskog* is Sweden’s largest forest owner, with approximately 15% of the productive forest land, Table 1.24. The average size of a privately owned forest is roughly 50 ha. In total, there are about 350,000 private forest owners in Sweden, of whom 70% live on their properties. The collective value of the private forest-owner holdings is of the order of € 70-80 billion [24].

Table 1.24 The largest forest owners in Sweden (“Skog” is Swedish for forest) [24].

Forest owner	Productive forest area (Mill. ha)
Sveaskog Ltd	3.40
Bergvik Skog Ltd	1.99
SCA Skog Ltd	1.91
Holmen Skog Ltd	1.00
The National Property Board Sweden (SFV)	0.88
The Church of Sweden	0.40
The Swedish Fortification Agency	0.10
Persson Invest Skog Ltd	0.06
Uppsala University	0.04
Boxholms Skogar Ltd	0.04
The Swedish Forest Society	0.03

Managing the forests for sustainability

Since the 1930’s, the total standing volume of Swedish forests has increased by about 80%. The fact that the forest volume is currently increasing faster than at the beginning of the 20th century can be explained by changes in land use and improved forest management. The annual growth increment is about 120 million m³f, and around 85 million m³ of forest is felled annually and is used as industrial raw material. Each year, the volume of forest thus increases by about 35 million m³f (net annual increment), Figure 1.18.

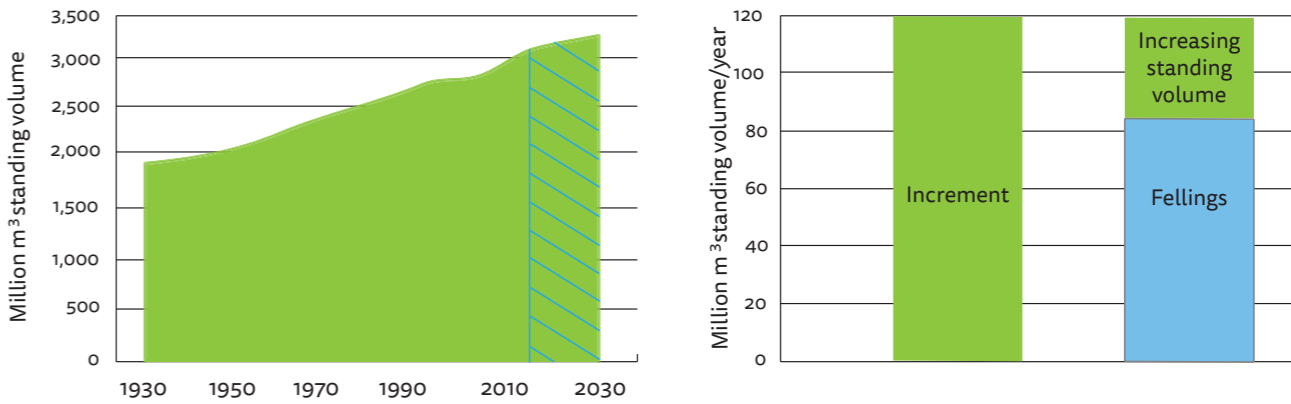


Figure 1.18 The increase in standing forest volume in Sweden since 1930 (left), and annual forest increment and felling (right).

Sustainable forest management is not just about preserving the quantity of forests for future generations, it is also about respecting the biological diversity of the forests, the ecology of the species living within it, and the communities affected by the forests. Sustainable forest management will, in other words, maintain the balance between economic wood production and respecting wildlife and vegetation, outdoor recreation, employment and local interests.

Already in 1903, Sweden introduced legislation that limited the amount of forest that could be harvested, and imposed an obligation on land owners to carry out regeneration after felling, contributing to sustainable management. Each year 170,000 ha are planted with some 370 million seedlings, and natural regeneration occurs in about 50,000 ha. The Swedish Forest Agency continuously monitors the forest regeneration. Sustainable forestry ensures an increase in the stock of growing wood, i.e. for each tree that is cut down at least two new ones are planted. Forest policy places equal emphasis on environment and wood production. The Swedish forest products industry knows that its future is linked to the protection and expansion of its forests. This, in combination with strong, effective legislation, ensures that more trees are planted than are harvested.

Swedish forest management is moving towards methods that enhance natural processes and produce forest structures which are environmentally appropriate, socially beneficial and economically valuable. Site-specific forestry takes into consideration the particular conditions of the individual site. This ensures greater variety and minimizes negative effects on animal and plant life. Major resources are being committed to conservation, education and development. The forest

worker of today is a skilled and environmentally conscious professional. Protected zones are left untouched on the banks of waterways, old trees are saved and dead wood is left in the forest. One consequence of this awareness is that large-scale clear-cutting is almost entirely abandoned today. It is estimated that the large industrial forest enterprises now leave some 10% of the potential harvest standing for ecological reasons.

The demand from customers and consumers for eco-friendly production of forest products has led to new strategies in the forestry sector. The forestry sector is well aware that caring for the environment has become a serious economic issue. Nowadays, suppliers of forest products have problems selling their products if they cannot demonstrate that the wood is coming from sustainable forestry. Through forest certification, the suppliers can demonstrate a commitment to the environment that end-users can have full confidence. Certification is usually verification from an independent third party that a product is in accordance with the description. Forest certification is voluntary and is an addition to national forest policies. There are two main schemes in Sweden: PEFC (Programme for the Endorsement of Forest Certification) and FSC (Forest Stewardship Council). In 2016, about 23 million ha of forest land were certified, Figure 1.19.

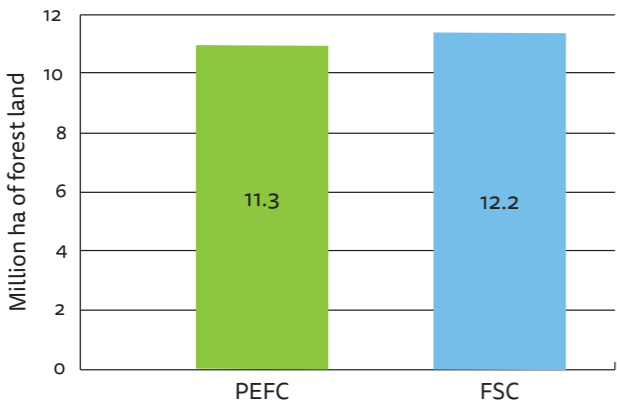


Figure 1.19 Certified forest land in Sweden in 2016. PEFC - Programme for the Endorsement of Forest Certification schemes, FSC - Forest Stewardship Council. Note that some forest land is certified in accordance with both PEFC and FSC.

The Swedish forest products industry

The forest products industry cluster is very complex and the composition of the companies is extremely heterogeneous. The companies differ in size and profitability, have different raw-material bases for their production and operate on different sectors of the market. A common factor is however that the companies are strongly dependent on each other for their survival. The cluster can be subdivided into six industrial branches with relatively similar conditions:

- 1) Industrial forest owners, as well as the private forestry sector, provide the industries with raw material, and the success of the industry on the market is decisive for the value of the forest which they own. A profitable forestry industry is also a precondition for Sweden's ability to

carry out extensive environmental conservancy measures. The forest raw material is delivered primarily to the sawmills and pulp mills.

- 2) The sawmills refine the most valuable parts the tree and are therefore responsible for 70-80% of the forest owners' profits. One third of the logs which are sawn become chips which are a raw material for the pulp industry (25% of the total chip requirement of the pulp industry comes from the sawmills). Two thirds of the sawn timber is exported without further refinement on the global market at extremely competitive prices. In general, over an economic cycle, the profitability of the sawmills is low. Global competition has forced the Swedish sawmills to become world-leaders in terms of productivity and quality, but the competition in these fields is razor-sharp and the sawmills must take a large share of the technological development taking place within the wood mechanical sector in order to survive. A positive feature of this development is that heavy work tasks have disappeared. In addition to continuing technical development, material and product developments, often in cooperation with small independent companies, will be important tools with which to meet the future competition.
- 3) Forestry waste and sawmill chips provide the raw material base for the pulp and paper industry. The raw material price is low and contributes only marginally to the profitability of the forest owners, but it can be decisive for whether or not the sawmills show a positive result. About 90% of the production goes to export, but the products may nevertheless be seen largely as highly refined (specialty pulps, carton board, diapers etc.). Profitability over an economic cycle has historically been high. A comprehensive restructuring of both the Swedish and the international pulp and paper industries is currently taking place, primarily because the demand for newsprint has drastically declined during recent years, and because of the competition from cheap raw materials from tree plantations in regions where the cycle from planting to felling can be as short as 10-15 years.
- 4) The board industry is of marginal importance in Sweden, because board materials are globally a bulk product with low added value commanding a very low price. The quality of the raw material is of little importance for the quality of the final product, and this means that rapidly growing raw materials with a growth cycle of 15-20 years from plantations are preferred over slowly growing Swedish tree species. The profitability is also affected by the distance to the final market. The raw material base is the same as that of the pulp industry, and this means that if a large-scale board industry is to be established in e.g. northern Sweden, it must be integrated with an extensive further refinement towards the end-use consumer products.
- 5) The profitability of the sector of the energy conversion industry that bases its production on wood as raw material is totally dependent on the energy content and cost of the raw material, and the price which the industry can receive for the energy which it produces. The raw material base is currently forest waste (in Sweden so-called GROT) and, however to a low extent, shavings from the timber industry at a much lower price, and the profitability is currently very mediocre. A scenario with a steadily increasing price for energy would however increase the ability of the industry to pay for its raw material, and this would have a direct effect on the raw material costs for the pulp and board industries, and indirectly on the costs for the sawmills. An increase in the production of energy based upon wood as fuel at the expense of the manufacture of products with a considerably longer life (e.g. sawn timber for houses, fittings and furniture) would be disastrous from a sustainability viewpoint.

- 6) The wood manufacturing industry, i.e. the wood mechanical industry excluding sawmills and board mills, bases its production primarily on timber from Swedish sawmills. It utilises one third of the sawn timber produced by the sawmills for the manufacture of products with in many cases a high added value. The link with the technical development of the sawmills is strong, but the companies are in general small or medium-sized enterprises. The fundamental problems facing this part of the wood mechanical industry are the shrinking local market, the low level of education at all levels in the companies, and the low profitability and thus poor capital generation, which means that the companies are finding it difficult to escape from the downward spiral and to expand into the global market. As a consequence, the majority of the wood manufacturing companies are gradually losing their competitive strength. Within 10-20 years, they will probably no longer exist and will probably not have been replaced unless clear measures are taken. The disappearance of the wood manufacturing industries would be a disaster for the Swedish sawmills.

In summary, it can be said that each of these industrial branches is finding it difficult to stand alone, i.e. the profitability of the Swedish forest products industry is dependent on a profitable and viable value-adding industry where the sawmills are responsible for the greater part of the forestry companies' financial profits. The sawmills are indeed strongly export-oriented but the domestic wood manufacturing industries are decisive not only for their profitability but also for the ability of the sawmills to develop new technology, new quality ranges and new products. Without the ability to dispose of by-products on the domestic market, i.e. chips to the pulp industry and shavings to the board industry or for energy conversion, the sawmills would hardly be able to show any profit at all. For their long-term viability, the pulp mills, the board industry and the energy-conversion industry are totally dependent on the cheap raw material derived from the forests and the sawmills. The cost of this raw material can be kept low as long as the sawmills are able to pay a good price for the roundwood. If this picture changes, there is a clear risk that large parts of the forest products industry will be forced to close down or change direction of production. The wood manufacturing industry is strongly linked to the sawmill production and it is in many cases a driving force for the development of sawmill technology and products. The carpentry and joinery sectors have to a great extent built up their activities on the basis of local raw material from the sawmills and their products are largely sold on the domestic market. For the wood mechanical sector there is a clear value chain consisting of both small and large actors in the sawmills, component-manufacturing, wood manufacturing and timber building industries. If the Swedish forest products industry is to survive, an increased competitiveness is required at all levels in this cluster.

As a consequence of the increasing competition from new and traditional industries based on renewable raw materials, the forest resources must be considered limited. There are forecasts which suggest that already by the year 2020 the consumption of wood in Europe can be as large as the total European annual forest increment [25]. According to the report "Innovating for Sustainable Growth: A Bio-economy for Europe", Europe needs to radically change its production, consumption, processing, storage, recycling and disposal of its resources. Bio-economy is considered to be one of the most important factors for a smart and green expansion in Europe. The forest-based sector's strategic research and innovation agenda for 2020 and Horizons Vision 2030 see the forest products industry as an important actor in the creation of a bio-based society.

In EU, measures which seek to improve the sustainability of resource utilisation are being discussed. EU's policies affect and regulate the current research, development and marketing

within EU. The most important policies which directly affect the forest-based sector are EU's strategy for sustainable development: Sustainable Development Strategy (SDS) [26], the EU Roadmap 2050 [27], and Directive 2008/98/EC—the recycling society directive [28]. The forest-based sector can contribute greatly to the EU commission's ambitious goal for a reduction of CO₂-emissions, i.e. a reduction by 80% by the year 2050 (Roadmap 2050), with the help of innovative production technology, less energy, an increased recycling of wood products, and the re-use and utilisation of lateral flows. The need to reduce the consumption of energy in the whole life-cycle of a building is an indication of the role which wood can play in the building sector.

A historical review

The exploitation of the forest as raw material began in the 16th and 17th centuries when tar was extracted from the forest raw material and exported in large quantities to the Dutch ship-builders. A by-product from the production of tar was charcoal, and potash – extracted from trees for the manufacture of caustic lye and soft soap – was another product that was sold in relatively large amounts to foreign customers. During the 17th century, pig iron was a large export product and this meant that the production of charcoal increased, since charcoal was essential for the high quality of the Swedish pig iron [29].

In the middle of the 19th century, the export of sawn timber increased rapidly for several reasons: an increased international need for sawn timber linked in the first place to Western Europe's economic expansion; a considerable easing of trade both in Sweden and abroad; problems in meeting the rapidly growing demand by Norway which had dominated the export of sawn and hewn timber from Scandinavia; the introduction of steam power for the saws which made it easier to start a sawmill away from waterfalls; the development of a company structure which made it easier to finance the expense of a sawmill installation; forest purchase and the development of a logistic infrastructure particularly rivers for log driving [30]. In the first half of the 19th century, the sawmills had begun to develop from small-scale businesses into an industrial activity on a larger scale [31]. In the 1840s, with the introduction of steam power for the operation of sawmills the volumes of sawn timber produced and consequently also the volumes exported increased. In the period from 1835 to 1870, the volumes produced increased from ca. 370,000 m³ to 3,500,000 m³ [32] and export from 190,000 m³ to 2,300,000 m³ [33, 34]. The growth of the pulp industry in the latter part of the 19th century led to an increasing opportunity to use the residues from sawing, and also the more slender tops of the trees, and this meant that the whole tree was industrially useful and that the pulp mills complemented the sawmills in an economically favourable manner. Over a period of twenty years around 1900, the annual production of pulp increased tenfold from ca. 90,000 ton to 900,000 ton [35]. During the 40 years prior to this (1870-1910), the sawmills had doubled their production and the export of sawn timber [33]. In the early part of the 20th century it was discovered that wood fibre could be used for the manufacture of so-called artificial silk from viscose pulp. During the 1930's, the procedures were developed so that pure cellulose could replace cotton for various purposes, including celluloid, Cellophane film, printing ink, turpentine, explosives, films, plastics and silk stockings.

During the Second World War, the exports of sawn timber, pulp and paper dropped, but the rationing of food and other necessities led to new innovations based upon wood fibres [33]. Cellulose feed became an emergency feed for cattle and horses. The manufacture of viscose pulp to replace textiles expanded and the aperitif before dinner contained alcohol from trees.



After the Second World War, many of the chemical products based on wood fibres were replaced by oil-based products and as a consequence wood chemistry research and development decreased, but the manufacture of paper pulp expanded and sawn timber maintained its position, although the profitability, in real terms, steadily decreased during the second half of the 20th century. The price of roundwood dropped at the same rate from the 1950s until today, but this was compensated for by cost reductions mainly through technology development for efficient harvesting. As a result, the net value (profit after cost for silviculture, capital costs of land etc.) to the forest owner has been maintained. With continuing pressure on prices in many mature forest products and a stagnation of the productivity increase in forestry during the most recent years [36], there is now a significant risk that even the net value from forestry will fall.

The importance of the forest products industry sector for the Swedish economy

The forest products industry plays a major role in the Swedish economy, accounting for between 9 and 12% of Swedish industry’s total employment, exports, sales and refinement value. The forest products industry account for nearly 3% of the Swedish gross domestic product (GDP), which is one of the highest shares in the world, Table 1.25.

Table 1.25 *The forest products industry share of the gross domestic product (GDP) in some countries and regions in 2011 [37].*

Country	Share of GDP (%)
Latvia	6.5
Finland	4.3
Estonia	4.3
Sweden	2.9
Lithuania	2.4
Austria	1.9
Slovenia	1.8
Czech Republic	1.8
Bosnia and Herzegovina	1.6
Canada	1.2
Belarus	1.1
Europe	0.9
Russian Federation	0.8
North America	0.7

The net annual exports (difference between export and import values) amount to more than € 10 billion. During the last fifteen years, the forest products industry has been responsible for 10-12% of the total Swedish exports, but if one takes into consideration what the company’s also import and calculates the net exports, the forest products industries have historically been responsible for an impressive 50-75% of the total Swedish exports, as shown in Figure 1.20 [39]. An interesting phenomenon was noticed in the financial crisis of 2008-2009 when the net export of the Swedish forest products industries managed to exceed 100%, because other industries had larger imports

than exports and this had a negative effect on the net export figures. The conclusion was that the forest products industries, admittedly with the help of a weak currency, saved the Swedish economic growth during the crisis years and not only managed to maintain their exports but even increased them [40].

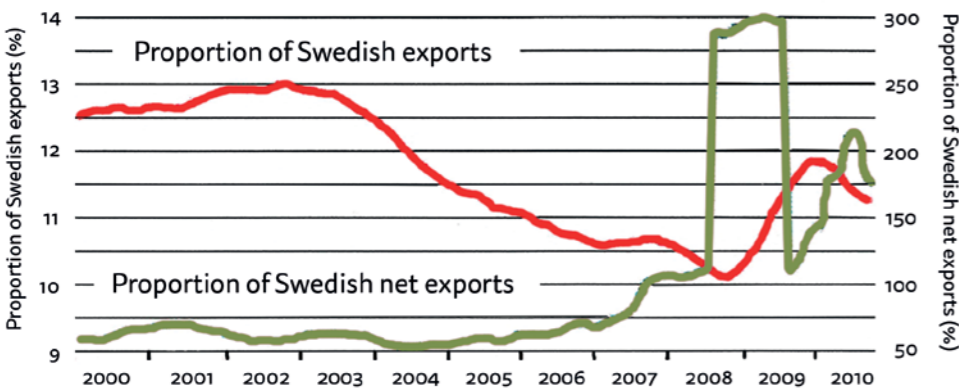


Figure 1.20 Forest products as a proportion (%) of Swedish exports and of Swedish net exports 2000-2010 [39, 40].

The forest products industry is heavily export-oriented, and as the raw material is mostly domestic and imports of forest products industry products are relatively small, this means that the forest products industry makes a significant contribution to Sweden’s trade balance. Of the pulp and paper production, close to 90% is exported, and the corresponding figure for sawn timber is almost 70% [22]. Although Sweden today has only about 1% of the world’s forest land, it is the second largest exporter of forest-industry products with a total annual value of approximately € 13 billion. Sweden is today the world’s third largest combined exporter of paper, pulp and sawn timber, Figure 1.21. For pulp Sweden is ranked No. 5, for paper No. 3, and for sawn timber No. 3. In Europe, the Swedish pulp and paper industry and the sawmill industry are the biggest producers after Germany. As much as a quarter of the paper pulp consumed in Europe is manufactured in Sweden. Of the EU countries’ consumption of sawn timber, 15% is produced in Sweden, and the corresponding figure for paper is 10%. Of Sweden’s exports, about 20% of pulp and paper and 35% of sawn timber went to countries outside the EU.

Nearly 80,000 employees work in the forest products industry and, including indirect employment by contractors and subcontractors, the total is nearly 200,000 employees, chiefly in the sparsely populated areas [39]. The forest products industry invests approximately € 1 billion annually [22]. At present, the base for the entire industry is the profitable annual extraction of approximately 85 million m³ of biomass in various forms from Swedish forests.

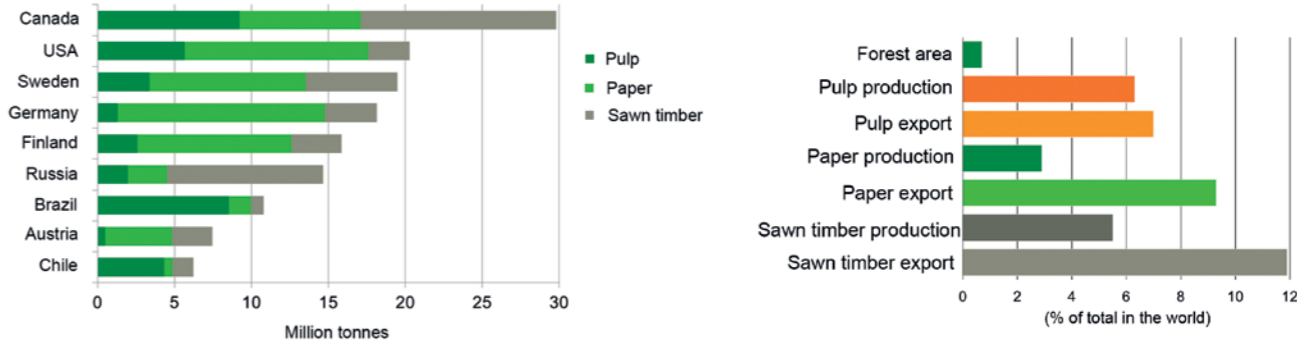


Figure 1.21 The relationship between the Swedish forest products industry and the forestry products industries in other countries year 2012. The world leading export countries of pulp, paper and sawn timber (left). Sweden’s share of the world’s total forest area, and of the production and export of pulp, paper and sawn timber (right). (Based on data from Confederation of European Paper Industries (CEPI), Producer price index (PPI), and Food and Agriculture Organization of the United Nations (FAO).

For what is the Swedish forest used today?

Figure 1.22 shows how the volume of annually felled forest is distributed and used by Swedish industries. The net import of 5 million m³Sub roundwood to Sweden is also included. The figures presented represent a “normal year” during the last decade.

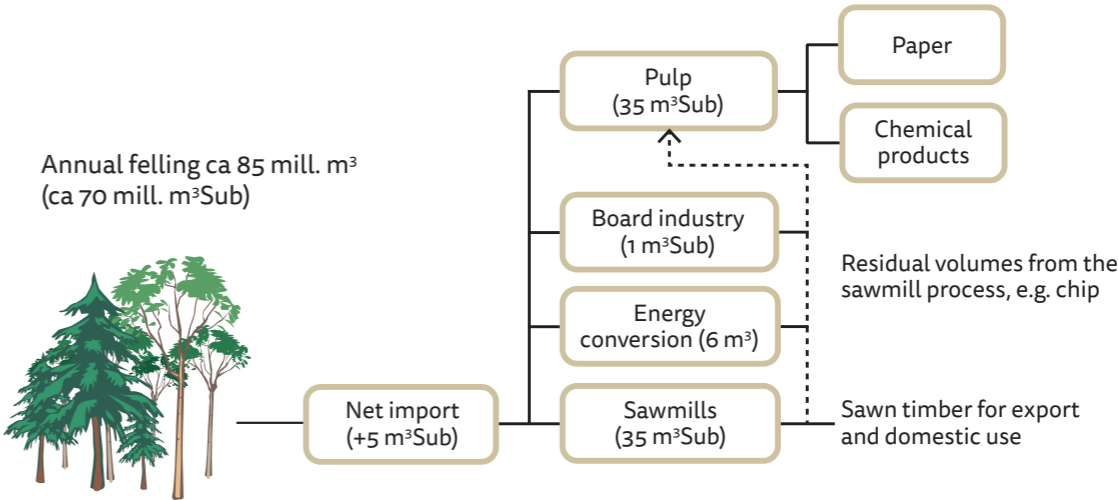


Figure 1.22 The use of roundwood from the Swedish forest: the product flows (volumes in million cubic metre solid wood exclusive bark (m³Sub) except for the energy conversion assortment where the volume of bark, branches etc. is included [41].

The pulp and paper industry and the sawmill industry each consume an annual volume of 35 million m³Sub of forest raw material. These volumes come directly from the forest, i.e. the roundwood has not been processed by any other industry. The board industry consumes less than 1 million m³Sub, and the energy conversion industry 6 million m³. The board industry is constantly decreasing in volume: In 1980, 32 mills produced 1.6 million m³ of boards and in 2013, there were 5 mills producing 0.6 million m³ [39]. The sawmills are also a secondary supplier of raw material (chips and sawdust from the sawmill process) primarily to the pulp and paper industry, but also to some extent to the board and energy conversion industries. This volume is annually about 18 million m³.

Figure 1.23 show the output from the forest products industry of sawn timber, pulp, and energy. The distribution of roundwood to the sawmill industry, the pulp and paper industry and to the energy conversion industry and the relocation of the wood raw material within these primary processes are also shown. If this relocation of wood is taken into account, on average in Sweden roughly 20% of the felled wood becomes sawn timber including a small volume of various types of board products, 36% become pulp mainly for papermaking, and 44% (including branches and tops) is used for energy conversion in thermal heating plants, industries and private homes.

Although a large proportion of the wood becomes fuel or paper, it is nevertheless the roundwood which passes through the sawmills which gives the forest owner the greatest income. Thörnqvist [42] has shown that at the beginning of the 21st century, the sawmills were responsible for 82% of the profits to the forest owners in southern Sweden, the pulp industry for 18% and the energy conversion industry for less than 1%. Thörnqvist suggested that, if corresponding estimates of the forest owner's profits were made in northern Sweden, the pulpwood share would probably be slightly larger, due to the different relations to the forest that apply in northern Sweden and to price differences in different parts of the country.

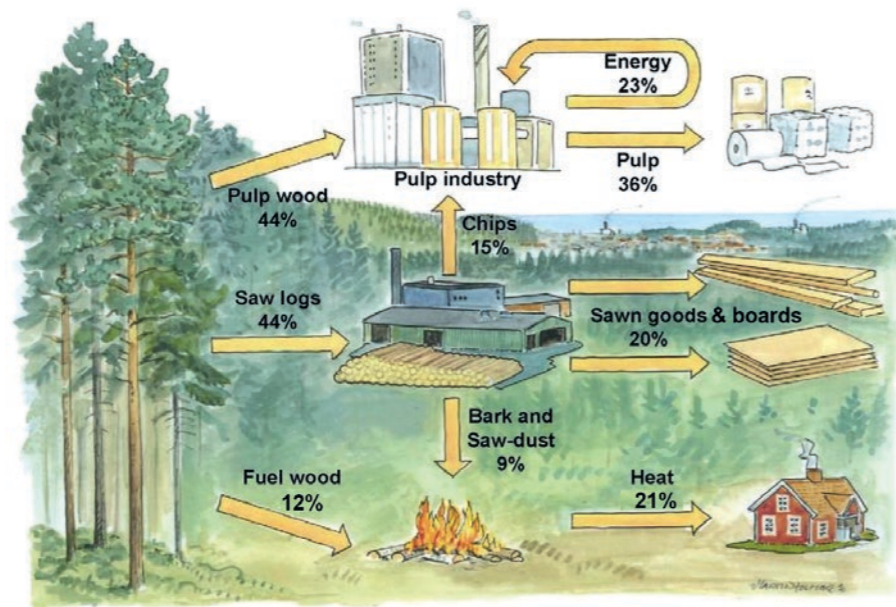


Figure 1.23 The distribution of roundwood to various industrial lines and the proportion of products after the refinement stage [41].

The use of sawn timber in the wood mechanical industry

About 17 million m³ sawn timber is produced annually in the Swedish sawmills, and two thirds of this volume are exported directly without any further refinement than seasoning and to some extent planning, Figure 1.24. The import of sawn timber to the Swedish wood industry is small (0.5 mill. m³) and consists mainly of hardwood species for carpentry work. The Swedish production of sawn timber from domestic hardwood species is negligible – an annual production of about 200,000 m³ sawn timber.

The domestic refining of sawn timber takes place in five main groups: 1) sawn timber for house building, 2) joinery and furniture manufacture, 3) packaging, 4) renovation and extension of existing buildings, and 5) other uses, which includes wood for agricultural buildings, installation work, DIY (do-it-yourself), and also a large number of other consumer products which it is difficult to define due to small volumes. The volume shares of each of these groups are presented in Figure 1.24 and in more detail in Figure 1.25.

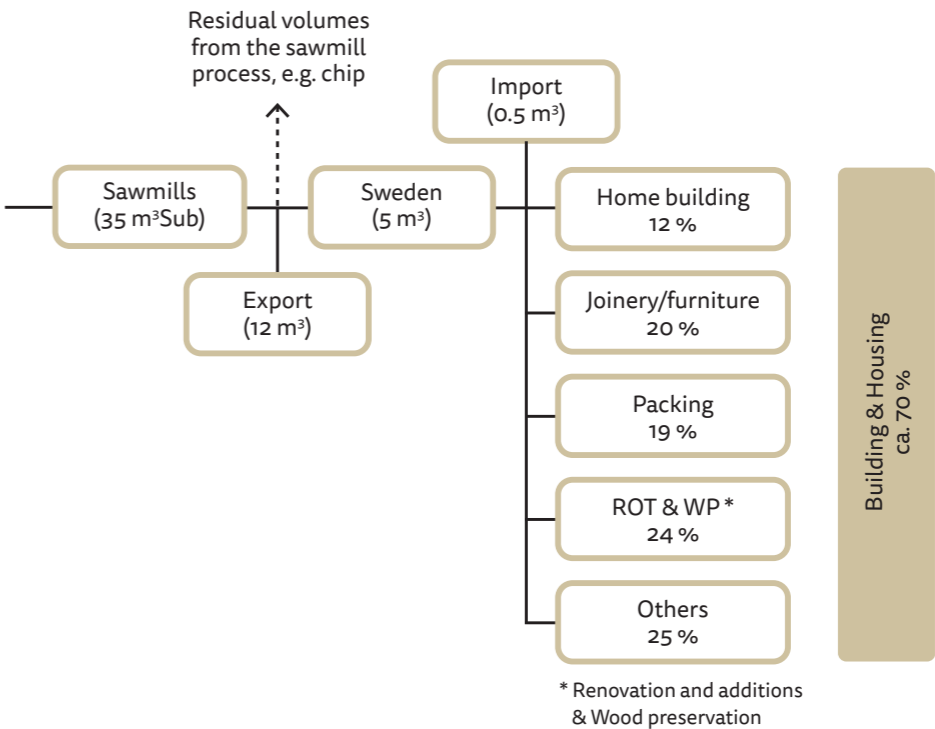


Figure 1.24 The use of sawn timber from Swedish sawmills. Two thirds of this volume are exported directly from the sawmills, and the rest is for domestic use.

The building and housing industry is the principal final user of the sawn timber sold in Sweden. The whole building sector including all installations amounts to ca. 70% of the volume of sawn timber used annually in Sweden. Nevertheless, only a small proportion (12% in Figure 1.24) of the sawn timber goes directly to house building. This means for example that less than 1% of the felled forest volume is consumed directly within the building industry. Most of the wood passes the wood mechanical industry to be refined into products which can be fitted on the building site, e.g. windows and stairs. Increasing the proportion of wood in the building, i.e. using wood as the framework material, would only marginally increase the total domestic use of wood, and this would hardly create new job opportunities either, since the degree of refinement is very low. Job opportunities are created when the wood is used as joinery, interior fittings and furniture.

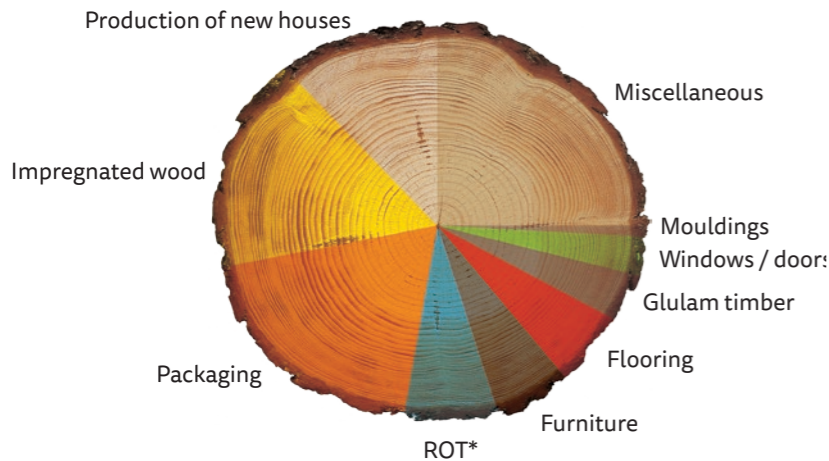


Figure 1.25 Distribution of the sawn timber that is sold annually in Sweden (5.5 million m³) between different users. *Renovation and additions [39].

Added value of the sawn timber in the wood mechanical industry

In Figure 1.26 the “added value in relation to sawn timber”, i.e. the price of the product in relation to the price of the sawn timber is presented for the five main groups of wood products, based on data from [39]. There is of course a wide variation in added value, between 1.5 and 30, depending on the products that are produced. Furniture has the highest added value, followed by joinery. The lowest added value is for products with a low degree of refinement after sawing, i.e. moulded construction timber, form work (wood used for shuttering for cast concrete), and impregnated sawn timber (preservation against decay).

The joinery and furniture industries together consume nearly as much sawn timber as is used directly in the production of new houses and for renovations and additions (about 20% in Figure 1.25), but the refinement value is 15-20 times higher within the joinery and furniture sector. The added value of the wood within the building industry is about 1.5 times, while the added value in the joinery industry is about 15 times and that in the furniture industry 30 times that of the sawn timber. The degree of refinement is of course strongly related to the number of job opportunities that can be generated.

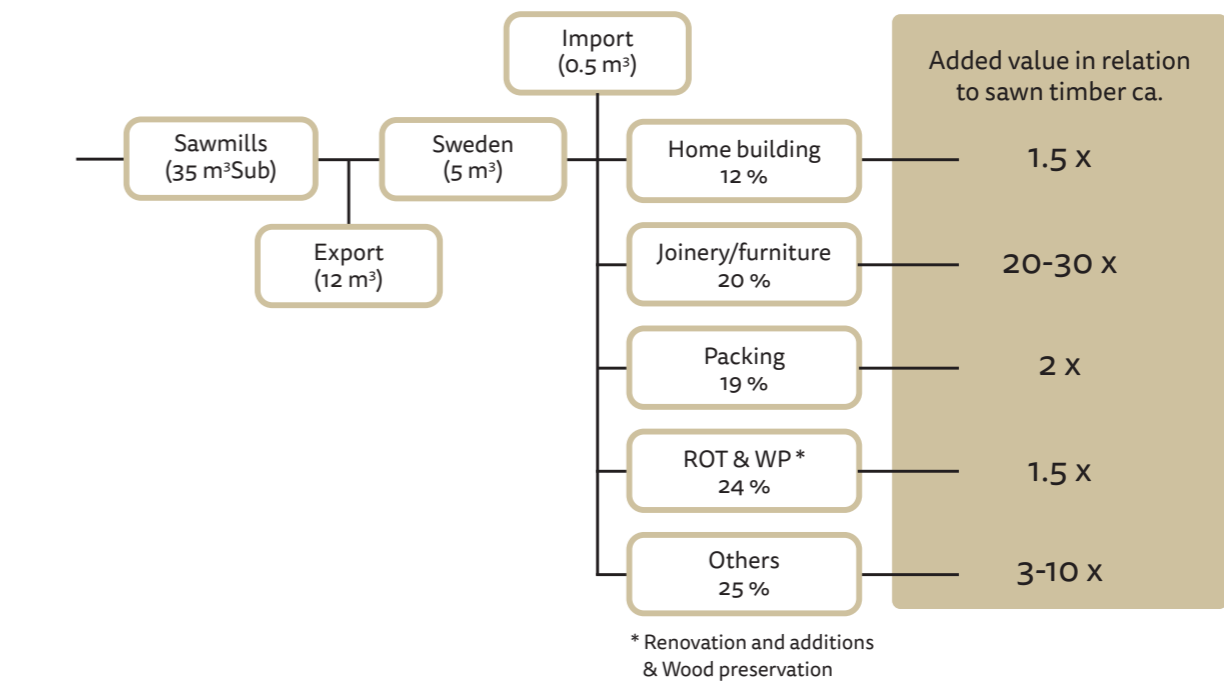


Figure 1.26 Added value in relation to sawn timber value for different groups of wood products produced in Sweden [41].

Outlook for the Swedish forest products industry

The Swedish forest products industry cluster has a long tradition and its importance for the Swedish economy cannot be underestimated. A detailed analysis, studying e.g. how different part of the cluster interact with each other, is hard to perform because of the complexity of the cluster and its international structure. We can assume, however, that the market and policy conditions will govern.

For Sweden to be able to be one of the leading forest products industry nations, new products with a greater added value, new processes and new value chains based on the forest raw material are essential. The value chains for the traditional solid wood products must also be made more effective. The added value of the Swedish forest raw material in all the product, production and sales stages must be kept high. This is accentuated if it is assumed that the future energy production will be based to a greater extent on biofuels, where the Swedish forest is an alternative which does not compete for the world’s water resources or with food production.

The energy sector is insensitive to knots and other blemishes in the wood. There is however a linear relationship between energy content and density, i.e. the growth condition is of great importance for the energy content of the forest biomass. All the forest biomass can in principle be used for energy conversion, but it must be considered important to use the most valuable parts of the tree for those products which can pay best for the wood and to burn those parts of the tree which have no other use, e.g. the stumps, bark and side-products, and branches and tops.

The Swedish sawmills are responsible for the greater part of the forest owners' profits, but two thirds of the sawn volume is exported, and the profitability of the sawmills over time is low. The manufacture within the country of wood products based on sawn timber with a high added value is low. Only about 20% of the sawn timber used in Sweden is used for such products. In addition, only a very small proportion of the native hardwood, which constitutes about 20% of the total forest volume [24], is used within the wood mechanical industry, while other wood species are imported. This indicates that there is a great potential for development and an increased production within the wood mechanical industry, through a greater domestic refining, efficient production and logistical systems, specialisation, material and production development etc. Such a development is well documented in other industries, e.g. the automotive industry. The "sawmill value chain" generates by-products which are currently being used mostly as fuel and as raw material for the pulp industry. A challenge is to develop alternative uses for these by-products, e.g. by creating new materials with a high added value. This will lead to a more efficient utilisation of the material at the same time as the emission of CO₂ is delayed for as long as the material is being used. The development shall also include the creation of systems which work from cradle-to-cradle and create circular business models where old products immediately become the raw material for new products and thus further delay the emissions.

The pulp and paper industry is involved in an extensive structural transformation while continuing to use the by-products from the sawmills [22]. Practically all the chips from the sawmills go to the pulp industry and this meets about one quarter of the industry's total raw material requirement. The remodelling of the pulp industry can have great consequences for the possibility of the sawmills to sell their primary by-product, the sawmill chips. New products based on sawmill chips may therefore be an important area of development for the sawmill industry to secure its future income, where wood-plastic composite products and self-bonding of fibre or chips are some examples.

Buildings and housing are, as already mentioned, the largest customer of the Swedish wood raw material, in the form of building materials, furniture and fittings. Globally, these products are now to an increasing extent being produced from non-renewable materials. Swedish wood products should have a good potential for taking market shares from these sectors, but a precondition for achieving this is to increase the degree of refinement of the products supplied to the building sector. The value of the products going to this sector is currently very low. For the industry to be competitive in spite of the relatively high wage level in Sweden, productivity must be further increased. Automation is an important aspect of this development [43]. There are still parts of the wood mechanical industry which for various reasons, e.g. small series, low profitability or complicated processes which make automation difficult and expensive, have a relatively low degree of automation [43]. The development potential of the wood mechanical industry in this sphere is also very large.

Although domestic refinement creates value and provides employment opportunities, the greater part (2/3) of the sawn timber is exported in its unrefined form. If the domestic refinement of the sawn wood were doubled, 100,000 new job opportunities could be created, many of them outside the large city districts. The furniture and joinery industries in Sweden currently use as much sawn timber as the whole building industry, but the added value of the wood within the furniture and joinery sector is 15-30 times higher than that in the building industry. An increasing degree of renovation of old buildings and the production of timber houses in Sweden or abroad may, however, also increase the need for new wooden furniture and joinery for these buildings. A greater

degree of cooperation between the building industry and the furniture and joinery industries in Sweden can be an opportunity to increase the refinement of Swedish sawn timber.

If the forest raw material is to be a part of a future sustainable society, it is essential to further develop not only the extraction of the raw material from the forest and the refining technology but also how the forest raw material is distributed between different users. The forest raw material now provides an important base for our energy system and the Swedish forest fuel handling is well developed [44]. At the same time, there is an increasing competition for the forest raw material both from the energy conversion industry and from other actors. A strategic raw material supply, incorporating strategies for how different materials are to be taken from the available forest resources, will therefore be an important aspect of future refinement chains. These strategies must meet the demand for an increase in the supply of raw material for fuel, in order to identify the correct products and thus avoid competition with other users of the forest raw materials, such as sawmills and the particleboard industry, which would press up the prices in an unsuitable manner [45]. Virgin forest raw materials shall as far as is possible be used in wood products, preferably in two or three cycles of use, before the materials are burned [46, 47]. This makes demands not only on how we use the wood from the forest but also on how we use wood in our products, so that the wood in its final stages can be burned without producing gases and ash that are harmful to the environment.

The welfare of Sweden depends essentially on its natural resources, of which the forest is the most important, not least in a sustainability perspective. The wood mechanical industry has a great economic significance for the value of the Swedish forest and for the profit in forestry. The importance of the pulp and paper industry, and also of the energy conversion industry based on forest raw material, cannot be neglected in this context, but it is nevertheless a fact that the sawmills are responsible for 70-80% of the forest owners' profits in Sweden.

The wood mechanical industry is to a great extent a small-scale industry and both the activities and the products are strongly differentiated (the sawmills are here the typical exception from small scale operations). This makes it difficult for the wood industry to adapt itself sufficiently rapidly to the new global conditions, with a risk for closure instead of expansion. If the wood industry in the future is to continue to be an important link in the forest products industry cluster, conditions for development must be created in both education and research which promote the different aspects of the companies with the aim of extending the global competitiveness of the wood industry.

In the future, we shall still need to build and to live. The fundamental needs of life have changed very little over the centuries, but technical and other developments naturally influence the industry and its products. Nowadays, only about 30% of the volume of timber passing through the wood industry becomes products with a value essentially higher than that of the raw material. The remainder of the wood is used chiefly for pulp production and for conversion into energy. This means that the Swedish wood mechanical industry "subsidizes" the raw material of both the pulp industry and the bioenergy sector, although at the end of the refinement process, these for the sawmill low value products, may also become high value products. This state of affairs may well be changed in the long term, particularly in view of the price development in the energy sector. If not, the Swedish wood industry must find ways to refine its by-products in a more profitable way than is currently the case. Otherwise, there is a great risk that the profit margins of the forest owners will shrink.

The Swedish wood mechanical industry is facing new challenges which probably differ from those seen in earlier phases of the industry's development. Previously, technology has been able to provide solutions to the changing demands of the market. For example, drying technology was developed to meet the greater demands from the market. Automation and optimisation gave a greater productivity and the Swedish sawmill industry's competitiveness increased [48].

The future challenge for the wood mechanical industry is to develop a global perspective with respect to both the market and the competition, and to be able to act in a volatile market with business-like challenges. These challenges must be dealt with in both a production and organisational manner in keeping with new business models.



The sawmill industry and its products

World-wide, Sweden is the third largest exporter of sawn timber. In Europe, the Swedish sawmilling industry holds a prominent position as the second-largest producer and the largest exporter of sawn softwood.

The sawmill industry

There is a long tradition of woodworking in the Swedish sawmill industry, ensuring high quality in production. Production is dependent on the raw material, the sawing technology and the final requirements of the produced products. Internationally, Swedish sawmills have a high productivity as a result of the continuous development and modernization of the industry.

The Swedish sawmills are owned by three different owner categories:

1. private owners (family owned), such as Martinsons, Vida Timber, Bergqvist,
2. large forest companies, such as SCA, Stora Enso, Setra, and
3. forest-owner associations, such as Södra, the Norra Group.

The privately owned sawmills stand for 66%, the forest-companies-owned sawmills for 22%, and forest-owner-association sawmills for 12% of the total production by volume.

Large investments in the modernization of the sawmills have resulted in an automated and high speed technology. This enables the sawmills to produce high quality products according to customer demands in an efficient way. The process is often fully automated and computerized - from debarking the logs to the drying and grading of the sawn timber. In the most high-technology mills, operatives are there only to ensure the smooth running of the processes. The labour force is well educated, with the skills to operate highly automated and computerized production units. Information technology is exceptionally advanced and is used extensively.

The Swedish sawmilling industry has undergone significant structural rationalization, resulting in fewer and larger companies and production units; the 20 largest producers today account for 70% of the total annual production, Figure 1.27. Further consolidation is to be expected in order to increase competitiveness. With few exceptions, the sawmilling industry is Swedish-owned and production units abroad are rare.

The sawmills obtain their raw material mainly from Swedish forests. These forests also supply other industries, but the sawmill industry competes mainly with the pulp industry for the raw material. In the future, it is likely that the energy sector will also become a serious competitor.

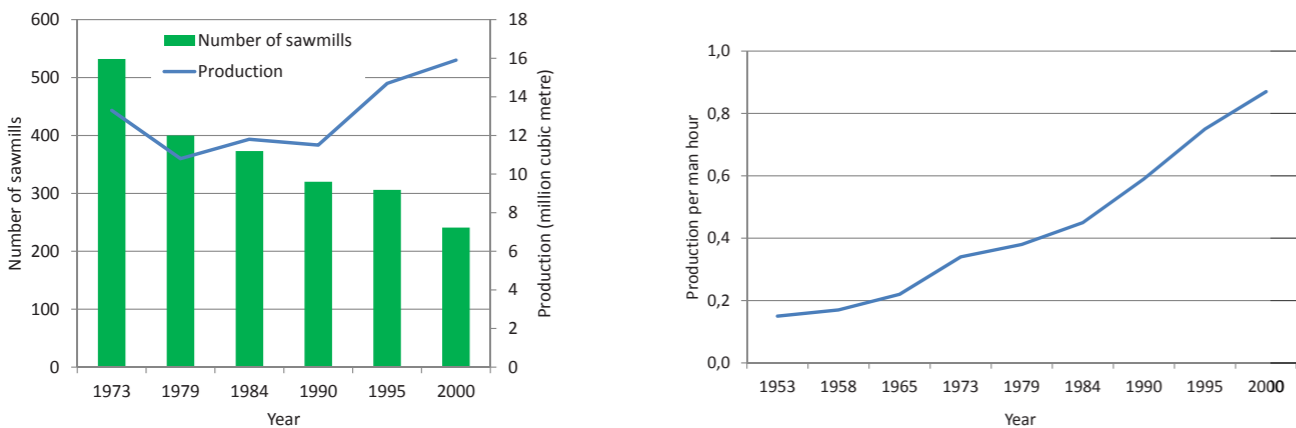


Figure 1.27 Number of sawmills between 1973 and 2000, and their total annual production (left). Productivity in Swedish sawmills between 1953 and 2000 (right) [49].

Today, the sawmill industry consists of approximately 50 companies or company groups with a total of 140 sawmills, all of which have an annual production of more than 10,000 m³ sawn timber. In 2014, the total production of sawn and planed timber was 17.5 million m³, of which 12.3 million m³ was exported, Figure 1.28. The sawn timber was mainly Scots pine and Norway spruce (98.8% of the total production).

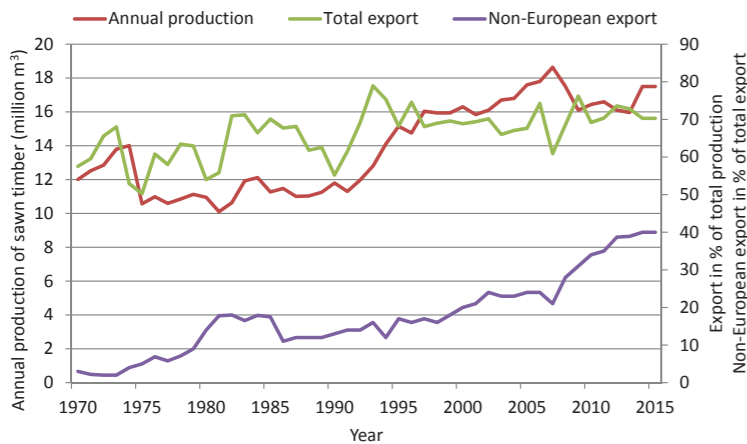


Figure 1.28 Annual production, export and non-European export of sawn timber from Sweden between 1970 and 2014. Ca. 70% of the sawn timber produced in Sweden is currently being exported, and of that volume about 40% is exported to non-European countries.

The most common value-added process in connection with the sawmill beyond drying of the sawn timber is planing. The total planed volume in 2000 was 3.2 million m³. Other than drying and planing, the most common value-adding processes are stress grading (600,000 m³ in year 2000) and length trimming to orders (500,000 m³). Sawmills with an annual production between 50,000 m³ and 100,000 m³ are of great importance for this production of value-added products. The value-

adding processes connected to the sawmill have increased significantly during the last 20 years, and include also components for the furniture, joinery and building sectors, wood for packaging, finger jointing, glulam production, and impregnated and surface-coated wood.

Sawmill equipment is expensive and must run for many years before it is exchanged. There is however a clear trend in the use of equipment for sawing. The number of frame saws has been decreasing. In 1970, 70% of all saw machines were frame saws, but nowadays they are rare. The numbers of band saws is also decreasing, although there is an increase in reducer band saws placed in combination with reducers. The reducer was normally a separate machine 40 years ago, but today it is more commonly integrated with either a band saw or a circular saw. Modern saw lines are often profile-reducing lines, where the profile reducers are robust machines with a very high capacity and good measurement accuracy, Figure 1.29. On the negative side, the investment costs are high and the volume yield of sawn timber is often low.

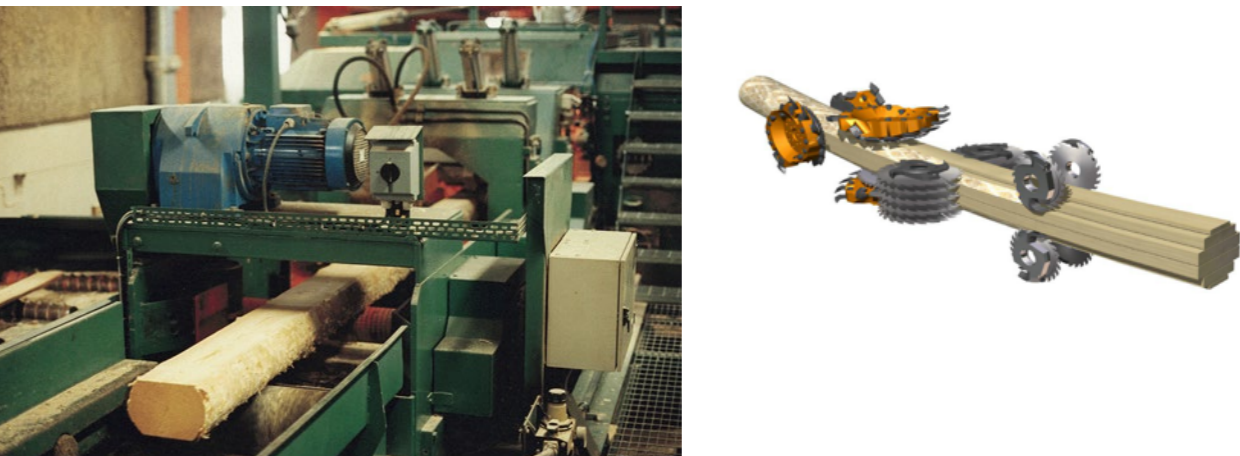


Figure 1.29 A profile-reducing line (left) and a sketch of a compact profile reducer for small logs (right).

It is extremely important for the quality of a wooden product that its moisture content corresponds to the climate in which the product is to be used. In Sweden, basically all sawn timber is kiln dried, about 50% of the sawn timber being dried in batch kilns and 50% in progressive kilns [49], Figure 1.30. Batch kilns have become more common in response to market demands for lower and more accurate moisture contents.

The delivery target moisture content is around 18% for sawn timber, but the Swedish sawmills also deliver timber with lower specified moisture content adapted to product and customer demand.

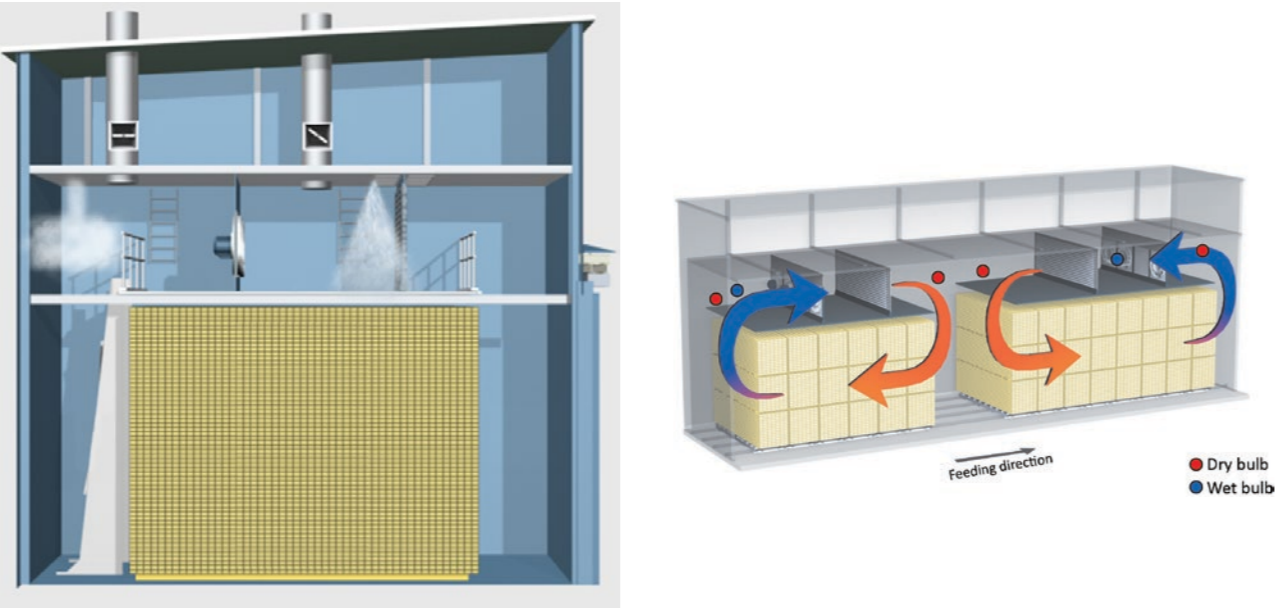


Figure 1.30 The basic construction of a batch kiln shown in section on the left and that of a two-zone progressive FB kiln (FB - feed back control) on the right. The basic principle of a progressive kiln is that the climate changes when the sawn timber is fed through the kiln. In the first zone, the air blows against the feeding direction whilst in the second zone the blowing direction is along the feeding direction.

The sawn timber

Sawn timber in Sweden is manufactured from Scots pine and Norway spruce, and the production is split roughly equally between these two. The production of sawn timber from other species (various hardwood species, larch and lodge pole pine) is very small in volume.

The colour of the sapwood of Scots pine is yellowish-white, while the heartwood is reddish and clearly demarcated from the sapwood. The texture is fine due to the slow growth rate. The wood is soft and has a medium density of 450-550 kg/m³. The strength properties are good and machining is easy. Scots pine is used for joinery, interiors and decoration such as doors, windows, flooring and indoor panelling as well as for furniture. It is also used as structural and non-structural construction timber.

The colour of Norway spruce varies from creamy white to light yellow, and the heartwood is not distinct from the sapwood. The wood is fairly straight-grained with a smooth and even texture. The wood has medium density slightly lower than pine. Strength properties are good and machining is easy. Norway spruce is the most important building and construction timber in Europe. The typical end-use is as structural timber in studs and beams for both interior and exterior use. It is also used for interior construction, joinery such as flooring and doors, carpentry, furniture, external panelling, and packaging.

Table 1.26 shows the properties of Scots pine and Norway spruce as average values based on small samples with no imperfections. In spite of the differences between Norway spruce and Scots pine, they can in fact be regarded as being equally good as construction or building materials.

Table 1.26 Technical data for small clear samples of Scots pine and Norway spruce at 12% moisture content and at a temperature of 20°C [50]. ⊥ - perpendicular to the fibres, || -parallel to the fibres, ⊥_R - in the radial direction, ⊥_T - in the tangential direction. V - in volume.

Property		Scots pine	Norway spruce
Density (kg/m³)		480-530	390-480
Shrinkage from green state to 0% moisture content (%)	⊥ _R	4.0	3.6
	⊥ _T	7.7	7.8
		0.4	0.3
	V	12.4	12.0
Tensile strength (MPa)	⊥ _R	3.0	3.3
	⊥ _T	3.0	3.4
		104	90
Bending strength (MPa)		87	86
Compression strength (MPa)	⊥	-	-
		47	45
Shear strength (MPa)		10	9.0-9.8
Impact strength (kJ/m²)		70	50
Torsion strength (MPa)	⊥	4.5	3.4
		16	9.0
Hardness	Brinell	⊥	1.9
			4.0
	Janka	⊥	250
			300
Modulus of elasticity (MPa)	⊥	460	350
		12,000	13,700
Thermal conductivity (W/m°C)	⊥ _R	0.12	0.10
	⊥ _T	0.12	0.09
		0.30	0.19
Heat capacity (J/kg°C)		1,650	1,650
Calorific value (MJ/kg)		16.9	16.9

Table 1.27 show standard dimensions of sawn timber, timber with one fine sawn face (re-sawn timber), and timber planed on all four sides that the Swedish sawmills normally produce. The cross-sectional dimensions are given at a target moisture content of 18% for sawn timber and 16% for planed timber. Other dimensions are however also available, since the Swedish sawmills can adapt their production to both the Swedish and international markets. The length of the sawn timber is up to 6 m (without finger joints).

Table 1.27 Cross-sectional dimensions in millimetres of sawn and planed timber.

Sawn timber		Timber with one re-sawn face		Planed timber	
Thickness	Width	Thickness	Width	Thickness	Width
12		10		9	
16		14		13	
19		17		16	
22		20		19	
25	25	23	22	22	22
32	32	30	28	28	28
38	38	36	34	34	34
50	50	48	45	45	45
63	63	61	58	58	58
75	75	73	70	70	70
100	100	98	95	95	95
	115		110		110
	125		120		120
	150		145		145
	175		170		170
	200		195		195
	225		220		220

Quality classes of sawn timber

The Swedish sawmills produce a wide selection of different grades of sawn and planed Scots pine and Norway spruce timber, in accordance with what is requested on different markets. For the European market, the standard EN 1611-1 [51] is typically applicable for appearance grading. The sawmills follow in general the standards for sawn timber that have been adopted in Europe (Table 1.28) and they have the capacity to produce and export large quantities of timber that complies with e.g. Japanese, American and Chinese national standards.

Table 1.28 Important European standards for sawn timber.

Standard	Name of standard
EN 336	Structural timber: Sizes, permitted deviations
EN 338	Structural timber: Strength classes
EN 384	Timber structures: Determination of characteristic values of mechanical properties and density
EN 408	Timber structures: Structural timber and glued laminated timber – Determination of some physical and mechanical properties
EN 1912	Structural timber: Strength classes – Assignment of visual grades and species
EN 14081-1	Timber structures: Strength-graded structural timber with rectangular cross section. Part 1: General requirements. Sawn timber
EN 1309-1	Round and sawn timber: Method of measurement of dimensions. Part 1: Sawn timber
EN 1313-1	Round and sawn timber: Permitted deviation and preferred sizes. Part 1: Softwood sawn timber
EN 1611-1	Sawn timber: Appearance grading of softwoods. Part 1: European spruces, firs, pines, Douglas fir and larches
EN 14298	Sawn timber: Assessment of drying quality

The Swedish sawmills are flexible in their approach to business and can also provide specially ordered grades of timber, and timber with special dimensions. There are two principal ways of grading sawn timber:

1. Appearance grading according to

a. standard EN 1611-1, or to the older grading rules, the so-called Green and Blue Books [52, 53]

b. purpose-grading
2. Strength grading

The quality of sawn timber can be specified with a number of natural features such as type and size of knots, resin pockets, fibre distortion, curly grain, bark callus, top rupture, resin wood, reaction wood, and also according to bio-deterioration, discoloration and production-related features. The parameters are assessed by appearance grading, which is done at the sawmills.

It is common for each timber piece to be stamped on the cross-section with a shipping mark, to enable the quality to be read in the stage between sawmills and trading. After processing such as planing and cleavage, these marks can be cut away or difficult to identify. The quality is then specified by the label on the package.

According to the standard for appearance grading (EN 1611-1), the grading may be done on both faces and both edges, or only one face and one edge. The varieties are then called G4 and G2. Grade type G2 is seldom used in Sweden, but is primarily used in the export of timber. The grades are followed by a number between 0 and 4 that indicates the quality of the sawn timber, 0 being the highest quality. Sawn timber can then be graded as G4-2, which represents a 4-sided visual grading of typical construction timber, corresponding to "5th quality" or "Kvinta" according to the old grading rules in the "green book". An approximate comparison with older grading rules is given in Table 1.29.

Table 1.29 Approximate relations between the grading rule in standard EN 1611-1 [51] and the two older rules.

EN 1611-1					
Two faces and two edges (G4)	G4-0	G4-1	G4-2	G4-3	G4-4
One face and one edge (G2)	G2-0	G2-1	G2-2	G2-3	G2-4
The blue book ¹⁾					
A		B		C	D
A1	A2	A3	A4		
The green book ²⁾					
U/S (unsorted)		5 th quality		6 th quality	
I	II	III	IV	V	VI

1) Nordic Timber Grading rules [50]
2) Guiding principles for grading of Swedish sawn timber [51]

According to the rules in the *Green book*, the sawn timber can be graded into six grades, where grade I corresponds to the highest quality. Grades I-IV are together usually known as U/S (unsorted), and grade V is commonly referred to as “Kvinta” and grade VI to rejections.

According to the rules in the *Blue book*, the sawn timber can be graded into three classes: A, B and C where grade A corresponds to the highest quality. Grade A can be subdivided into grades A1-A4. Grade B is the most common quality for construction, while Grade C is mainly used in packaging, Table 1.30. Figure 1.31 shows some example of grades for pine and spruce.

Table 1.30 The uses of different timber grades.

Type of product	Grades	Species
Building timber	G4-2 to G4-3	Pine and spruce
Graded construction timber	G4-0 to G4-3	Pine and spruce
Tongued and grooved timber with sawn face	G4-2 to G4-3	Pine and spruce
Formwork timber	G4-4	Pine and spruce
Packaging timber	G4-3	Pine and spruce
External cladding, bargeboard	G4-0 to G4-2	Pine and spruce
internal cladding	at the lowest G4-2	Pine and spruce
Joinery timber for internal use	at the lowest G4-1	Pine and spruce
Floorboards	at the lowest G4-2	Pine and spruce
Fencing	G4-0 to G4-2	Pine and spruce
Mouldings	A to B	Pine and spruce

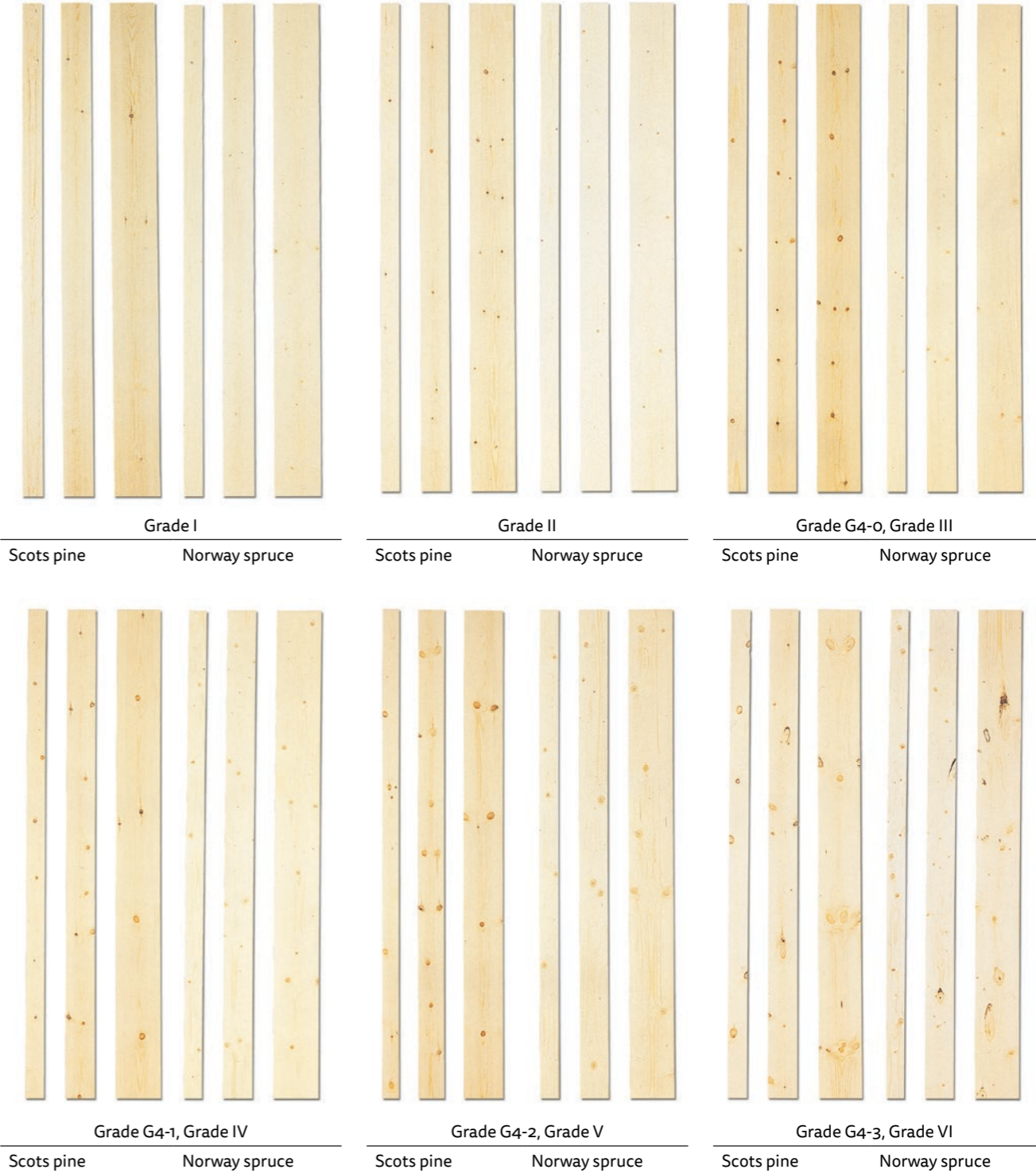


Figure 1.31 Appearance of sawn timber of Scots pine and Norway spruce of different grades, according to the *Green book* (Grades I to VI) and to the standard EN 1611-1 (Grades G4-0 to G4-3).

Grading according to EN 1611-1 or to the green and blue books is not related to the wood’s destination. Many sawmills have therefore supplemented these standards with their own purpose-grading. A common example is the grade called “green Kvinta”, which is sawn timber where sound “grade B knots” are allowed, but where dead or rotten knots are restricted. Another example is “grade A waned timber” which is sawn timber passing all the requirements for grade A timber except that for wane. In the 1970’s, a purpose-sorting system was developed called *Eurograding* (End-User Requirement-Oriented Grading of Softwood). It was never widely applied, but the definitions of defects in wood and measure indications in the Eurograding system became precursors for a number of purpose-grading systems that have been developed since then.

There are two purpose-grading systems which differ in principle:

- Determined systems
- Open systems

A determined system is limited to a number of well-specified grades, whereas an open system allows customers to specify their own needs freely. The open system is a pattern allowing quality specifications to follow a given course, which is necessary for facilitating communication between buyers, sellers and sorters. The open system normally includes the option of having different quality demands for different surfaces of the sawn timber.

For a user-friendly way to describe wood products, the wood industry, construction and trade companies in timber and building contractors in Sweden have jointly created a basic range of wood products called *VilmaBas*. Each product specification, called a property declaration, is identified with a VilmaBas product identification, a VB-code. The product is described with a selection of properties (see www.vilmabas.se). For comparable products, each producer can add the VB-number or the property declaration to their products and all parties in the value chain can then safely use a VB-code as a reference.

Strength grading is used to ensure that the sawn timber has a defined strength value. Many parts of a building are load-bearing, for example floor beams, roof trusses and certain parts of timber-framed walls. It is often necessary to calculate the loads involved and then choose a dimension which can carry these loads. The timber for these purposes is called construction timber, and it is strength-graded, either by machine or visually, on the basis of various strength-grading rules, Table 1.31. Visual grading carried out by an approved grader. Machine grading of timber is carried out on the principle that stiffness is related to strength. Construction timber can also be delivered as finger-jointed timber, which can be manufactured in any practical length. The strength classes indicate the bending strength in MPa in vertical bending (when bending the high end vertically).

Table 1.31 Strength classes for visually graded and machine-graded construction timber of Scots pine and Norway spruce. The visually graded timber is denoted with classes T0 to T3, while the machine-graded timber has the same marking as the strength classes.

Type of grading	Strength classes				
	C35	C30	C24	C18	C14
Visually graded ¹⁾	-	T3	T2	T1	To
Machine graded ²⁾	C35	C30	C24	C18	-

1) According to SS 23 01 20 [52], 2) According to SS-EN 14081-1 [53] and SS-EN 338 [54]

Modification of sawn timber

Sawn timber is modified to improve its resistance to decay and to fire, and to improve its dimensional stability. The processing and finishing technologies for sawn timber often require the use of chemicals in the form of adhesives, paints and coatings, as well as preservation treatment and thermal modification, to improve the wood’s (biological) long-term durability (fungi and insects/termites) and moisture resistance. The application of wood preservatives is done under very strict control in closed systems conforming to the relevant national regulations. Preserved timber for construction, agriculture, landscaping, marine, railway and garden products, and many other applications, provides an extended service life and a good alternative to non-renewable materials.

Preservation of wood against decay

Scots pine and Norway spruce have in general a low durability for exterior use. Unprotected sapwood should not be used at all outdoors, and the heartwood should only be used above ground. This means that all constructions outdoors made of pine and spruce, especially those which are firmly fixed in ground and water, require adequate protection against decay. Only treatment with approved wood preservatives gives the wood a complete protection in exposed positions. Coating with oil on the surface gives only a superficial and short-term protection, because it is not able to penetrate into the wood.

Impregnation with various approved chemicals in a pressure treatment process is the most common modification process used for sawn timber in Sweden. This treatment gives the timber a chance to be used in applications where unprotected wood fails to meet the requirements. Mainly Scots pine is used for this treatment. The pine sapwood is able to absorb impregnants while the heartwood may only accept a superficial penetration. To impregnate pine to get better durability, all the sapwood must be impregnated to the heartwood. In impregnating of spruce only a limited quantity of impregnating agent penetrates into the wood (because of aspirated pits). Impregnated spruce has therefore less protection than impregnated pine.

For preservative-treated wood sold in the Nordic countries, a classification system has been developed by NTR (Nordic Wood Preservation Council) based on European standards for treated timber. The classification applies primarily to preservative-treated pine, but also to industrially treated spruce. The different classes of treated timber according to the NTR rules are shown in Table 1.32.

Smaller dimensions, i.e. 38 mm and less in thickness, and cross-sectional dimensions up to a maximum of 50x125 mm, are normally preservative-treated in NTR class AB. Larger dimensions are always treated in NTR class A. For the Swedish building trade’s standard assortment, this means in practice that 45x145 mm and larger dimensions (and dimensions of 63x63 mm and larger) must always be treated in NTR class A. This classification makes it easier, for both the builder and the consumer. In this way the correctly treated wood is automatically chosen for the correct end use.

Table 1.32 Wood preservation classes according to Nordic Wood Preservation Council (NTR) system.

Class	Marking ¹⁾	Use	Penetration
M		Wood in sea water	 Full penetration of the sapwood
A		Wood in contact with ground and (fresh) water and in permanent safety installations	 Full penetration of the sapwood
AB		Wood above ground	 Full penetration of the sapwood
B		External joinery above ground	 Min. 6 mm lateral penetration of the sapwood
NTR spruce ²⁾		NTR spruce applies only to the products: cladding for outdoor use, barge boards, weather boards and battens	 Min. 6 mm lateral penetration of the sapwood

1) Marking is both preservation class and colour, 2) “Gran” is spruce in Swedish

KEY FIGURES 2016

Swedish forest products industry

Number of companies: ca. 9,000

Number of employees: ca. 200,000

Revenue (€): 25 billion

Export (€): 13 billion (80% is export)

Key export markets: Great Britain, Germany, Italy, Egypt, Norway, France, Spain, China, Japan, Algeria, The Netherlands, South Arabia



Logs transport

Sweden



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Forest, forest products industry and primary wood products

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Spruce forest

Kladje, Slovenia





Scots pine
Sweden

2 Properties and use of sawn timber and engineered wood products

Wood as an engineering material

From the beginning of time, wood has been a material satisfying human needs. It was, and still is, a very important construction material dating from the first man-made shelters, homes and simple vessels. At the end of the 19th century, nearly all ships were still made of wood, and wood remains an important raw material in shipbuilding, although it is not used to the same extent today. The north American term *lumber* means wood that is to be used for building, construction, paper-pulp production etc. Lumber can refer to wood at any point in the manufacturing process from the forest to the final products aimed for the consumer. In the English-speaking area, the term usually refers overturned, fallen trees, while the expression *sawn timber* means the sawn product. In this chapter “wood” is the general term, “roundwood” is a log for industrial use, and “sawn timber” is the sawn product, i.e. boards and planks. Certain wood products have well-established names, e.g. for LVL – laminated veneer lumber. These names are not changed.

With the development of technology, the use of wood has significantly improved. The development of new wood-based products has led not only to the elimination of strength-reducing defects in the wood structure, but also to a reduction in the negative effects of anisotropy and inhomogeneity. The application of “engineering principles” has led to an increase in size and improved mechanical properties of wood-based products, and permits new and broader applications. The wooden “skyscrapers”, i.e. the multi-storey timber buildings that have gathered momentum in European countries in recent years, are one example of such development. To further improve the physical and mechanical properties of the wood material and the products for which it is used, wood can be modified by chemical, thermo-hydro-mechanical or other processes. The wood modification field is undergoing huge developments at the present time, driven in part by environmental concerns regarding the use of wood treated with certain classes of preservatives. Several “new” technologies such as thermal modification, acetylation, furfurylation and various impregnation processes have been successfully introduced onto the market, and show the potential that these new technologies have.

One of the key features in wood processing is that the dimensions of the tree are changed to those of an engineered material with well-defined properties and dimensions adapted to the purpose for which it is to be used. Such well-defined wood products have been widely developed during the last century and nowadays they are commonly called EWPs - engineered wood products. EWPs are among the

most important, innovative wood products used worldwide. EWPs also referred to as reconstituted wood, wood-based products, or wood-based composites, are wood components in general and structural components for industrial use in the production of furniture, for interior and exterior joinery, in the construction of buildings and in infrastructural timber constructions such as bridges, towers, and pathways. The basis of the EWPs is usually sawn timber, veneer, wood chips or fibres, which are moulded with adhesives to appropriate structures and shapes. EWPs have successfully replaced classical building materials such as metal, concrete, and bricks. Their advantage is in their high load-supporting capacity in relation to their weight, their proper dimensional stability and their flexibility for adaptation to the required shapes and dimensions of the structural element.

EWPs have in general poorer mechanical properties than sawn timber in the longitudinal direction but, because of their more consistent properties in planar directions and in the cross section of the composite, the safety margins in strength can be kept narrower than when sawn timber is used, Figure 2. 1.

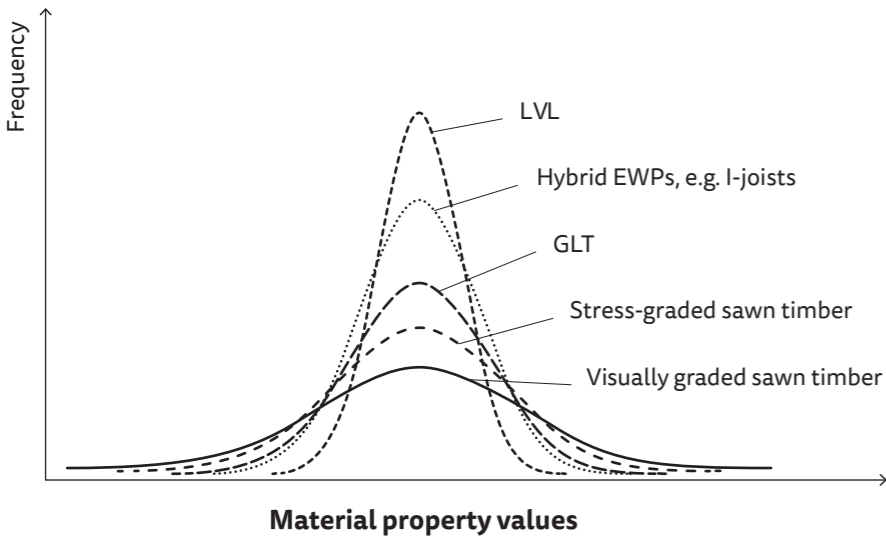


Figure 2.1 Principal distribution and variability in mechanical properties of wood and different EWPs. LVL – laminated veneer lumber, GLT – glued-laminated timber.

Figure 2. 2 show the principal ways that are currently being used in the industry to convert trees to wood products. After the forest is harvested, the roundwood is sorted into different classes depending on their intended use. To produce wood for construction purposes, sawmilling is today the dominant process, yielding sawn timber in well-defined dimensions as well as by-products such as bark, sawdust, and chips. An alternative process is the production of veneers for subsequent use for the manufacture of plywood, elements for construction purposes (laminated veneer lumber) or moulded products (laminated veneer products) and high-density materials for interior and special applications (high-pressure laminated veneer). After the transformation of the roundwood in the sawmill, the sawn timber does not usually have the dimensions required in the final use, and a lot of effort is being devoted to transforming the sawn timber into dimensions and grades that suit the products requested by the consumers. Joining wood is a major step in these processes and adhesives of different types are the key component.

Trees or parts of trees that are not suitable for use in the sawmill or in veneer processes have, if used for industrial purposes at all, three main uses: paper-pulp production, the manufacture of wood-based composites or energy conversion. These processes also use the by-products from the sawmill and veneer processes or residues from other wood-working industries, and in some cases also an agricultural waste. The board industry produces a variety of wood-based panel products (oriented strand board, flake board, particleboard, hardboard, insulation board, low-, medium- and high-density fibreboards, cement-bonded board etc.) based on comminuted wood in different sizes from long and thin flakes (veneer flakes) to fibre bundles that are commonly bonded together by an adhesive or by integral bonding achieved by an interfelting of fibres and in some cases by a ligneous bond. Other materials may be added to improve certain board properties. Wood plastic composites (WPC) are a rather new building material on the market, based on a thermoplastic matrix and a wood component. The matrix is usually recycled polyethylene or polypropylene, and the wood is sawdust or shaving residues from the wood industry [1].

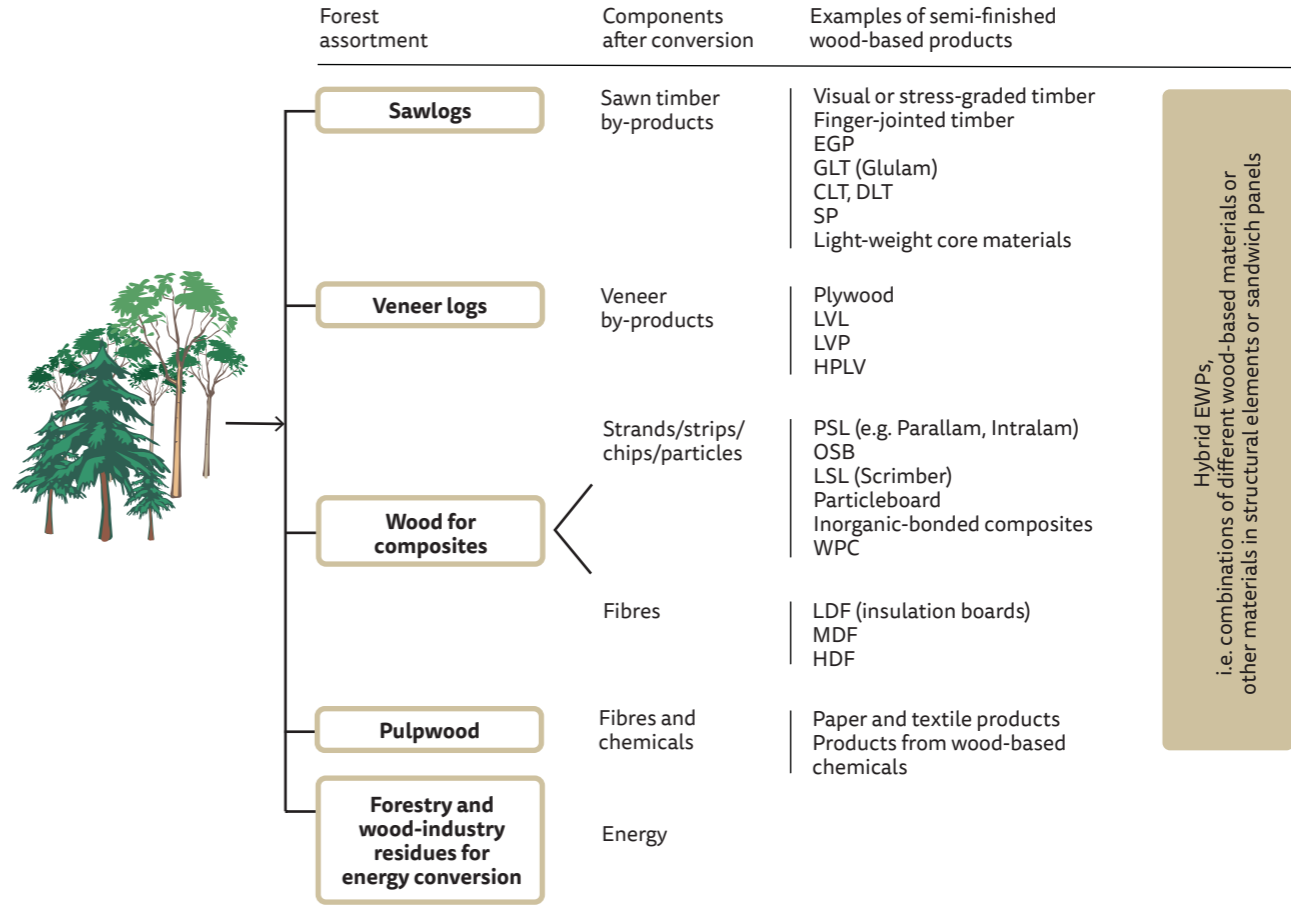


Figure 2.2 The industrial use of the forest resource. Depending on species, dimensions, and categories, the forest raw material is sorted after harvesting into different classes according to their industrial use. EGP – edge-glued panels, GLT – glued-laminated timber, CLT – cross-laminated timber, DLT – dowel-laminated timber, LVL – laminated veneer lumber, LVP – laminated veneer products (moulded products), HPLV – high-pressure laminated veneers, LDF/ MDF/ HDF – low/medium/high-density fibreboards, PSL – parallel strand lumber, OSB – oriented strand boards, LSL – laminated strand/scrimbed lumber, WPC – wood plastic composites.

The construction of environment-friendly and energy-efficient buildings, labeled with the term *green buildings*, is an on-going global trend. Different types of innovative EWPs are being used in the construction of green buildings, resulting in new opportunities for the forest products industry, Figure 2.3.

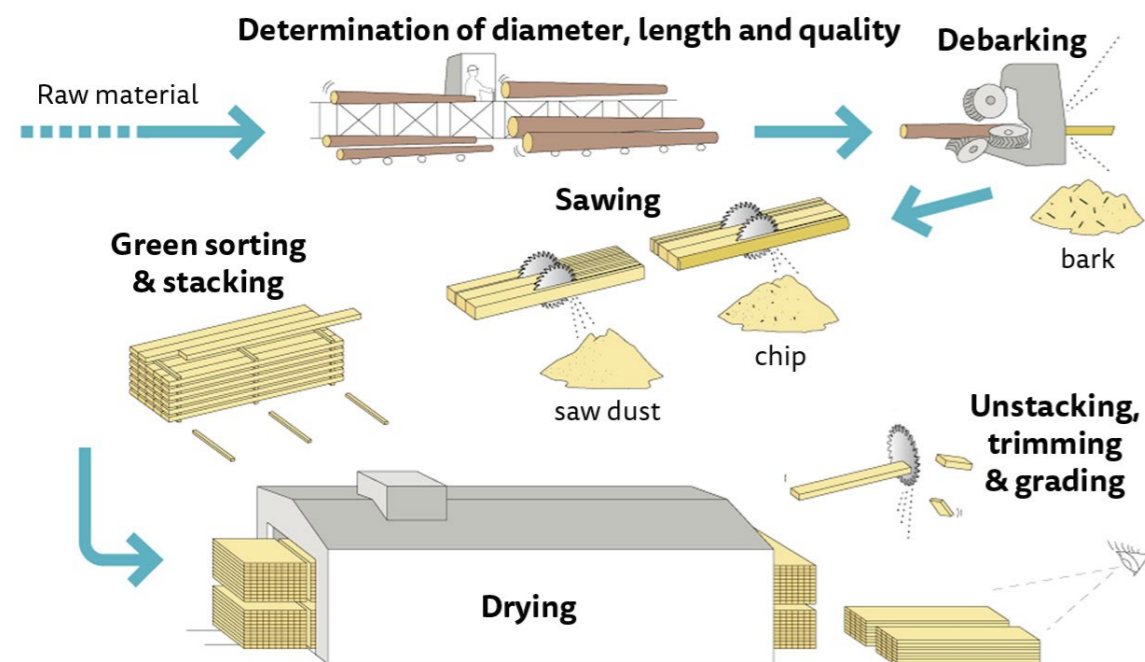


Figure 2.3 The amounts of energy used for the manufacture of timber for construction is low relative to other materials such as concrete, gypsum or steel, and most of the energy used in their manufacture is generated from bio-based by-products from their own value chain.

There is a constant demand for wood and wood products on the world market, and already in 2020, a balance in wood supply will be difficult to maintain on the European level. In the period from 2030 to 2040, the missing volume of roundwood could be as large as 50 million m³ per annum [2]. This in combination with a global increase in environmental concern, means that the development of new innovative EWPs is important. In such a context, EWPs have two important advantages: (1) they are structural materials which include strength, environment-friendliness, simple handling and appropriateness for industrial use, (2) they ensure a high total raw-material utilization from the forest to finished products provided that most of the by-products from the production are utilized in new products.

There are also numerous challenges associated with the use of EWPs, especially in the construction of timber buildings, and these challenges are best met through further research and more pilot projects to increase the knowledge of life-cycle costs, construction costs, maintenance costs and acoustics, through a general increase in the number of timber buildings that are being erected.

Sawn timber

As seen in chapter 1, the production of sawn timber is today an important industry, especially in countries with large forest areas. Although sawn timber does not usually have the dimensions required in the final product, it is a standardized product with a wide range of uses and is generally delivered from the sawmill as dried sawn timber with rough surfaces, or after additional planing or moulding.

Planed or moulded sawn timber is a high-quality product with strictly defined dimensions, moisture content and quality requirements, often for use in a specific finished product. Nowadays, most ordinary construction timber also has planed surfaces with rounded edges to make the timber pleasant to handle. The dimensions of sawn timber can be defined as multiples of the length and cross section (see e.g. Table 1.31), or as customer adapted. The technical characteristics of sawn timber are defined by different standards (see Table 1.32).

The production of sawn timber can be distinguished as being either primary or secondary. The result of primary sawing is un-edged flitches or cants. In secondary sawing, they are re-sawn, edged, and trimmed to an accurate length in order to complete the prismatic shape of sawn timber. Primary and secondary sawing are in general carried out simultaneously at the sawmill, but when in the case of some valuable furniture woods, the flitches are in general not edged at the sawmill.

According to the position in the log, sawn timber is divided into:

- sideboards, i.e. sawn timber from the outer parts of the log, and
- main or center yield, the most valuable part of the log, Figure 2.4.

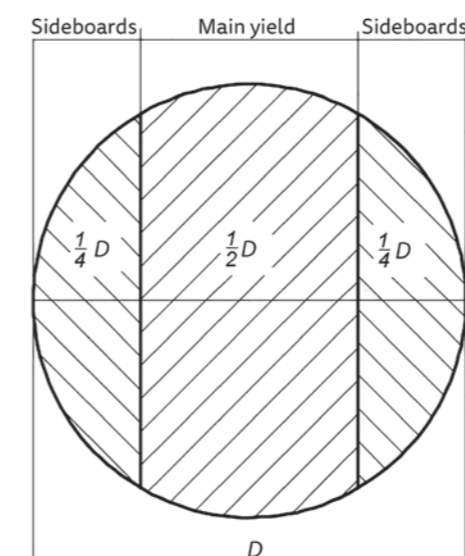


Figure 2.4 Cross-sectional view of a log, showing the definition of sideboards and main (centre) yield when the log is sawn [3].

Sawn timber can also be classified according to its location with reference to the pith [3], Figure 2.5.

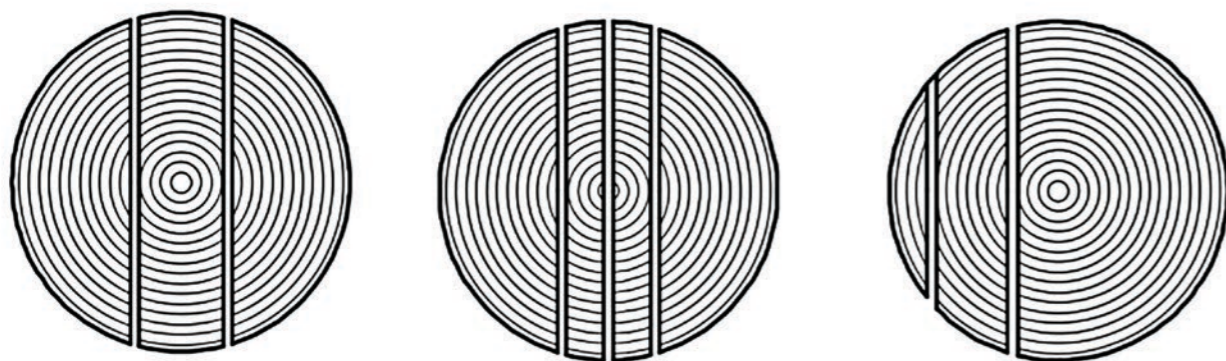


Figure 2.5 Cross-sectional view of logs showing the classification of sawn timber according to its location to the pith (from left): sawn timber with the pith enclosed, sawn timber with heartwood and sawn through the pith, and sawn timber without pith.

Depending the degree of processing, sawn timber is divided into un-edged and edged, and the edging can be either parallel or conical. In conically edging (taper-sawing), the saw-kerf follows the bark side of the board and the width of the board varies along its length. In a parallel edged board, the width is constant along its length and, in this case, one can choose to follow either the pith or the bark side of the sawn timber. Following the bark side gives a more straight grained timber.

Sawn timber can also be classified according to the annual ring orientation in its cross-section, or how it is sawn according to the rays:

- 1) vertical annual rings, i.e. boards sawn in the radial direction of the log and edged so the face of the board is occupied by rays over at least 3/4 of the total area.
- 2) half-radial boards, i.e. boards where the face is occupied by rays over at least 4/10 of the total area, and
- 3) flat-sawn boards, i.e. boards where the face is occupied by rays over less than 4/10 of the total area.

For species with rays that are not clearly visible, such as Scots pine and Norway spruce, it is easier to classify according to the angle between the tangent to the annual rings in the cross-section and the face of the sawn timber, Figure 2.6. In the standard EN 844-3 [4], three classes of sawn timber are defined based on the annual ring orientation: radial boards (vertical annual rings) with tangent angle of 60-90 degrees; half-radial boards with a tangent angle of 30-60 degrees, and flat-sawn boards with a tangent angle less than 30 degrees. When the annual ring orientation decreases from 90 to 60 degrees, the shrinkage and the swelling across the wood (in width) increase by ca. 10%. A consequence of this definition related to the annual ring orientation is that the pith and most of the juvenile wood must be removed if the wood is to have vertical annual rings. When the annual ring orientation is between 80 and 90 degrees, it is usually said that the wood is fully quarter sawn.

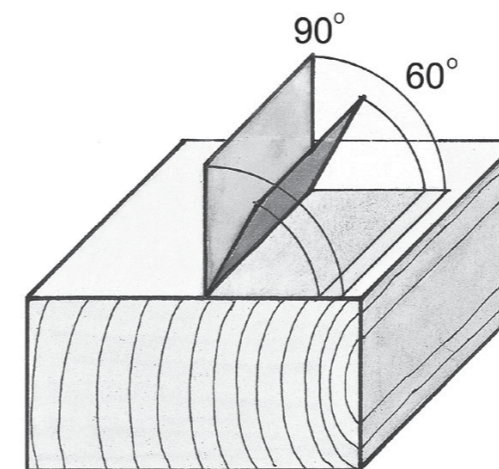


Figure 2.6 Classification of sawn timber according to the annual ring orientation in the cross section [3, 5]. By definition, annual rings are vertical (radial sawn timber) when the angle between the flat side of the sawn timber and a tangent to the annual ring on the surface of the timber is between 60° and 90°; half radial between 30° and 60°, and tangential or flat sawn between 0 and 30°.

Knots in flat-sawn timber are less of a problem in further processing than knots in sawn timber with vertical annual rings, but in general radial-sawn timber is considered to be a more high-quality product. The benefits of radial-sawn boards over flat-sawn boards are less shrinkage and swelling in width, less distortion, and less raised fibres after machining. The radial section also has a better abrasion resistance and this is favourable especially for softwood used for flooring [5].

Stress-graded construction timber

Stress-graded construction timber has defined strength characteristics corresponding to modern methods of construction, Figure 2.7. Softwoods are usually strength graded in different classes, so-called C-classes, according to the standard EN 338 (see e.g. Table 1.35). It can optionally be finger-jointed lengthwise and is then produced and controlled according to the standard EN 385. Stress-graded construction timber is dried to a moisture content of $15 \pm 3\%$, and is used mainly for load-bearing structures such as wall frames, ceilings, and visible details with prominent aesthetic requirements.



Figure 2.7 Examples of construction timber [6].

EWPs - engineered wood products

The successive reduction in quality of the forest raw material and the demand for wood components with more well-defined properties increases the interest in EWPs. The need for components with larger dimensions than sawn timber and with specified strength properties and good shape stability also contribute to the interest in EWPs. Enlarged dimensions and improved properties are successfully achieved through sorting the sawn timber and thereafter gluing it in width, thickness and/or length, where the development of cheap synthetic adhesives in the second half of the 20th century has been an important component in that development.

EWPs can be classified in many ways: for their use, their raw material, shape, type of construction element etc. In the following, the classification follows the system presented in Figure 2.2, i. e. based on a type of component after conversion of the roundwood.

EWPs based on sawn timber

EWPs from sawn timber have been strongly developed during the last decades, presenting new types of construction elements such as CLT. The increased interest in multi-storey timber buildings has been one of the major driving force for that development in Europe, a trend now also seen in US and Canada. The terms mass timber products and mass timber construction are becoming more common in a timber-building context for the use of EWPs from sawn timber such as CLT, DLT or GLT.

EGP – edge-glued panels

An edge-glued panel is a board of width-wise glued lamellae of solid wood, Figure 2.8. The lamellae are sometimes joined length-wise, especially in panels of low-grade wood. EGPs are used for furniture, for exterior and interior joinery purposes, or as a core for sandwich panels with outer sheets of a more high-quality wood or non-wood material. EGPs can be a substitute for other panel products such as particleboard, MDF/HDF, plywood in furniture and interior fitting production. Furniture manufacture based on EGPs is growing and the EU market is oriented towards natural and ecological materials for the production of furniture and interior design.

The lamellae and the outer layer are glued with adhesives of various of types depending on the properties asked for in the application. EGPs are produced with three levels of adhesive-bond quality: 1) interior adhesives that are not moisture resistant, 2) intermediate moisture resistant adhesives, i. e. lower resistance to moisture than exterior but greater than interior adhesives, and 3) exterior adhesives that are moisture resistant. Minimum requirements for each type, developed from the results of long-term exposure studies, are detailed in product standards for EGPs. The most common adhesives in EGPs for interior use are PVAc adhesives. Technical characteristics of EGPs are defined by the standards EN 1,2775, EN 13,017-1, EN 13,017-2, EN 13,353, and EN 13,354.

GLT – glued-laminated timber

Glued-laminated timber (GLT), commonly referred to as “glulam”, is a structural element made of sawn timber glued together with a parallel fibre orientation to straight beams or members with a curvature, Figure 2.9 [6]. In Europe, as well as in other parts of the world, GLT is used in a wide variety of applications, ranging from supporting beams in residential framing to major structural elements in non-residential buildings, such as girders, columns and truss members. These elements are commonly used for the construction of office buildings and schools, as well as in the industrial structure for the construction of bridges. Both softwood and hardwood are used in GLT, but the most common species for GLT production are Norway spruce, Douglas fir, larch, Scots pine, southern pine, radiata pine, and yellow poplar. For structures that are expected to be subjected to prolonged exposure to moisture, a preservative treatment is used.

GLT is designed according to specific strength characteristics, and special adhesives are used to achieve good durability and strength of the bond line, Table 2.1. Standard lengths are from 3.6 to 12 m. The manufacture of GLT is very similar, regardless of factory and country and strength-graded sawn timber is generally used. The cross-section of the GLT can be built-up from lamellae of approximately the same strength, so-called “homogeneous glulam”. In order to utilize the strength of the timber in the best way, high-strength sawn timber is however used for the outer parts of the beam where the stresses are highest, so-called “combined glulam”. GLT has considerably better shape stability and mechanical properties than sawn timber.

Table 2.1 Examples of mechanical properties of glued-laminated timber in different strength (GL) classes according to standard EN 14,080 (c – combined glulam).

Strength values (N/mm²) in:	GL24c	GL28c	GL30c	GL32c
Bending, $f_{m,g,k}$	24	28	30	32
Tensile strength parallel to grain, $f_{t,o,g,k}$	17.0	19.5	19.5	19.5
Tensile strength perpendicular to grain, $f_{t,90,g,k}$	0.5	0.5	0.5	0.45
Compressive strength parallel to grain, $f_{c,o,g,k}$	21.5	24.0	2.5	24.5
Compressive strength perpendicular to grain, $f_{c,90,g,k}$	2.5	2.5	2.5	2.5
Shear strength, $f_{v,k}$	3.5	3.5	3.5	3.5
Modulus of elasticity, $E_{o,g,mean}$	11,000	12,500	13,000	13,500
Density, $\rho_{g,k}$ (kg/m³)	365	390	390	400

The major advantage of GLT is its high strength and stiffness, which makes it possible to manufacture structures for wide spans and high load-bearing capacity. Compared to concrete and steel, GLT has in many advantages areas such as:

- Environment: GLT products are more environment-friendly than concrete and steel; they are fully recyclable and require less energy in manufacture.
- Easy to use: GLT products are lighter than equivalent concrete or steel products, e.g. the weight of a GLT beam is about one-sixth of the weight a concrete beam of the same size, and two-thirds of the weight of a steel beam.

- **Fire:** GLT has a significant advantage during a fire because it will not collapse directly when the temperature increases, which is common in steel-frame constructions. During the burning process, a charred surface is created around the unaffected core of the GLT. The speed of charring is slow (ca. 40 mm/hour) and is predictable, and this means that coarse supporting beams can keep their load-bearing capacity for hours in a fire.
- **Architecture:** GLT can be produced in many shapes and sizes, and provides significant flexibility in design and construction.
- **Appearance:** The natural look of GLT gives aesthetic value in architecture.
- **Thermal characteristics:** wood is an efficient insulating material with high energy efficiency.
- **Maintenance:** GLT has a high natural resistance to environmental pollution, and in a properly designed structure it requires almost no maintenance.

In GLT manufacture, only adhesives that have a documented high strength and durability under long-term loads are used, and only those adhesive for which the producers have a long practical experience. The different adhesives that can be used for GLT are well regulated and under constant control. In Europe, the formal requirements are given by the standard EN-301 [7] which classifies two levels of moisture resistance; type I and II. The type I adhesives can be used in all climates, while adhesive of type II has restrictions limiting where they can be used.

The traditional and very common adhesives used in the manufacture of GLT are those of the synthetic two-component PRF type (phenol-resorcinol-formaldehyde). All PRF adhesives used for GLT production are of type I. PRF adhesives give a dark reddish-brown bond line. MUF (melamine-urea-formaldehyde) adhesives are now being increasingly used. These also belong to type I. The bond lines of MUF adhesives are initially bright but may darken with time.

CLT – cross-laminated timber

Cross-laminated timber (CLT), also called X-lam, is in general a flat, multi-layered timber member consisting of odd numbers of layers, of which every second of three is orthogonally bonded to the others. CLT is used for the manufacture of structural elements for mainly buildings and bridges. The thickness is around 70 mm, but CLT multi-layered blocks with a thickness of up to 600 mm are also available, Figure 2.10 [9].

In the mid-1990s, a joint industry-academia research effort in Austria resulted in the development of modern CLT, and this product has since gained increasing popularity in residential and non-residential applications in several countries. Many impressive low- and mid-rise buildings built around the world using CLT illustrate the many advantages that this product has to offer in the construction sector [8]. By the nature of its design, CLT has an inherent load-bearing capacity and can be used in both vertical and horizontal assemblies. The sawn timber in the outer layers of CLT panels used as walls is normally oriented vertically, parallel to gravity loads, to maximize the wall's vertical load-bearing capacity. Likewise, for floor and roof systems, the outer layers run parallel to the major span direction. Since wall, floor and roof sections made of CLT are formed off-site in a factory, the on-site construction time is short. CLT is today commonly used as a structural system in multi-storey timber buildings and can be used as an alternative to concrete and steel. Technical characteristics are defined by the standards ETA 06/0138, EN 08/0271, EN 14,080, and EN 1,995-1-1/2.

DLT – dowel-laminated timber

Dowel laminated timber (DLT) is a mass timber product that can be used for floors, walls, and roof structures. Historically, it is known as *dübelholz* in Europe. The concept of using hardwood dowels to hold softwood boards together was conceived in Switzerland in the 1990s. Professor Julius Natterer spearheaded the development of *brettstapel*, as he believed that this efficient method of construction could be used to make beautiful, low-carbon, healthy buildings that are quick and easy to build. Several companies in Germany, Austria, and Switzerland adopted this idea and started to manufacture DLT commercially, using automated systems for drilling and inserting the dowels, Figure 2.11 [10].

In DLT of hardwood, dowels are used to edge-bond boards, creating a panel which is particularly efficient for horizontal spans and allows architectural flexibility. The dowels are friction-bonded to the boards.

DLT is the only all wood mass timber product – in concept, it involves neither adhesive nor steel nails. With no metal fasteners, DLT panels can be easily processed using CNC machinery, creating a high tolerance structure element, which can also contain pre-integrated acoustic materials, electrical conduits, and other service runs. DLT is also easy to recycle since it consists only of wood.

Unique to DLT as a mass timber product, a wide variety of profiles can be integrated into the bottom surface of the panel. Each finger-jointed board goes through a moulder, allowing a limitless range of different profiles to be explored and exposed in the bottom of a panel.

Multi-layered shuttering panels

A type of panel used for shuttering is composed of three layers, where the two outer layers have a thickness of 6 to 9 mm, and the middle layer has a thickness of 9 to 15 mm, Figure 2.12. The middle layer is oriented at an angle of 90 degrees to the outer layers. Standard dimensions are a width of 500 mm, a length of 1,500-3,000 mm with intervals of 500 mm. The standard thickness of the panel is 27 mm. The outer layers are made of spruce or fir, obtained by gluing lamellae with a width of up to 140 mm. The middle layer is made of low-quality sawn timber.

The panels are glued with waterproof melamine-urea-formaldehyde adhesive and the surfaces are protected by a layer of melamine and the edges by an acrylic coating. A high modulus of elasticity of the panels is very important. A shuttering panel can be used as a formwork up to 40 times.

Panels consisting of 3- or 5-layers with the construction similar the shuttering panels, but with a higher demand on appearance, are also produced for exterior and interior construction work. The thickness can be between 13 and 80 mm. Common species for the panels are Norway spruce, larch, and Douglas fir, but thermally modified timber is also on the market.

Light-weight core materials

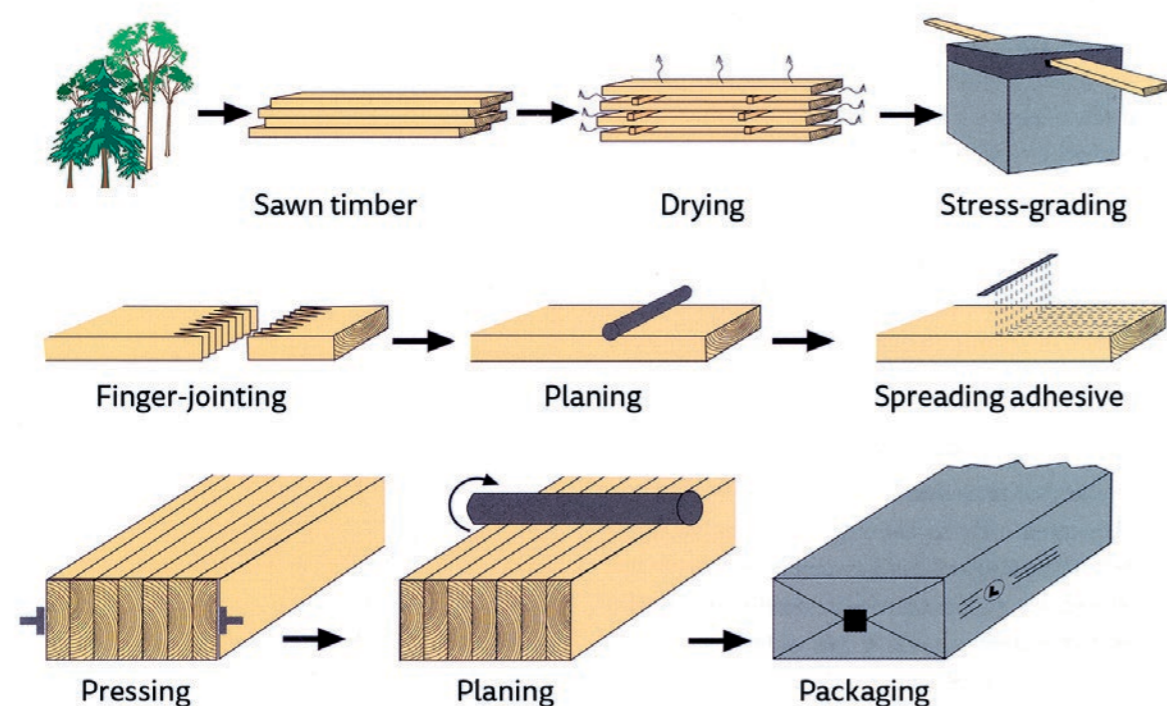
Light-weight materials based on wood for interior fittings and furniture have been of interest for at least the last fifty years, mainly for cost-reducing reasons. Today, the increasing care of the

environment and the growing interest in the concept of a sustainable society provide further impulses for the development of light-weight materials. The main benefits of these materials for furniture applications are their high strength-to-density ratio and low weight. A low weight is an advantage in the transport and handling of products and it also lowers the transportation costs. In terms of recycling and resource-efficient material management, light-weight materials made of wood, paper or recycled cellulosic materials have been developed in recent years, mainly in the furniture industry.

Light-weight materials can be divided according to their function and structure into three categories: 1) *light-weight materials* which combine materials with a low weight-to-strength/stiffness ratio, 2) *structural light-weight materials* which are structures mainly for building purposes that, with a minimum of weight, can distribute applied loads, and 3) *light-weight systems* – a superposition of the functions of light-weight materials, providing not only supporting functions but also thermal insulation, etc.

During recent years, several ideas for light-weight panels of exclusively solid wood that combine low weight with high strength have been presented. These panels are mainly for buildings and other structural systems due to their wide range of advantages, i.e., high strength-to-weight ratio, low cost of the framework, and good thermal and sound insulation properties [11]. Dendrolight® is a core material available on the market that consists of layers of cross-aligned sawn timber with longitudinal kerfs, which are glued to the surface layer at an angle of 45 degrees [12]. Another material is a three-layer-panel with a core of low-grade sawn timber that has a pattern of hollow cells which reduce its weight [13]. A stiff and very form-stable light-weight panel for use in furniture making, for door blanks and for the construction of internal wall elements was suggested by Professor Dick Sandberg' group in the beginning of the 21st century and is shown in Figure 2.13 [14].

The main steps in manufacture of glued-laminated timber (GLT)



2.8



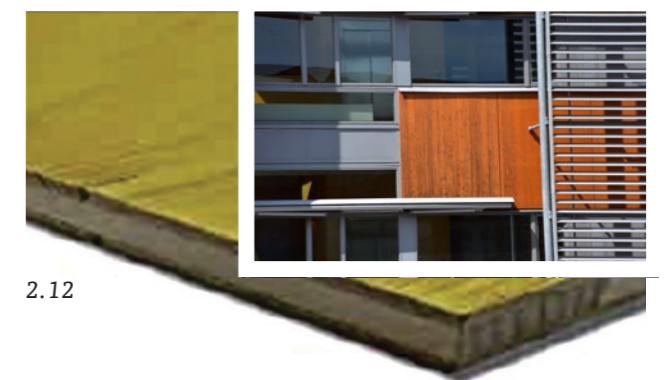
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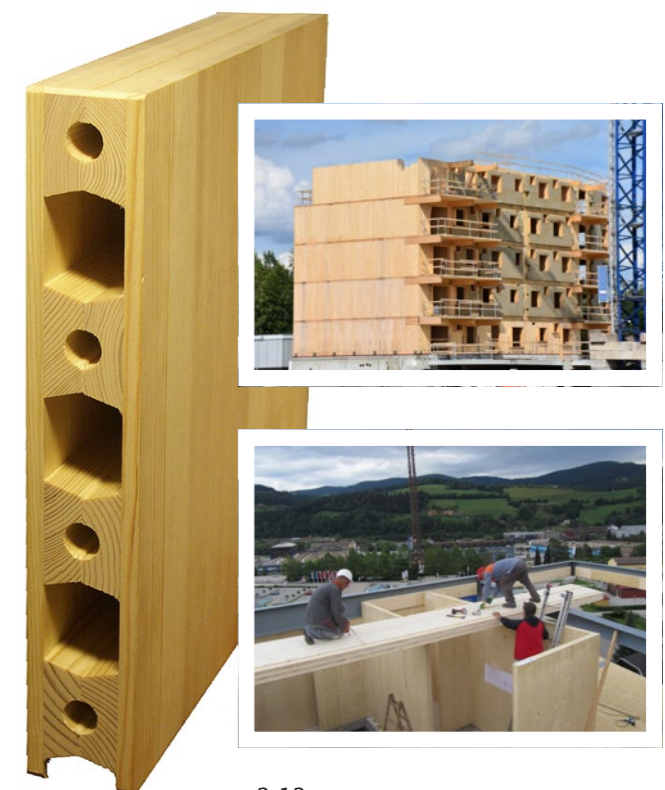
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Figure 2.8 Example of an edge-glued panel of beech.

Figure 2.9 Glued-laminated timber.

Figure 2.10 Cross-laminated timber.

Figure 2.11 Dowel-laminated timber.

Figure 2.12 A shuttering panel.

Figure 2.13 An example of a light-weight panel of solid wood. The holes in the core elements are for efficient assembly.

EWPs based on veneer

EWPs based on veneers are plywood, laminated veneer lumber, laminated veneer products, and high-pressure laminated veneer.

Plywood

Plywood is the oldest EWP, is being already used by the ancient Egyptians. Plywood is a rigid board composed of an odd number of veneers bonded together so that the fibre orientation of each veneer is perpendicular to the fibre orientation of the adjacent veneers, Figure 2.14. The most commonly used raw materials are spruce, pine, beech, birch, and poplar.

There are numerous grades, but plywood can be divided into plywood for constructional (exterior) purposes, for interior use (joinery and decorative plywood) and for special applications such as concrete shuttering, marine-plywood, plywood with special surface layers etc. Board types in which veneer sheets are glued to a timber-strip core, i.e. a core plywood or face-glued block-board, are also assigned to the class of plywoods.

The properties of plywood depend mostly on the wood species, veneer thickness, board thickness and type of adhesive. The density of the veneer ranges from 500 to 700 kg/m³. The thickness of boards ranges between 4 and 50 mm, the length of 2,200 to 2,500 mm, and common widths are 1,250, 1,500, and 1,850 mm. Technical characteristics are defined by the standards EN 636, EN 12,369-2, and EN 13,986.

LVL – laminated veneer lumber

Laminated veneer lumber (LVL) is board material made of veneers with the thickness of 2-4 mm bonded together with the same fibre orientation in the layers, Figure 2.15. LVL is used as free-standing girders or for flanges, for different types of composite girders, as a formwork for moulding, also as reinforcement in zones with extraordinary bending and tensile loads. LVL is also used for the internal cover of containers for transport, railway thresholds, electricity and telephone poles, windows and door frames.

LVL was introduced in the USA around 1960. Initially, the product was not commercially successful, and production was suspended. In 1968, the American Trus Joist Company Corp. (now Trus Joist MacMillan) developed a continuous production line and began manufacturing LVL under the brand name Microllam® [15, 16]. In Europe, a pilot production started in Finland in 1975, and a line for regular production started in 1980 for an LVL product with the brand name Kerto. Currently, most LVL is being produced in the USA, Finland, Japan, Australia and New Zealand, and veneers of different species of low and medium density are used.

The number of veneers placed in LVL depends on the dimensions of the board. After pressing of the LVL where the width is usually about 2 m, LVL is cut to the final width and length. The manufacturing process is continuous, and the pressing length is unlimited, but LVL does not usually exceed 25 m due to transport restrictions. The most commonly used adhesive is a water-resistant phenol-formaldehyde adhesive.

The design of LVL is intended to eliminate strenght-reducing defects and thereby to achieve a high strength, improved dimensional stability, and homogeneity of both physical and mechanical properties. The veneer is graded, so that low-quality veneers are placed in the core, and the high-quality veneer is used as the outer layers, thus improving both flexural strength and modulus of elasticity.

The mechanical properties of LVL are better than both sawn timber and glued-laminated timber, Figure 2.16.

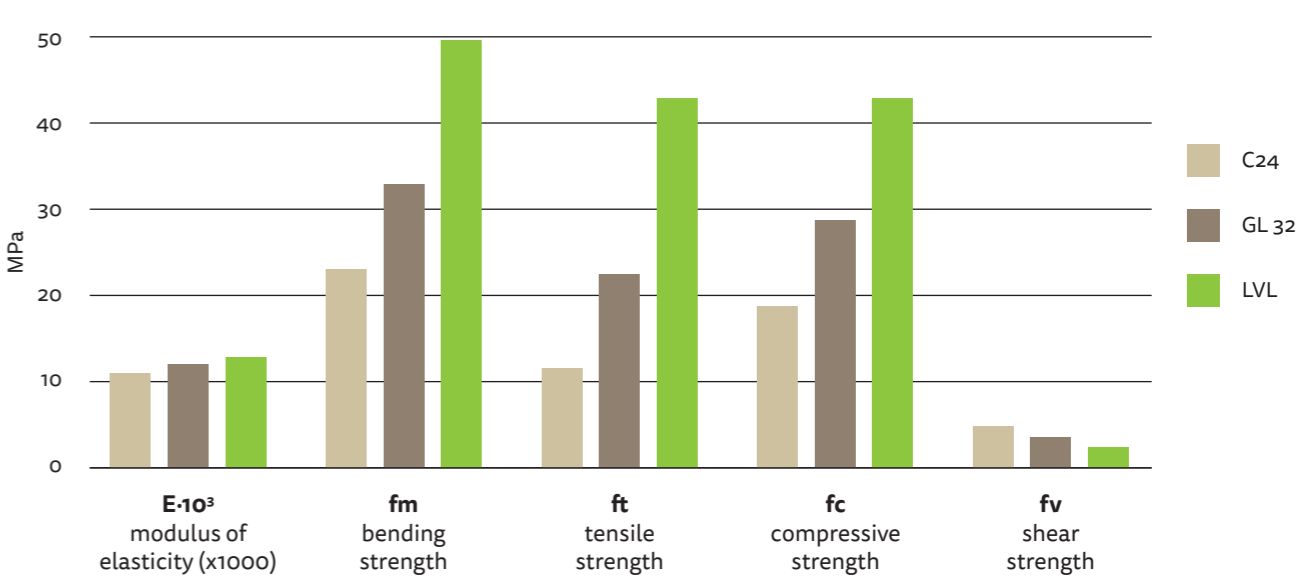


Figure 2.16 Mechanical properties of stress-graded construction timber (C24), glued laminated timber (GL 32) and LVL [6].

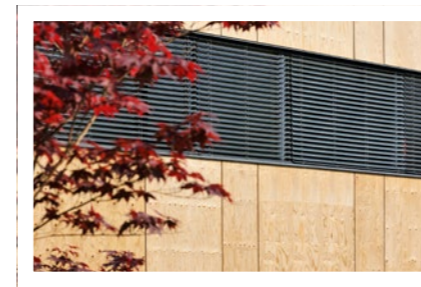
LVP – laminated veneer products

Laminated veneer products (LVP) consist of veneers bonded together with an adhesive under pressure into a predetermined shape and usually under an elevated temperature to decrease the curing time of the adhesive. The process used to manufacture such products is generally called *laminated bending* and it is used for the manufacture of components for exterior and interior use. LVP is especially known for the use in the production of furniture, Figure 2.17.

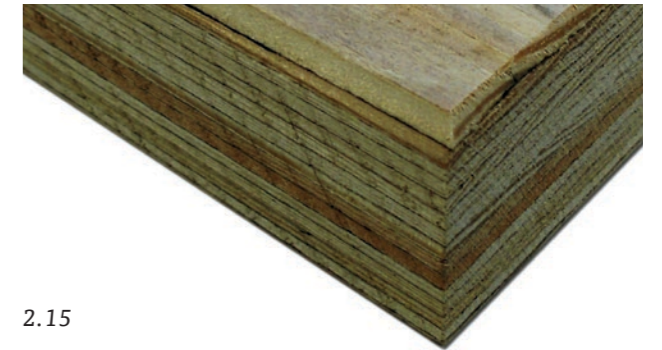
Different techniques for forming LVPs have been developed during the last hundred years: male and female moulds, pressing lamination to shape by means of metal tension bands or with an inflated flexible rubber hose and a metal strap, etc. A good overview of the various techniques for forming LVP can be found in [17, 18]. The most frequently used industrial method for bending laminated assemblies to the desired shape and applying the requisite pressure to achieve proper bonding together of the laminae is to press the assembly in a mould between shaped male and female forms [18]. The adhesive is extremely important for the function of the final LVP, and the development of synthetic adhesives has contributed to the development.

HPLV – high-pressure laminated veneer

High-pressure laminated veneer (HPLV) is a material that has been compressed in the transverse direction in order to increase its density, Figure 2.18. This process is commonly called densification [19]. One of the reasons for densifying wood in the transverse direction is to produce high-quality components from timber of low quality. However, densified wood has an undesirable property, viz.: a tendency to recover all or part of its compression-set and return to its initial dimensions when subjected to humidity. In most of the densification processes that have been industrialized, this recovery problem has been solved by the development of adhesive-impregnated products, which are now being commercially produced.



2.14



2.15



2.17



2.18



Figure 2.14

Plywood.

Figure 2.15

Laminated veneer lumber.

Figure 2.17

A laminated veneer product.

Figure 2.18

High-pressure laminated veneer.

EWPs based on strands, strips, chips, particles or fibres

EWPs based on strands, strips, chips and particles include parallel strand lumber, oriented strand boards, laminated strand lumber, particleboards, inorganic-bonded composites, and wood-plastic composites.

In the 6th century, the Japanese produced materials from fibres similar to today's fibreboard, but the first industrial production of fibreboard was the Masonite process invented in the USA in the 1920s. In 1931, the Swedish engineer Arne Asplund patented an improved method of defibrating wood chips and a fibreboard production based on this method started in 1932. Production of particleboard began in 1941, and oriented strand boards were first produced in 1978 [20]. The development of parallel strand lumber started in the 1970s, by MacMillan Bloedel Ltd in Vancouver B.C. and came onto the market in 1984 under the trademark Parallam.

PSL – parallel strand lumber

Parallel strand lumber (PSL) is a beam element manufactured from parallel-oriented veneer strips (strands), typically 15-20 mm wide and 3 mm thick, Figure 2.19. The degree of raw material utilization is up to 80%. Low-quality veneer and small-diameter roundwood, as well as waste from veneer peeling, can be used in the production. The manufacture of PSL is based on a technology which makes it possible to convert small-diameter trees into elements with large cross-sections (up to 30 x 50 cm²) and lengths up to 20 m. PSL is used in the construction of large buildings, primarily in girders, beams, and pillars.

PSL shows the same advantages as LVL, except for the opportunity for layering veneer strands by grade. Strength is instead enhanced by densification of the PSL in production.

OSB – oriented strand boards

Oriented strand boards (OSB) are developed from wood strands which are typically 15-25 mm wide, 75-150 mm long and 0.3-0.7 mm thick, cut from logs of small diameter, Figure 2.20. A water-resistant adhesive is used to bond the strands together and the boards are fabricated under pressure at a high temperature with a higher density as a result. The strands in the face layers are aligned parallel to the length direction of the board, whereas the internal strands are deposited randomly or perpendicular to the face layers. OSB is, therefore, a multi-layer board, used in a large variety of structures or for decorative purposes. The boards are used for under-floors, ceilings and sometimes walls, but also in packaging and for pallets, and they have replaced plywood and particleboard in many applications. OSB is actually a second generation panel that evolved from the original waferboard developed in the United States.

Different species such as aspen, southern yellow pine, white birch, red maple, sweetgum and yellow poplar have been used as raw material in North America, but in Europe, spruce and pine are more common as raw materials for the production. Technical characteristics are described in standards EN 300, EN 12,369-1, and EN 13,986.

Properties and use of Sawn timber and Engineered wood products

LSL – laminated strand lumber

Laminated strand lumber (LSL) uses a manufacturing technique similar to that of PSL production, which makes it possible to convert small-diameter trees into elements with a large cross-section area, but tree tops and branches can also be used, Figure 2.21. The strands (often aspen) are arranged parallel to the length direction of the board and glued with a water-resistant adhesive. LSL can have dimensions up to ca 140 mm in thickness, 1,200 mm in width and 15 m in length. LSL is known by its commercial name *Timber Strand* in North America, and in Europe as *Intralum*. LSL is used mainly in construction primarily for girders, beams, and pillars.

The debarked roundwood is flattened and partially split in the longitudinal direction using so-called scrimming rollers, and the dried strands or "scrimms" are further processed using fine scrimming rollers. Several LSL elements are in general layered to each other to increase the thickness and properties required of the final component. The orientation of the mats in LSL is parallel (i.e. the fibre orientations of all the scrimms run parallel to each other), perpendicular (i.e. different layers are oriented at 90° to each other) and also totally random before the mats are laminated together under pressure to a component of beam or panel size. In general, a phenol-formaldehyde adhesive is used.

PB – particleboard

Particleboard (PB) is manufactured from wood particles of various dimensions, cut mechanically by chippers, flakers etc., and the board is in general three-layered, Figure 2.22. The outer layers consist of small particles for a smooth and tight surface, and the inner layer consists of large particles acting more or less as fillers. The mechanical properties depend on the size and on the arrangement of the wood particles. All types of wood species can be used as raw material in particleboard production, although manufacturers prefer softwood. The boards can be up to 40 mm thick, up to 2,070 mm wide, and between 2,800 and 5,610 mm in length.

The manufacturing process for PBs is a so-called dry process, i.e. an adhesive is added to bond the particles, and there are two different methods of production; hot pressing and extrusion, which give different types of boards with different particle orientations. In hot pressing, the particles are oriented parallel to the panel surface, whereas in the extrusion process they are oriented perpendicular to the surface. In furniture and door manufacture, extruded PB with internal holes can be used to achieve good acoustic properties and a light weight, Figure 2.23.

For construction purposes, a special PB called LSB-P5 with a thickness of 22 mm is used for exterior conditions, Figure 2.24. This board has a high bending and internal bond strength, as well as low thickness swelling in humid conditions. The board is used in construction, primarily in free-standing elements, or in combination with other elements and building materials, such as floor coverings and partition walls in conditions with a high relative humidity.

PB can be covered with a melamine-resin-impregnated paper or a laminate for use primarily in furniture manufacture and for interior joinery, Figure 2.25. These types of PB surface are resistant to light, water, shock, scratching, and abrasion. With a wide selection of colours and textures, these types of PB are widely used. The thickness is between 6 and 38 mm, and the boards are most 2,820 mm in length and 2,070 mm in width. Technical characteristics are defined by the standards EN 312, EN 14,322, and EN 14,323.

IBC – inorganic bonded composites

Inorganic bonded composites (IBC) are boards or other types of constructional elements produced from comminuted wood (wood wool, particles or flakes) or other types of fibre of vegetable biomass blended with cement, magnesite (MgCO_3) or gypsum. However, the most expedient binder giving strength, durability and acoustic insulation properties is Portland cement. In this process, heat is not required.

IBCs have a long history that started with commercial production in 1914 in Austria that produced magnesium-oxide-bonded wood wool (excelsior) boards. The wood-cement boards are used for specialized structural applications. They have outstanding properties in terms of their resistance to fire, durability, sound insulation and stiffness, which render the product most suitable for internal wall constructions in public places, the lining of lift shafts, the construction of cabling ducts, soffits, motorway acoustic fencing and the cladding of prefabricated house units. The cement-bonded board is harder and more resistant than its components alone, with a lower cost and lower density than concrete.

Many manufacturers use additives like mica (silicate/phyllsilicate minerals), aluminium stearate and cenospheres (a lightweight, inert, hollow sphere made largely of silica and alumina, and filled with air or inert gas) in order to achieve certain board qualities. Typical cement fibreboard is made of 40-60 weight-% cement, 20-30% fillers, 8-10% cellulose, 10-15% mica. Additives such as aluminium stearate and polyvinyl alcohol (PVA) are normally used in quantities less than 1%. Cenospheres are used only in low-density boards with quantities between 10-15% [21].

WPC – wood-plastic composites

Although EWP based on strands, strips, chips and particles have been made with thermosetting adhesives for many years, only in the last three decades has a serious attempt been made to incorporate wood flour and chips into thermoplastics in order to produce wood-plastic composites (WPC). The term WPC refers to any composite that contains wood particles and a thermosetting or thermoplastic polymer. In contrast to the wood-thermoset composites, wood-thermoplastic composites have seen a phenomenal growth in the United States in recent decades and for this reason, they are often referred to simply as wood-plastic composites with the understanding that the plastic is always a thermoplastic. In a WPC, the dry weight percentage of the wood component is typically in the range of 50-60% [22]. New compounding techniques and interfacial treatments utilizing coupling agents make it feasible to disperse large volume fractions of hydrophilic wood in various plastics. These compounds can be continuously extruded, thermoformed, pressed, and injection moulded into any shape and size, and they thus have the potential to replace natural wood in many applications.

Today, WPCs are classed as a building material and they have their main markets in the US [23]. The European WPC market is also steadily expanding. In general, WPC products are marketed as a low-maintenance building material with a high ability to resist fungal decay, although combinations of wood and polymers often have a poor long-term durability when exposed outdoors. A major cause can be insufficient wood-polymer adhesion due especially to an intrinsically low compatibility between the wood substance and the polymers used. Adhesion failure is usually caused by

the hygroscopicity of the wood and the differences in hygro-thermal properties between the components.

Fibreboards

A large number of EWPs based on fibres have been developed in the form of panels. The various types of fibreboard derived from wood are insulating fibreboards, or low-density fibreboards (LDF), medium-density fibreboards (MDF), and hardboards or high-density fibreboards (HDF).

The manufacturing processes are divided into two principal classes; dry and wet processes. In the dry process, the bonding of fibres is accomplished by the use of an adhesive, generally a phenol-formaldehyde or urea-formaldehyde resin. In the wet process, the cellulose fibres bind together by hydrogen bonding. This bonding of the fibres is achieved through drying and compression of the wet fibres, and no adhesive is used to bind the fibres together. This process is used for the production of paper, paperboard, insulating fibreboard, semi-hard boards and hardboards.

Fibreboards obtained by the wet process are used for insulation (insulation boards). Their advantage compared to other insulating materials is that they are purely bio-based. They also have good acoustic properties and a low water vapour permeability [8].

MDF is manufactured by a dry process where bonding of the fibres takes place at a temperature of 150 to 220°C. The density is typically between 600 and 800 kg/m³. The main advantage of MDF is its homogeneous structure which means that its properties are similar in all directions of the board. Figure 2.26. The most common dimensions of MDF are 3-40 mm in thickness, 2,500-2,800 mm in length, and 675-1,250 mm in width. Technical characteristics are defined by standards EN 622-5, EN 12369-1, and EN 13986.

MDF is used in the production of curved components of furniture or for interior purposes, Figure 2.27. It can be painted or coated with veneer or different types of foil. This type of MDF is produced by longitudinal slits that make it flexible. Typical dimensions are a thickness of 9.5 mm, a length of 2,800 mm, and a width of 1,080 mm. Technical characteristic are defined by standards EN 622-1, EN 622-2, and EN 310.

Fibreboard can also be coated with a melamine paper or a laminate and is used mainly for furniture and interior joinery, Figure 2.28.



2.19



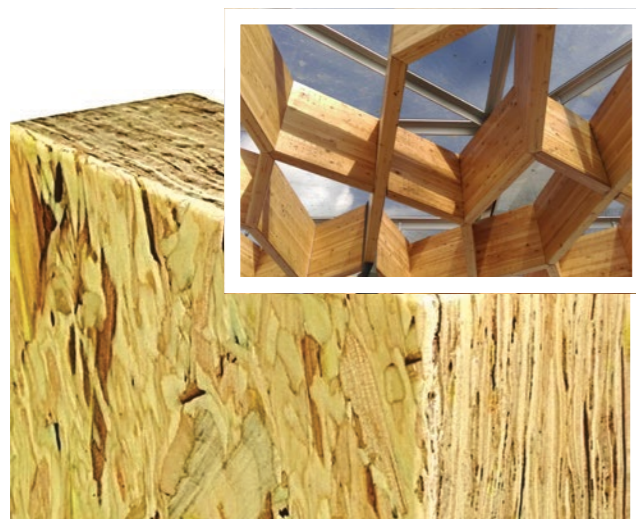
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Properties and use of Sawn timber and Engineered wood products



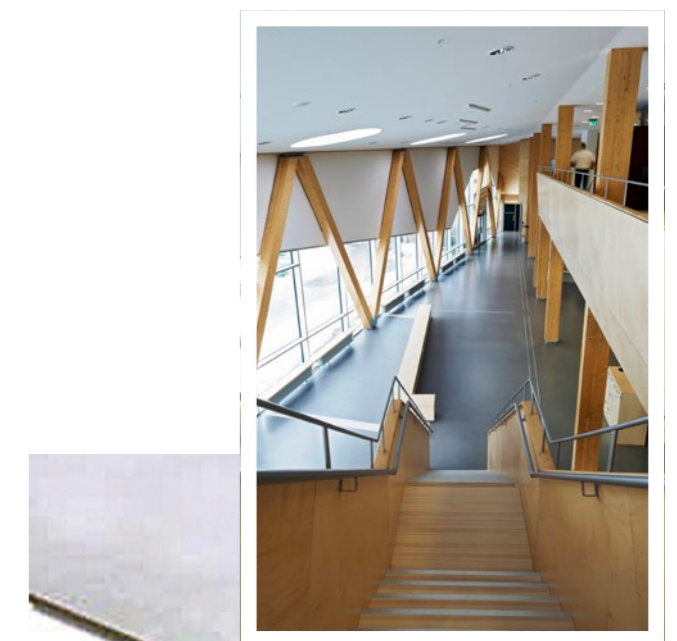
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- Figure 2.19 Parallel strand lumber.
 Figure 2.20 Oriented strand board.
 Figure 2.21 Laminated strand lumber.
 Figure 2.22 Particleboard.
 Figure 2.23 Tubular particleboard.
 Figure 2.24 Construction particleboard LSB-P5.
 Figure 2.25 Surface-laminated particleboards.
 Figure 2.26 Medium density fibreboard (MDF).
 Figure 2.27 Flexible medium density fibreboard for curved products.
 Figure 2.28 Surface-coated fibreboard.

Hybrid EWP

Hybrid EWPs consist of EWPs in combination with other materials or other EWPs, Figure 2.29. Typical hybrid EWPs are:

- sandwich panels, e.g. a core of an insulation material, honeycomb etc. and outer sheets of a board material such as plywood, OSB, or MDF, or
- construction elements such I-joists or ribbed elements.

By combining different materials, the properties of the hybrid EWP can be designed specifically to give e.g. low weight, high strength, or low heat transmission.



Figure 2.29
Examples of a hybrid EWPs, i.e. an I-joist with flanges of LVL and the web of OSB, and hybrid cross-laminated timber.



CLT with glued-in timber rib developed by CBD d.o.o. Hybrid CLT developed in a Wood Wisdom Net research and development project, <https://www.hcltp.com/>

Environmental aspects of EWPs

Forestry and forest-related industries have never before been as focused as they are today of the major challenges of the future. Instead of utilising the earth's limited resources, we have to use renewable materials, fossil fuels must be phased out and individual consumption must to a greater degree reflect a concern for the climate and a care for the environment. In this context, the emissions of carbon dioxide have been in focus for a long time. One way of reducing the emission of carbon dioxide is to use a greater proportion of wood products and to increase the life of these products so that the carbon is bound over a longer period of time or to replace energy-intensive materials with wood-based products [24].

Although wood is a natural material, bonded wood products have caused some environmental concern related to formaldehyde and other volatile compounds in the adhesives used in bonded wood-based products. Heating increases the problem, as it raises the vapour pressure of reactive chemicals. Isocyanates can react rapidly with compounds in the human body. Both emulsion polymer isocyanate (EPI) and polyurethane (PU) adhesives contain isocyanates. The preparation and processing of epoxy-resin also pose significant health risks in the form of e.g. allergies. There are also legal requirements which aim to depress the levels of emission, especially of free formaldehyde.

The foremost area of environmental concern with regard to adhesives has been the emission of formaldehyde from bonded products, particularly those using urea formaldehyde (UF) adhesives. Products bonded with UF-based adhesives such as plywood, MDF and PB are often used e.g. in kitchen joinery and furniture and they may, therefore, lead to an increase in the level of formaldehyde in the indoor air. Formaldehyde can also be released from acid-curing inks and varnishes. Formaldehyde can react with biological systems in reactions similar to those used for the curing of adhesives. The problem can arise from both unreacted and generated formaldehyde. Unreacted formaldehyde is a problem during the manufacturing operation and in freshly produced composites, but formaldehyde emissions from composites decrease with time after production. Formaldehyde can also be generated by the decomposition of some formaldehyde copolymer adhesives, in particular, the UF adhesives. These adhesive bonds are more prone to hydrolysis, generating free formaldehyde.

The greatest concern about formaldehyde is with PB, due to the large volumes used indoors and a large amount of adhesive in the product. The particleboard industry has therefore together with adhesive manufacturers focused over a long period on reducing formaldehyde emission from the boards. Figure 2.30 shows the reduction in formaldehyde emission from particleboards in Europe from 1970 to 1990.

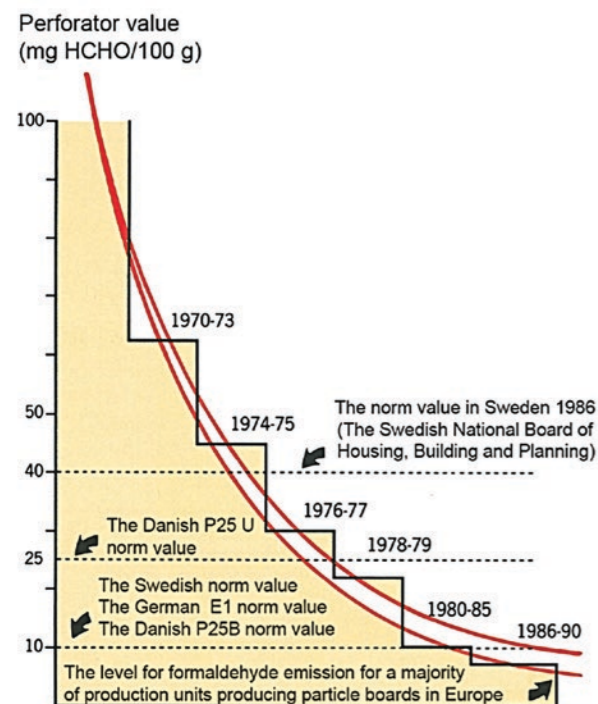


Figure 2.30

Content of cleavable formaldehyde from particleboards in Europe from 1970 to 1990, measured as perforator value and expressed as mg formaldehyde per 100 g dry material. The perforator method is described in the standard EN-120.

European standards recommended in 2000 by the European Panel Industry defined formaldehyde emissions ratings. Original ratings included E1, measuring 9 mg/100 g and below, E2, measuring greater than 9 mg/100 g to below 30 mg/100 g, and E3, measuring a greater than 30 mg/100 g ratio. Pressure for more stringent standards led to a new rating classification, E0, based on emissions measuring 0.5 mg per liter and below. Europeans test methodology is based on the Perforator Test Method, which measures the formaldehyde levels inside the wood specimen.

Producers and customers should prefer boards classified as E1 to minimize the negative impact on human health. In 2004, IARC (International Agency for Research on Cancer) classified formaldehyde emissions higher than 7 mg/m³ as proven carcinogens.

There are many materials in the construction and housing industries that compete with wood, e.g. steel and concrete for frames and large constructions, bricks for walls and facades, and PVC and other plastics for windows, building features and furniture. For wood as a material to be competitive against those materials, the environmental advantages of wood are not sufficient, i.e. that wood shows lower emissions of carbon dioxide according to calculations based on LCA criteria. Wood must also be competitive for its technical qualities, show a high material utilisation during further processing, and not least, must show a competitive economic yield during usage.

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Oak forest

Bosnia and Herzegovina





Star-sawing
Sweden

3 Industrial manufacture of single-family timber houses in Bosnia and Herzegovina

The tradition of wood construction

Nowadays, the use of natural materials in construction is increasing and emphasizing the need for sustainable development. This means that residential buildings must save energy, with only a small contribution to the global CO₂ emissions. To better understand how residential buildings should be built in the future, it is necessary to consider the traditional construction methods.

The architecture in Bosnia and Herzegovina (B&H), and particularly Bosnian architecture, arose in four basic developmental periods when political and social changes influenced the creation and development of specific cultural and architectural traditions. Each period affected the overall picture of Bosnian architecture and contributed to the development of cultural diversity and specific architectural expression in the country. In the distant past, wood was intensely used as one of the most important structural materials, available locally since ancient times.

The medieval period in Bosnia lasted until the arrival of the Ottoman Empire, and the social structure in Bosnia at that time was organized in “unions”. These were special family communities, groups of several families, who shared common interests and grouped together with their homes. The families lived mainly in houses known as “Dinara houses”, typical medieval residential buildings, specific for the Balkans but first emerging in the centre of Bosnia, Figure 3.1. The Dinara house was made mostly of wood and usually had only one room with a soil floor and a fireplace in the middle of the house, hand-made furniture, wall-mounted tables for food storage, and other utility articles. This two-storey home was mostly set with its longer side along the contours of the ground - the basement on the slope, with an apartment on the upper storey, with an open fireplace [1].



Figure 3.1 A traditional Bosnian Dinara timber house [1].

Larger houses were built with stone on the ground floor and a timber upper floor, with protruding steep roofs which protected the walls, Figure 3.2. The uniqueness of the Bosnian mountain house was in the, due to the cold climate, certain facades also had timber panels or shingles for thermal insulation. Such a house consisted of four components:

1. In one part of the house (depending on the terrain) the basement was dug in wholly or in half. In Bosnia it was called 'magaza'.
2. On the ground floor, a kitchen with a fireplace called "simply house" in Bosnia as well as in Uskoplje, with its pantry, and a wooden floor room often used for sitting and sleeping. Above the fireplace, an entire section was open to the roof. This area was used for drying meat and other smoked products.
3. The upper floor could be reached through a passage (cefernjak) by a wooden staircase (basamaci). It was closed with a wooden cover for the safety of children and adults at night. Upstairs, there was a balcony made of timber, from which one could enter the room by one or more entrances.
4. The upper floor was intended for daily rest and sleeping. The loft was intended for storing crops.

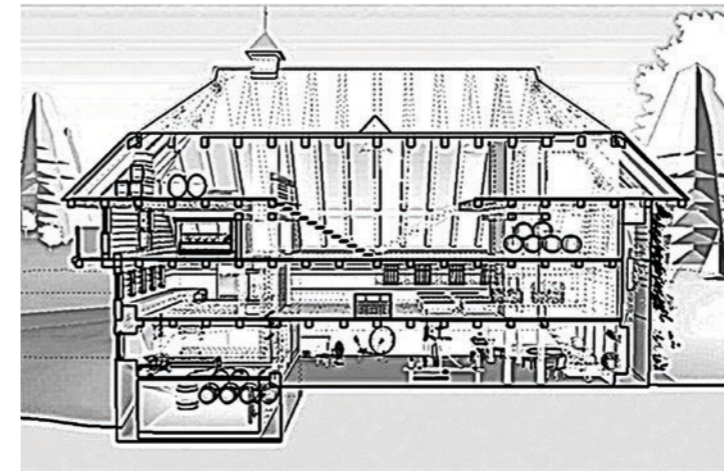


Figure 3.2 Longitudinal section of a large Dinara house [2].

The upper part of the house was borne by timber beams, usually oak, covered with boards, with reed and plaster. This part was entered by a wooden ladder through an opening located in one corner of the house, or externally by a staircase. The stairs always ended in a timber balcony or oriel window or the so-called sofa, used for seating during the summer, with an extended roof. The roof was high and steep, and it could have a polygonal shape, with all four surfaces of equal length, or semi-inclined, if two surfaces of the narrower sides of the house were shorter and created a gable. If the roof was covered with shingles, the house could be made without a single iron component. The eaves extending significantly over the walls of the house to protect the wooden parts from the impact of rainwater.

Around the house, usually behind it, was a fruit grove, the so-called "bašča", as well as a garden for the main crop, usually fenced in by a wicker balustrade. Other vegetables were planted on larger plots.

In the 15th century, the Ottoman Empire spread to the territory of B&H. Recognizing the need for the development of urban planning, urban areas began to sprout and develop their basic form, with an organization noticeable today. The architectural theorist Dušan Grabrijanje defined the basic organization of the typical Bosnian city. Recognizing the five basic units of organization of the city, Grabrijan characterized the so-called unwritten laws of building in B&H. According to him, the surrounding hills define the shape of the city, the main road is its backbone, the bazaar is the heart of the city, urban life, vegetation is the lungs, and the river spirit of the city is the source of its vitality.

According to these standards, the foundations of Bosnian houses were built of stone, ground clay, adobe and wooden links, the first floor was a timber structure, and the roof was almost always made of wood, later of roofing tiles. Organizationally, the typical Bosnian house from the 17th century consisted of five elements: a fence, which defined the street and which clearly separated the private from the public space, a courtyard, which was usually covered with rounded stones for easy maintenance, a fountain, as an essential part of hygiene before entering the house, the ground floor or the semi-private room where the family gathered and, verandas and the first floor which was a private corner and was used mainly for relaxation and enjoyment or to view the surrounding countryside.

The traditional Bosnian house had both a high technical quality as well a high living quality. The interior and exterior were naturally overlapping and were oriented towards the inner garden, which provided an intimate residential atmosphere, Figure 3.3. These houses were located in the historical city centers and urban areas across the region. In the urban context, they had a strong connection with nature and were usually built on the slopes of the hill providing a pleasant view, the sun, and intimacy [2].



Figure 3.3 House of Svrza in Sarajevo [3].

The favourite building material for our forefathers was the tree. The ground floor, where the bedrooms were located, was built of wooden elements. Plaster, in addition to its aesthetic value, also served as a disinfectant. In the Bosnian construction, there was continuity in the use of wood and wood-based panels, dating from ancient times. Timber construction was perfected in the unique residential architecture [2]. Other natural materials such as wood and stone were also used up to the end of the 19th century when B&H was annexed by the Austro-Hungarian Monarchy.

In a relatively short period of Austro-Hungarian rule, Bosnia felt a significant impact in the field of urban planning and architecture. Some of the changes adopted by the Austro-Hungarian Empire was the creation of new building norms and laws such as the obligation to obtain building permits, regulation of human and fire protection, and regulation of the wall thickness and height of buildings. Some of the urban changes introduced the classification and zoning of streets, regulation of harmonious design with the environment and respect for the regulatory plan. There was also a change in the general design philosophy that developed into two distinctive architectural styles: Art Nouveau and pseudo-Moorish architecture. Art Nouveau architecture appeared because of the political directions of attempting to relieve Bosnian culture of its past and assimilating it into the European direction [4].

Pseudo-Moorish architecture took a different position – the influence of Moorish architecture in Spain. This included the use of ornaments and other Moorish design strategies that did not completely match the previous standards and original Bosnian architecture. Both changes contributed to an even greater diversity of a relatively complex urban environment in Bosnian cities. During this period, especially cities began to change their original character and

physiognomy. Most of the projects during the Austro-Hungarian rule concerned the design of administrative buildings. The City Hall in Sarajevo (Figure 3.4) was a typical example of the so-called pseudo-Moorish style, where decorations and arches of a Moorish character were used, mixed with formal and traditional norms in the modern architecture of the 20th century [4].



Figure 3.4 Sarajevo City Hall "Vijecnica" [3].

After the Second World War, B&H became part of the Yugoslav federation. Political power in Yugoslavia favoured industrialization, and this, in turn, demanded the development of residential areas in order to meet the migration from rural to urban areas. As a method of overcoming cultural conflicts since World War II, an anti-historical view was primarily applied, combined with a contemporary style as the basic architectural style for the majority of construction projects in the country. As a result, homogeneity in the choice of materials replaced the traditional variety in construction, and concrete became the main material used [5].

Prefabricated timber houses

Due to the intensive use of steel and concrete in recent decades, wood has, to a certain degree, lost its importance in B&H. However, this is not the case in other European countries with a long tradition in the construction of timber that has been retained and even improved up to the present day (the Scandinavian countries, Germany and Austria). This is supported by data that shows that over 90% of single-family houses in Sweden are built with a timber frame [6].

The innovative timber construction in Europe is based on the use of ecological materials, primarily wood, and different engineered wood products (EWPs). The construction of low-energy houses, as well as the construction of passive houses, results in an annual energy consumption of less than 15 kWh/m². Such houses have become the need of modern society. This low-power consumption is due to the exceptional energy efficiency of these facilities. Given the fact that around 40% of the total energy consumption in Europe is in the construction and housing sector, with two-thirds of the energy being consumed in households with a further growth potential in the coming years, the

construction of a passive house has become extremely important for reducing energy consumption. The implementation of standards and the issuing of certification for the construction of new and the renovation of existing buildings is becoming a common practice in some European countries. This is leading to the development and support of standards related to wood products that are being installed in these facilities. Subsidies that individual countries in western Europe give to encourage green building are important starters for the use of EWPs. This is reflected in the timber industry and in the research and development domain, where innovative wood-based products with significantly improved characteristics (compared to conventional products made of sawn timber) are being developed. In the last few years, due to the impact of European trends, construction workers, apartment buyers and timber house manufacturers in B&H have slowly been changing their opinions in a positive way regarding the use of timber in construction.

The export of prefabricated houses is growing continuously and, according to data from the Foreign Trade Chamber, the value for 2013 was € 5,624 million, for 2014 € 11,297 million, and for 2015 € 12,816 million.

Examples of producers of prefabricated timber houses in B&H are companies such as *A.S.B. Expan Inc.* in Bihać, *Dominvest Inc.* in Žepče, *Savox Inc.* in Milići, *Grossist Inc.* in Prijedor, *Steco Inc.* in Bijeljina, and *Agroflora Inc.* in Kozarska Dubica, which are mainly active on the domestic and regional markets. Two major industrial manufacturers with a long tradition are *Krivaja-TMK Inc.* in Zavidovići and *Promo Inc.* in Donji Vakuf.

The development in B&H of prefabricated structures based on light-weight construction elements and laminated timber constructions began back in 1950. Most Bosnian timber house producers nowadays offer houses with wood panel construction, and timber frame structures and massive wood construction systems are also used. From the beginning until today, the company *Krivaja-TMK* with its own engineering, production and assembly facilities, ground-storey and low-energy building techniques (passive house) was and still is the market leader in this field.

Another industrial manufacturer of prefabricated houses in B&H with a tradition of over 50 years is the *Promo* company. In recent years, export to countries in the region and to the countries of western Europe, especially Austria, France, Sweden and Italy has significantly increased. They are also present on the middle eastern and African markets.

Both manufacturers produce objects for a variety of uses, such as dwellings, schools, hospitals, kindergartens, industrial and agricultural buildings, facilities for catering, entertainment, leisure, recreation and sports facilities, halls, etc. Figure 3.5 shows a flowchart for the industrial production of prefabricated timber houses in B&H.

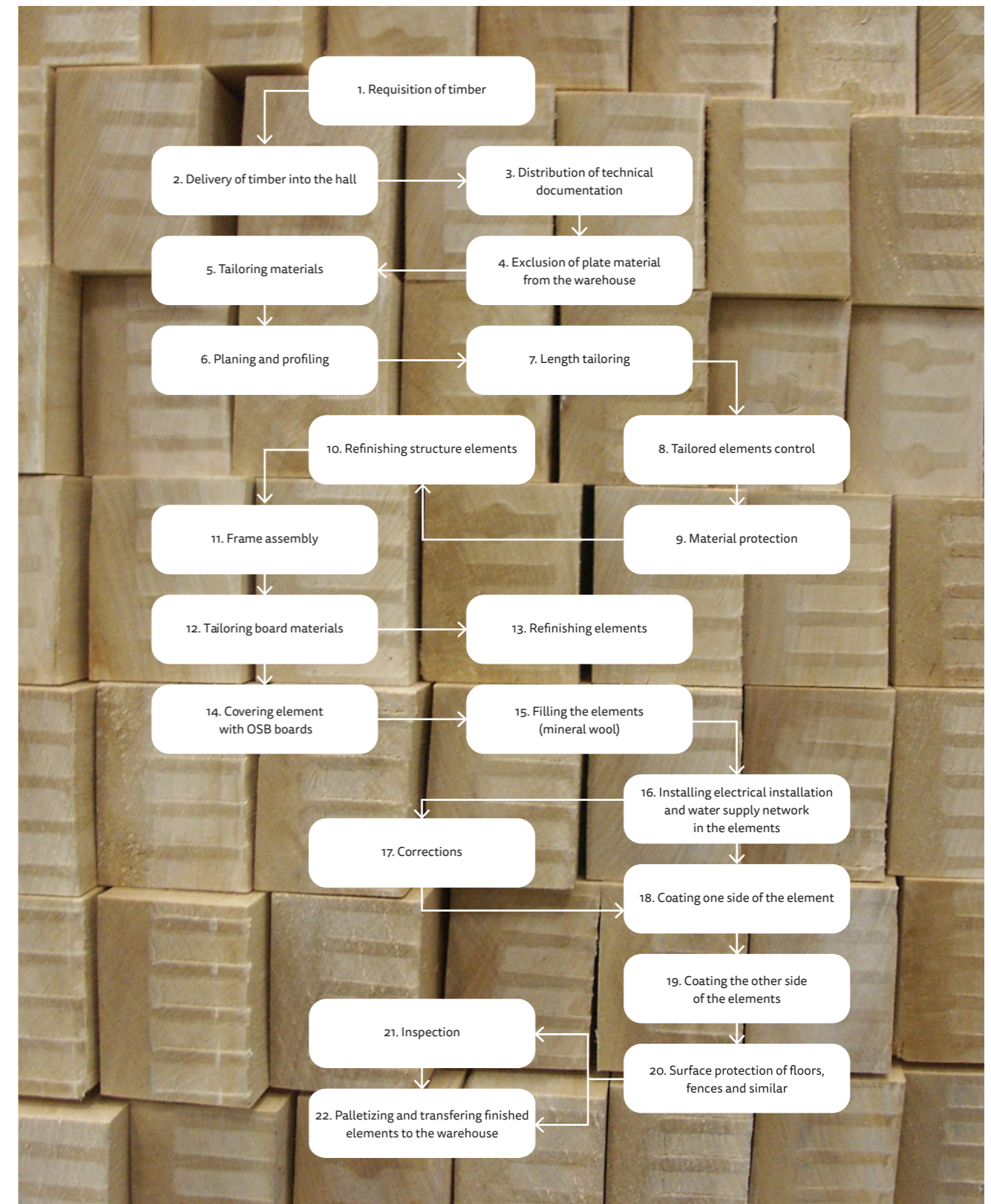


Figure 3.5 Flow chart of prefabricated timber houses in B&H.

Building components in single-family houses

A technical description of the typical products of a prefabricated house manufacturer, Krivaja-homes, is presented below.

The exterior wall

Energy-technical requirements in the construction of single-family houses have significantly changed in the past few years. Houses with low energy consumption were rarely built a few years ago, but today due to the increased customer demands, they have become a standard. The supporting structure for the external panel consists of timber elements with a thickness of 45-60 mm and a width of 100-200 mm, depending on the total width of the wall. The spaces between the timber elements are filled with high quality self-supporting mineral wool. Before the assembly, the timber is treated with a impregnated preservative (Poligrund-D from Borosol) as a protection against decay by fungi.

Timber frames are covered with particleboard or OSB, on both the interior and exterior sides. Before nailing the inner boards, a polyethylene (PE) foil is placed on the frame, on the inside of the panel to serve as a vapour barrier and prevent the penetration of moisture into the insulation, which could lead to condensation of water and a reduction in the thermal insulation properties of the wall and mould growth. These panels are transported and assembled on site. After the building has been assembled, the walls are lined on the outside with expanded polystyrene (EPS), e.g. Styrofoam™, which is covered by three layers of plaster.

The basic offer is mineral mortar colour according to the tastes of the client. The inner sides of the walls are covered with gypsum board with a thickness of about 10 mm, Figure 3.6.

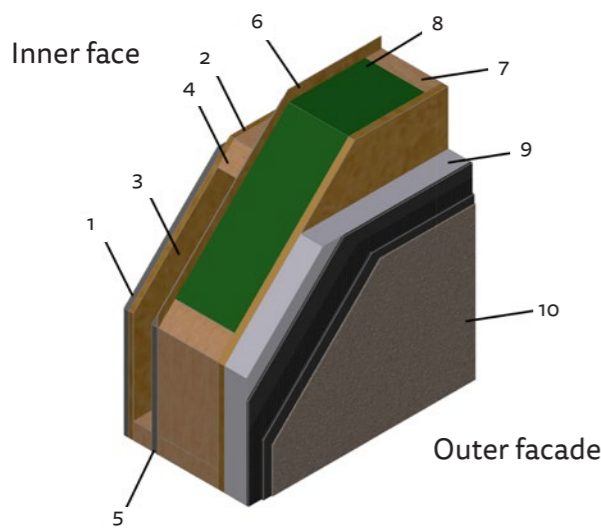


Figure 3.6
Cross-section view of the outer wall of the house: (1) gypsum board 10 mm (2) OSB 10 mm, (3) installation channel 50/50 mm, (4) 50 mm mineral wool, (5) 10 mm OSB, (6) polyethylene foil, (7) structural frame 45x100 mm², (8) 100 mm mineral wool, (9) 100 mm expanded polystyrene (EPS), and (10) ca. 8 mm smoothing mass, facade [8].

Following the latest trends in construction and energy conservation, outer walls with a 20 cm thick thermal insulation with an additional facade insulation with a thickness of 6 cm are produced. This wall has a heat transfer coefficient (k) of 0.140 W/m²K, and the facility is placed in the category of low-energy buildings, i.e. buildings whose annual heating requires less than 40 kWh/m², Table 3.1.

Table 3.1 Insulation standard in modern construction in B&H.

Wall thermal insulation thickness (mm)	Façade thermal insulation thickness (mm)	Total thickness of the wall (mm)	Heat transfer coefficient, k (W/m²K)
120	50	205	0.207
140	50	225	0.188
200	60	295	0.140

Partition walls

Interior partition walls are made according to the same principle as the exterior walls, with post-and-beam elements with dimensions of 45 x 50 mm to 60 x 100 mm, clad with plywood or OSB. The timber is protected from decay and insect attack. The space between the studs is filled with mineral wool with a thickness of 50 to 160 mm to provide both thermal and acoustic insulation, Figure 3.7. After assembly, the final lining of walls is made of plaster panel, whose compounds are paper tape and plaster.

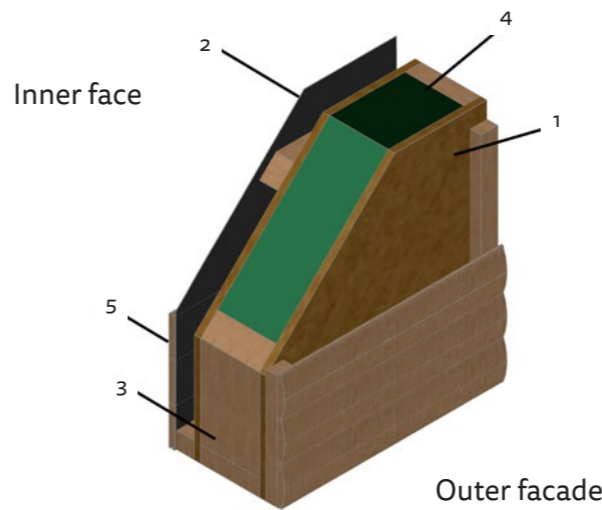


Figure 3.7
Cross-section view of a partition wall: (1) 10 mm gypsum board or OSB (2) polyethylene foil, (3) 45x100 mm² structural frame, (4) 100 mm mineral wool, and (5) 10 mm OSB [8].

In the sanitary facilities and parts of the kitchen where the walls are lined with ceramic tiles, the wall panels are clad with water-resistant gypsum board or plasterboard. The walls are made in panels with a height of 2,300-2,500 mm. The elements are fitted with doors and windows according to the planned layout.

Installations

During the production of the wall panels, electrical cable installations, as well as plumbing and sewage systems are installed. Electrical installation cables are laid in non-flammable plastic pipes of an appropriate diameter. During the facility installation, cables are drawn horizontally above the ceiling and connected with the main-terminal cabinet.

Roof and ceiling constructions

The ground floor ceiling structure is made from timber trusses of fir. Truss bars, as well as timber parts of the wall, are protected and connected with the help of timber connectors of metal.

The timber trusses are covered by a panel with a thickness of 22 mm, over which a foil permeable to water vapour is placed. It is then fitted with binding expansion strips and strips of tile, and clad with tiles, Figure 3.8.

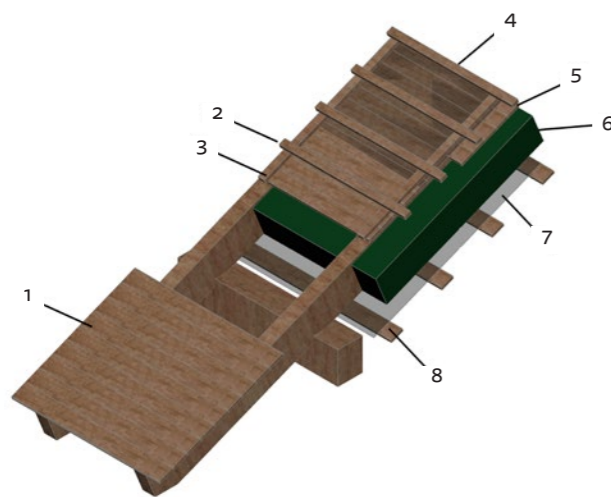


Figure 3.8
Cross section view of the roof structure: (1) roof tiles, (2) lath 40 x 40 mm², (3) counter-lath 40 x 40 mm², (4) permeable foil, (5) 22 mm plank boarding, (6) roof rafters (mineral wool), (7) polyethylene foil, (8) 22 mm lath, and 12.5 mm gypsum board on the inner side [8].

The ceiling is formed beneath the truss by nailing the formwork at distances 300 to 400 mm, to provide a substructure support for plaster boards. A polyethylene (PE) film is nailed to the formwork to act as a vapour barrier in the outer wall. Mineral wool with a thickness of 100-200 mm is used for thermal insulation.

Construction of floor joists

The floor joists are made of timber beams with a cross section area of 60 x 200 to 80 x 220 mm² depending on the structural requirements. The timber beams are preserved against decay, and they are covered by a “blind layer” of sawn timber with a thickness of 40 mm or by a 22 mm thick OSB, which serves as a substructure completing the floor. A PE film and mineral wool with a thickness of 50-100 mm are inserted between the beams for thermal and sound insulation, Figure 3.9.

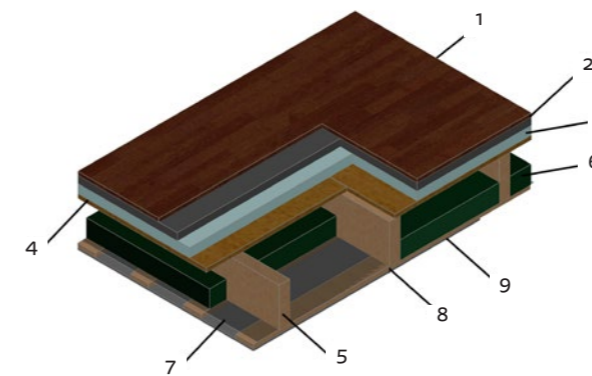


Figure 3.9
Cross-sectional view of a floor element: (1) flooring, (2) 50 mm screed strips, (3) 50 mm expanded polystyrene (EPS), (4) 22 mm thick OSB, (5) laminated beams 80 x 220 mm², (6) 100 mm mineral wool, (7) polyethylene (PE) film, (8) 22 mm lath, and (9) 12.5 mm gypsum board [8].

Solid wood elements and board material are cut to required dimensions in the preparatory department. These tailored materials are transported to the production hall for large construction elements, where the frames are assembled and filled with insulation material. Windows and doors are installed, as well as the final internal and external cladding. Transportation from one workplace to another is mechanized. A panel production line system is shown in Figure 3.10, and a technical description of a prefabricated timber house from the manufacturer *Promo Inc.* is presented in Figure 3.11.

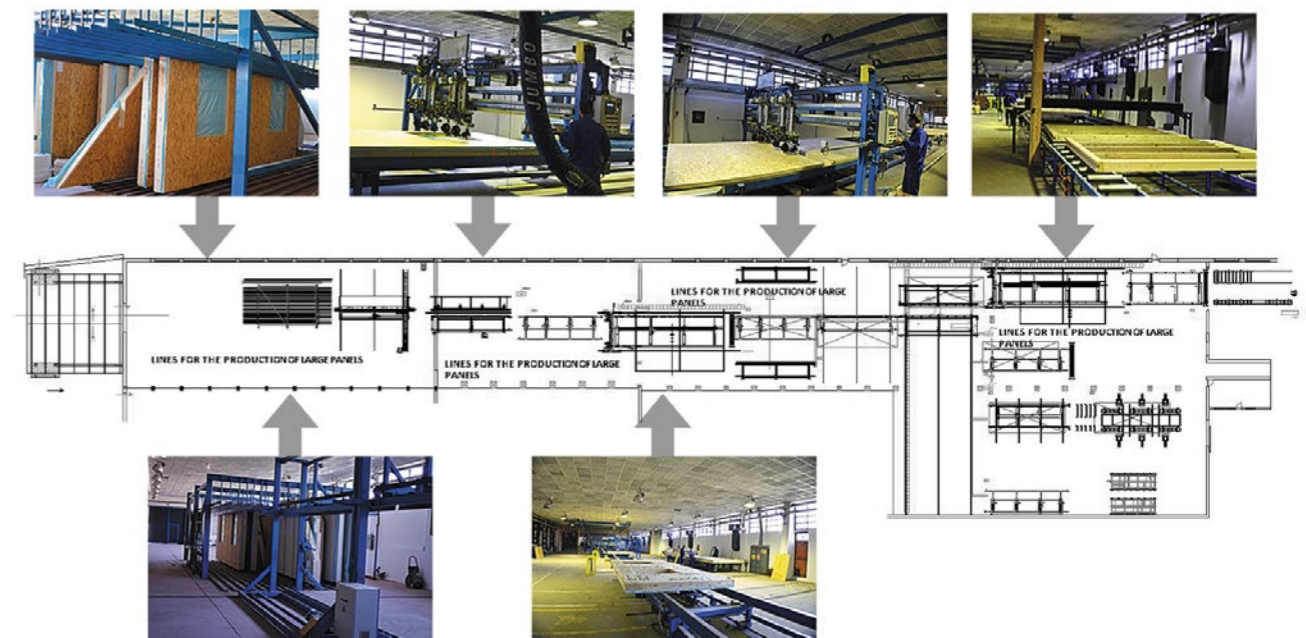


Figure 3.10 Production line of construction elements at the Krivaja-TMK factory for prefabricated timber houses in Zavidovići [8].

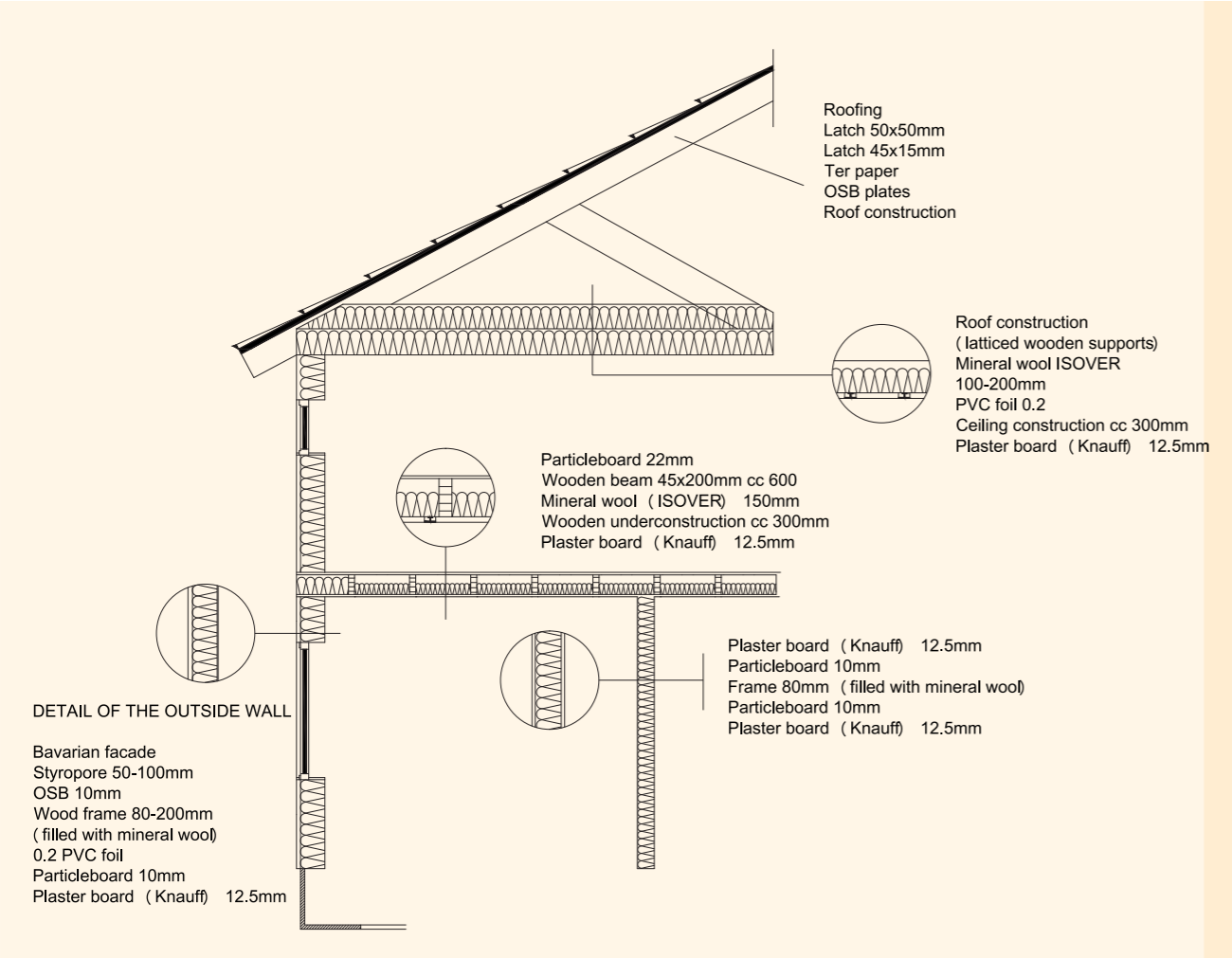


Figure 3.11 Technical description of prefabricated timber houses of the Promo company [7].

Prefabricated timber houses with thin walls, as well as objects where cranes have no access, are systems in which panels are stiffened and connected to the upper and lower cornice to create a compact unit. Thicker walls are made of the so-called “large-panel” system, where an entire wall is made in a factory in a single piece and is lowered by a crane into place. Some basic types of single- and two-storey house produced in B&H are shown in Figure 3.12. The construction of prefabricated houses is similar to that in Sweden and Austria. The timber frame design is easily changeable and flexible. Comfort in these houses is comparable with that in houses built of other materials.



Figure 3.12 Some basic types of prefabricated timber houses in B&H [9].

Korjenić and Klarić [10] conducted a survey in 2011 to determine the conditions of living in prefabricated timber houses in B&H and to decide whether the conditions of living in prefabricated timber houses is good or not, and whether or not the scepticism towards timber as a structural material in homes is justifiable. The houses were produced by local companies in B&H.

Figure 3.14 shows the results of this survey. A sample of 40 persons living in prefabricated timber houses located in different regions under different climatic conditions was taken in this survey. 97% of these respondents expressed a positive attitude towards living in prefabricated houses, and it can be concluded that there is a great potential in B&H for this type of housing. After talking with the persons individually, a general dissatisfaction with the lack of professionalism and lack of knowledge of the workers assembling the houses was observed. Respondents made it clear that more attention should be paid to the connection points of the elements and details of the openings.

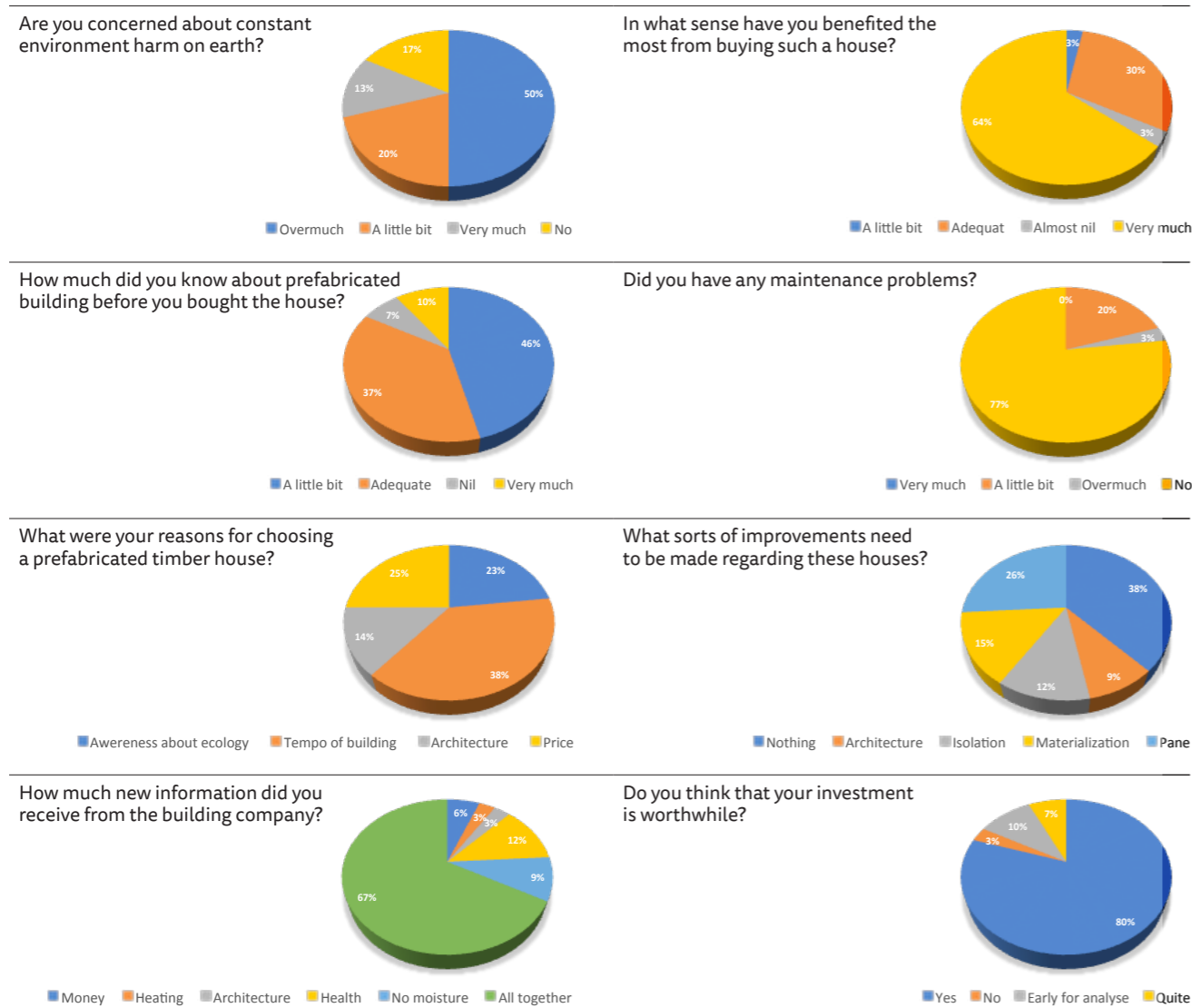


Figure 3.13 Results of the survey about living in timber houses [10].



Photo: Miran Kambič

It should be noted that the respondents have lived in prefabricated timber houses for only a few years. The residents in these houses have not experienced a long-term stay and it is not therefore surprising that no problems in the maintenance of the houses have yet been encountered.

We can conclude that the new insulating materials, EWP's and building technologies represent a renaissance for the use of timber in modern construction. B&H has a long tradition of industrial manufacture of prefabricated timber houses, but these have not been significantly accepted by the local population.

Due to the constant increase in the price of energy used for cooling and heating, new technical regulations and standards, noticeable climate changes with unpredictable floodings, the better proclamation of investors, designers and customers, the interest in a more efficient use of wood in B&H is increasing. Modern prefabricated timber structures are not only a challenge, but also a solution to future environmental and energy problems. Nowadays, in addition to expensive and non-ecological concrete buildings, more conscious clients are seeking low-energy prefabricated buildings. This also contributes to the awareness that bio-based materials can be used in the process of making a home. The foundation of low-energy buildings is certainly wood.

Nowadays, new energy technologies are either seamlessly integrated into the existing building types as new designer additions, or present a welcome starting point for the creation of entirely new building types using bio-based materials - local wood offering a sustainable environment-healthy living space.

The traditional architectural and urban elements will transform residential housing typology into the best solution for low-energy building requirements in urban regions in B&H, as desired by Bosnian architects who use contemporarily sustainable and natural structures and materials [11]. The strong tradition in prefabrication of the buildings in B&H, and the richness of the natural local renewable materials (wood, sheep wool, straw) present a strong base for the development of innovative approaches in the building sector using natural resources.

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Figure 3.14 Hotel PINO, Sarajevo, Studio Zec

House N

Sweden





4 Industrial manufacture of single-family timber houses in Sweden

The industrial manufacture of timber housing has a long tradition in Sweden [1], but compared to other manufacturing industries the timber housing industry has developed weakly [2]. Today's timber housing companies do not fully utilise materials and methods that are adapted for the efficient manufacture of houses in a factory and the level of automation is as low as the productivity, leading to long lead times from ordering to moving in [3]. This means that the possibility of utilising the environmental advantages that wood from Scandinavian forestry offers during production, e.g. single-family housing is lost.

That which distinguishes traditional building (construction industry) from another manufacturing industry is that the product is manufactured at its final location (on-site) instead of being moved there in its final shape [4]. Industrial construction means that the manufacture of the house components takes place in an industrial production environment (off-site), with only assembly at the building site [5]. The timber housing industry in Sweden can be regarded as an industry intermediate between the manufacturing industry and the construction industry [6]. The method of producing a house or parts of a house in an industrial production environment is termed "prefabrication", which is the dominant method of building single-family houses in Sweden. The definition of a wooden house depends upon the choice of material in the load-carrying frame [7]. Of the on-site and prefabricated single-family houses built in Sweden, approximately 90% have timber frames and wood is also used in carpentry and furnishings [8]. A single-family timber house in Sweden usually has a floor area between 50 and 250 m² and seldom more than 2 storeys.

The beginning and growth of industrial timber building

The manufacture of prefabricated timber houses in a factory began in Sweden during the 1800s. A precursor in this instance was the architect Fredrik Blom (1781–1853) who probably got his inspiration, ideas, and impressions for prefabricated and moveable buildings from his journeys to England, a country with an earlier tradition for the manufacture of prefabricated houses in iron. The first factory for the manufacture of houses was, according to Blom's concept, designed at the end of the 1830s and produced wall elements in timber that were mounted together rationally during the erection of the house. The house could be dismantled and was thought to be easily moveable. During the second half of the 1800s and the beginning of the 1900s, a number of timber house manufacturers emerged in the south of Sweden, with a substantial part of the production intended for export. Several of the companies that produced timber houses were also involved in

carpentry and furniture. Many of these timber house companies were integrated with a sawmill, where timber house manufacture began as a complement to provide further sales opportunities for the sawn timber [1, 9, 10]. There are also examples of steelworks which left the steel industry and instead switched over to wood processing, e.g. the manufacture of timber housing.

The first decades of the 1900s meant a build-up phase for many timber house manufacturers. In 1918, a comprehensive standardisation began within the field of residential construction and for construction materials, which meant a great deal for the industrialisation of prefabricated timber houses. From 1930 to 1940, Swedish timber house companies increased their production of houses from 1,000 to 9,200 per year. During the years following the Second World War, there was a great demand for housing and a large number of prefabricated house manufacturers developed, Figure 4.1.

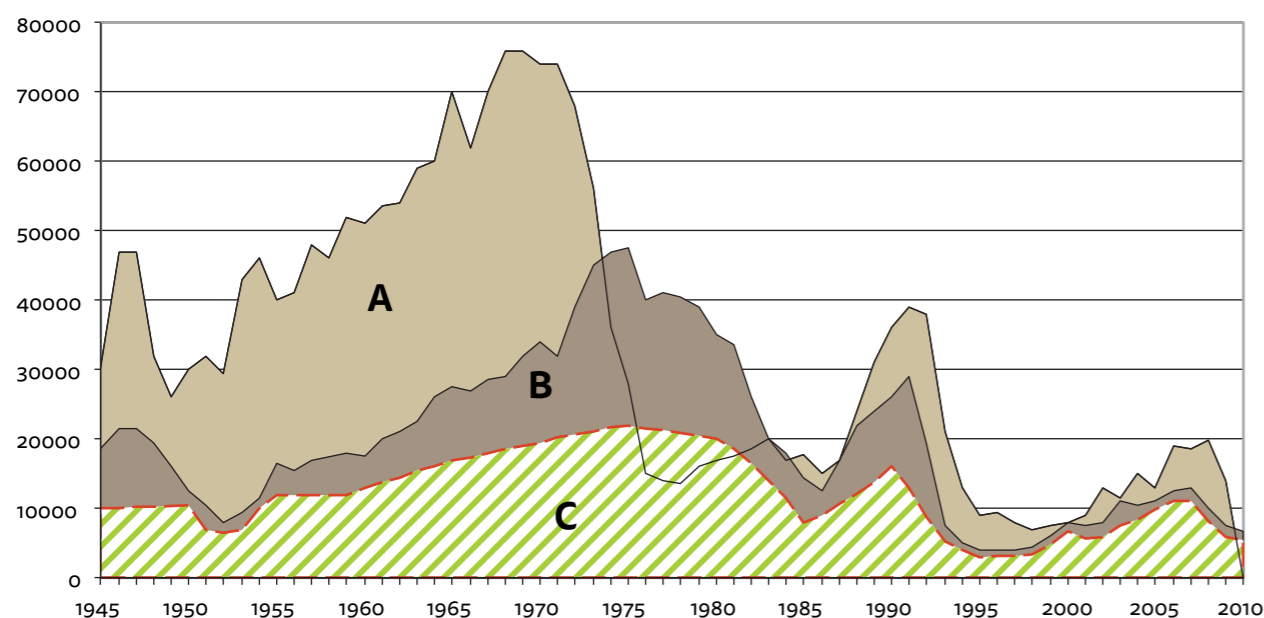


Figure 4.1 Housing production in Sweden between 1945 and 2010 [11, 12].

A) Number of flats in multi-dwelling units.

B) Total number of single-family houses.

C) Number of single-family houses from timber-house manufacturers.

During the 1950s, there was a technological reorganisation in the industry, the major significance of which was to replace sawdust with mineral wool to insulate prefabricated building units. Mineral wool changed the production technique in that the walls began to be manufactured of studs using different panel materials as facings. Other important, influential factors were access to larger and better lorries for transport from factory to building site and a further standardisation of carpentry, windows and doors. The number of timber house companies increased even more and by the mid-1980s there were approximately 70 companies in Sweden. The period between 1945 and 1990 was successful for the building of single-family houses with timber frames, with a peak in 1975 when approximately 46,000 timber houses were produced, of which half were produced in a factory, Figure 4.1.

Industrial manufacture of single-family timber houses in Sweden

In the last two decades, the building of single-family houses has been significantly lower than the peak year of 1975 and the number of prefabricated houses has essentially not exceeded 10,000 houses/year [11, 12]. Of the total on site built and prefabricated single-family houses that have been built in recent years in Sweden, 80-90% were timber houses [2, 13, 14].

The typical Swedish timber house company is a SME (Small or Medium sized Enterprise), often family-owned with manufacturing that is largely custom-designed [14, 15]. Some of the companies that have previously only produced single-family houses have even begun to produce multi-family dwellings. They then essentially use the same building and production techniques as for single-family houses [16]. Development within the timber housing industry towards prefabrication has been similar throughout the Scandinavian countries, and prefabricated housing in these countries has not been viewed as a worse alternative than on site built houses. Prefabrication has instead been regarded as a method to manufacture houses faster and better [1, 17].

Today's producers of single-family houses in timber

During a long succession of years, the construction industry focused overall on prefabrication, standardisation and methods for production management at the expense of customization. This has also applied to many companies that manufacture single-family houses in timber. During the last decade, timber-house companies have, however, focused more and more on the customer and their demands in housing [18].

A majority of timber-house companies in Sweden apply production methods that do not greatly differ from those used for the on-site building of timber housing [19, 20]. An essential difference between on-site building and prefabrication is however that prefabricated units are manufactured in dry and warm premises.

The production costs for timber-house-company products have increased year after year without the cost increases actually being questioned. The timber house industry could have retained its profit margins by raising the product price instead of becoming more efficient and finding alternative materials that are better suited to production. Of course, one such approach contributes neither to rendering manufacturing more efficient nor to providing the customer a cheaper and better end product. In recent years, many of the industrial companies have therefore directed their attention towards the production process, and to attain a more efficient production, principles according to Lean Construction have been introduced, i.e. principles where Japanese car manufacture has served as a source of inspiration [17, 21, 22, 23]. The reason for introducing principles according to Lean Construction is to minimise the waste of resources, eliminate over-production, reduce unnecessary transfers of materials and unnecessary stocks and reduce the waiting times. While attention has been directed towards the production process, an improved communication and an increased collaboration between timber-house companies and subcontractors has been considered more and more important for reduced costs. A computer tool for 3D modelling is an important instrument in this work [17].

The totally dominant frame system for the manufacture of single-family houses in timber in Sweden is based on timber studs. The timber stud system means that the walls consist of standing wall studs with insulation material inserted between the studs. The stud construction is usually fitted with

gypsum or wood-based panel materials inside and outside, with some type of façade covering. The façade covering can be brick, plaster or timber panel. The level of completion in the factory varies depending on the choice of façade covering and only timber façades can be prefabricated. The floor structure is prefabricated in the same way as the wall unit and is consists of beams at a certain distance from each other with inlaid insulation and wiring. Manufacture is based on either surface elements or volumes. Among businesses, there are two strategies: either to manufacture plane elements in plant and transport these to site for final assembly or to assemble the plane elements together in the factory and ship them as complete volumes to the final building site, Figure 4.2.

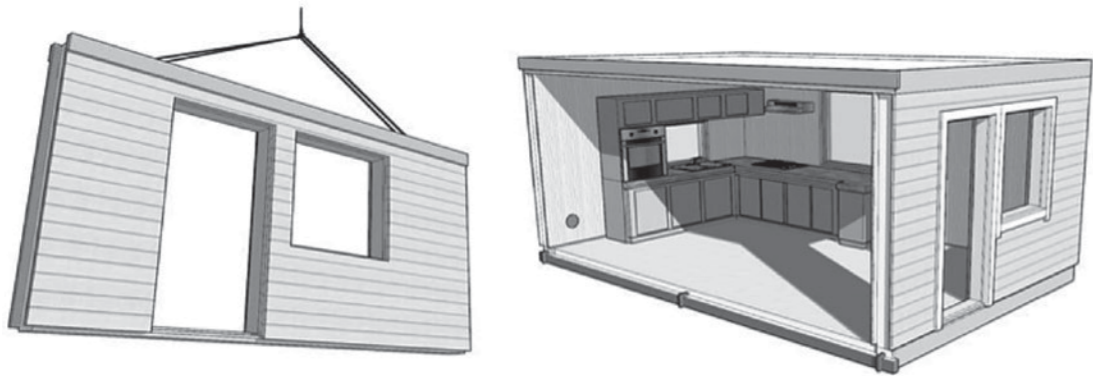


Figure 4.2 Example of prefabricated wall element (left) and prefabricated volume with timber frame (right).

A few manufacturers use a so-called massive timber construction system, i.e. wall units and joist floors that are made of CLT [24]. During manufacture of the unit, the shapes are trimmed and openings are made for windows, doors, etc. and the thickness is levelled. The producers of houses with massive timber construction systems do not have their origins in the tradition and company culture of manufacturing single-family houses. The reason for manufacture CLT for construction is, among others, that it is possible to use a sawn timber with a lower purchase price, since the demands placed on its quality are low. Characteristic of a CLT system is that the wall unit and joist floors have a high load-bearing capacity and stiffness. These qualities are the main reasons why CLT is used in the first place for early multi-storey buildings. Examples of multi-storey buildings with a massive timber construction system are the Stockholm Science City Foundation [25] and the Limnologen multi-unit dwellings in Växjö (see Figure 5.4) [26].

The level of automation is generally low among timber-house companies and the development that has prevailed within e.g. the automobile industry has not been applied in timber-house companies. Vehicle manufacturers abandoned manual methods during the early-1900s in favour of mass production [27, 28]. During the 1970s, Japan took advantage of the experiences of the automobile industry regarding quality work, reliability and investment in well-adapted production equipment. This knowledge was transferred to housing production via the Toyota Homes company [28]. The methods applied by Swedish manufacturers of timber houses in a factory are based mainly

on manual methods, and the same methods and materials are widely used as in the construction industry in general [29, 30]. During the recent years, a number of timber-house companies have invested in production lines with partially automated functions. These investments have initially applied to equipment for wall production [31].

A CAD system in 2D is used mainly for the construction of timber housing, although the timber-house industry in general is moving more and more towards construction in 3D. The 3D program is a prerequisite for the efficient management of production equipment and for the generation of cutting bills (i.e. a summary of the dimensions and number of pieces of timber to be cut). IT support is not used to the same degree in the production phase as in the construction phase [19]. This means that when the production of the physical house begins, drawings and supporting documents must be printed on paper and distributed to the production personnel. The paper-based basic drawing data brings with it certain disadvantages, besides worsening productivity. There is a risk that late changes to a design may be lost and there is a risk that various versions of the basic document may be circulating simultaneously in production. In the end, this leads to delays and additional costs. Because existing 2D-CAD systems generally do not allow cutting bills to be automatically generated, it is common that the cutting bills for timber components specifying building features, e.g. external walls, are manually produced during the production planning. The manual handling is time-consuming and introduces a risk of errors, which of course results in disturbances to production.

The timber house industry in Sweden uses approximately 300,000 m³ of sawn timber annually, equivalent to 7% of the Swedish timber market, Table 4.1. This is not equivalent to more than the annual production of sawn timber in a medium-sized Swedish sawmill. The timber house industry's usage of wood products is, however, dispersed over many consumption locations and the needs for different cross-section dimensions and specific timber grades vary between individual companies. This generally means that no individual supplier of wood products can alone satisfy the demands of a timber-house factory. Purchasing is also managed by the knowledge of the purchaser regarding the local material property differences.

Table 4.1 Consumption of sawn timber in Sweden distributed among different industries [32].

Sector	Timber volume [million m ³]
Single-family houses	0.3
Multi-unit dwellings	0.1
Other buildings	1.3
Carpentry	0.9
Furniture	0.3
Packaging	0.8
Other	1.3
Total	5.0

Another factor that affects the purchasing of timber is the extent to which the timber-house manufacturer can relay the supplier's capacity to deliver according to agreed requirement specifications, i.e. how well the delivered product meets the quality requirements. During the

purchasing of wood products, in general, it is important to monitor the properties of the delivered material in order to obtain an optimal return in the continuous process [33]. Routines to monitor the delivered material vary between the companies, from a careful follow-up and compensation when necessary to a stated approach where large deviations from the required specifications are accepted. The sawn timber delivered is in most cases sorted in accordance with traditional sawmill sorting regulations [34, 35, 36]. Sawmill grading is not in general performed with the final use of an individual piece of sawn timber as the starting point, but rather from the practical considerations with the producer. This result in a grading of material that does not fulfil the requirements set forth by the orderer. The occurrence of timber waste is dependent on numerous factors, e.g. the timber lengths are not optimal or that the actual sawmill-graded timber does not meet to the actual needs [37].

Several of today's timber-house companies manufacture their building elements themselves, such as roof trusses, joist floors, and wall units, whereas the doors, windows and carpentry are almost always purchased ready-made from external manufacturers. For their own production, the timber-house companies purchase timber material in the dimensions and lengths offered by the suppliers, i.e. sawmills and timber product wholesalers. The timber-house industry has no common requirement specifications for sawn timber, but each individual company formulates its own requirements and qualities [38]. A relevant question to ask is why the standardisation work within the timber house industry which began in 1918 has advanced no further.

Johansson and Gustafsson [39] conducted a study of the requirements generally placed by the processing wood industry on products of hardwood and logistics service. The study illustrates the requirements that a number of timber-house manufacturers place on interior panels and mouldings. In this case, moisture content, appearance and colour, number of knots, length and cross section dimensions, as well as shape stability are considered to be the most important qualities to specify. The timber-house industry has on several occasions expressed a desire to purchase important quantities of ready-made material, i.e. timber cut to specific lengths and with the right quality, and prefabricated components [13, 40]. The properties of the prefabricated material begin with the requirements placed by the customer, especially considering that it is the customer who bears the responsibility for the requirement specification [41]. The timber industry's desire to increase the purchase of important quantities of ready-made material has not, however, been followed by a willingness to pay for the increased level of service, so that the actual development in this trend has been only modest.

A timber supplier's inability to adapt the material to suit end-use applications tends to reduce the competitiveness of timber over other substitute materials [42]. An example of this is studs in sheet metal that dominate the construction of multi-unit dwellings [41].

The cost for timber material constitutes only a fraction of the total cost of a house. Brege et al. [29] have shown that building materials comprise 25% of the total construction cost for a single-family house with a timber frame and that the timber itself comprises only a few per cent of the total construction cost, Figure 4.3. This means that the price of timber has a minor influence on the house's final price and that there is room to pay a higher price for the wood material purchased by the house manufacturer or to use other types of products as well, e.g. engineering wood products. The costs due to a lack of quality at the timber-house factories as a consequence of deficiencies in wood products are significant, but there are few if any follow-ups available.

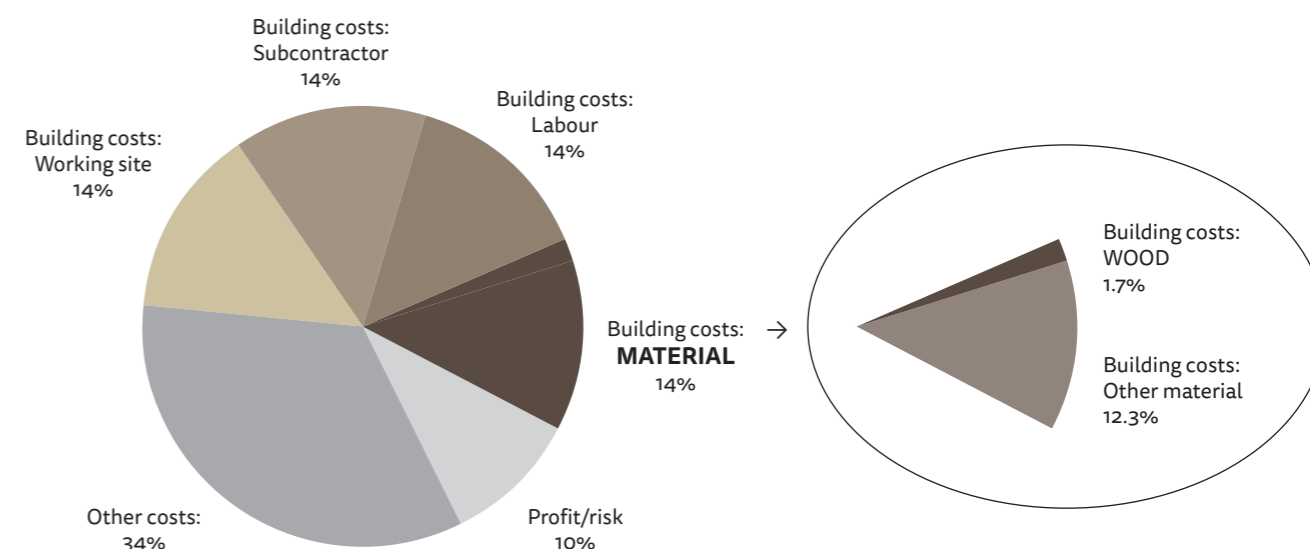


Figure 4.3 Distribution of costs during the manufacture of single-family timber houses [29]. The total building cost is 56% of the total manufacturing cost. The cost for timber makes up 1.7% of the total manufacturing cost or 3% of the total building cost.

The timber-house factory of the future

Based on the conditions for the Swedish single-family timber housing industry, and that which has here been stated, the following scenario for this industry in ten years' time can be seen.

The timber-house factory of the future is an automated and efficient assembly factory that is similar to modern manufacturing industries and has a rational production process based on ready-made components. The organisation is process-oriented and works with long-term planning so that subcontractors are able to participate actively in both material and component manufacturing. There are carefully prepared requirement specifications for all incoming timber, where the specifications are adapted to the timber's qualities and area of use. An automated production places different requirements on the qualities of incoming material than manual methods. The qualities included in the requirement specifications include moisture content, geometry, dimensional stability and sometimes even strength. For façade panelling, for example, the specification includes requirements with regard to knots, surface quality, and durability, and the façade will be delivered as system components for a specific house.

Wood product suppliers to the timber-house factory of the future are only those that are prepared to live up to the requirements placed on the timber with regard to dimensions, quality, delivery accuracy and price. Critical for the grading and development of timber with the right qualities is that the grading and inspection equipment must successfully measure actual qualities. Further, a properly outlined requirement specification will guarantee that the material developed corresponds to the actual requirements placed on the timber during use. A close proximity to the timber source will minimise transport and thus have a lower impact on the environment.

The timber-house factory of the future is very aware that wood material with the right qualities also can have it a higher purchase price compared to the price paid for a less processed timber. By purchasing ready-made wood products from suppliers, the responsibility to fulfil the responsibility is on the supplier to meet to the requirement specification.

The requirements placed on the incoming wood by the timber-house manufacturer can be a driving force for technological and product development within the construction material area. Various techniques are now available for gluing sawn timber to other dimensions than the original sawn timber can offer. A changed outlook to sawn timber with full acceptance from the timber user for e.g. timber glued together would also lead to a change in the way of working for forestry. The now prevalent fixation on the adaptation of trunks to logs for sawing in requested lengths would instead be replaced by an outlook where the tree's qualities would to a greater extent dictate the positioning of the cutting. In this case, the emphasis would be on optimal log lengths for efficient handling and on an optimal performance in the process from the forest and through the sawmill.

A model for the wood product supply to the timber-house factory could be designed so that the company develops a specification for the different wood qualities needed. This work must be placed in relation to the actual qualities that the wood product develops when being handled along the chain from felling in the forest through the sawing and on the drying.

A prerequisite for the timber-house factory is that information relating to the construction and manufacturing is handled in a common information system from which the business system also can retrieve information [19]. From automatically generated cut bills, the specification would be sent to the wood material supplier who would ensure that the ready material is delivered to the customer on time. In this way, the customer would know the quantity of timber being supplied and that this wood product fulfils the outlined requirements.

New techniques within automation and robotization make it possible to use industry robots in new ways to meet the challenges that the timber-house factory of the future presents. These can be active safety solutions that allow robots to be "co-workers". This also means that the process to handle programming will be efficient and that the operations conducted by the robot will be performed and the construction solutions adapted to the conditions of the robot's technology.

By preparing the house as much as possible in the factory, using adapted materials and methods, the cost of building a single-family timber house can be reduced. The use of adapted materials and methods will also mean a reduced environmental strain in the form of material and energy waste.



A simplified method for the cost analysis of the processing of wood material

In this study, the costs of cutting timber into components for trusses and wall units were determined for two single-family timber house companies. Some comparative figures for the production in the two companies are presented in Table 4.2.

Table 4.2 Comparative figures for the companies studied.

Key data	Company A	Company B
Production (number of houses/year)	120	700
Total number of employees	47	400
Number of employees in factory production	27	145
Volume of sawn timber purchased (m ³ /year)	9,000	19,000

Process flow

Both companies prefabricate plane elements with timber studs and joists. Custom designs offered by both the companies mean that successive houses in the production differ from each other and that it is difficult to save time by coordinating material production. Company A customises designs to a higher level than Company B, which means that Company A is less able to combine the processing documents for several houses when cutting material in larger batches. The designs of the building units at the two companies are similar, so the processing costs for the cutting operation are directly comparable between the two companies. The general materials flow and manufacturing process is illustrated in Figure 4.4.

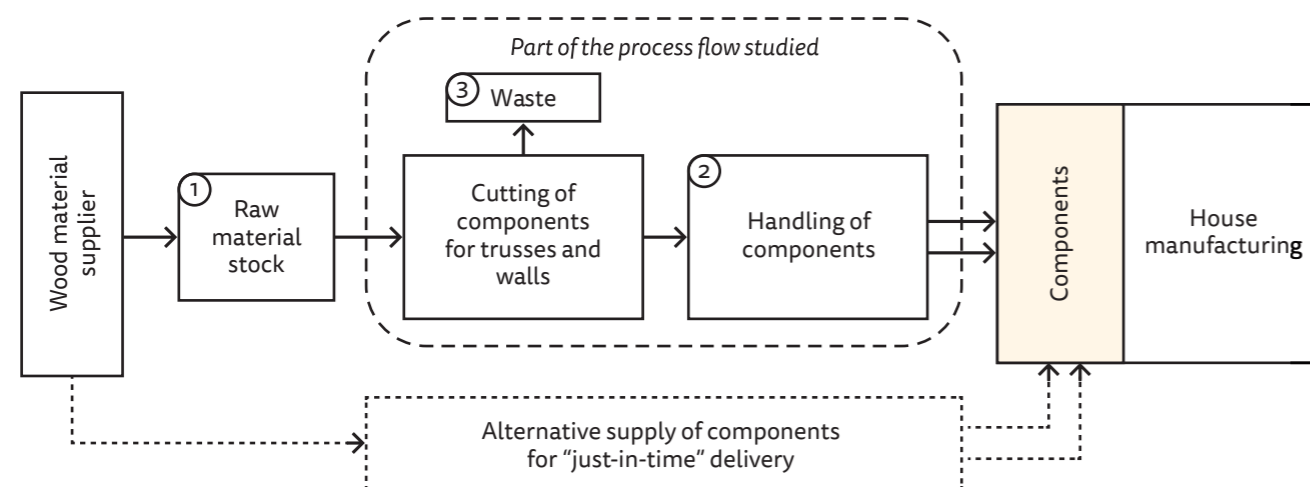


Figure 4.4 Flow in the processing of timber components for trusses and wall elements, also showing an alternative supply of components. The numbers 1, 2 and 3 refer to position 1-3 in Table 4.3.

Industrial manufacture of single-family timber houses in Sweden

Both companies have their own specifications based on the actual needs of the company and on the standardised sawmill grading rules. The sawn timber suppliers to the two companies consist of a number of sawmills that are located mainly in southern Sweden. The stations for cutting components for trusses in the two companies are essentially the same. The main difference is that in Company A the operator personally carries the timber from the stack to the saw table, whereas in Company B the timber is fed automatically. Company B's feeding equipment ensures that the next piece of sawn timber arrives on the saw table while the operator is still cutting the first piece of timber, and the material that the operator has just cut is being removed to the depot. At both companies, information from databases is automatically sent to the cutting operator regarding the geometry and the number of components. During the period of the study, Company B cut components for three houses simultaneously with the same truss design. Similar coordination was not possible at Company A. The effective operator time at both companies consists only of the time the operator is working on the material processing. Disturbances, such as conversations with colleagues and private needs, were deducted from the operator's time so that a fair comparison could be made between the companies.

Both companies produce wall frames consisting of studs. The frame produced by Company A consists of sawn timber studs, built as a crossed stud frame with insulation in two crossed layers to minimise thermal bridges. The wall frame produced by Company B includes a light-weight stud instead of a sawn timber stud. The light-weight stud is insulated to hinder thermal bridges. The differences in the wall constructions at the two companies mean that the quantities and dimensions of the timber differ.

In order to calculate the manufacturing costs, the equivalent costs for raw materials, personnel and expenses have been used. The equivalent costs are based on direct materials costs for sawn timber, indirect materials costs, direct labour costs, and indirect labour costs as shown in Table 3. The capital cost for the equipment used for cutting was low (less than € 2 per m³ cut timber) and about the same for the two companies, so it was excluded from the manufacturing cost presented here.

The processing cost is defined as the difference between the total manufacturing cost for a given volume of cut material (timber components) and the cost of purchasing the timber. The processing cost was studied by measuring the material waste and the consumption of time and material. The present study covers only the material waste due to timber differing in length from the specifications. The loss of entire pieces of wood due to quality defects, which both companies sort prior to the cutting operation, is not included in the waste. The study has been limited to the cutting part of the operations partly because both companies were considering basing their production on components purchased from a supplier that would offer them just-in-time delivery. To calculate the cost of components, a standard model has been used. The model includes material costs and manufacturing handling costs consists of 20% material costs and 60%, salary costs. Costs for salary and materials were valid at the time of measurement.

Table 4.3 shows the material consumption during processing when the sawn timber was cut into components. It can be concluded that the material utilisation during cutting is high with only 3-4% waste at both companies. This means that their processing costs consist mainly of manufacturing costs.

Table 4.3 Volume of sawn timber and components, and operator time during cutting of components. Positions 1-3 are shown in Figure 4. 4.

	Position	Company A	Company B
Volume of sawn timber for cutting (m³)	1	7.01	9.05
Volume of cut material, components (m³)	2	6.78	8.76
Volume of waste material, length discrepancies (m³ (%) of raw material)	3	0.24 (3.4)	0.29 (3.2)
Total efficient operator time (hours:minutes)		12:19	10:11

Table 4. 4 shows a cost calculation for cutting the sawn timber into components. The processing cost is about 20% higher per unit volume of components at Company A than at Company B. A decisive reason for this is that Company B cuts its sawn timber for more than one house at a time, whenever this is possible. Another reason for the greater efficiency of Company B is its handling equipment, which automatically ensures that the timber products reach the operator.

The cost differences between the companies are not large, and the processing costs amount to approximately 1/3 of the total manufacturing cost and that 2/3 of the cost of components for trusses and wall frames is related to raw material. This indicates that the ability to pay for components is about 30% higher than the price of sawn timber. In general, it is important to note that all the supporting documents for the operator at the cutting saw must have complete, correct information. When the operator is forced to stop working on the material processing to locate the supporting documents, this leads to an increase in cost. The study clearly shows an example of how manual handling, in this case during the cutting of the material, results in additional costs in both the actual operation and also later in the production phase.

Table 4. 4 Manufacturing costs during the cutting of components.

	Company A	Company B
Direct material costs, purchase of timber (220 €/m³)	1,542	2,118
Indirect material cost (20% of material cost)	308	424
Direct labour costs (30 €/h)	369	339
Indirect labour cost (60% of salary)	222	203
Total cost (€)	2,441	3,084
Sales of waste material (25 €/m³)	-6	-8
Total manufacturing cost (€)	2,435	3,076
Total manufacturing cost (€/m³ cut material)	359	351
Processing cost (€/m³ components)	132	110

Following tradition, the majority of single-family houses in Sweden are built with timber frames. Many of these wooden homes also use timber in their façade coverings. Using wood can give housing manufacturers a competitive advantage compared to using other materials, especially environmental advantages. Any advantage on the European market is especially valuable to Sweden, because the Swedish single-family timber house industry is weakly represented on this market. The arguments for the use of wood cite this material’s greater inclusion of carbon and

reduced emissions of greenhouse gases. Nevertheless, the costs of sawn timber and assembly for the housing manufacturer must be the same as or lower than the equivalent costs for alternative building materials in order for these arguments to be compelling. The overriding question for the single-family timber house industry in Sweden is how to produce houses at an attractive price.

The development of production technologies and methods which began during the first decades of the 1900s has not shown the same continuity as the development in many other industries. One hypothesis for this lack of development is that quality discrepancies in incoming sawn timber lead to increased costs due to material waste and extra work in the factory as well as productivity losses. A general problem (but not a universal problem) in the Swedish single-family timber house industry is that the house manufacturers cannot specify their own production costs in detail [30]. Therefore, it is impossible for them to assess the costs that arise due to sawn timber that does not fulfil requirement specifications.

The case study revealed that the waste that arises from quality discrepancies in incoming sawn timber was very low, and the volume yield in cutting sawn timber to components for trusses and wall frames was greater than 93%. This simple study shows that two thirds of the cost of producing a given volume of components is related to the raw material, and that one third is related to processing. It is extremely important to maintain a high volume yield in the sawn timber processing. This prerequisite has been difficult to accomplish for sawn timber at a sufficiently low cost. It is vital to note that the low percentage of waste in the study does not reflect the general pattern of the industry. One reason for the high volume yield in this case study was that only the sawn timber rejected at the cutting station was included and gave no consideration to waste due to quality deficiencies in the delivered product or to sawn timber that was rejected before or after the cutting station. In total, the timber waste in single-family timber house companies is much greater and arises during several operations in the production process, such as stocking, material processing, assembly in the factory and assembly at the building site. Waste can also result from complaints about ready-made houses. Waste during the assembly process in the factory may depend not only on poor timber quality but also on assembly errors. Errors in assembly can arise from deficiencies in timber qualities, incorrect instructions and supporting drawings, poor concentration and carelessness. Moreover, the operators do not always know about the requirement specifications during assembly. The dismantling of already assembled material always leads to rejection and the need for substitute material.

To provide a general picture of the costs due to quality defects in the sawn timber, that may arise in the single-family house industry, an example is given below. The magnitude of these costs is difficult to determine, but it can be estimated based on experience. Table 4. 5 presents an example from a timber-house manufacturer of the additional costs for material waste and production because of the delivered sawn timber did not fulfil the requirement specification outlined by the company. Of the total cost for timber, 14% represents additional costs due to quality deficiencies in the delivered timber. This estimate is based on the fact that productivity increased by 20% when the timber fulfilled the company’s outlined specifications and that half of this increase was related to the quality of the timber.

In Table 4. 5, it is also evident that the costs associated with a lack of quality and errors in length in delivered timber amount to 8% of the total cost for the timber. In all, according to the company’s estimate, the cost of additional work in the factory due to a lack of quality in the timber amounts to

17% of the total cost of the timber. The cost of errors in length is estimated to be 3% of the timber cost, which agrees well with the results presented in the present study.

Table 4.5 Example of additional costs during timber-house manufacturing as a result of deviations from the requirement specifications in delivered sawn timber.

		Additional cost (€) due to	
		Length error	Quality error
Timber cost per house (€)	10,000		
Production cost in the factory per house (€)	9,000		
Additional cost for timber due to deviations from requirement specification		300	500
Additional cost for production due to deviations from requirement specification		338	562
Sum additional costs per house:		638	1,062

Swedish manufacturers of single-family timber houses have a long tradition of prefabrication, but the companies exhibit a low level of automation. Increased automation may be one way to reduce the cost in the prefabrication of single-family timber house manufacturing. The expected cost reductions have not, however, been investigated in this study. Compared to on-site building, prefabrication provides numerous advantages: lower production costs through rational, multiple manufacturing, less risk of negative influences from the weather during construction and fewer errors in each building's body.

The Swedish manufacturer of single-family timber houses generally has a means of production that is technically underdeveloped compared to other manufacturing industries in spite of the fact that Sweden has a long tradition of manufacturing prefabricated timber housing and that timber housing dominates the market in Sweden.

A prerequisite for an increased utilisation of wood as a building material during the construction of single-family houses in the rest of Europe is that production must be more efficient, i.e. technology, production methods and materials that lie on the leading edge of technology as well a system-component-based purchase of sawn timber, components, and other wood products.



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Roundwood storage

Sweden



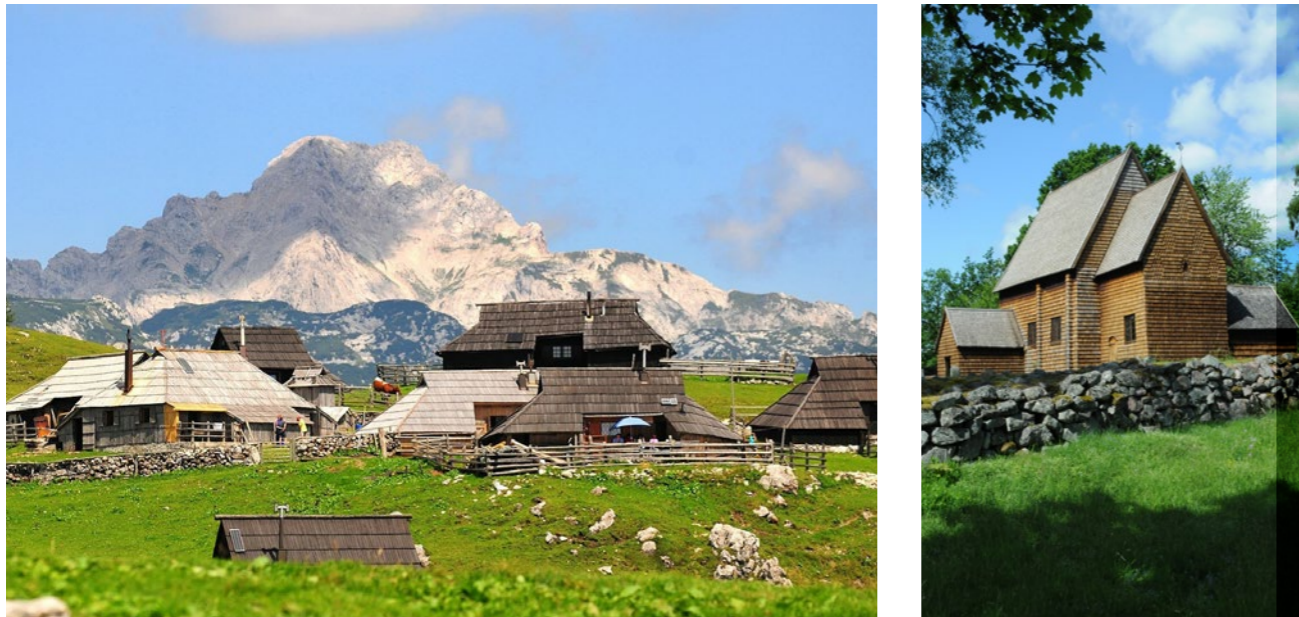


Figure 5.1 Historically equivalent uses of timber in construction: timber sheep farmers house, Velika planina, Slovenia (left), timber church from the 13th century at Granhult, Sweden (right).

In Slovenia, the predominant methods of timber construction include timber-panel, timber-frame, and cross-laminated timber (CLT) systems, Figure 5.2. Timber-panel construction has been present in Slovenia for more than 35 years. Pre-fabricated construction started after World War II, when barracks were erected for the people who had been left without shelter and for those who had migrated from the countryside to the cities. However, in the past 30 years, timber construction has undergone major changes in Slovenia.

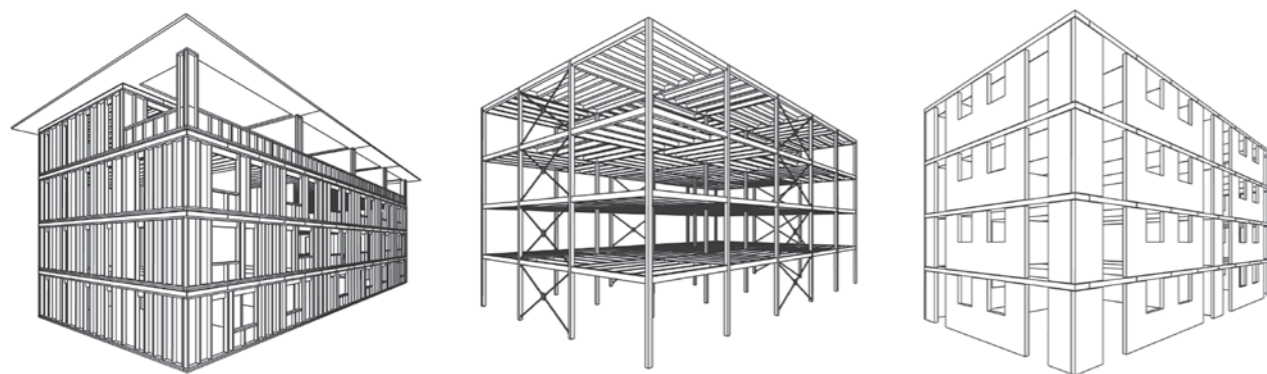


Figure 5.2 Timber-construction principles, from left: a timber-panel system, a timber-frame system, and a massive-timber system based on CLT.

Timber buildings in Slovenia and Sweden

In timber-frame buildings, the basic vertical load-bearing elements are timber frames made of glulam. Panel-wall elements are mounted onto the frame construction and the exterior is covered with different wood-based or non-wood-based façade materials. Depending on the dimensions, one can distinguish between single-panel and macro-panel wall systems.

In the mid-1990s, Austria undertook a joint industry-academia research effort that resulted in the development of modern CLT, a new type of wood-based panel, and this product has since gained popularity in both residential and non-residential applications in Slovenia as well as in the rest of Europe. In 2016, the global production of CLT was 680,000 m³ [2].

In Slovenia, the first pre-fabricated houses were built in the early 1970s. They had very good thermal properties, thermal transmittance of the best panel-wall elements being much lower than provided by the regulations. For example, thermal insulation improved nearly three times from 1963 to 1972, and after 1992 it was almost four times better than specified by the then valid national regulations.

By 1992, the external wall elements met the requirements currently applicable in Slovenia regarding energy-efficient construction. The heat-transfer coefficient of exterior walls was lower than the prescribed limit value of 0.28 W/m²K, but had not reached the value for timber-frame constructions of 0.20 W/m²K [3]. Therefore, all prefabricated timber-framed structures set up before 1992 need renovation to enhance the energy efficiency of the building by 2020.

In Sweden, it was not possible to use timber as a frame material in the construction of houses with more than two storeys until 1995. Regulations that regulated the choice of frame material excluded timber, as a result of a number of devastating fires in Swedish cities during the 19th century. As a consequence, no development of multi-storey timber building took place and other materials such as steel and concrete were used. Today, the use of timber as a material in multi-storey housing has increased to approximately 15% of all newly built multi-storey buildings. Developments towards an industrialised construction and manufacture within the timber building sector have in recent years led to an increase in prefabricated structural components of solid wood, engineered wood products, and non-wood materials that are assembled at the construction site. The main timber-construction principles are the same in Sweden as they are in Slovenia.

In contrast to multi-storey housing, the industrial manufacture of single-family timber housing has a long tradition in Sweden. The factory manufacture of prefabricated timber houses began in Sweden during the 1800s [4]. During the second half of the 1800s and the early 1900s, numerous timber-house manufacturers emerged in Sweden. For several decades, about 90% of the on-site and prefabricated single-family houses built in Sweden have timber-frame systems, but this is not the case in the rest of Europe where less than 10% of the single-family houses have a timber framework [5]. In Slovenia approximately 20% of the single-family houses are built with a timber-frame.

Building techniques

Wood products and construction systems

The primary wood products used in timber construction in both Slovenia and Sweden range from sawn timber to various engineered wood products (EWPs). In mass-timber structures, glued-laminated timber (glulam), CLT, laminated-veneer lumber (LVL), and laminated strand lumber (LSL) are used for walls, floors, and roofs. In timber-frame structures, timber wall sections are assembled from studs and crossbars of various dimensions. For the exterior and interior faces, besides solid wood various panel-based products are used, including drywall panels and gypsum board, particleboard, cement-bonded panels, fibreboard, oriented-strand boards (OSB), and LVL.

Although the production of CLT and its use in timber construction is increasing, the use of sawn timber has lost its historical dominance and has been replaced by a number of EWPs which have made a significant contribution to the development of a new approach to contemporary architecture.

Several techniques are available for the construction of buildings with supporting frameworks of timber. Table 5.1 identifies the key figures in timber-based construction in selected European countries.

Table 5.1 Key figures in timber-based construction in selected European countries [6-10].

	Sweden	Slovenia	Finland	Austria
Consumption per capita of sawn timber [m³]	0.57	0.40	0.89	0.61
Share of detached houses in residential construction [%]	39	40	38	42
Market share of wood in detached houses [%]	80-90	5-10	80-90	40
Market share of wood in multi-story construction	15	-	4	2
Maximum number of floors allowed from timber, with sprinklers in 2014	>20 (since 1994)	5	8 (since 2011)	4 (varies by region)
Key multi-story construction techniques in timber	Module Timber-frame Mass-timber	Timber-panel Timber-frame Mass-timber	Timber-frame Timber-panel Module	Mass-timber Supplier of components

A common way in both Slovenia and Sweden is to use structural timber members to form a frame which is covered by structural wood panels, where the foundations are generally of concrete. This building technique is often used in the construction of single-family houses, as well as in the construction of multi-storey buildings, Figure 5.3.



Location | Mölle, Sweden
Type of building | residential building
Year of construction | 2013
Architect | Elding Oscarson
Construction company | Dan Olsson Bygg, Pål Svensson
Construction description | steel structure, timber-frame, CLT
Energy efficiency | low-energy
Area | 300 m²
Façade | wood – Douglas fir, glass envelope



Location | Kurešček near Ljubljana, Slovenia
Type of building | residential building
Year of construction | 2013
Architect | Mojca Gregorski, Miha Kajzelj
Construction company | KLH Massivholz GmbH
Construction description | timber-frame, CLT
Energy efficiency | low-energy
Area | 300 m²

Figure 5.3 Several techniques are available for the construction of buildings with supporting frameworks of timber: the single-family building “Mölle by the sea” in Sweden, and The Scandinavian House at Kurešček in Slovenia.

Another technique uses CLT for the supporting framework, wall flooring and roofs. The external walls have a load-bearing and stabilizing function, and have to be insulated to give the building a high level of energy efficiency. Internal walls for stabilization are made of CLT, while sound-insulating walls between rooms are of traditional timber-frame structure. The most appealing reason for using the CLT system is to give the construction a high load-bearing capacity and high stiffness, and this technique is well adapted to the construction of multi-storey buildings, Figure 5.4.

A third technique is a system of columns and beams, where glulam is used to a large extent for the load-bearing structure. Not surprisingly, their initial use was for multi-storey buildings, mainly building for industrial, storage or shopping centre use, Figure 5.5.



Location | Växjö, Sweden
Type of building | residential, 4 houses
Year of construction | 2006-2009
Architect | Ola Malm, Arkitektbolaget Kronoberg AB
Construction company | Thyréns
Construction description | CLT from Martinsons
Energy efficiency | low-energy
Area | 3,560 m²
Façade | wood panels and plaster
Number of floors | 1+7 (concrete + wood)

Figure 5.4 The use of CLT as load bearing, stabilizing and thermal insulating walls in modern multi-storey timber construction: Limnologen four 8-storey CLT buildings in Växjö, Sweden (N.B the weather protection of the building under construction to the left).



Location | Växjö, Sweden
Type of building | educational
Year of construction | 2011
Architect | Mats White, Jais Arkitekter
Main contractor | Videum AB
Construction company | PEAB Sweden
Construction description | visible GLT framework
Energy efficiency | low-energy
Area | 6,320 m²
Number of floors | 3

Figure 5.5 Glulam (GLT) and CLT framework under erection for an educational building: House N at Linnaeus University in Växjö, Sweden.

The primary criteria of timber-construction systems are load-bearing strength, rigidity, lateral stability, wind resistance etc., but these systems must also satisfy modern criteria for fire safety, permissible sound levels and energy efficiency. Special consideration must be given to these functional criteria in the case of multi-storey buildings and well-tested technical solutions are now widely available.

Several timber-house companies in Slovenia and Sweden manufacture building elements such as roof trusses, joist floors and wall units themselves. In contrast, they almost always purchase the doors, windows and carpentry ready-made from external manufacturers. Industrial prefabrication is the dominant method of building single-family timber houses in Slovenia and Sweden.

There is today only one manufacturer of CLT in Sweden (Martinsons), but there are several companies marketing CLT in Sweden. The producers of houses with CLT systems do not however have their origins in the traditions and company culture associated with single-family timber houses. During the manufacture of these CLT elements, the shapes are trimmed, openings are prepared for windows, doors, etc., and the thickness is levelled if necessary. Prefabricated CLT elements are delivered directly to the construction site.

In Slovenia there is no production of CLT, but Slovenian manufacturers have a close cooperation with Stora Enso, Hasslacher, KLH and the other producers, mostly in Austria. The CLT products are expected to play an important role in the future for single- and multi-storey timber buildings in Slovenia, Figure 5.6.

In the past 30 years, modern timber construction has undergone major changes, and the most important changes being the transition from on-site construction to factory prefabrication, the transition from elementary measures to modular building, and the development from a single-panel system based on small individual elements (1.25 to 1.30 × 2.5 to 2.65 m) to a macro-panel system. The macro-panel system provides the whole wall assemblies, including windows and doors, which are constructed in a horizontal plane in a factory and then transported to the building site.

These changes have greatly improved the efficiency of fabricating contemporary timber structures and present a great architectural potential for the 21st century.

Re-organization | shifting market shares → concrete | CLT

CLT is not competing with current | past timber engineering, but substitutes mineral based building products like masonry or reinforced concrete.

> 35 production sites worldwide
> 95% of production in Central Europe

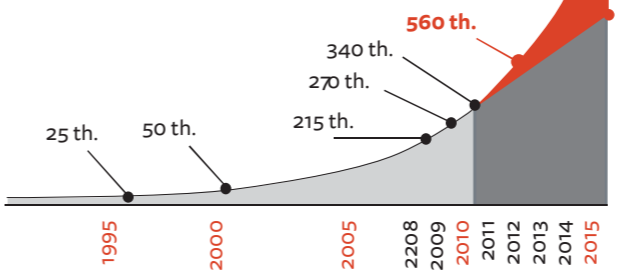


Figure 5.6 Global production of CLT 1995-2015: 35 production sites worldwide, 95% of production volume in Central Europe (Schickhofer G. Institute of Timber Engineering and Wood Technology, Graz University of Technology).

Construction on-site

The oldest method of construction is on-site, where the building materials are transported to the construction site and the various elements are then assembled and erected. The method requires a great deal of organization and planning on the building site, and risks associated with damage to materials and prefabricated structural components, and moisture damage must be considered, Figure 5.7.



Location | Ljubljana, Slovenia
 Type of building | building for education
 Year of construction | 2009-2012
 Architect | Ira Zorko, collaborators: Janko Rožic, Aleksander Saša Ostan, Nataša Pavlin et al.
 Construction company | RUBNER d.o.o., SGP Tehnik d.o.o.
 Construction description | CLT
 Energy efficiency | low-energy, 35 kWh/(m²a)
 Area | 1,726 m²
 Number of floors | 2

Figure 5.7 Prefabricated CLT elements are transported to the construction site and then assembled and erected manually, Waldorf School in Ljubljana, Slovenia.

Of necessity, on-site construction tends to take a long time. In Slovenia, a non-negligible number of timber houses have appeared recently, constructed on-site by smaller tradesmen (carpentry workshops), but on-site construction is very rare in Sweden for single-family houses, although it occurs with larger buildings where the frame is of glulam or CLT.

Off-site prefabrication

In both Slovenia and Sweden, the trend is towards a higher degree of prefabrication, where a greater part of the building work takes place at an industrial plant in a well-controlled environment with approved quality assurance. The actual on-site assembly of the building until the roof is laid then takes only one or two days. The prefabrication can include various components such as wall and floor elements, roofs, trusses etc., but also modules, so-called volumes. Both components and modules are prefabricated with insulation, installations, windows and doors, Figure 5.8.

Prefabricated components of timber are relatively light in weight and can be erected to heights of several storeys using simple lifting equipment. With prefabricated timber modules, the total cost is up to 20-25% lower than building on-site, due partly to a time saving of up to 80%. In Slovenia, most of the large house manufacturers offer off-site prefabrication houses. In Sweden, the off-site manufacture is totally dominating for single-family houses and this method of manufacture is also becoming more and more common for multi-storey housing built with different building systems.

Timber buildings in Slovenia and Sweden



Figure 5.8 Examples of off-site prefabrication: assembly of wall elements in a horizontal position, wall elements on their way from the factory to the building site, and assembly of elements.

Modular systems

Working with modular systems is a great help, since it is difficult to design traditionally and then translate the design to an industrial context. It is easier to adapt the construction and organization of the building to the limits of the system from the beginning. For example, the modules have to be of a size that can be transported by lorries and that will fit on roads and pass under bridges. The modules also have coarser structural beams than in conventional construction, which can be a challenge if the building height is restricted. In addition, the system requires an early commitment in the project, with very little scope for making changes later. The advantages of industrial timber construction are: shorter time on the building site, less transport, less disruption for neighbours, good cost control and no drying time compared with that for in situ concrete construction, Figures 5.9-10.

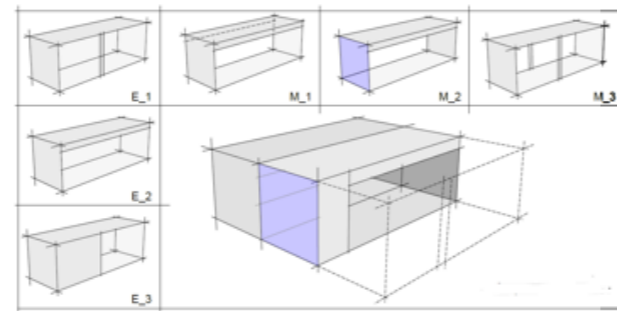
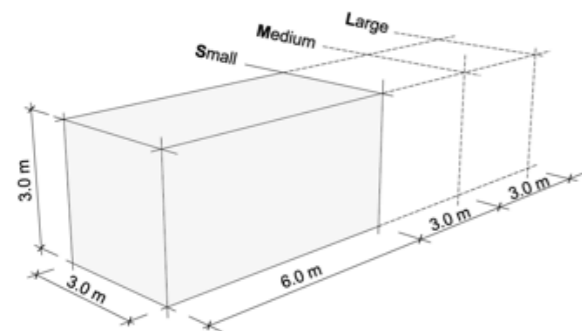


Figure 5.9 Basics in construction with modules showing some characteristics for the technique: joints - prefabricated and special joints between modules; layout - raster required; fabrication - complex prefabrication with finishing predominantly at manufacturing site, transport and on-site assembly with flat-bed trailer and heavy lifting equipment (Camp Wildalpen).

Sources: Schickhofer G, Flatscher G, Ringhofer A. Institute of Timber Engineering and Wood Technology, Graz University of Technology (upper) and Holzbox (lower).

Timber buildings in Slovenia and Sweden



Figure 5.10 "Skagershuset", Sweden.

Location | Årsta, Stockholm, Sweden
 Type of building | residential, 33 apartments
 Building year | 2013
 Architect | OWC Björn Ahrenby, Joan Anguita, Anna Montagut
 Construction company | Moelven
 Construction description | 112 prefabricated modules
 Energy efficiency | low-energy
 Area | 4,817 m²
 Number of floors | 3
 Façade | untreated cedar panel



Figure 5.11 "Ekorren", Sweden.

Location | Skellefteå, Sweden
 Type of building | residential, 54 apartments
 Year of construction | 2009
 Architect | Magnus Silfverhielm, AIX Arkitekter
 Construction company | Plusshus
 Construction description | Setra's Trälyftet building system with glulam
 Energy efficiency | low-energy ,25 kWh/(m²a)
 Area | 5,100 m²
 Number of floors | 6
 Façade | painted wood boards



Figure 5.12 "Strandparken", Sweden.

Location | Sundbyberg, Stockholm, Sweden
 Type of building | residential, 124 apartments, 4 houses
 Year of construction | 2012- 2013
 Architect: Wingårdhs Arkitekter
 Construction company | Martinsons
 Construction description | CLT
 Energy efficiency | low-energy
 Number of floors | 8
 Façade | cedar shingles

Extensions

Timber offers a great opportunities for solving housing shortage in fast growing cities in 21st century. It is a potential for changing and modernizing existing, older buildings – increasing building height and density, which are often constructed from concrete, mainly through additional storeys or roof extensions. The simplest method is to fit the old building with a new roof designed so that a number of apartments can be built into the attic space. As timber structures are light, there are often margins for building additional storeys. In such cases, the use of prefabricated components is often suitable. Naturally the design must be verified to ensure that there is a margin for absorbing the additional vertical loads and ensuring horizontal stability, Figure 5. 13.



Figure 5.13 Timber offers a great potential for changing and modernizing existing, older buildings which are often constructed from concrete, mainly through additional storeys or roof extensions, from upper left: Plogen in Umeå, Sweden, Terme Čatež, and Hotel Breza in Slovenia.

Multi-storey buildings

Extensive research has shown that material-neutral building regulations are preferable and, for over three decades, function-based regulations have been common in Europe. This has led to an increase in the construction of multi-storey building, and the height of such buildings. Institutional changes, promotion campaigns, and technological development in the 1990s, novel industrial multi-storey timber construction practices have been emerging in some European countries, Table 5.2.

Table 5.2 Present stage and future suggestions for multi-storey timber buildings – “wooden skyscrapers”.

1995	5-storey building, Wälludden, Växjö, Sweden
1995-2005	3-5 storey buildings in several European countries
2008	8-storey tenant-owned apartments, Växjö, Sweden
2009	9-storey tenant-owned apartments, London, UK
2011	7-storey multi-family house, Berlin, Germany
2012	8-storey tenant-owned apartments, Bad Aibling, Germany
2013	9-storey apartment building, Milan, Italy
2013	10-storey building in Melbourne, Australia
2015	14-storey apartment building, Bergen, Norway
2017	18-storey residential building, Vancouver BC, Canada
2018	24-storey building HoHo, Vienna, Austria
2020?	30-storey building, Canada
2025?	34-storey building, Stockholm, Sweden
?	80-storey building, London, UK

Although the development and implementation of timber constructions in multi-storey buildings is at different levels in different European countries (the permitted height of timber buildings is still restricted by law), the trend towards an increasing use of timber is clear. The main reasons for timber to be used for building are that it is renewable and available locally, and that it is beautiful, sensuous and has superb technical characteristics. The growing environmental awareness is also advantageous for wood as a construction material, where the choice is motivated by the fact that wood is a renewable material and that its use reduces CO₂ emission, provided that the raw material is harvested in forests where sustainable forestry with replanting and management plans is practised. Timber construction also leads the way in terms of energy-efficient building. Many responsible contractors, architects and businesses now choose a timber construction because of its efficient use of both resources and money.

The increase can also be attributed to several other important factors, such as the lower cost of timber-buildings compared with construction using other materials, and the advantages of using timber in industrial building.

Of the primary criteria (load-bearing capacity, rigidity, lateral stability, wind resistance etc.), the question of lateral stability is especially important because the construction is relatively light. A common practice in buildings with six or seven storeys is to build the ground floor in concrete and secure the timber structure to the concrete. Wind loads are transferred via joist elements and shear walls to the ground. Good stability is achieved by utilizing diaphragm action.

Although the trend is clear, there are still several technical problems to be solved before timber is again the major construction material in multi-storey buildings. The main areas for further development are:

Fire protection: It has taken a long time to solve fire requirements in the initial projects. The impression is that the authorities involved were not used to interpreting legislation as it applies to higher timber-framed residential buildings. Table 5.3 summarizes the allowable numbers of storeys in Slovenia and Sweden depending on whether or not a sprinkler system is installed for fire protection.

Sound proofing: Insulation against noise transmission in timber buildings is another issue which requires further research to ensure a high-quality living environment.

Prefabrication of elements: Construction time must be reduced and quality improved through off-site prefabrication.

Installations: Installations should be integrated into the framework to a greater extent than today. A greater extent of prefabrication has been requested to avoid extensive subsequent installation work at the construction site.

Weather protection during the construction period should be specified at the planning stage and quality assured with flexible protection. Experience shows that protection by tents with overhead travelling cranes is a great benefit not only for a dry structure, but also for the work environment (see Figure 5.4). The speed and ease with which the height can be increased is extremely important [11].

Exterior façade maintenance: The cost of façade maintenance throughout the life cycle in relation to the cost of investment requires further monitoring. There is a risk that short-term decisions will create additional costs in the long term.

There are also other important questions such as how to increase the value of the whole design and construction process to the client, how to reduce the cost of timber building in use, and has to achieve greater regulatory harmonisation and produce authoritative national guidance documents.

Table 5.3 Number of storeys allowed to be built in a timber building in Slovenia and Sweden.

Building properties	Sprinkler	Sweden ¹⁾	Slovenia ²⁾
Load-bearing structure	YES	≥ 5	≤ 5
Load-bearing structure	NO	≥ 5	≤ 3
Timber façade claddings	YES	≥ 5	max. 6 ³⁾
Timber façade claddings	NO	≤ 2 (incl. 0)	max. 3 ³⁾
Wall and ceiling linings in flats (surface linings of ordinary timber)	NO	≤ 2 (incl. 0)	- 4)
Wall and ceiling linings of untreated timber in escape routes	NO	≤ 2 (incl. 0)	- 4)
Wall and ceiling linings of fire-retardant-treated timber in flats	NO	≥ 5	- 4)
Wall and ceiling linings of fire-retardant-treated timber in escape routes	NO	≥ 5	- 4)

1) references [8 and 12], 2) reference [13], 3) see Table 8 in [13], 4) see Table 5 in [13]

In Sweden, the market share of the use of timber in multi-storey buildings increased from 1% in 2000 to 15% in 2012 [12], while in some other countries, as in Slovenia, the growth has been very slow. In Slovenia there is only a very small share of timber multi-storey buildings; mostly two-storey buildings as tourist facilities, schools and some residential buildings, Figures 5.14-17. In addition to the differences in the culture of using wood in construction, there also appear to be regional differences across Europe, as to which of the specific timber multi-storey construction techniques are favoured, associated with the preferred forms of contracting [14]. According to Mikkola [15], Europe can broadly be divided into three market segments: Nordic countries favour turnkey solutions with a high rate of prefabrication and as complete part deliveries as possible [16]. Western Europe favours EWP-based systems solutions, in which only the frames are supplied, and the other subcontractors continue the work on-site until the finishing of the building [7], and Central Europe favours prefabricated components that are ordered and assembled by the builder and not by the material supplier which is also the case for Slovenia [17].

It would require both increasing competition within the multi-story timber construction sector and increasing co-operation between wood product suppliers and the construction sector to attract investments, to reduce costs, and to make multi-storey buildings practices more credible throughout the construction value chain.



Location | Skellefteå, Sweden
Type of building | infrastructure, car park
Year of construction | 2009
Architect | Magnus Silfverhielm, AIX Architects
Construction company | Martinsons
Construction description | Martinsons concept is based on a column and beam frame in glulam combined with a bearing cassette joist made of CLT
Area | 700 m²
Energy efficiency | low-energy
Number of floors | 4
Façade | Norway spruce ribbed facade panels



Location | Skellefteå, Sweden
Type of building | residential, 3 houses
Building year | 2008, 2009, 2010
Architect | White Arkitekter
Construction company | Martinsons
Construction description | CLT
Energy efficiency | low-energy
Number of floors | 6
Façade | GLT-board facades

Figure 5.14 The car-park building “Ekorren” and the apartment building “Älvsbacka strand” in Skellefteå, Sweden.



Figure 5.15 Residential building "Portvaken" in Växjö, Sweden.

Location | Växjö, Sweden
 Type of building | residential, 64 apartments
 Year of construction | 2009
 Architect | BSV Arkitekter
 Construction company | Martinsons
 Construction description | Glulam frame
 Energy efficiency | passive house, 15 kWh/(m²a)
 Number of floors | 8



Figure 5.16 Punkl youth hostel in Ravne na Koroškem, Slovenia.

Location | Ravne na Koroškem, Slovenia
 Type of building | Touristic
 Year of construction | 2011
 Architect | Maruša Zorec & Arrea d.o.o.
 Construction company | Kograd IGEM d.o.o.
 Construction description | CLT
 Area | 1,575 m²
 Energy efficiency | low energy use, 22 kWh/(m²a)
 Number of floors | 2



Figure 5.17 The Polzela Kindergarten in Šoštanj, Slovenia.

Location | Šoštanj, Slovenia
 Type of building | education facility
 Year of construction | 2014
 Architect | Mojca Gregorski, Miha Kajzelj, Matic Lašič,
 MODULAR arhitekti d.o.o.
 Construction company | Esotech d.d., Tesarstvo Hudovernik,
 Hasslacher
 Construction description | CLT
 Area | 3,783 m²
 Energy efficiency | low energy use, 27 kWh/(m²a)
 Number of floors | 2

Initiatives supporting the use of timber in Slovenia and Sweden

Positive aspects of timber as a structural material include its strength, environment-friendliness, simple handling and appropriateness for industrial use, but a knowledge gap in timber engineering has led to a failure to use timber by engineers and architects. Attitudes towards timber construction also vary between Slovenia and Sweden. In Slovenia, people have concerns regarding fire safety and the durability of timber building, but this is not the case in Sweden [18]. To overcome these negative attitudes towards wood as a construction material, there are considerable activities both Slovenia and Sweden to promote the use of timber.

Initiatives in Slovenia supporting timber constructions

The latest European policy strategies and actions are affecting Slovenian research and development in the field of wood science and timber architecture. In 2008, the Slovenian Government adopted the National Energy Efficiency Action Plan 2008–2016 [19], the objective of which, in accordance with Directive 2006/32/EC [20], is to achieve a 9% saving of end-use energy through the implementation of planned instruments, which cover measures for efficient energy consumption, energy services, and the development of energy-efficient technologies and products.

In 2008, in accordance with directives of the European Parliament and Council (EPBD) 2002/91/EC (2002) and EPBD 2010/31/EU (2010), Slovenia adopted the national construction legislation "Rules on efficient use of energy in buildings", which were amended and republished in 2010 [21]. The rules lay down the minimum technical requirements and guidelines for constructing low-energy houses today, where the energy consumption for heating today is approximately 40-50 kWh/(m²a) and will in future be nearly zero.

Green public procurements

Green public procurement in the construction sector in Slovenia is primarily affected and regulated by the technical specifications and criteria for buildings as specified in Annex 7 of the *Decree Amending the Decree on Green Public Procurement* [22]. In the category of buildings, it is generally required that 30% of in-built material (by volume) must be timber or timber-based (50% of this can be substituted by products with EcoLabels I or III). Furthermore, an award criterion gives additional credit if the 30% minimum threshold for in-built material is exceeded.

Economic incitements for timber buildings

Like several other European countries, Slovenia is increasing the energy performance of buildings by encouraging investors or buyers to select more energy-efficient technologies through measures that make them more price-competitive, e.g. through low-interest loans or subsidies. In Slovenia, investors can receive low interest rate loans to build passive and very low-energy houses. Nowadays most timber houses built in Slovenia meet the requirements of the *International Passive House Association*. The reason is that timber building manufacturers have a high knowledge level and

tradition within this technology. Furthermore, lower interest-rate loans are also offered by the *Slovenian Environmental Public Fund*. These loans are intended for the construction or renovation of passive or very low-energy houses or for energy-efficiency measures (installation and replacement of solar collectors, biomass boilers, heat pumps, ventilation with recuperation, external building fixtures, heat insulation of the façade and roof) and for changing old windows with high quality energy-efficient windows in wood. From 2008 to 2011 the *Slovenian Environmental Public Fund* allocated € 21,832,400 in loans and this led to savings of about 85,000 MWh in energy and about 13,000 tons of CO₂.

Subsidies from the *National Energy Efficiency Action Plan 2008-2016* [10] also provide support for energy efficiency. These subsidies are available to those undertaking measures to improve energy efficiency, including the construction of passive and very low-energy houses and the comprehensive renovation of existing residential buildings. The subsidies have led to a significant increase in the number of passive timber houses and very low-energy timber houses in Slovenia [23]. The level of subsidies depends on the energy class of the renovated or newly built house and the type of insulation material. The highest subsidy, € 125 per square metre of heated area, can be allocated for the construction of a residence in the lowest energy class (less than 10 kWh/m²a), insulated to at least 75% using material of natural origin (e.g. cellulose flakes, wood fibre, etc.). Subsidies are available for a maximum of 200 m² of net heated area in the building. With optimal construction design and components, the subsidies may entirely cover the price difference between a passive timber house and a house built to the currently valid regulations.

Award for timber construction

The first national award for timber construction in Slovenia was presented in 2013 and the winners were selected by an interdisciplinary committee that included two architects, one expert from the field of sustainable construction and efficient energy use, one civil engineer and one expert from the carpentry sector. There were awards in four categories: residential buildings, public buildings, business-industrial buildings, and engineering works and technical solutions. There was also a special award from the committee for achievements in the field of technical solutions. This is awards event seeks to promote the positive image of timber, strengthen awareness about wood and encourage the use of wood both in construction and in everyday use, Figure 5.18.

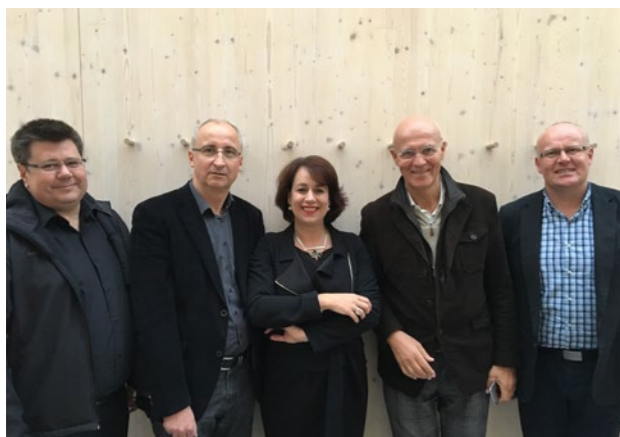


Figure 5.18
The 2nd National Award for the Best Wood Construction 2016 was awarded by the evaluation committee composed of two architects, one expert from the field of sustainable construction and efficient energy use, one civil engineer and one expert for wood and wood products.

Timber buildings in Slovenia and Sweden

Other activities for wood promotion in Slovenia

The national action plan *Wood is beautiful* includes promotional activities that directly improve the state of the Slovenian wood-processing industry and improve the Slovenian transition to a low-carbon society.

SPIRIT Slovenia – Public Agency for Entrepreneurship, Internationalization, Foreign Investments and Technology continues in 2017 to work on the promotion of wood and wood products with the aim to enhance the general awareness of wood and to encourage the use of timber in building construction, as well as to inform the public about many structural advantages of timber in construction, its positive effects on the micro-climate within the building, the fact that it is a sustainable and renewable building material, and social responsibility in balancing environmental, social and economic values.

Ljubljana - *European green capital 2016* - the first and only green oasis in central and southeastern Europe. Numerous changes have happened in a short period, which is one of the reasons why Ljubljana has become *European Green Capital 2016*. Ljubljana has 542 square meters of public green space per resident, while the city features 80 hectares of newly maintained green spaces, and green spaces are still being created from degraded urban land. Wood has a very special character in Ljubljana's green projects with a focus on the green city of tomorrow. Some showcase projects has been built as a dialog, showing that wood is the material of the future in urban construction and living, which will contribute in an essential way to new, cleaner and more healthful building practices.



Figure 5.19 Ljubljana – European Green capital 2016, Mobil timber-frame unit, Pavilion ZPE.

Initiatives in Sweden supporting timber construction

In Sweden, a national strategy for *more wood in construction* was implemented in 2004, striving to further develop industrialized production processes [24]. The vision of this strategy was that wood would be a self-evident material alternative in all construction work in Sweden within 10 to 15 years, and at a somewhat later date even in Europe. To reach this goal, operationalized objectives were formulated as follows:

- Increased competition in terms of construction materials and techniques. More choice alternatives will increase the competition on the market, and this can lead to decreasing costs and better products.
- The provision of new jobs by increasing the extent of further processing of wood as a raw material.
- A decrease in construction defects due to a greater degree of industrialized prefabrication. This has the advantage that construction elements can be built indoors, which leads to improved construction conditions for the product and a better work environment for the employees, which will improve quality control.
- Environmental protection by sustainable construction. Substituting steel and concrete with wood will reduce CO₂ emissions considerably.
- Giving wood the chance to catch up with other construction materials that were treated preferentially due to the prohibition of wood in certain constructions.

In Sweden there is a wide range of programs to promote multi-storey timber buildings.

Swedish national timber construction strategy

In 2006, the Swedish government appointed a National Timber Construction Strategy Committee, with the primary task of promoting the use of wood in apartment houses and public buildings. It is based on analyses carried out by the Swedish Ministry of Enterprise, Energy and Communications. A number of measures have been implemented within the framework of the strategy, including continuing training for those actively involved in the construction sector and “initiative projects” involving the construction of multi-storey buildings in the towns of Falun, Skellefteå and Växjö. In addition, joint action projects have resulted in the construction of buildings in several locations. In parallel with this, the timber industry is taking action through the *Swedish Wood Construction Council*. The two organisations have held a number of seminars and inspirational days throughout Sweden.

The *National Timber Construction Strategy* came to an end in December 2008. It is, however, continuing to operate under the name *Wood City 2012*, a project which will involve further municipalities and regions. The *Continuing Training Programme* has been implemented jointly by Luleå University of Technology, Linnaeus University, University College Dalarna and RISE - Research Institutes of Sweden. This programme has been carried out in close collaboration with major wood construction projects in Falun, Skellefteå and Växjö, for the purpose of:

- monitoring and recording several aspects of timber construction projects, including residential quality, planning and decision,
- making process, technical/functional solutions, aesthetic aspects, the environment and life cycle targets, management and life-cycle economy, as well as timber system suppliers,
- making presentations and drawing conclusions at seminars held in connection with the construction project and at specialist workshops,
- ensuring the availability of records and information,
- providing a natural link with education and research at universities and institutes,
- creating the basis for the development of strong supplier groups in the timber construction sector [25].

Nordic Wooden Cities

The project “Nordic Wooden Cities” must also be mentioned. This project links together Sweden, Denmark, Norway, Finland and Iceland in a cooperation aiming at developing modern wooden cities. Wood should play a more central role in urban development in all kinds of buildings. A close collaboration on the political and administrative levels, information sharing, sharing of “best practice” experience in the whole range of the building process, innovation promoting and supporting cooperation between the public and private sectors are of utmost importance for the Nordic delegates involved in this project. Today, 17 members are engaged in “Nordic Wooden Cities” project, and new members are welcome to join [26].

A similar regional approach has been successfully implemented in the “Välle broar” project in the municipality of Växjö, by the project coordinator Hans Andrén; where the public sector, industry and academia have a common ambition to lift timber construction to the next level. All three sectors have a common denominator in triggering the use of timber in construction and the understanding that no sector can do everything on its own but that there is considerable benefit if the sectors work together. In that way, timber construction can be lifted to a higher level.

Scandinavian countries might be an good example for other European countries in the way of cooperation for increased use of timber in building.

Award for timber construction

The *Architecture in Wood Prize* is one of Sweden’s biggest and most important architectural competitions, presented every four years to a building that represents good architecture in wood and that reflects and improves the times in which we live. The winner of the prize 2016 was the 12th winner since 1967, when it was established by the Swedish Forest Industries Federation, Figure 5.19.



Figure 5.20 The Swedish Timber Prize publications - The government of Sweden encourages more building in wood. Sweden's Timber Prize is an competition, open solely to designs that showcase excellence in wood use and that rewards buildings that incorporate wood holistically with other materials.



Pedestrian bridge over Skellefteå river

Short facts

Builder: Martinsons Träbroar AB, 2011
Owner: the Swedish Transport Administration
Total length: 182 m, span 130 m
Deck width: 4 m
Towers: 24 m
The estimated service life is 80 years

Future development in timber buildings in Slovenia and Sweden

The development of timber building in Slovenia and Sweden after the function-based building regulations that were introduced in Europe nearly three decades ago has shown an incredible growth.

It seems that the timber construction system in Sweden is passing from a formative to a growth phase, while in Slovenia it is still in the formative phase. Single-family timber housing has a long tradition in both countries, but it is more dominant in Sweden than in Slovenia. Timber for multi-storey building structures has a market share of about 15% in Sweden but is almost non-existent in Slovenia.

The use of timber in building structures is promoted to different degrees; in Sweden there is a wide range of programs to promote multi-storey timber buildings, whereas in Slovenia there is since 2014 a program to promote the use of wood in general, but not specifically for the construction of multi-storey buildings. In 2014, Slovenia also adopted the Green Public Procurement (GPP).

Wood is usually perceived as a “traditional” material. However, the properties of this material have now for some time made it possible to design free shapes and highly complex structures. Thanks to the new developments in computer design and digital fabrication, timber construction industry is experiencing significant innovations in fabrication technology and structural applications [27-28].

Long-term cooperative programs, including lobbying efforts and promotional campaigns are needed to make it possible to use traditional and new products that are ideally suited for contemporary residential and non-residential architecture.

There are numerous challenges associated with the construction of timber buildings, and these challenges are best met through further research using scientific examinations as a basis and more pilot projects presenting the technological potential, new production methods which allow completely new ways of building in wood making it superior to other building materials in economic and energy terms, to increase the knowledge of life cycle costs, construction costs, maintenance costs, sound and vibration, through the general increase in the number of timber buildings that are being erected.

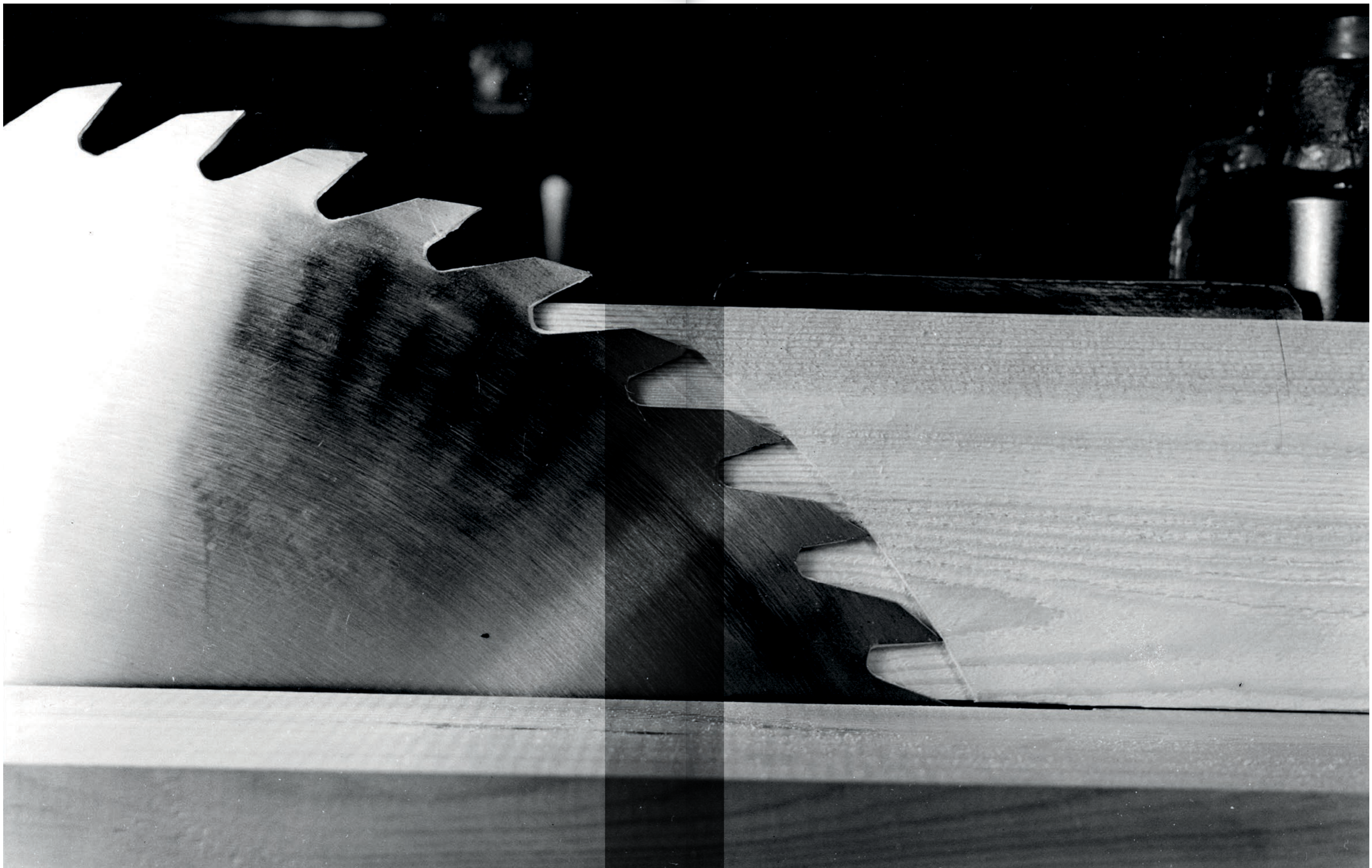
There are opportunities for further development and future trends in high prefabrication, partnership and increased responsibilities for planning and construction, and the improved and systematic feedback of experience and team cooperation. Demonstration projects are vital to show the various actors, e.g. the forest products industry, architects and designers, builders, and housing associations, the technical and business potential of wood as a multi-purpose building material that should be used sensibly.

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Timber buildings in Slovenia and Sweden

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Wood related industry, research and education in Bosnia and Herzegovina

Industries (examples)

Sawmills and producers of EWPs

Stupčanica, www.prominvest.ba
Rosewood, www.rosewood.ba
Euroholz, www.hoovers.com

Manufacturer of timber buildings and windows

Krivaja homes, www.krivajahomes.com
Promo, www.promo.ba
A.S.B Expan, www.asb-expan.com
Dom Invest, www.dominvestbih.com
Steco Centar, www.stecocentasr.com
Savox, www.savox.ba
Grossist, www.drvenekuce-grossist.com
Kontinetal, www.kontinental.biz
Prograd, www.prograd.ba
Dusa Komerc, www.dusa.ba
Sejdic Commerce, www.sejdic-commerce.com
Fagus Haus, www.fagushaus.biz

Institutes

ZEDA-LIND
www.zeda.ba

Associations and academies

Foreign Trade Chamber Of B&H
www.komorabih.ba
Chamber of Economy of the Federation of Bosnia and Herzegovina
www.kfbih.com
Chamber of Commerce and Industry of Republic of Srpska
www.komorars.ba
Wood Cluster Hercegovina
www.dkh.ba
Wood Cluster Prijedor
www.drvo-pd.com

University education

University of Sarajevo
Mechanical Engineering Faculty
Department of Wood Technology
www.mef.unsa.ba
Faculty of Forestry
www.sfsa.unsa.ba
Faculty of Civil Engineering
www.gf.unsa.ba
University of Bihac
Faculty of Technical Science
Department of Wood Technology
www.tfb.unbi.ba
University of Banja Luka
Faculty of Arhitecture,
Civil engineering and Geodezy
www.aggfbl.unibl.org
Faculty of Forestry
www.sfa.unibl.org



Wood related industry, research and education in Slovenia

Industries (examples)

Sawmills and producers of EWPs

Sawmill ŽAGA CUGMAJSTER d.o.o., www.zaga-cugmajster.si

GOZDNO GOSPODARSTVO SLOVENJ GRADEC d.d., www.gg-sg.si/en

Hoja d.d., www.hoja-global.com

GG Novo mesto d.d., www.ggnm.si/si/kontakt

GGP Postojna d.o.o., www.ggp.si

Manufacturer of wooden houses and windows

Lumar inzeniring IG d.o.o.
Green Building Group, www.lumar.si

Jelovica d.d., www.jelovica.si

Kager House d.o.o., www.kager-house.com

Marles Houses Maribor d.o.o., www.marles.com

Riko Hise d.o.o., www.riko-hise.si

Adria dom d.d., www.adria-mobilehome.com

Podgorje d.o.o., www.podgorje.si

Inles d.d. / Retno & Triglav, www.inles.si

LIP Bled d.o.o., www.lip-bled.si

M Sora d.d., www.m-sora.si/en

Institutes

Slovenian Forestry Institute
www.gozdis.si

Pulp and Paper Institute
www.icp-lj.si/institut/?lang=en

Inštitut za les in konstrukcije
www.ilkon.si

Slovenian National Building and Civil Engineering Institute ZRMK
www.zag.si/en

The ZRMK Technological Centre
www.gi-zrmk.si/en

Institut Jožef Štefan
www.ijs.si/ijsw/V001/JSI

Associations and academies

Wood Industry Cluster
www.lesarski-grozd.si

The Furniture and Wood-Processing Industry Association
www.gzs.si/zdruzenje_lesne_in_pohistvene_industrije

Ministry of Agriculture, Forestry and Food
www.mkgp.gov.si

Ministry of Economics Development and Technology
www.mgrt.gov.si/si/delovna_podrocja/lesarstvo/

Wood Industry Directorate
www.mgrt.gov.si/si/delovna_podrocja/lesarstvo/

Društvo inženirjev in tehnikov lesarstva Ljubljana
www.ditles.si

Zavod za certifikacijo gozdov
www.pefc.si

The Association of Slovenian Manufacturers of Pre-Fabricated Houses
www.splms.si/index.php/si/kontakt-2

Chamber of Architecture and Spatial Planning of Slovenia
www.zaps.si/

Architects Association Ljubljana /Društvo arhitektov Ljubljane
www.drustvo-dal.si/

University education

University of Ljubljana
Biotechnical Faculty –
Department of Wood Science and Technology,
www.bf.uni-lj.si

University of Ljubljana
Faculty of Civil and Geodetic Engineering
www.en.fgg.uni-lj.si

University of Ljubljana
Forestry and Renewable Forest Resources
www.bf.uni-lj.si/en/deans-office/study-programmes/academic-study-programmes/forestry-and-renewable-forest-resources

University of Maribor
Faculty of Civil Engineering, Transport Engineering and Architecture
<https://www.fgpa.um.si>

University of Primorska, Faculty of Built Environment
www.fgo.upr.si

Higher Vocational College of the Wood Technology Maribor
www.lesarska-sola-maribor.net

Škofja Loka School Center Wood Engineering
www.scs.si/o-mic-u/mic-english

Educational Centre of Novo Mesto wood technology
www.ecnm.si/home



Wood related industry, research and education in Sweden

Industries (examples)

Sawmills and producers of EWPs

- Derome, www.derome.com
- Martinsons, www.martinsons.se/home
- Norra Timber, www.norra.se/sawn-timber/Pages/default.aspx
- SCA, www.sca.com/timber
- Setra Group, www.setragroup.com/en
- STORA ENSO, www.storaenso.com
- Sveaskog, www.sveaskog.se/en
- Södra, www.sodra.com/en/wood
- VIDA, www.vida.se

Manufacturer of timber buildings

- Derome, www.derome.com
- Lindbäcks, www.lindbacks.se/en/bygg
- Martinsons, www.martinsons.se/home
- Manufacturers of single-familly houses, www.hus.se/hustillverkare
- villaportalen.se/tillverkarregister/trahus

Institutes

- Skogforsk – Forestry Research Institute of Sweden
www.skogforsk.se/english/
- RISE, Research Institutes of Sweden
www.ri.se/en
- IVL – Swedish Environmental Research Institute
www.ivl.se/english/startpage.html

Associations and academies

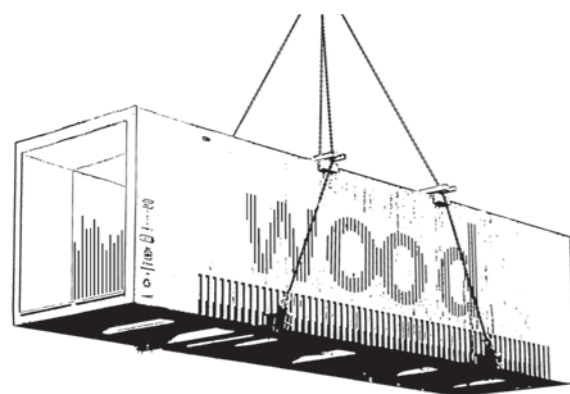
- Swedish Forest Industries Federation
www.forestindustries.se
- Swedish Wood
www.swedishwood.com
- Swedish Federation of Wood and Furniture Industry
www.tmf.se/in-english
- KSLA, The Royal Swedish Academy of Agriculture and Forestry
www.ksla.se/en
- The Swedish Wood Building Council
www.trabyggnadskansliet.se/english
- Trästad Sverige/Wood City Sweden
www.trastad.se
- WoodCenter North
www.ltu.se/centres/TraCentrum-Norr-TCN?l=en
- Architects Sweden
www.arkitekt.se/in-english
- Nordic Wooden Cities
www.nordicwoodencities.com

University education

- Luleå University of Technology, Wood Science and Engineering
www.ltu.se/research/subjects/Trateknik?l=en
- Luleå University of Technology, Timber structures
www.ltu.se/research/subjects/Trabyggnad?l=en
- Swedish University of Agricultural Sciences, Forest Products
www.slu.se/en/departments/forest-products
- KTH, Building Materials
www.kth.se/en/abe/om-skolan/organisation/inst/byv/avd/byma
- Lund University, Structural Mechanics
www.byggmek.lth.se/english
- Linnaeus University, Building Technology, lnu.se/en/research/searchresearch/wood-building-technology
- Linköping University
www.iei.liu.se/machine/areas?l=sv#topp



Chair legs
Sweden

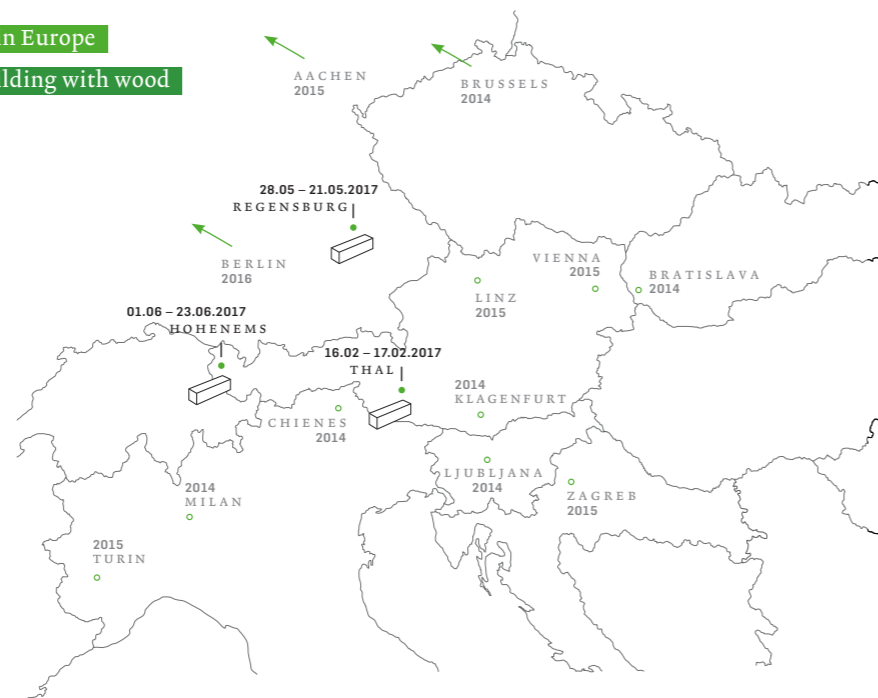


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An initiative of proHolz Austria in cooperation with the Department of Timber Construction at the Technical University of Munich; supported by the European Confederation of woodworking industries (CEI-Bois), the European Organisation of the Sawmill Industry (EOS) and the European Panel Federation (EPF).

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RUMELISIAD, that was held in Bursa in 2006, today is a representative of more than 300 members from 11 different Balkan countries, more than 30 thousand employees in 43 different sectors, million dollars of investment in 38 different countries and above 1,5 billion dollars of trade volume to 146 different countries.

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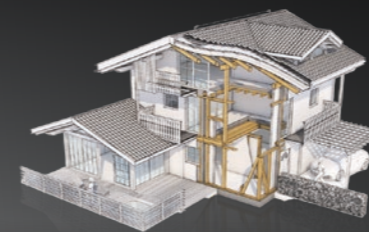
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