Funded by the
Erasmus+ Programme
of the European Union

PUB-WOOD

Sustainable Public Buildings Designed and Constructed in Wood (Pub-Wood)

Project number: 2018-1-LT01-KA203-046963

International Market Report on Wooden Public Buildings

Riga, 2019

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INTRODUCTION

The Pub-Wood Project is a two-year project that aims to develop a trans-disciplinary and transnational course/ elective element in the EU HEIs on the design, construction and management of sustainable public wooden buildings in order to enhance the quality and relevance of students' knowledge and skills for future labour market needs.

The specific objectives of the project are:

1) To strategically research at which level sustainable design, construction and management of wooden public buildings are to be planned and implemented in the partner countries.
2) To educate all participants (students, teachers, entrepreneurs) in the field of the sustainable wooden construction.
3) To develop and implement the new strategic trans-disciplinary module/elective element, which meets the needs of the HEIs and market representatives, fulfils the future challenges of sustainable public wooden buildings' design, construction and management.
4) To improve competencies of students and teachers in problem solving and team work, innovative thinking, motivation, awareness of cross-professional project input and project management by using real problem-based and blended learning approaches.
5) To ensure open awareness of the project results to local, national, EU level and international target groups.

Present report aims to nationally and internationally assess the opportunities and issues on public buildings' design and construction at participating countries as well as will provide information on knowledge gaps in education and research.

1. NATIONAL WOODEN/TIMBER BUILDINGS' MARKET REVIEW

1.1. LATVIA

1.1.1. Macroeconomic Outlook

The development tendencies of the macroeconomic indicators in the Republic of Latvia are positive; currently the main macroeconomic indicators are growing. The summary of several macroeconomic indicators for Latvia can be found in Table 1.1.

Table 1.1. Main macroeconomic indicators (Ministry of Finance. Republic of Latvia, 2018)

	2016	2017	2018	2019	2020	2021
Forecast						
Gross domestic product (GDP), mln EUR*	25038	27033	29039	30841	32639	34442
growth at current prices, %	2.9	8.0	7.4	6.2	5.8	5.5
growth at constant prices, %	2.1	4.6	4.2	3.0	3.0	2.9
GDP deflator, %	0.9	3.2	3.1	3.1	2.7	2.5
CPI (annual average), %	0.2	2.9	2.5	2.5	2.2	2.1
Average monthly wage of the employed in the economy, EUR	859.0	926.0	1002.9	1063.0	1121.5	1177.6
growth at current prices, %	5.0	7.8	8.3	6.0	5.5	5.0
growth at constant prices, %	4.8	4.7	5.7	3.4	3.2	2.8
Employment, thsds	893.3	894.8	905.5	906.4	906.4	905.5
growth, %	–0.3	0.2	1.2	0.1	0.0	–0.1
Jobseeker rate, %	9.6	8.7	7.7	7.4	7.0	6.8

Economic forecast summary for Latvia – the schematic analysis of the GDP growth and the indicators of labour market (on November 2018) are shown at Figure 1.1.

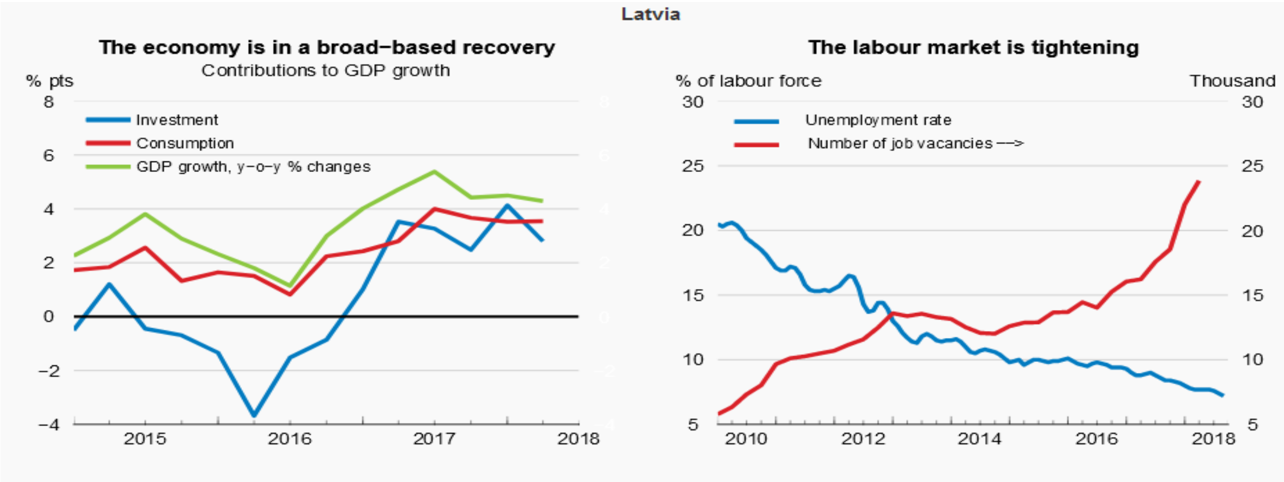


Fig. 1.1. The summary of economic forecast for Latvia and indicators of labour market. Source: Central Statistical Bureau of Latvia; Eurostat; and OECD Economic Outlook 104 database.

General economic indicators of Latvia in period from 2014-2018 are represented in Table 1.2.

Table 1.2. General economic indicators of the country (developed by the authors)

Indicator	**2014**	**2015**	**2016**	**2017**	**2018**
Annual change in real GDP (seasonally and working-day adjusted, %)	1.6	0.0	0.9	3.2	4.1*
Nominal GDP (thous. Eur)	23618163	24320324	25037682	27033056	29039000**
Nominal GDP per capita (EUR)	11 843	12 300	12 779	13 926	n/a
Annual average HICP inflation (%) (2015=100)	99.79	100.00	100.10	103.00	n/a
Annual change in nominal export of goods (%)	0.02	0.01	0.00	0.11	n/a
Annual change in nominal import of goods (%)	0.00	–0.01	–0.02	0.15	n/a
Average gross monthly wages and salaries (EUR)	765	818	859	926	1003**
Unemployment rate (%)	10.8	9.9	9.6	8.7	7.3*

Data: CSB (Central Statistical Bureau of Latvia)
* - EU Commission forecast (Directorate-General for Economic and Financial Affairs (DG ECFI https://ec.europa.eu/info/business-economy-euro/economic-performance-and-forecasts/economic-performance-country/latvia/economic-forecast-latvia_en)
**-Main macroeconomic indicators and forecast. Ministry of the Finance of Latvia. http://www.fm.gov.lv/lv/sadalas/tautsaimniecibas_analize/tautsaimniecibas_analize/galvenie_makroekonomiskie_raditaji_un_prognozes/

Growing economic development tendencies and existing wood export opportunities can be identified as favourable for public wooden buildings. As often, the conflict between time, cost and quality can be observed. Overall economic performance can be found also in Table 1.3.

Table 1.3. Indicators (European Commission, 2018)

Indicators	2017	2018	2019	2020
GDP growth (%, yoy)	4.6	4.1	3.2	2.9
Inflation (%, yoy)	2.9	2.7	2.7	2.4
Unemployment (%)	8.7	7.3	6.7	6.5
Public budget balance (% of GDP)	–0.6	–0.8	–1.0	–0.7
Gross public debt (% of GDP)	40.0	37.1	35.5	35.7
Current account balance (% of GDP)	0.7	–0.0	–0.4	–0.4

Reducing unemployment rate, growing salaries, increase of GDP and prices in general can be observed in the current economic situation.

1.1.2. Construction Market

According to the Ministry of Economics of Latvia (2017), ,,the Latvian Construction Council, the largest non-governmental organizations in the construction sector and the Ministry of Economics have agreed on the vision of development of the Latvian construction sector for 2024 (hereinafter - the Strategy) and approved it at the Council meeting.

The development strategy of the construction industry combines the interests and needs of industry and government, as well as defines the objectives of the sector and the priority activities for balanced development of the industry. The main task of the strategy is to establish a unified policy for the development of a sustainable and competitive construction industry in Latvia. In order to achieve the vision of the development of the Latvian construction sector, the Latvian Construction Council has defined five strategic development goals of the sector:

- Reduce construction bureaucracy by reducing the overall process time by 50% and digitizing solutions, thus ensuring a more efficient construction process;
- to increase productivity in the sector three times to reach the top 10 EU Member States;
- increase the turnover of the construction industry from the current EUR 1.5 billion per year to EUR 3 billion per year;
- to improve the system of education and professional qualifications of construction specialists, ensuring that highly qualified specialists are in each construction profession;
- improve the quality of construction services, while creating a unified quality measurement system.

"The construction industry needs change, increasing its productivity, innovation, export capacity, and highlighting industry achievements. Working with the Strategy, the Ministry of Economics has supported the development vision proposed by the industry. The goal of the construction strategy is to support the construction industry's shift towards higher productivity, "emphasizes Arvils Ašeradens, Deputy Prime Minister and Minister of Economy.

"The balanced development of the construction industry after 2024 is essential to replace the programs funded by the EU funds with new financial instruments for the growth of national economy and exports. At the same time, the construction sector and the Ministry of Economics need to work at the new level of development of the competitiveness of the industry, promoting the development of experts' competences, service quality, e-processes and construction processes, as well as raising the reputation of the industry. The success of the implementation of the construction strategy will depend on how active the industry will be involved in the development and implementation of measures, "said Gints Miķelsons, chairman of the Construction Council of Latvia. In detail, with the Latvian Construction Sector Development Strategy approved by the Latvian Construction Council for 2017-2024“ (Rubesa – Voravko, 2017).

Indicators of construction sector can be observed in Table 1.4.

Table 1.4. Construction sector indicators in Latvia

Indicator	2016	2017	2018
Turnover of the construction sector (€/year) or Volume of construction works (€/year)	1 425 952 200	1 735 951 800	n/a
Volume of public buildings' construction (€/year)	n/a	n/a	n/a
Share of construction sector output in GDP/GNP (%)	5.42	6.06	n/a
Number of construction companies	11755	11559	n/a
Number of employees in construction sector (thousands)	66,1	63,1	n/a
Share of employees who work in construction sector (% of all employees)	7.4	7.0	n/a
Construction export (€/year)	100 899 600	121 110 600	n/a

Data: CSP

The most important legal acts can be found in Table 1.5.

According to Simon Hardiman, Construction21 International (2018), ,,the economic crisis caused significant falls in productivity in building construction (–61.8%) and civil engineering (-36.6%) between 2008 and 2010. Productivity is recovering, although figures for 2015 show that building construction (-31.5%) and civil engineering (–25.9%) still remain significantly below 2008 levels. Profitability has also been negatively affected. This is evidenced by a 13.9% decline in construction sector turnover to EUR 7.4 billion and a 13.3% decline in gross operating surplus to EUR 1.1 billion between 2008 and 2013. Construction sector employment also declined by 17.9% between 2007 and 2013. However, in contrast, the number of construction sector companies in Latvia grew by 14.6% between 2008 and 2014, reaching 25,202 in 2014. The new construction law was adopted by the Parliament in July 2013 and came into force in October 2014.

Table 1.5. Most important legal acts (developed by the authors)

Legal act	Description
Construction Law	Construction Law [Būvniecības likums] [online]. Adopted on 07.09.2013. Effective: 01.10.2014. Latvian Herald [accessed on 10 September, 2017]. Vol.146 Iss. 4952, 30.07.2013. Available at: https://likumi.lv/doc.php?id=258572
Local government Sustainable Development Strategy 2015-2038	Local government Sustainable Development Strategy 2015-2038 (version 1.0)
Latvia's Sustainable Development Strategy by 2030	Latvia's Sustainable Development Strategy by 2030 (version 1.0)
Latvian National Development Plan 2014-2020	Latvian National Development Plan 2014-2020 (version 1.0)
Cabinet Order No. 611 Riga, October 5, 2015 (protocol No. 45, § 91) Forest and related sector development guidelines for 2015-2020.	Cabinet Order No. 611 Riga, October 5, 2015 (protocol No. 45, § 91) Forest and related sector development guidelines for 2015-2020. Accepted: 05.10.2015. Entry into force: 10.5.2015. Published: Latvijas Vēstnesis, 196 (5514), 07.10.2015. OP number: 2015 / 196.1

The key objective of the new law is to simplify the regulatory framework, shorten the pre-construction process, reduce the administrative burden and increase the construction of new buildings in Latvia. The new law also includes requirements for construction workers to better assure the safety of construction workers and the community. Latvia is also taking action to improve the energy performance of residential, central government and municipal buildings, for which EUR 280 million in EU funds have been made available for the 2014-2020 period. 'Increasing Energy Efficiency in Multi-Apartment Buildings 2014-2020' is a scheme that provides grants, guarantees and loans to encourage and support multi-apartment building renovation projects. The scheme has a budget of EUR 166.5 million, including EUR 141.5 million of ERDF funding. The Latvian construction sector is predicted to record negative growth in 2017 (-5.4%), with positive growth forecast for 2018 (+7.3%). However, the growth rate is expected to slow down progressively until 2022. Delays in the absorption of EU funds and the deferral and concentration of large infrastructure projects over the 2018-2020 period may lead to a construction 'bubble', which could cause price increases and may affect the quality of construction works". Construction production is shown in the Figure 1.2.

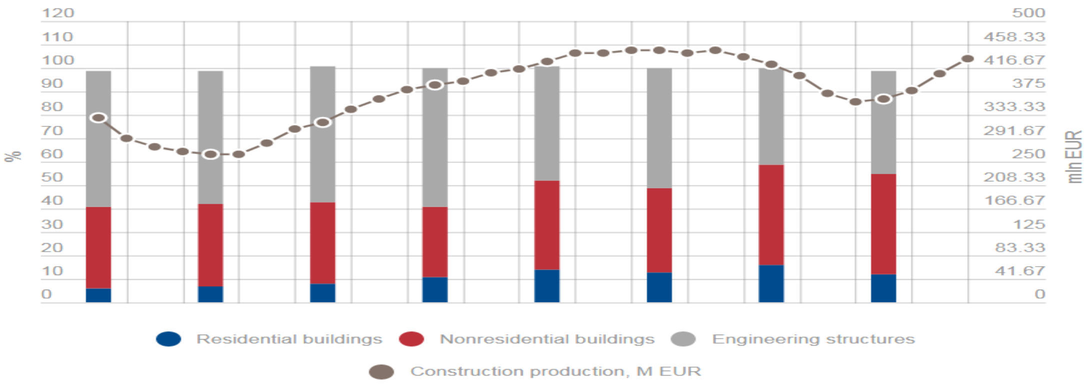


Fig.1.2. Structure of Construction Production, %. Source: CSP, as cited by LIIA.

Export of Construction Services in 2017 by country, %, can be found in Figure 1.3.

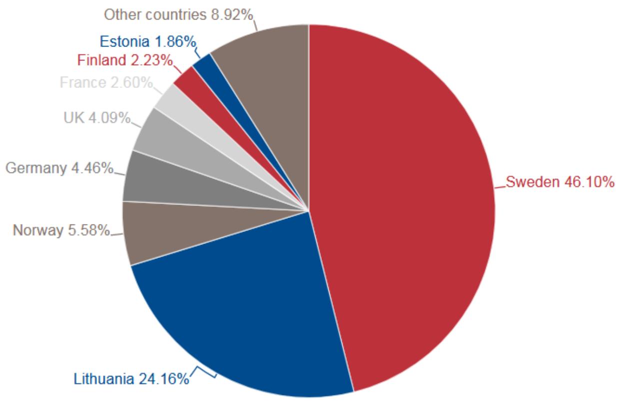


Fig. 1.3. Export of Construction Services in 2017 by country, %. Source: Bank of Latvia as cited by LIIA

Statistics on foreign trade of building materials can be found at Figure 1.4.

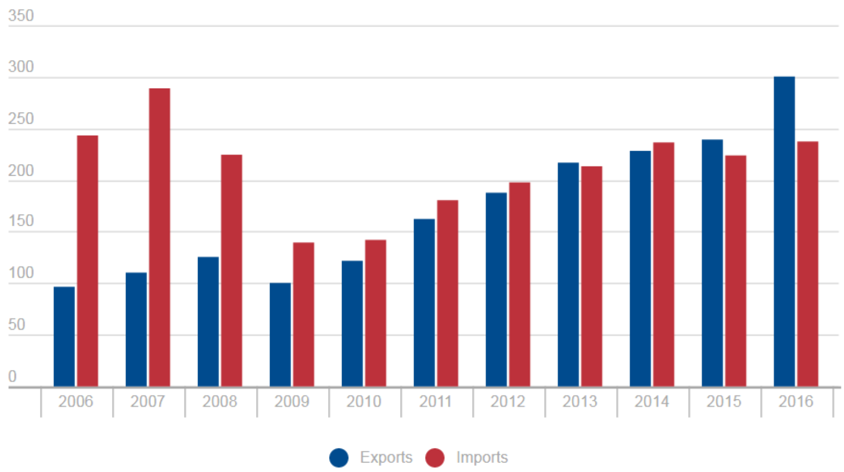


Fig. 1.4. Foreign Trade of Building Materials, mln EUR. Source: CSP, as cited in LIIA

The economic development is very important for the development of construction industry and a new construction in particular. The most of the indicators shows positive tendencies of the development of the construction industry and economy of Latvia in general. Great importance have investments in the industry, entrepreneurial environment in general and purchasing power, both of private sector and entrepreneurs. The research on public wooden buildings can be found in the next subpart of the report.

1.1.3. Public Wooden Buildings

1.1.3.1. Definition of Public Building

Public building - a building in which more than 50% of the total area of the building is public spaces or premises for the provision of public functions or engineering structures intended for public use (such as public stage, stadiums) (Cabinet of Ministers Regulation No.331. Riga, 30 June 2015 (prot. No. 30, 50th).

1.1.3.2. Local wooden building traditions

According to Martinsone I. (2015), ,,the main building materials for interwar period were wood, concrete, reinforced concrete, iron and bricks1, but in the 1930s, as the technology evolved, a number of building materials added a lot of new materials. Basically, the building materials were produced in the local industry using the available natural resources of Latvia.

The state's significant subsidies for the purchase of timber were facilitated by the proliferation of large tree buildings in the countryside of Latvia - from 1920 to 1930 more than 300 thousand wooden buildings and only under 31 thousand were restored or rebuilt. Moorish building2. Construction work in the countryside was so intense that, despite state-designed model plans and accessible advice, the quality of the wooden building process was difficult to control. Errors in the preparation and construction of timber significantly reduced the lifespan of the cranes, and they were flammable. The widespread use of easy-to-access wood led to unlawful waste in timber, causing great losses for both logging and the economy as a whole. In this context, the discussion about the use of unknown clay and other locally available materials - calcium, sand, rust, lime, bundle, twigs - was used to explore the use of folk construction techniques to create fireproof structures while saving building materials3. Separate measures for stimulating the construction of fireproof buildings in the countryside were made at the beginning of the 20th century - funds for construction benefits were provided and sample farms were arranged. The Construction Law, issued in 1925 and supplemented in 1930, provided loans and materials for building fireproof buildings. However, the issue of cheap, durable and fireproof materials and construction techniques continued to be a topical issue. At the beginning of the 30's, the preparation of self-manufactured cement bricks was encouraged in the countryside using a Finnish specimen - only cement 4, gravel and water needed to make it. The cost per square meter of brickwork of cement-based ceramics was similar to the price of wooden walls - cement tiles were significantly cheaper than a ceramic base. In addition, they could be made in close proximity to the direct construction site, saving the cost of transportation of materials” (Martinsone, 2015).

According to Vides Vēstis (2014), the following wooden real estate objects may cause an interest.

Some examples (Vides Vēstis, 2014; Zviedrāns, 2003):

1) Liepaja, Palmu iela 6. Building during repair.

Already from time immemorial, the most accessible man has been a tree. It is a material that, according to UNESCO studies, has been recognized as the most suitable for the construction of human housing. Historic wooden buildings in Latvia are the most dangerous construction phenomenon. The prolonged, unproductive exploitation of these buildings and the lack of efficiency has done not only to the buildings themselves, but also created a psychological barrier against them. Consequently, we will hang over the wooden buildings longer.

By the beginning of the 20th century, the wood was used for structures, for the protection of the bark (birch), from the roots and tops it got the tar, from the resin - turpentine and rosin. With careful management, there were only germs left by the rooms. The oldest type of construction of wooden buildings, which has survived to this day, is log homes, which can be divided into two groups - t.s. folk and professional builders built. With the construction of a nation, we understand rural buildings built by either the peasants themselves or from the beginning of the 18th century. In the 2nd half, the carpenters living in the countryside, who were engaged in the construction of buildings at times. The oldest buildings that have survived to this day have been built log cabins from the bottom of the cobbled logs. Already from the 18th century 2nd floor Kurzeme and Zemgale begin to build buildings from the enclosed logs and connect corners to t.s. smooth packs, which also used to be called German or Russian pods. Already by their name it can be understood that these types of connections were taken from professional carpenters, who were usually German or Russian. Field-built buildings are constructively simple with a small margin of resistance, often sinking with poor material use. Consequently, these buildings are more susceptible to human neglect, care or not, and the use of materials that are not suitable for later repair. The roof is the part of the building that needs to be given the most attention, because it is built in lightweight construction. Until the 20th century In the 20th and early 30's rooftops were mostly covered with straw, reeds, ceilings, chips. These materials are relatively easy and air permeable. Applying asbestos cement plates, roof tiles or tin roofs becomes more severe and there is a very significant change in attic climate that can be compared to tropical global warming. If there is no ventilation on the roof, then a very short time (in comparison with the probable life of the building under the most favorable conditions) will result in a tragic result - all roof-related structures must be replaced or substantial reinforcement must be made. It is for these reasons that the 20th century. In the second half of the year, the technical condition of rural wooden buildings deteriorated dramatically. If there is no roof, there is no building. Traditional roofing is the most suitable for historic buildings in the countryside.

2) Riga, Daugavgrivas street 7. The building was partially burned out in 2000. Restoration started in 2002.

Professionally built wooden buildings are located in towns or former manor centers. They are the best-quality wooden structures that are found in the historic building of Latvia. Riga suburbs, Kuldiga, Aizpute, Cesis, Limbazi, Ventspils, Liepaja, Kraslava, Talsi and others. These are populated places where there are many such buildings. It's a pity to watch that it is often demolished that quality wooden building just because it is down and old. Compared to rural buildings, professionally constructed buildings use high-quality materials and structures have a very large reserve. Also, the roof construction is solid - with a roof chair, it is most commonly intended for the roof to be tiled. Even if the building is not maintained and maintained for long periods, the main faults can only be hidden in the lower vein, at the eaves and under the window sills. They are the most sensitive wooden building sites that have been prosthetic, replaced and repaired at all times. Nowadays, seeing a damaged tree, the first thought is to demolish the house, because the economic and green approach is forgotten - everything can be repaired. Log houses have the advantage that the walls are designed as a monolithic block (with a coat and cabinet), the partitions are tied with a swallow-tail connection, and if the pans are still well-matched, then this building is very durable. It's easier to loop and prosthetic.

3) Crane structure. Liepaja, Friča Brīvzemnieka Str. 53. The construction of rafts was transferred to the current site in the 19th century. the end. Handled and prosthetic in the 20th century. Middle of the 90's.

The next stage in the development of wooden buildings is the construction of stalls with slug filling. In Latvia, the first pillar buildings began to be built in Kurzeme. 17th century - 18th century In the 1st half of the buildings, the lower castle - the custodian and the pillars were made of oak wood. This type of building was a kind of derivative of the German figurines. As there were more timber in Latvia, sections between columns were filled with treated wooden logs - slabs, or, as in Liepaja, say - for parcel trees. Such buildings were built in Liepāja until the 20th century. 20th-30th years. Constructively, this is a more durable construction compared to a log building, if a corner connection is blown, the building can break. However, it is easier to repair such buildings, which can be done in stages. In Liepaja, two, three old buildings of this design are handled annually.

4) Liepaja, Palmu iela 6. The structure of the tent pillar structure, the original cladding is preserved, the damaged parts of the porch are prosthetic, windows and doors are repaired. Cheap houses

19th century In the 70's, with the rapid development of industry, in Riga and in the small towns of Vidzeme demand for small apartments increased. This niche was occupied by two-story wooden buildings, which were built in a wooden frame construction with fillings. Above the boards on the outside, nail a roofing board and then planks. 20th century At the beginning, the facade began to cloak or even be covered with bricks and stones. After construction costs, such buildings were very cheap and externally visually solid, but the basic principles of construction physics were not respected. The roof papier created an air and moisture-proof surface, resulting in a tree deteriorating over time. Plaster and bricklaying reinforced it further. Nowadays, it is the most problematic group of wooden buildings with poor heat resistance - the splinters between the planks are glued only to the tows, the structure does not have a used suit, overlap or spunge. Usually these buildings require additional thermal insulation. If the building is in poor technical condition, the cost of renovation is very high - it is necessary to remove the cladding, roofing, to protect the structure, to heat it and to finish it again. But there are also well-preserved buildings of this type.

5) House as a knit - Aluksne district, Gaujiena Rectory. The smooth thicker and lower armpit grabs the board, which drove moisture across the cap.

To make the wooden building feel good and its owner is satisfied with the place of residence, it should be noted that the tree was a living organism and thus more sensitive to weather and environmental influences such as rain, sun, fungi, insects, etc. Wooden buildings should be carefully monitored and kept up-to-date. In the middle of the 80s I visited a friend in a country house in Piebalga. The building was built by craftsmen from Latgale in the 20th century. In the 20th Very high quality log building in smooth packs, without cladding and internal plaster - as a fairy tale. But I noticed a single part of the wooden wall (woolen) wrecked outside, although I had never seen anything in the rest of the building. It turns out that they had arrived in a firewood building - an old tiled log house in the churches, and gradually spread across the building. Basically, this building is destined for death. The wooden structures of the building are interconnected (like knitting, weave). When cutting a wall, widening the columns, cutting the door threshold, partially or completely removing the roof chair, the building can begin to gradually deform and even crush. Until such a situation had arrived Ungurmuizh's house, where in the 20th century In the 50's, when setting up a school, almost all the original partitions were cut, which served as links between the two vaulted facades. Externs without these walls formed a "belly". What is eternal if properly maintained. The building must have a sufficient moisture content of 50%–60% so that it does not dry up - no cracks, tears and deformations. Central heating is the biggest disaster in wooden buildings. Repairs should not involve experimentation with unknown synthetic materials. The merchant is ready to sell you everything. And he will never say that it has any bad qualities, but about one of the next issues of the "Voices of the Environment" (Zviedrāns, 2003).

1.1.3.3. Wooden construction market

According to Ms. Urpena, E., Ministry of the Economics of the Republic of Latvia, 2018, ,,the construction of wooden buildings in the world is developing rapidly, and it is important for Latvia, as one of the leading woodworking countries, to promote this high value added segment in Latvia using local building materials. The industry has significant growth opportunities, boosting sales to as much as one billion euros. There are both professional builders and architects in Latvia who have the potential to develop wooden constructions and develop a wooden house industry, for example, a strong cross-linked hardwood panel (CLT) producer in Jelgava. The construction of wooden buildings has significant advantages over traditional construction:

– up to 30% shorter construction time;
– all ambiguities solved and optimization done at the design stage;
– eco-friendly and carbon-encapsulating building material is used;
– 5-6 times less weight than reinforced concrete, therefore, less freight transport units are needed and less capacity building equipment on the construction site is needed;
– clean and quiet construction process;
– high fire and seismic resistance.

Prime Minister Arvils Ašeradens called on representatives of the construction industry, construction products manufacturers, municipalities, educational and scientific institutions, insurers and the State Fire and Rescue Service to discuss building opportunities for building wooden buildings in Latvia this week.

Participants in the discussion acknowledged that the promotion of wooden buildings would be promoted as a common awareness of the benefits of timber, as well as good examples of which state support is important, including public procurement for the construction of multi-dwelling wooden buildings.

After the discussion, the Minister of Economic Affairs A.Ašeradens emphasized that "2017. We have already taken a significant step in this direction along with the approved changes in the construction standard, providing for the possibility of building wooden buildings up to six storeys in height. The state must play a key role in promoting wooden buildings and create examples that demonstrate a variety of opportunities. "

In turn, the chairman of the Valmiera City Council, Jānis Baiks, during the discussion, said that the promotion of wooden building construction requires state support and Valmiera would be ready to be the pioneer in this field, implementing the first wooden high-rise building construction project in Latvia".

,,According to DNB banka's statistics for 2016, residents of Latvia slowly start to evaluate the value of trees in construction, and the proportion of loans to wooden houses reaches 23%. At the same time, wooden house manufacturers admit that wood frame buildings in Latvia still have a relatively low demand, while people are only gradually "acquainted with the tree". One of the reasons is that some of the society's misconceptions about the use of wood in construction"(SIA TV NET, 2017).

Main indicators of wooden construction market are shown at Table 1.6.

Table 1.6. Main indicators of wooden construction market (developed by the authors)

Indicator	**Description**		
The percentage of the countries' area, that is covered by forest	**52%**		
Number of public wooden buildings (2018)	**n/a**		
Indicators	**2016**	**2017**	**2018 (Jan–Sept)**
Turnover of the wooden construction (€/year)	–	–	–
Number of companies at wooden construction sector	–	–	>12
Number of employees at wooden construction sector	66,1 thsd	63,1 thsd	–
Wood export (tons/year)	2,094,822.2	2,266,381.7	1,924, 783.6
Three major export markets	Great Britain Estonia Germany	Great Britain Estonia Germany	Great Britain Estonia Germany
Wood import (tons/year)	740 024,6	803 844,2	688 563,3
Domestic price of wood (€/m^3) *Specified according to the types of wood* *Case of pulpwood*			

Birch			
Kurzeme region	28–32	29–46	29–44
Vidzeme region	28–34	29–46	44–61
Spruce			
Kurzeme region	29–33	31–47	48–63
Vidzeme region	29–32	31–47	50–63
Pine tree			
Kurzeme region	29–33	31–47	48–63
Vidzeme region	29–33.5	31–49	50–65
Smoothie tree			
Kurzeme region	28–32	30–48	48–64
Vidzeme region	28–33.5	29–49	47–64
Aspen			
Kurzeme region	18–23	20–33	41–43
Vidzeme region	21–26	21–38	32–45
Spruce saw (length 4.8 meters)			
Diameter 10–13			
Kurzeme region	48–51	48–51	50–74
Vidzeme region	41.5–45	41.5–50.5	47.5–66
Diameter 18–20			
Kurzeme region	68–73	68–75	75–78
Vidzeme region	70–73	70–74	73–85
Diameter 35–37			
Kurzeme region	71–73	71–77	80–83
Vidzeme region	60–73	60–74	72–84
Pine saw (length 4.8 meters)			
Diameter 10–13			
Kurzeme region	75	75	75–87
Vidzeme region	35–41	37–50.5	47.5–66
Diameter 18–20			
Kurzeme region	78	78	78–146
Vidzeme region	59–64	61–72	71–81
Diameter 35–37			
Kurzeme region	40–46	40–46	50–72
Vidzeme region	40–61	47–72	70–82

Plywood (birch, grade B)			
Diameter 21–22			
Kurzeme region	50–65	65–80	78–90
Vidzeme region	50–75	63–77	68–90
Diameter 31–32			
Kurzeme region	60–75	70–85	83–90
Vidzeme region	60–86	63–87	75–95
Fuel wood (mixed)			
Kurzeme region	16–21	20–28	27–37
Vidzeme region	21–23	20–33.5	27–36

**-data CSB, Mežsaimnieks (2018a; 2018b)*

Latvian Wood Construction Cluster is working in Latvia. Examples of wooden buildings in Latvia can be found in the 1.3.6. subpart of this report.

1.1.3.4. Technologies

There are two different wood construction systems – heavy timber framing and light wood framing (Ching, 2009). Classification of hardwood and softwood has a botanical characteristics (Kubba, 2017). Different types of wood have multitude of uses and in some cases may be interchangeable (Kubba, 2017). Wood beams can include solid sawn lumber, glue-laminated timber, parallel trand lumber, laminated veneer lumber, and different wood spanning systems exist as well (Ching, 2009).

Advanced framing, or optimum-value engineering (OVE) as it is sometimes referred to, consist of a variety of framing techniques. Designed to reduce the amount of lumber used and waste generated in the construction of wood-framed structures (Kubba, 2017). ,,Modern OVE advanced framing techniques include the spacing of studs at 24-inch on center (o.c.); 2-foot modular designs that reduce cutoff waste from standard-sized building materials; in-line framing that reduces the need for double top plates; building corners with two studs; and insutated headers over exterior building openings (or no headers for non-load-bearing walls)" (Kubba, 2017, p. 301). Timber is of aesthetically pleasing appearance, its manufacture requires much less energy, structural timber sections have good fire resistance. It may have some effects of ,,imperfection", and can be a subject to insect attack, untreated timber may burn readily in fire, and timber may creep under load (Taylor, 2000), so techniques should be applied properly (Taylor, 2000).

1.2. LITHUANIA

1.2.1. Macroeconomic Outlook

Lithuania is a member of the European Union since 2004 and the Euro Zone since 2015. It is the largest economy among the three Baltic countries. Lithuania belongs to the group of very high human development countries (according to Human Development Index takes place 35 in the world) (UNDP, 2018). Lithuania is also a member of the World Trade Organization (WTO) and the Organisation for Economic Co-operation and Development (OECD).

Lithuania was the first country to declare independence from Soviet Union in 1990 and rapidly moved from centrally planned to a market economy, implementing numerous liberal reforms. It enjoyed high growth rates after joining the European Union along with the other Baltic countries, leading to the notion of a Baltic Tiger (Global Tenders, 2018).

GDP growth reached its peak in 2008. Similar to the other European countries, the Lithuanian economy suffered a deep recession in 2009, with GDP falling by almost 15%. After severe recession, country‘s economy started to show signs of recovery already in 3rd quarter of 2009 and returned to growth in 2010 with positive increase of GDP by 1.3%.

In 2015 Lithuania has entered Euro Zone; however, the growth has decelerated, weighed down by the external environment. Exports to Russia have plummeted as a result of the trade restrictions imposed by it and the country’s economic deterioration. Despite the unfavourable external environment, domestic demand has thus far remained resilient, with both household consumption and domestic investment growing at a healthy pace (Bank of Lithuania, 2015).

After a significant slowdown in 2015, the development of Lithuania’s economy in 2016 has grown stronger. Lithuania’s GDP reached EUR 34.4 billion in 2016, a 2.3% growth compared to 2015 and 22.8% to 2010 (European Construction Sector Observatory, 2018). Economy grew by 3.9% in 2017 and is expected to grow by 3.4% in 2018, according to projections of the Ministry of Finance of the Republic of Lithuania (2018).

After the peak of 4.1%, which was recorded in 2011, the inflation rate has been declining and entered negative number of –0.7% in 2015 (European Construction Sector Observatory, 2018). However, in 2016 it went up and stood at 0.7% in 2016 and rapidly increased to 3.7% in 2017. According to projections of the Ministry of Finance of the Republic of Lithuania (2018) inflation is estimated to reach 2.7% in 2018.

Average unemployment rate in Lithuania was 7.1% in 2017 and is expected to reach 6.3% in 2018. This is well above the 2010 level of 16.4% and has been improving ever since.

In terms of demographics, the total population of Lithuania was 2.9 million in 2016, however, this figure is forecast to decrease by 4.8% until 2020, by 16.5% until 2030 and by 32.2% until 2050, ultimately reaching 2.0 million. In addition to the declining demographics, net migration has also been negative for the past decade, with an average of 32,000 people emigrating each year over 2010–2016. Lithuania’s working age population, which made up 66.4% of the total in 2016, will have shrunk to 53.7% by 2050, while people aged 65 or older will make up 32.3% of the total. The decreasing and ageing population challenges Lithuania's growth prospects and fiscal balance (European Commission, 2017).

Still, economic growth remains robust driven by household consumption which strengthened in the first half of 2018. It should be noted that the relatively fast economic expansion, which has been maintained for some time, leads to a widening output gap, which shows the extent to which the current economic development has deviated from its sustainable path. A widening output gap leads to imbalances, which are now mostly noticeable in the labour market and are among the main reasons for the rapid wage increases (Bank of Lithuania, 2018).

General economic indicators of Lithuania for the last five years are provided in Table 1.7.

Table 1.7. General economic indicators of the country (developed by the authors)

Indicator	2014	2015	2016	2017	2018*
Annual change in real GDP (seasonally and working-day adjusted, %)	3.5	1.8	2.3	3.9	3.4
Real GDP per capita (EUR)	11,300	11,600	12,000	12,700	n/a
Annual average HICP inflation (%)	0.2	–0.7	0.7	3.7	2.7
Annual change in nominal export of goods (%)	–0.7	–0.4	3.5	13.6	5.7
Annual change in nominal import of goods (%)	–1.2	6.2	3.5	12.8	6.0
Average gross monthly wages and salaries (EUR)	714.5	756.9	784.0	840.4	915.2
Unemployment rate (%)	10.7	9.1	7.9	7.1	6.3

* Forecasts

Data sources: Statistics Lithuania (2018), Eurostat (2018), Ministry of Finance of the Republic of Lithuania (2018)

At a glance, macroeconomic situation in Lithuania is favourable for construction sector. However, according to the Global Competitiveness Report 2017-2018, Lithuania ranks only 52nd in terms of financial market development, 52nd in terms of ease to access to loans (European Construction Sector Observatory, 2018). Average gross monthly wages and salaries increasing, yet are still very low in the context of the other European countries.

Modern buildings in Lithuania are mostly constructed from steel and concrete as use of these materials is cheaper compared to wood. Therefore it seems that sustainable wooden construction is still not affordable for majority of the Lithuanian public institutions and enterprises that build public buildings for their activities.

1.2.2. Construction Market

Till the crisis construction sector was one of the most developing industry branches in Lithuania. This was mainly caused by the growth of national industry, good credit terms, possibilities given by EU Structural Funds, a larger demand for residential, commercial and industrial buildings, increasing selection of new building materials and technologies. Development of construction sector promoted the growth of the production of building materials as well as the demand for sales, transportation and storage services (Co$_2$olBrics, 2011). Materials, produced in Lithuania, including wood, became popular enough in the markets of EU countries, such as Sweden, Norway, Germany, etc.

Productivity fell significantly in building construction (–64.9%) and civil engineering (–32.8%) between 2008 and 2010, due to the harsh economic climate following the crisis (Construction 21 International, n.d). After the crisis construction sector started to recover since 2012, however, it is still subjected to fluctuations.

According to the data provided in Table 1.8, construction sector in 2016–2018 (Q1–Q3) created about 6% of GDP and there were more than 7,000 enterprises, 7% of all employees in Lithuania, working in this sector.

Among the main economic activities, only the construction sector was declining in 2016. In the first half of 2016, the volume of construction of non-residential buildings and civil engineering works has decreased significantly. This development was significantly affected by the decrease in the use of EU funds. Only the volume of the construction of residential buildings was increasing (Bank of Lithuania, 2016).

In 2017, investment in construction reached the stage of tentative recovery and the emerging pick-up in activity in the construction sector has also contributed to the growth of the entire Lithuanian economy. The recovery of investment in buildings and structures was mostly driven by private sector investment that is financed from other sources than EU assistance funds (Bank of Lithuania, 2017).

In 2018 an upturn in construction investment encouraged activity in the construction sector. After a few years' break, this sector is once again one of the main driving forces behind growth in the Lithuanian economy (Bank of Lithuania, 2018).

Mild growth is predicted for Lithuanian construction sector for the coming years, although it will slow down considerably up until 2020 due to the limited opportunities on the domestic market. However, the international construction activities are increasing (see Table 2). The outlook for the Lithuanian construction sector is moderate, with growth being forecast an annual average rate of 2.6% between 2017 and 2025 (European Construction Sector Observatory, 2018).

The main advantage of Lithuanian construction companies is a highly qualified engineering team: constructors who are capable of creating and implementing unconventional – or even entirely new – technical and architectural solutions. Experience, responsibility and access to modern technology guarantee work of high quality (Enterprise Lithuania, 2016).

Key competitive advantages (Enterprise Lithuania, 2016):

- Growing specialization;
- Significant knowledge, well-developed skills;
- Highly skilled engineering staff;
- Focus on high quality;
- Strong base of traditional apprenticeship training.

Construction sector indicators are shown at Table 1.8.

Table 1.8. Construction sector indicators (developed by the authors)

Indicator	**2016**	**2017**	**2018 Q1-Q3**
Volume of construction works (thousand €/year)*	2278909	2563712	2118012
Volume of public buildings' construction (thousand €/year)	862041	1000845	800412
Share of construction sector output in GDP (%)	5.88	6.10	5.89
Number of construction companies	7315	7749	8029
Number of employees in construction sector (thousands)	105	99	n/a
Share of employees who work in construction sector (% of all employees)	7.6	7.3	n/a
Construction export (thousand €/year)	232720	275443	210275

*In territory of Lithuania only

Source: Statistics Lithuania (2018)

The most important laws and legal acts that regulate activities of the construction sector are provided in Table 1.9. At present, requirements in the field of construction acting in Lithuania can be classified into five separate levels. Three upper document levels in Table 1.9 are compulsory while the two lower ones – not compulsory, selective only (Samofalov & Papinigis, 2010).

In summary, construction market in Lithuania slowly recovers from the crisis and is affected by external environment conditions as well as the EU funding. Only residential sector was growing rapidly in previous years, the growth of public building sector was moderate. It is forecasted that the construction will slow down considerably up until 2020 due to the limited opportunities on the domestic market.

Lithuanian construction companies are highly qualified to design and build (or be subcontracted to build) public and private housing, as well as industrial and commercial property, throughout Europe and Scandinavia. As the construction of the public buildings needs public and/or private sector investments and wooden construction is expensive, it can be predicted that more opportunities for construction of public wooden buildings exist in the markets abroad, i.e. Scandinavian countries.

Table 1.9. Most important legal acts (developed by the authors)

Legal act	**Description**
Law on Construction of the Republic of Lithuania (2017)	Establishes all essential requirements for construction works which are being built, reconstructed and repaired within the territory of the Republic of Lithuania, and *inter alia* the minimum requirements for energy performance of buildings.
Construction technical regulations (STRs)	Construction technical regulations (STRs) subdivided in three principal groups (organizational, technical, and economical) are the next laws according to the importance of legal acts and they are the basic regulation documents for a practicing engineer. Currently there are 64 valid standards (the list is available at http://www.am.lt/VI/index.php#a/16982). The most important standard that regulates design of timber buildings is STR 2.05.07:2005 “Design of wooden structures”.
Technical standards	Technical standards requirements, which can neither be disputed nor changed by alternative ones (to this level belong only documents mentioned in the Construction technical regulations).
Other standards	Standards selectively used for materials, methods of analysis, products, technological processes, control methods etc. Not compulsory, selective only.
Recommendatory type standards	All standards not mentioned above are of recommendatory type (internal institution rules, recommendations issued by professional associations, aids published by research institutes, textbooks, guidelines etc.).

1.2.3. Public Wooden Buildings

1.2.3.1. Definition of Public Building

Public building is a building designed to meet the needs of the society and in accordance with the provisions of the STR 2.02.02:2004, used for the purposes of hotels, administration activities, trade, provision of services, catering, transport, culture, science, treatment, recreation, sports or religion.

Types of the public buildings:

1. Hotel buildings: hotels, motels, guest houses.
2. Administrative buildings: administrative buildings of state and municipal administration offices, prosecutor's offices, courts, other institutions and organizations, embassies, banks, post offices, stock exchanges, labour exchanges, insurance institutions, office lawyers, notaries, bailiffs, information centres and other buildings.
3. Commercial buildings: shops, shops-operators, pharmacies, bookstores, shopping pavilions, tents, kiosks and other buildings.

4. Service buildings: baths, beauty centres, laundry facilities, repair shops, reception-outlets, car-care centres, car wash facilities, funeral homes, crematoria and other buildings.
5. Catering buildings: canteens, restaurants, cafes, bars and other buildings.
6. Transport buildings: airfield, sea and river fleet, railway and bus station buildings, customs, transport tickets' shops, travel agencies and other buildings.
7. Cultural buildings: theatres, cinemas, cultural houses, clubs, libraries, museums, archives, exhibition houses, planetariums, radio and television and other buildings.
8. Scientific buildings: institutes and research institutions, observatories, meteorological stations, laboratories (except of production laboratories), general education, vocational and high schools, kindergartens and other buildings.
9. Therapeutic buildings: hospitals, clinics, polyclinics, sanatoriums, rehabilitation centres, special health care buildings, health facilities, nursing homes for medical care institutions, veterinary clinics and other buildings.
10. Recreational buildings: tourist centres, rest homes, youth hostels, camping buildings, rural tourism buildings, hunting lounges and other buildings.
11. Sports buildings: sports halls, tennis courts, swimming pools, slides, yacht clubs, shooting halls, stadiums, riding halls and other buildings.
12. Religious buildings: catholic churches, orthodox churches, chapels, synagogues, prayer houses, cathedrals and other buildings.

1.2.3.2. Local wooden building traditions

Wood has always been the natural building material in the Nordic and Baltic countries, since the very beginning of human settlement in these areas. Traditional houses on both sides of the sea were built of timber, the raw material coming from local pine or oak. The most important tools were the broadaxe and the plane, both of which were handled by local craftsmen or by the homeowners themselves (Sandström, 2011).

For centuries Lithuania was known as a land of endless lush forests, interrupted only by rivers. As such, the traditional architecture in Lithuania is wooden. Most (~90%) of the buildings constructed in Lithuania before the year 1940 are built of wood. In smaller towns, almost every building that had been constructed before the 20th century is built of wood. Wooden churches (both Catholic and Orthodox) are common in villages; there are even wooden mosques and synagogues. Some of the wooden buildings are very elaborate and with intricate details (TrueLithuania, n.d.).

At the end of the 19th and the beginning of the 20th century, there were various wooden public buildings related to entertainment and recreation in the urban environment of Vilnius and Kaunas (Lukšionytė, 2011).

The architecture of urban entertainment and recreation was created by professional architects according to designs drawn up in advance and coordinated with the building divisions of municipalities. The so-called Swiss style that was prevalent in the resorts of other European countries was characteristic of its style (a decorative structure of coupled or diagonally crossed elements used in the pediments of projecting canopies and porches, as well as in open galleries between the responds, represent the Swiss style). Those elements – rafters or king posts, which reinforced the responds – were shaped, and tracery was inserted between them. The most characteristic representative of this trend was the Summer Theatre in Vilnius (Lukšionytė, 2011).

Buildings with a fachwerk (timber framework) structure enriched the arsenal of instruments of resort architecture (see Fig. 1.5).

Fig. 1.5. Building tradition – fachwerk. Villa Flora, Kalno St 7, Juodkrantė (Ptašek, 2011)

The diversity of resort architecture was also supplemented with local ethnographic traditions, which are especially obvious in the seaside region. Quite often elements of different styles harmoniously match in a single building, which was tolerated in the period of Historicism as an additional means of expression. The appearance of new types of buildings is also of great significance to resort architecture: kurhauses, restaurants, bathing places, and minor structures – arbours, and observation decks – markedly enriched and added variety to resort (Ptašek, 2011).

Ideas of international regionalism in architecture have had and still have a significant effect on the development of wooden architecture in Lithuania. These creative concepts encourage making more meaningful, qualitative, attractive and more considered architecture. The impact of these ideas on professional Lithuanian architecture could be traced back to the beginning of the 20th century (Gabrėnas, 2012).

1.2.3.3. Wooden construction market

Wood processing sector

Statistical information on the wood manufacturing and wood construction is very limited in Lithuania. Indeed, the forest industry is one of the most important sectors in the Lithuanian economy. Forests and wood product industries provide over 60,000 jobs in forestry and logging, wood manufacturing and the paper and furniture industries (Kobuszynska, 2017).

Forests cover more than 33% of the territory in Lithuania. Therefore, the wood industry is by tradition one of the largest and strongest in Lithuania. The wood processing sector[1] accounts for about 2.0% of GDP, employing around 32.2 thousand workers or 3.5 percent of total employment. 2257 companies were active in the sector at the beginning of 2016, 99.8 percent of them were SMEs. Around 2/3 of production is exported to more than 90 countries around the world (Enterprise Lithuania, 2015).

In 2015 exports of the wood processing sector grew 1.6 % while total exports of goods declined 5.7 %. Exports of the wood processing sector amounted to 763 million EUR last year.

The most important export markets for the wood processing sector in 2015 were Germany (15.5 % of total exports of wood and wood manufactures), followed by Norway (15.4 %), Latvia (9.3 %) and the United Kingdom (7.1 %) (Fig. 1.6.). European Union countries accounted for almost 70% of exports by the wood processing sector (Enterprise Lithuania, 2015).

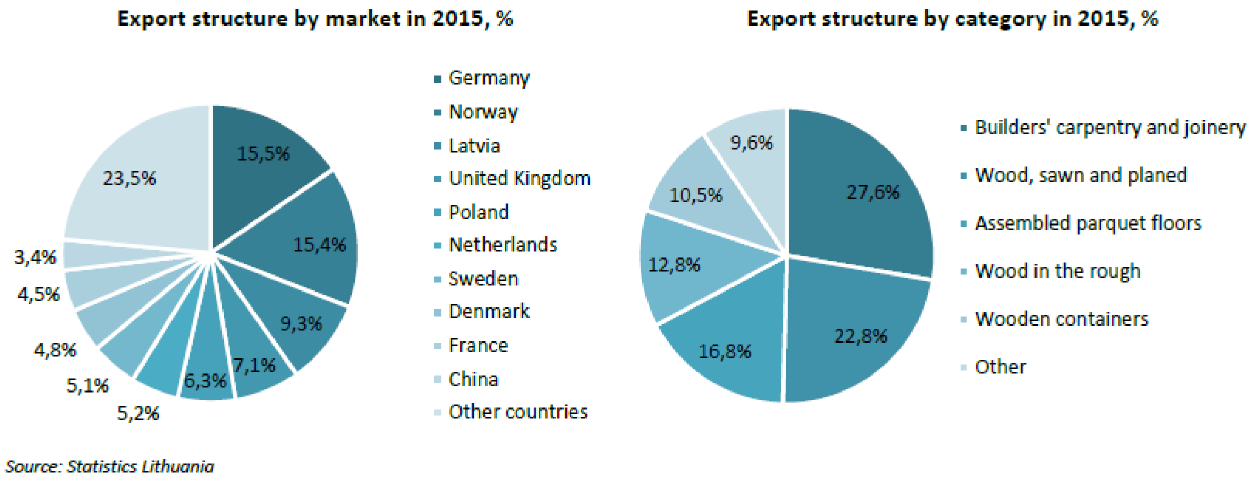


Fig. 1.6. Exports of Lithuanian produced wood and wood manufactures (Enterprise Lithuania, 2015)

In 2016 output of sawmills increased to 1.41 million m³. Production of plywood veneered panels and similar laminated wood amounted to 43,500 m³. Production of veneer sheets amounted to 79,000 m³ and increased by 14% (State Forest Service, 2017).

The portion of sawn wood in total wood industry export was 7%. The value of sawn wood increased by 12% compared with 2015. Exports amounted to 932,000 m³, i.e. 14% more than in 2015.

Total Lithuania’s imports decreased by 3% in 2016 (–2% in 2015). Imports of wood industry products increased by 5% and reached EUR 1182 million. The main import partners were Poland, Latvia, Germany, and Belarus. The amount of imported sawn wood increased by 24% up to 755,000 m³. The biggest share of it was imported from Belarus. It amounted to 277,000 m³, i.e. increased by 35% comparing with 2015 (State Forest Service, 2017).

[1] Includes forestry and logging (NACE A02) and manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (NACE C16)

Strengths of Lithuanian wood processing industry (Enterprise Lithuania, 2015):

- Efficient application of modern technologies and innovative business solutions;
- Strategic proximity to major markets;
- Good availability of raw materials;
- High flexibility to handle non-standard orders.

Wooden construction sector

Like elsewhere in Europe, natural and eco-friendly wooden houses are raising merits in Lithuania, so the woodhouse industry is experiencing a stage of growth: new enterprises are established, business is expanded not only in the Lithuanian market but in foreign markets as well (ALHP, 2018).

However, construction of the modern wooden public buildings is still limited. Wood is mostly popular in residential construction (family houses), construction of recreational facilities (rural tourism homesteads), traditional food restaurants and bathhouses. Indeed, there are examples of modern public wooden buildings (see Part 4).

According to Centre of Registers, there are 21,971 registered public wooden buildings in Lithuania, however, majority of these buildings were built many years ago.

Available statistics on wooden construction market in Lithuania is provided in Table 1.10.

According to the Association of Log Houses Producers (ALHP) (2018), today there are about 120 producers of log houses and about 100 producers of timber-framed houses in Lithuania. Most of them are small-sized enterprises with up to 50 employees, while the others can be attributed to the category of medium-sized and large enterprises.

Lithuanian producers of wooden houses consume approx. 300 thousand m^3 of top-quality timber, mainly pine logs, per year. This accounts for roughly 8% of the total quantity of wood consumption in Lithuania per year. About 30% of wood is imported from Russia, the Ukraine and Belarus.

Producers of wood houses export about 75% of their products to Scandinavian and Western European countries. The biggest export markets for wooden houses are Norway, Denmark, Sweden, Germany, France and the Netherlands. Some Lithuanian producers of wooden houses carry out their business in foreign countries only (ALHP, 2018).

Solid wood products, which are more perfectly processed from the technological point and closer to tradition, their qualities and application possibilities in architecture, today are supplemented by products of joint timber. The popularity and attractiveness of wood image is testified by materials imitating wood. A wish to avoid the physical changes characteristic to natural wood related to appearance to such materials is the outcome of contemporary society’s view to existence. With the help of modern technologies, wooden linear, planar and cellular structures allow for realization of complex, precise wooden structures possessing good physical and aesthetical properties to express different ideas of architectural forms conceived by architects/ designers. In Lithuania innovative ways of wooden structures are applied fragmentally and inadequately to the use of wooden architecture in the past (Gabrėnas, 2012).

Table 1.10. Main indicators of wooden construction market (developed by the authors)

Indicator	**Description**		
The percentage of the countries' area, that is covered by forest (State Forest Service, 2018)	33.2% (2,189 million hectares) in 2017		
Number of public wooden buildings (2018) (Centre of Registers, 2018)	21,971		
Indicators	**2016**	**2017**	**2018**
Turnover of the wooden construction (€/year)	n/a	n/a	n/a
Number of companies at wooden construction sector	n/a	n/a	n/a
Number of employees at wooden construction sector	n/a	n/a	n/a
Export of wood products and furniture industry (bill. EUR/year) (Enterprise Lithuania, 2016–2017)	2 342.808	2 235.300	n/a
Three major export markets (Forest Industry products)	Germany Norway Latvia	Germany Norway Latvia	n/a
Import of wood products and furniture industry (1000 EUR/year) (State Forest Service, 2017)	748 423	n/a	n/a
Domestic price of wood (€/m^3) (Miško birža, 2018). *Raw wood* Eagle logs Pine logs Algae logs Birch logs Aspen logs Oak logs Ash tree logs	n/a	57–73 50–70 46–70 45–140 40–54 60–250 50–130	n/a

1.2.3.4. Technologies

Modern wooden construction technologies which are being used in the construction:

1. Glued laminated timber (Glulam). It is the main timber engineering material which is used for modern timber buildings. Mainly all prefabricated glulam elements are assembled on the construction site. This type of material is very commonly used for sport's buildings, roofs of shopping centres.
2. Prefabricated timber frame buildings. This technology of wooden houses is mostly used for residential houses but thanks to lightness and ease of erection of such type of buildings, this technology is being used also for public buildings (kindergartens, schools, low-rise office buildings).
3. Cross laminated timber (CLT). The cross laminated timber is an engineering timber based material on which there are some ongoing projects. Cross laminated timber panels will be used as load bearing structure for internal and external walls and ceiling.

1.3. FINLAND

1.3.1. Macroeconomic Outlook

In Finland, the economic situation has been raised in the last years. In Table 1.11 there is presented situation in a numbers. General economic indicators of the country are shown at Table 1.11.

Table 1.11. General economic indicators of the country (developed by the authors)

Indicator	2014	2015	2016	2017	2018
Annual change in real GDP (seasonally and working-day adjusted, %)	–0,6%	0.1%	2.5%	2.8%	2*
Nominal GDP per capita (EUR billion)	37615	38245	39327	40638	*
Annual average HICP inflation (%)	0.55%	–0.25%	1.10%	0.5%	*
Annual change in nominal export of goods (%)	–0	–5%	0,5%	3%	2%
Annual change in nominal import of goods (%)	–1%	5%	0%	4%	3%
Average gross monthly wages and salaries (EUR)	3143	3214	3368	3596	*
Unemployment rate (%)	8,4%	9,2%	8,9%	7,1%	*

As can be seen from the spreadsheet above, the economic situation has been turning to positive direction last few years and that makes the moment suitable for investing into building public buildings, which increases the economy also. It has been calculated that one construction worker produces four more jobs and that is the reason why governments will most likely try to fight economical decrease by starting big projects.

The unemployment rate is still relatively high and the need for jobs could be cured by investing into public wooden buildings. Increased demand of wood would also cause companies to hire more employers to work with wood industry including transportation of wood.

1.3.2. Construction Market

Turnover of construction industry in Finland has grown rapidly over the past few years. Indicators of the construction sector are shown at Table 1.12.

Table 1.12. Construction sector indicators (developed by the authors)

Indicator	2016	2017	2018
Turnover of the construction sector (€/year) (Tilastokeskus 2/2017)	32 786 M€	36 266 M€	n/a
Volume of public buildings’ construction (€/year)	n/a	n/a	n/a
Share of construction sector output in GDP/GNP (%)	6.9	7.1	n/a
Number of construction companies	40 891	41 110	n/a
Number of employees in construction sector (thousands) (Tilastokeskus 3/2017)	158	166	n/a
Share of employees who work in construction sector (% of all employees)	7.3	7.6	7.8
Construction export (€/year)	91 M€	96 M€	n/a

Volume of public building construction is nowadays quite large. Volume in m3 is 2018 about 4 milj.m^3 according building permits, as shown at Figure 1.7.

Fig. 1.7. Volume (m3) of public building's in Finland (Rakennuslehti, 2018)

In construction area there are also some specific acts, such as *Act on certain requirements concerning asbestos removal work (864/2015)*. The overview on acts are presented in Table 1.13.

Table 1.13. Most important legal acts (developed by the authors)

Legal act	Description
Land use and Building act 132/1999	Most important act that regulate building
Health protection act (763/1994)	–
Environmental protection act (527/2014)	–
Occupational safety and health act (738/2002)	–
Act on certain requirements concerning asbestos removal work (864/2015),	–

The most important legal act directing construction policies is Land use and building act (132/1999). Other relevant acts are Health protection act (763/1994), Environmental protection act (527/2014) and Occupational safety and health act (738/2002).

1.3.3. Public Wooden Buildings

1.3.3.1. Definition of Public Building

In Finland there is no legally binding definition to term “public building”. The term “public space” is used in legislation, but neither that has no definition. Public space is defined in publication ”Kenelle kaupunkitila kuuluu? kaupunkien julkiset tilat oikeuksien verkostona” (Neuvonen 2017). According to Neuvonen (2017) Public space are defined to be spaces that are in everybody’s use. Also there are “semi-public places”. Big parts of semi-public places are in use of public administration or trade. It is possible to decline use of semi-public buildings. Based on this publication public building is a building that is open for everybody and owner and maintained by public sector.

1.3.3.2. Local wooden building traditions

In Finland the oldest founded timber logs are from 900 BC, but there are no buildings from that time. Oldest wooden building is from year 1441. 1500-decades wooden buildings were timber log buildings. Some of those were with chimneys and glass windows. In 1600-decade water powered sawmills were invented and sawing timber logs to lumber was possible. These lumbers was used first to roofs in buildings. On 1800-decade some timber log walls was covered outside with wooden sawed boards (Luukkonen 2017)

Later in 1930s there became a new building solution, a building with wooden frame and sawdust insulation. After World War II there was a need to build inexpensive wooden buildings. For that a famous Finnish architect Alvar Aalto was one of those who was behind of type drawing for standard one family house as called “Rintamamiestalo” (veteran’s hause). These buildings were with concrete basement, and walls and ceiling with wooden frame with sawdust insulation. These building were 1,5 floors high (Luukkonen 2017). This technique was in use to end of 1950s.

In 1960s wooden buildings were not so common as before. In wooden buildings, insulation material changed from sawdust to mineral wool. In 1970s there was quite common to build flat roof. Later flat roofs changed to sloped roofs because of moisture problems. The energy crisis in 1973 has a big effect to building solutions. The impact was big especially to thermal insulations and air tightness of building envelope. In 1980s plastic vapour barrier was under debate. It was thought to be a reason for mould problem and indoor air problems. In 1990s wooden single family houses were quite popular.

In 1900-decade wood has been quite popular material in buildings with roofs with long span dimension. Wooden roof trusses, glued laminated timber beams was used at example with single-slot or tree-pin peripheral.

2000-decade there is all kind of building from wood. Product that are widely used are glued laminated timber, LVL (laminated veneer lumber), all kind of timber (planer or not). Also CLT-product are now in market. This kind of solutions building construction book (Ilveskoski 2014, p.179-191).

1.3.3.3. Wooden construction market

Construction of Wooden buildings has grown in last years, but the share of wood construction in total construction has decreased. Share of wood construction in right now about 30 % (Pekka Pajakkala 2018). Main indicators of wooden construction market in Finland are shown at Table 1.14.

Wood as a frame material has a 29 % share in the market. Wood as a façade material has major role. In the last decade share has been 35-45 % in the market.

In different type of buildings, Wood has a major role in the single family houses. About 88% of all single family houses made in year 2017 was wooden frame buildings. In high-rice apartment buildings wood is as a frame only in 4.8% (Pekka Pajakkala 2018).

1.3.3.4. Technologies

In Finland organisation Finnish wood research Oy has done new standard solution system RunkoPES and HalliPES. PES means wood element systems. With that is possible to design wood building without knowing who will build that. These runkoPES and halliPES systems has a solutions from different kind of wooden material. At an example CLT (Cross laminated Timber), glued laminated timber, LVL (laminated veneer lumber) (Puuinfo 2013). HalliPES systems is a solution for halls with bigger span dimension. RunkoPES and HalliPES are base systems, which can be implemented with other solutions.

Also in Finland there are many different solutions from different companies. Thera are space elements solutions at an example.

Table 1.14. Main indicators of wooden construction market (developed by the authors)

Indicator	**Description**		
The percentage of the countries' area, that is covered by forest	**75%**		
Number of public wooden buildings (2018)	**n/a**		
Indicators	**2016**	**2017**	**2018**
Turnover of the wooden construction (€/year)	n/a	n/a	n/a
Number of companies at wooden construction sector	n/a	n/a	n/a
Number of employees at wooden construction sector	n/a	n/a	n/a
Wood export (tons/year) (Tulli 2019)	8.6 milj.m3	9.4 milj.m3	n/a
Three major export markets (Tulli 2019)		China 18%. Egypt 14%. Japan 11%	n/a
Wood import (tons/year)	0.6 milj. m3	0.7 milj. m3	n/a
Domestic price of wood (€/ton) (Luke 2019) *Specify according to the types of wood* *Lumber (sahateollisuus 2019)*	pine 53,3 €/m3 spruce 55,3 €/m3 birch 41,5 €/m3 lumber pine 183 €/m3 lumber spruce 188 €/m3	pine 55 €/m3 spruce 57,7 €/m3 birch 42,7 €/m3 lumber pine 175 €/m3 lumber spruce 193 €/m3	pine 60,5 €/m3 spruce 64,3 €/m3 birch 45,9 €/m3 lumber pine 195 €/m3 lumber spruce 200 €/m3

1.4. DENMARK

1.4.1. Macroeconomic Outlook

The Danish economy has embarked on a boom. More than ever before the workforce has set a record, and prosperity has never been greater. Growth is expected to lift employment by nearly 70,000 people during 2018 and 2019 (Finansministeriet, 2018).

Denmark is a small open economy, which is entirely dependent on the development of exports and thus the development abroad. It is crucial for the production in Denmark how the exports develop. This is entirely dependent on the growth of the world economy. General economic indicators of Denmark are shown at Table 1.15.

Table 1.15. General economic indicators of Denmark (developed by the authors)

Indicator	2014	2015	2016	2017	2018
Annual change in real GDP (seasonally and working-day adjusted, %)	1.6%	2.3%	2.4%	2.3%	1.2%
Nominal GDP per capita (EUR billion)	0.0000448	0.0000455	0.0000463	0.0000470	0.0000473
Annual average HICP inflation (%)	0.6%	0.5%	0.3%	1.1%	0.8%
Annual change in nominal export of goods (%)	2%	3.8%	1.1%	6.3%	3.1%
Annual change in nominal import of goods (%)	1.8%	3.1%	–3.2%	7.7%	6.0%
Average gross monthly wages and salaries (EUR)	6334€	6422€	4690€	6630€	–
Unemployment rate (%)	6.8%	6.3%	6.3%	5.9%	5.1%

Note: The tables are calculated on the basis of figures from statistikbanken.dk (Danmarks Statistisk, 2019)

The indicators related to the overview of the construction market are shown in the next subpart.

1.4.2. Construction Market

In the building and construction industry, in the last quarter of 2018, 0.9% less hours were worked than in the quarter before. Danish Construction sees the development as a prime sign that there is a slowdown on the labour market.

The construction companies choose so far to keep the employees they have, even if there is a little less to do. Therefore, in the fourth quarter of 2018, we saw a continued increase in employment in construction of 0.5%, although the number of hours worked went in the opposite direction.

It is clearly that 2018 was another really good year for the construction market. "We must enjoy it while it last, because much indicates that 2019 will be somewhat more turbulent, says chief economist Bo Sandberg, Dansk Byggeri" (Dansk Byggeri, 2019). Construction sector indicators in Denmark are shown at Table 1.16.

Table 1.16. Construction sector indicators in Denmark (developed by the authors)

Indicator	2016	2017	2018
Turnover of the construction sector (€/year) or Volume of construction works (€/year)[1]	6,699 million €	7,182 million €	7,600 million €
Volume of public buildings' construction (€/year)[2]	2.5 billion €	2.7 billion €	2.8 billion €
Share of construction sector output in GDP/GNP (%)[3]		No data found	No data found
Number of construction companies[4]	1213 companies	1260 companies	1346 companies
Number of employees in construction sector (thousands)[5]	161.700 pers.	166.500 pers	172.500 pers
Share of employees who work in construction sector (% of all employees)[6]	6.15 %	6.21 %	6.31 %
Construction export (€/year)[7]	9.8 billion € 1)	8.8 billion € 1)	No data found

Note: Data is calculated on the basis of figures from statistikbanken.dk, and: 1. (Danmarks Statistisk, 2019); 2. (Dansk byggeri, 2019); 3. (Trading Economics 2019); (Dansk byggeri, 2019);4. (Erhvervsstyrelsen, 2019); 5. (Dansk byggeri, 2019); 6. (Dansk byggeri, 2019); 7. (Dansk byggeri, 2019).

The most important legal acts in Denmark are shown at Table 1.17.

Table 1.17. Most important legal acts (developed by the authors)

Legal act	Description
Building Act (*Byggeloven*)	The Building Act formulates the general rules in the building area, and it regulates both the design of buildings and the exploitation of properties. The Building Act primarily regulates the construction, interior design and maintenance of buildings. The purpose of this is to ensure that buildings are constructed and furnished so that it offers satisfactory protection against fire, and secures safety and health. Source:https://www.retsinformation.dk/Forms/r0710.aspx?id=183662
Executive ordern on Building Regulations 2018 (BR18) (*Bygningsreglementet 2018*)	The Building Regulations specify the requirements of the Building Acts and contain the detailed requirements that all construction works must meet. The requirements of the Building Regulations must ensure that a construction is carried out and arranged, so that it is satisfactory in terms of fire, safety, health and energy consumption (only use phase related energy consumption – not embodied energy of building materials). Violation of the Building Regulations may result in a penalty in the form of a fine. source: http://bygningsreglementet.dk/
Planning Act (*Planloven*)	The Planning Act is the law on planning, and establishes the basic rules that public authorities shall follow when planning, including; • the protection of the country's nature and environment through prevention of pollution • to create and maintain valuable buildings • to involve the public in planning source: https://www.retsinformation.dk/forms/R0710.aspx?id=200614
SBi-Guidelines (*Statens Byggeforskningsinstitut anvisninger)*	SBi (*Statens Byggeforskningsinstitut*) Guidelines are building technical guidelines that explain how to build buildings according to the current laws and regulations. source: https://sbi.dk/
Construction Products Regulation (CPR)	Regulates CE-marking of building materials. The CE-marking is a statement that the product meets the requirements of the directives and standards. The CE-marking is thus not a quality mark. But the requirements of the legislation are based on environmental considerations and consumer safety and health. source: https://www.ds.dk/da/standardisering/ce-

	maerkning/introduktion
Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)	Regulates chemicals in building materials. REACH requires communication regarding to the information on chemicals among supply chains. It ensures that manufacturers, importers, and also their customers are aware of information about health and safety of the products supplied. source: https://mst.dk/kemi/kemikalier/regulering-og-regler/faktaark-om-kemikaliereglerne/reach/
Environmental Protection Act	The purpose of this Act is to contribute to safeguarding nature and environment, thus enabling a sustainable social development in respect for human conditions of life and for the conservation of flora and fauna. Regulates the handling of construction and demolition waste. source: https://www.retsinformation.dk/Forms/R0710.aspx?id=207970

Definition and information related to the wooden public buildings can be found in the next subpart.

1.4.3. Public Wooden Buildings

1.4.3.1. Definition of Public Building

The definition of “Public Buildings” includes buildings when they are for the greater part financed by the state, regional and local authorities and bodies governed by public law.

In addition, buildings:

a) with guarantees made by the public authorities are also considered public aid in this context.

b) that are established for the specific purpose of meeting needs in the public interest, and do not have an industrial or commercial character.

In Denmark, there are about half a million residences built as social housing.

Social housing estates are built at minimal expense and designed to keep the rental rate affordable for persons with limited means. What characterises social housing in Denmark is primarily that no one profits from the rent, and the estates are built by means of public funding. In return, the municipality that has financed the erection of the estate typically gets every third vacant home for its disposal.

1.4.3.2. Local wooden building traditions

During the late middle ages, a slow transition began from the traditional wooden buildings in towns and villages towards half-timbered properties.

In 1820, the forest only covered 3-4% of the country's area due to extensive farming and ship construction (Dansk Skovforening, 2018).

Around 1900, the use of load-bearing wooden constructions in dwellings with more than two floors was banned, which is primarily due to a number of extensive fires, and secondly, that at that time there was no suitable forest for timber. The result was that the development of wooden buildings slowly declined.

In the post war years, a number of places in the country used wood to quickly and cheaply reduce housing shortages. The designs, prefabricated elements and partly reused materials for these wooden buildings were primarily imported from Sweden and Finland (Storvang, 2005).

If one disregards cottage buildings in rural or semi-rural location, wooden buildings have until the turn of the millennium taken a modest place in the Danish construction sector. Of the 6,600 private single-family houses built in 1997, only approx. 5% were wooden buildings (Træ-Industri-Byg, nr. 8-1997).

1.4.3.3. Wooden construction market

According to Træinformation CEO Mikael Koch, wood still only has a small role in the construction market in Denmark. This is due to a mixture of prejudices and traditions. We are extremely good at making cement in Denmark and selling cement plants worldwide. After the Second World War, the Marshall Plan brought a lot of cement and steel for reconstruction. Wood, on the other hand, has gone a bit in oblivion, although in recent years it has become more visible in architecture.

Wood has been given a renaissance as decorative interior cladding, but we only use a very small volume compared to if we would make load-bearing structures in wood. This would really start to change something in the use of resources and in the sustainable agenda (Kjaergaard, K. B.).

Main indicators of wooden construction market in Denmark are shown at Table 1.17.

1.4.3.4. Technologies

Mikael Koch, CEO Træinformation, points out that we in Denmark lack builders who are willing to use wooden constructions on a larger scale, and that the Danish contractors therefor lack experience with the material. (Kjaergaard, K. B.)

“We have no CLT production in Denmark yet and although some architects have experimented on a smaller scale with the material, we lack the big breakthrough. Vandkunsten has used glulam and CLT in “Gentofte lethal” and is in the process of making a social housing construction in Lisbjerg near Aarhus, where wooden frame elements, CLT and concrete are included.” Says Mikael Koch.

Glulam is used in many different types of construction. Glulam has a long history of use in dwellings, schools, sport arena and industrial buildings but has become increasingly popular in other structures such as churches and bridges.

There are also an expanding industry of prefabricated wooden facade and roof elements, wooden frame element buildings and modular houses in Denmark.

Table 1.17. Main indicators of wooden construction market (developed by the authors)

Indicator	**Description**		
The percentage of the countries' area, that is covered by forest[1]	14.5% - (2017)		
Number of public wooden buildings (2018)[2]	**n/a**		
Indicators	**2016**	**2017**	**2018**
Turnover of the wooden construction (€/year)[3]	1.544 million € (11.577 million DKK.)	n/a	n/a
Number of companies at wooden construction sector[4]	509	n/a	n/a
Number of employees at wooden construction sector[5]	6.888	n/a	n/a
Wood export (tons/year)[6]	n/a	n/a	n/a
Three major export markets[7]	n/a	n/a	n/a
Wood import (tons/year)[8]	n/a	2,0 mil tons	n/a
Domestic price of wood (€/ton)[9]	n/a	n/a	n/a

Note: Data is calculated on the basis of: 1)(Skovforeningen, 2019); 2)It is possible to buy more detailed inventories. (Danmarks statistik 2019); 3) (Danmarks statistik 2019); 4) (Danmarks statistik 2019); 5) (Danmarks statistik 2019); 6) -; 7)-; 8)(Tmi, 2019); 9) -.

The information related to the technologies applied in wood public buildings in Denmark is described further.

1.5. UNITED KINGDOM

1.5.1. Macroeconomic Outlook

The United Kingdom has been a member of the EEC (later European Union) since 1973, however, in June 2016 a referendum about its continuation within the Union was narrowly one by the 'Leave' position. This outcome has been come to be known as 'Brexit'. A new relationship between the EU and the UK has yet to be agreed. This uncertainty has had a significant effect on the UK's economy, though the 2008 recession had a significant effect on the UK's economy as well.

The United Kingdom was significantly affected by the 2008 economic downturn. It was only until the quarter between July to September 2013 its economy recovered to pre-downturn size (Figure 1.8). However, some sectors, including manufacturing, have struggled to recover (Figure 1.9).

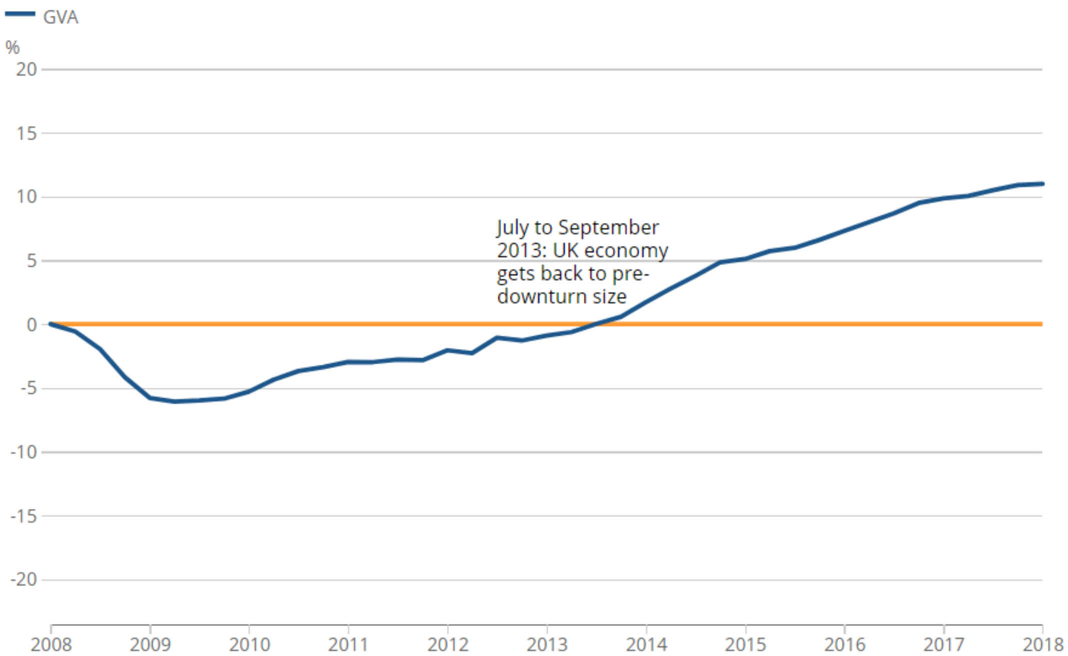


Fig. 1.8. Percentage change in gross value added (GVA) since Quarter 1 (Jan to Mar) 2008 (ONS, 2018)

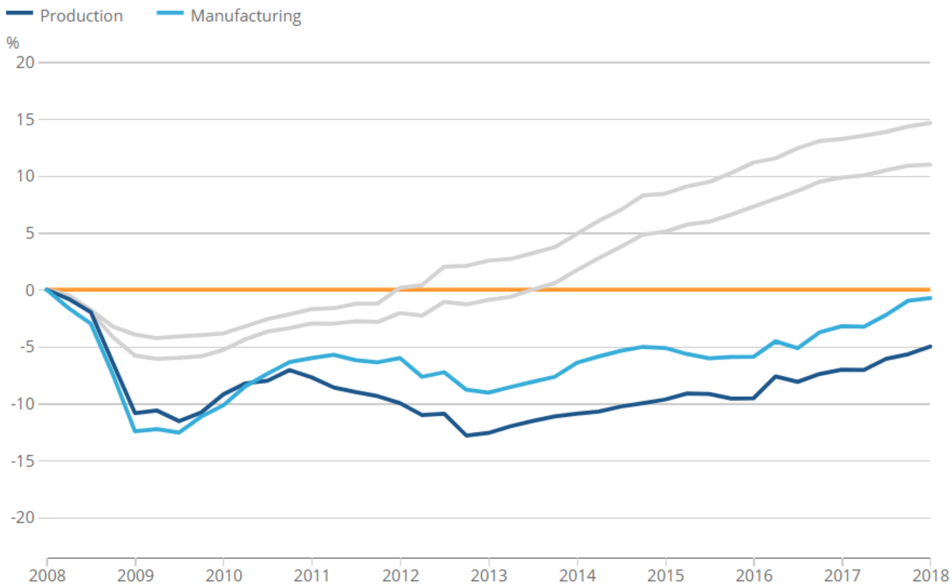


Fig. 1.9. Percentage change in gross value added (GVA) for Production and Manufacturing since Quarter 1 (Jan to Mar) 2008 (ONS, 2018)

The EU is the UK's biggest single trading partner: it accounted for 48% of goods exports from the UK and 39% of services exports in 2016. The effects to the economy due to the uncertainty surrounding Brexit vote have been quite hard to establish and are based on projections of where the economy would be had the 'Remain' position prevailed. An analysis by the Financial Times – based on IMF data (Figure 1.10) indicates that UK went from the strongest performing economy within the G7 to the worst performing following the EU referendum. The reasons for this are complex, but the uncertainty surrounding Brexit has certainly affected investor confidence.

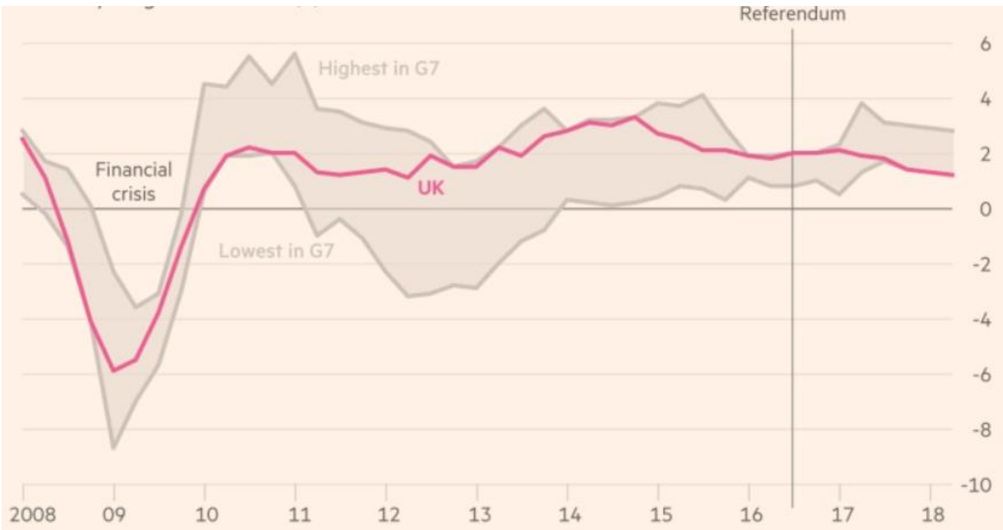


Fig. 1.10. Year-on-year growth in GDP (%) of the UK relative to other G7 economies (Giles, 2018)

1.5.2. Construction Market

The UK's construction industry has manifested a more complex process of recovery since the 2008 recession (Figure 1.11), but has mostly recovered. The housing market has been undergoing a more sustained growth (Figure 1.12), but the non-domestic market provides a more complex picture (Table 1), with little forecast growth in the non-housing sector with the exception of infrastructure. According to the Construction Skills Network (2019), the public non-housing sector is estimated to have fallen to its lowest level since 2007 in real terms, whilst there has was a 24% decline in new orders for office construction in 2017. The depressed growth in commercial and public non-housing has had a detrimental effect in the growth of the public buildings sector.

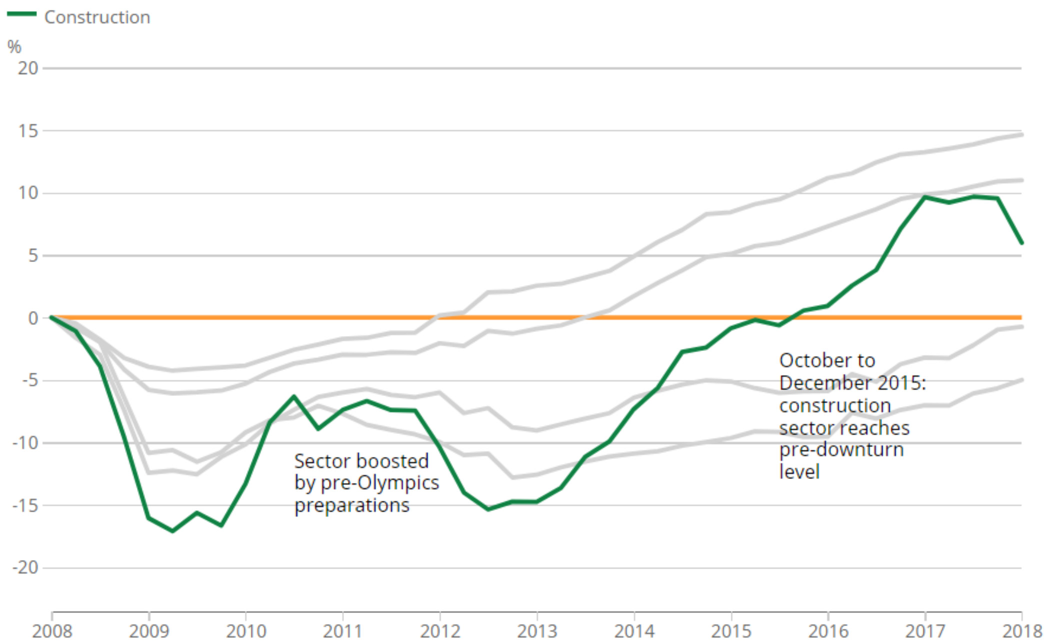


Fig. 1.11. Percentage change in gross value added (GVA) for Construction since Quarter 1 (Jan to Mar) 2008 (ONS, 2018)

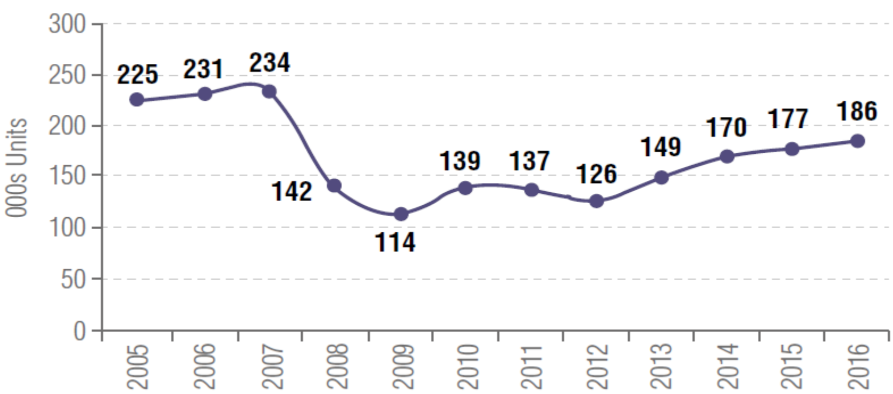


Fig. 1.12. UK Housing Starts 2005 - 2015 (Egan Consulting, 2016)

Table 1.18. UK Construction Industry Structure and Output - 2018

Sector	Output Share (2018 estimate)	Actual Output (in £ Million, 2016 prices)	Forecast 2019 (Annual % change, real terms)
Private Housing	22.3%	37,022	3%
Commercial	18.0%	29,843	-5%
Housing (Repair and Maintenance)	17.4%	28,851	3%
Non-housing (R&M)	17.3%	28,698	1%
Infrastructure	12.6%	20,957	9%
Public non-housing	5.8%	9,670	–1%
Public housing	3.7%	6,219	3%
Industrial	3.0%	4,994	0%

Source: Construction Skills Network (2019)

1.5.3. Public Wooden Buildings

1.5.3.1. Definition of Public Building

The current definition of a public building in the UK is that occupaied by a public authority and/or frequently visited by the public.

The term ‘frequently visited‘ can be broken down as a daily attendence during operational hours by persons for purposes unrelated to their residence, employment, education or training.

A private school for instance that does not offer community functions would therefore not be classed as a public building as it would be solely for education purposes. However, Schools are still under the building regulations for standards as a public building due to section 4 of Act 7.

The UK building regulations descibe a public building as a building that is or consists of; a theatre, public library, hall or other place of public resort, a school or other educational establishment not exempted from the operation of building regulations and a place of worship. A building not to be treated as a place of public use are those that contain a shop, warehouse or dwellings.

1.5.3.2. Local wooden building traditions

For millennia timber was the main construction material in the UK, frequently combined with stone or wattle-and-daub, according to availability of local materials. This tradition extended well into the 15th and 16th century and is typified by the Tudor period construction. Following the Great Fire of London, the use of timber in the external and party walls of houses was discouraged, this was coupled with the advancement of the industrial revolution that allowed for increased production of bricks due to the growth in coal production, and the transportation of bricks further across the country, first thanks to the canal network and then the rail network. Construction in general, and housing in particular, were significantly changed, though timber still remained at the heart of housing construction to this date. It should be noted that in the UK the distinction between a “masonry house” and a “timber frame house” needs to be qualified. A typical 21st century masonry house consists of concrete ground floor, timber floor joists with particle board decking at first floor and timber trussed rafters at roof level. Internal non-load bearing walls are typically made from timber “stud walls”. Internal load-bearing walls are made from blockwork (typically autoclaved concrete) and external walls consist of two leaves: an external clay brick wall and an internal blockwork wall (typically aerated concrete). A typical timber frame house will still be clad with a leaf of clay bricks in order to “look like” a masonry house. Therefore, the only substantial difference between a “masonry house” and a “timber frame house” in the UK is the composition of the load bearing walls and inner leaf of the external wall system.

In common with most European countries, the UK has a wealth of historical long-span timber structures. Westminster Hall in the Houses of Parliament is one such example. Since the advent of the industrial revolution, gradually long span members in timber were replaced by cast or wrought iron members, these would later be replaced by steel and reinforced concrete members. During the 20th century three or more storey buildings (housing and non-housing) were built using structural members made from steel, reinforced concrete and masonry. Timber rarely played a role in this segment until the early 21st century. During the experimental project called TF2000, it was demonstrated that six-storey mulit-occupancy housing was viable and safe. After this historical landmark and the growing presence of glulam in the UK market, timber was gradually incorporated into larger buildings, and therefore ultimately into public buildings including schools, supermarkets, and hotels.

1.5.3.3. Timber frame construction market

The information contained in this section is obtained from two primary sources commissioned by the Structural Timber Association – STA (https://www.structuraltimber.co.uk/). The first report titled “Annual survey of UK structural timber markets – Market report 2016” was prepared by Egan Consulting. The second report titled “Timber frame construction market report (UK) 2018” was prepared by MTW Research.

Both reports analyse the UK Timber Frame construction market, which encompasses a wide range of products within both the domestic and non-domestic sectors. MRW Research (2018) estimated that the industry would have started just under 61,000 units by the end of 2018, with a market estimated at just over £743 million (€ 836 million) at manufacturers’ selling prices by year end. The report estimates that the sector underwent a 4% growth during 2018. The industry is strongly dominated by 1-2 storey housing construction using open panel construction (refer to Figures 1.13–1.15). To year end December 2018, an estimated 58,000 timber frame homes will be started.

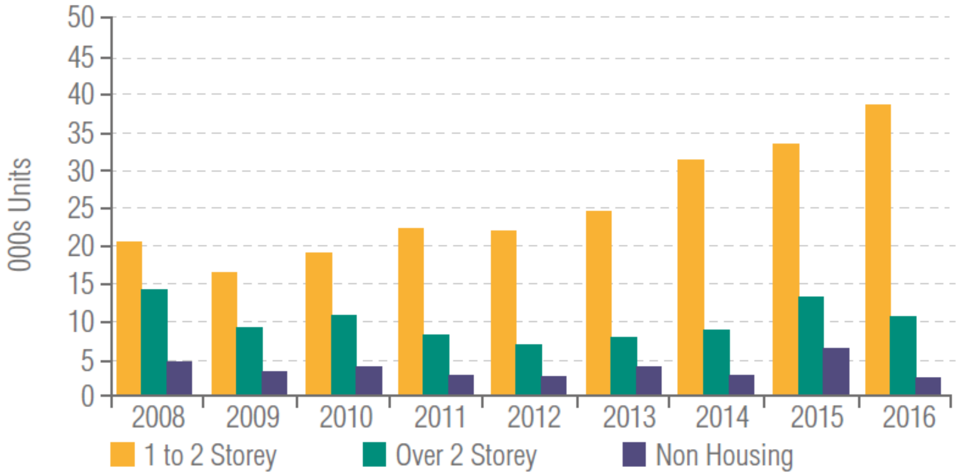


Fig. 1.13. All timber frame development by category 2005 – 2016 (Egan Consulting, 2016)

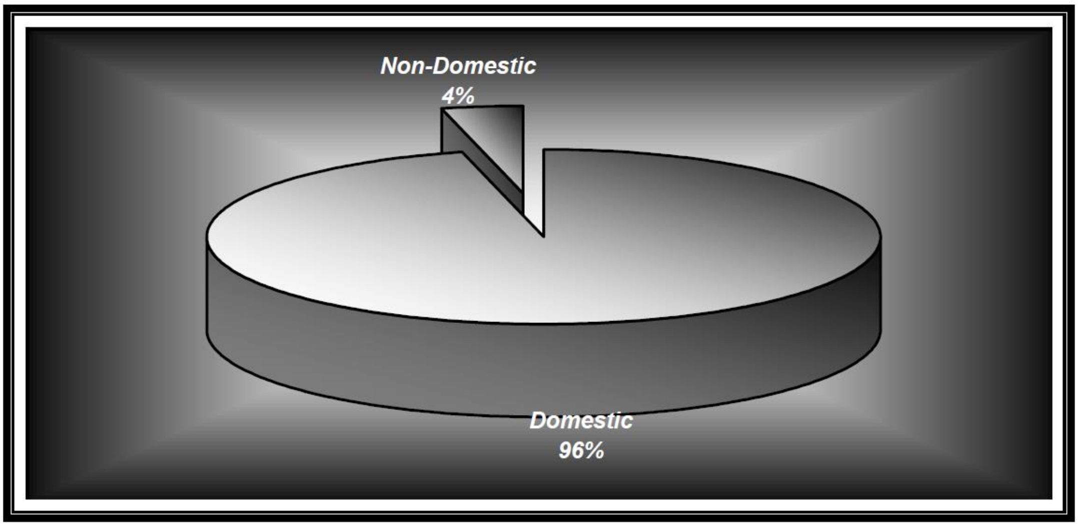


Fig. 1.14. Volume share by domestic & non-domestic timber frame construction 2018 (MTW Research, 2018)

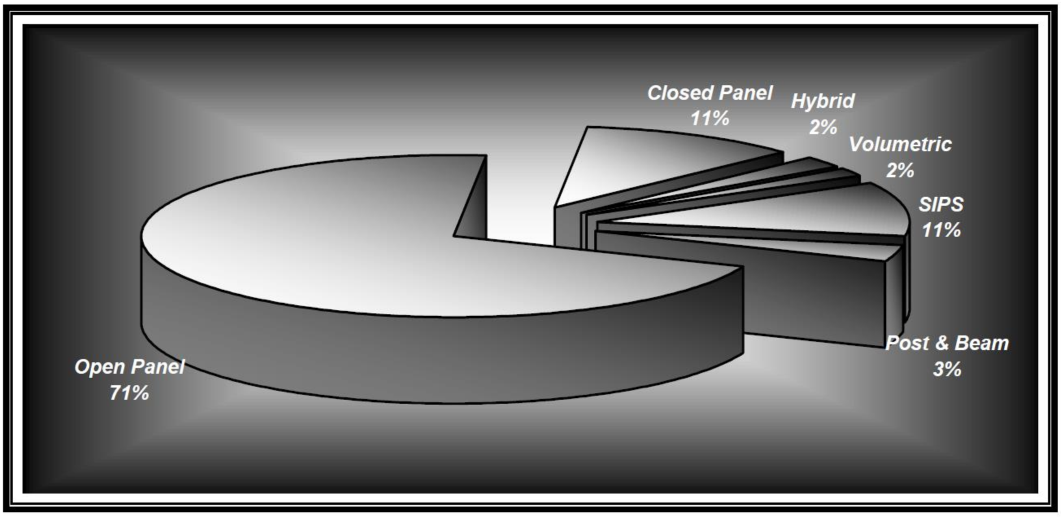


Fig. 1.15. Value share by timber frame product type in 2018 (MTW Research, 2018)

In terms of the UK housing market timber frame has been making significant inroads into the conventional masonry wall construction market (Figure 1.16). Nevertheless, the constant encroachment of timber frame housing into the masonry house market is an important trend.

It is interesting to note that in Scotland the majority of new build housing is made from timber (Figure 1.17), however, this should be seen in the context in which England has 83.1% of the housing market (Egan Consulting, 2016).

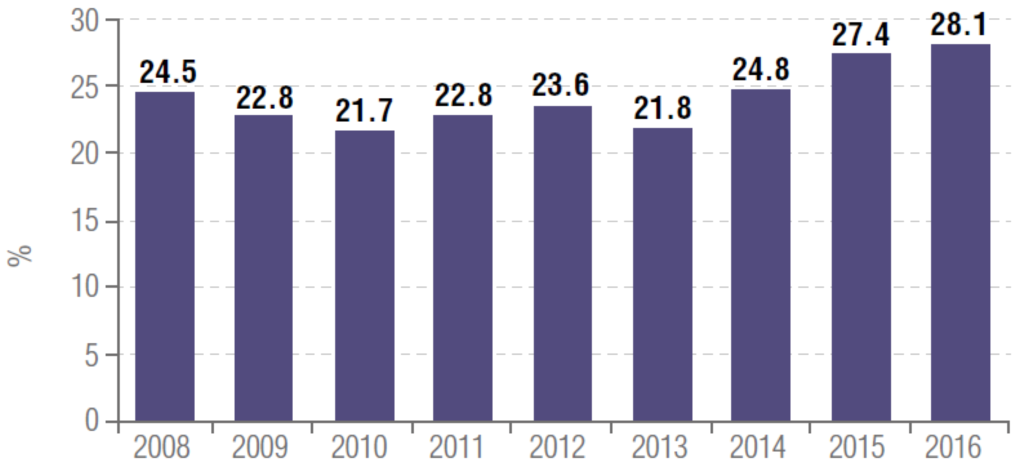


Fig. 1.16. Timber frame % market share of new housing 2008 – 2016 (Egan Consulting, 2016)

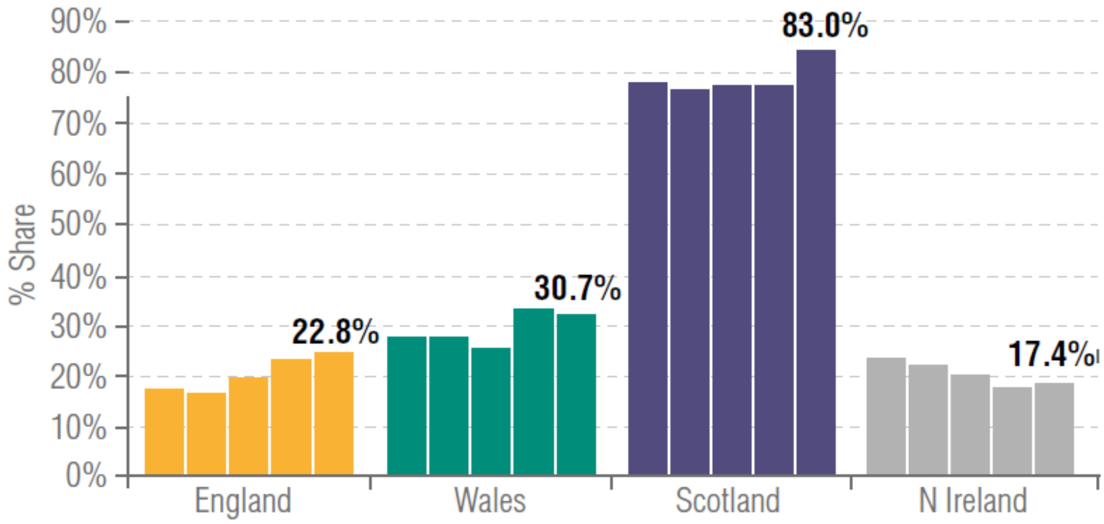


Fig. 1.17. Timber frame % share of each country's starts 2012 – 2016 (Egan Consulting, 2016)

The reasons for timber frame housing's advance are analysed by MTW Research and listed below:

- *"Fast Erection Time - e.g. houses weather tight in just a few days.*
- *Demand Fulfillment - TF industry well placed to satisfy additional demand.*
- *Higher Quality Finish - prefabrication in factory often enables higher quality control.*
- *Fire Risk Assessment - Given the qualities of the material, greater consideration and stringent guidelines are inherently considered during timber frame building construction. (e.g Site Safe)*[2]
- *Appearance - same appearance as traditional brick & block if required, or can be clad in a wide range of materials, enhancing the flexibility of design.*
- *More Exacting Specification - due to greater control over manufacturing in factory conditions.*
- *Minimum Acoustic Requirements - increasingly stringent regulations on sound transference are met by insulation on interior & exterior walls.*
- *Lower Cost - reduces material & on-site labour costs, lessening the need for highly skilled contractors on site.*
- *Health & Safety - generally perceived to offer enhanced on-site safety than traditional construction.*
- *Environmental Benefits - enhanced thermal efficiencies, ability to reach higher energy efficiencies 'building fabric', rather than adding renewable energy etc to boost rating.*

[2] Multi-storey timber buildings have received some bad press over the last decade and a half due to some large scale fires during construction. This has resulted in the adoption of strict safety procedures on site.

- *Lower 'Snagging' Rates - Sources suggest that timber frame building occupiers have less complaints than traditional construction.*
- *Less Waste - OSM (Off Site Manufacture) technology provides manufacturers better control over waste*
- *Lower Maintenance - Reduced moisture content of timber frame houses can mean in lower drying & shrinkage rates resulting in less 'making good' and redecoration than a traditional brick/block/mortar construction.*
- *Reduced CO2 Consumption - Typical reduction of 4 tonnes of CO2 per domestic timber frame dwelling constructed.*
- *Suitable for Most Developments - lightweight structure typically enables greater applications in brownfield developments.*
- *'Dry' Construction - no drying out time required for plaster etc., minimising cracks and reducing overall build time.*
- *Versatility of Finish - can be clad in almost any material to match the surrounding environment.*
- *Flexibility of Design - timber frame is more suitable for less traditional designs as cost can be controlled."* (MTW Research, 2018)

MTW Research (2018) also identifies that timber frame housing has been and is projected to remain cheaper than traditional masonry housing even with its associated additional costs in terms of fire and safety. In fact it is estimated to provide savings of the order of 10% compared to masonry construction (Figure 1.18).

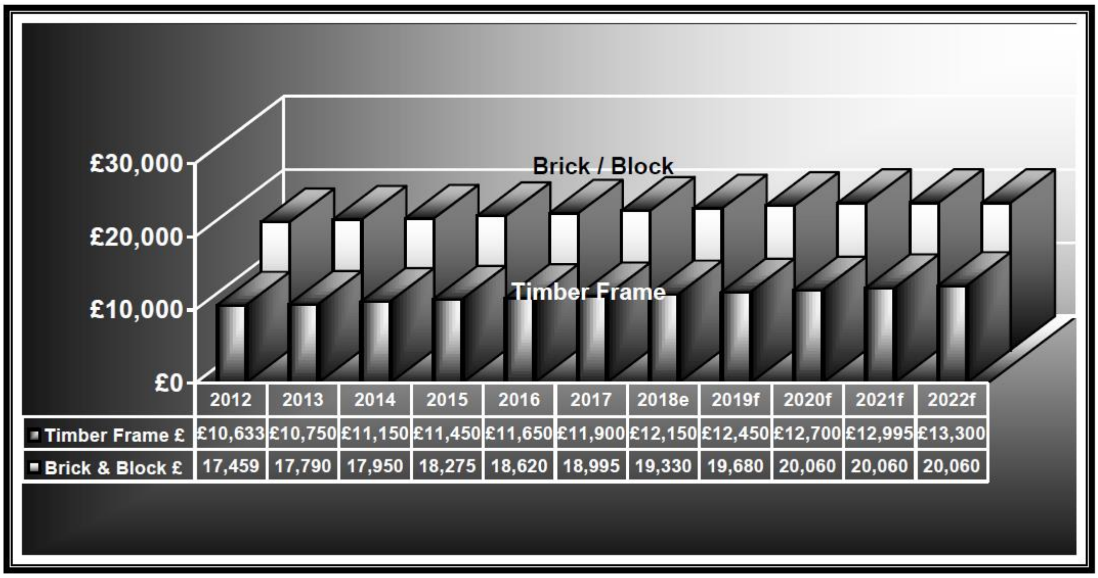
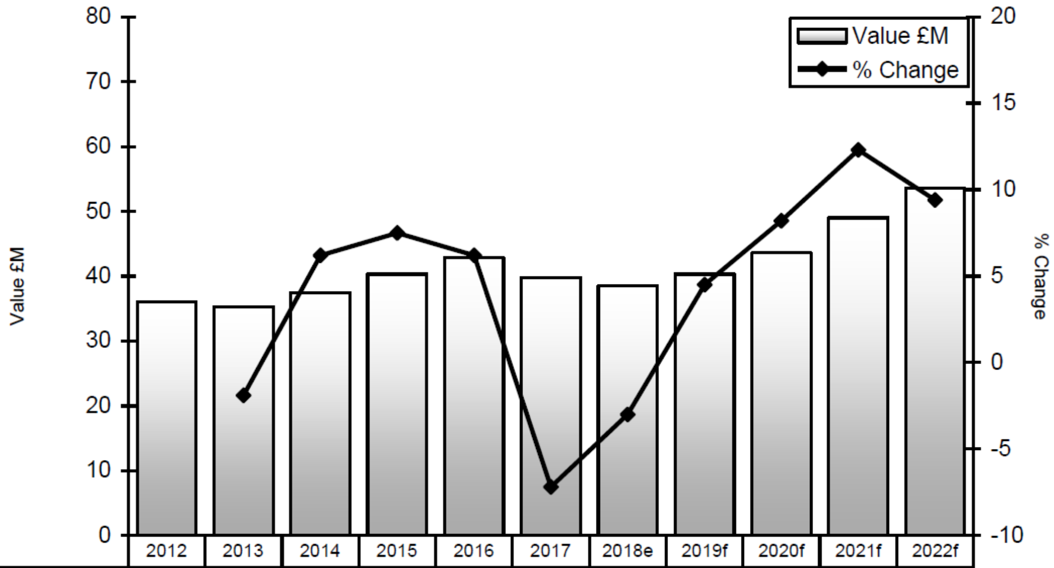


Fig. 1.18. Average build costs (in £) of timber frame vs traditional brick/block 2012-2022 (MTW Research, 2018)

According to Egan Consulting (2016) non-housing applications for the timber frame sector have fallen significantly from over 13% in 2015 to 5.7% for 2016. The MTW Research (2018) report estimates that the segment had fallen further to just 5% of the entire UK timber frame construction market in value terms, albeit still a sizeable £39 million and 2,600 units started. As outlined before, growth in larger scale capital investment in education, health, leisure and retail sectors has slowed down, which has dampened the opportunities for growth for the non-domestic timber frame sector. Nevertheless, it should be noted that against the quite weak performance of the non-housing sector in the UK, the fact that the timber frame sector has remained fairly stable is positive. MTW Research (2018) has a fairly optimistic outlook, as it states *“lower profitability levels in the non-domestic sector have also increased the popularity of MMC* [Modern Methods of Construction] *and OSM* [Off Site Manusfacturing] *solutions as well as reducing on-site labour costs, reducing health and safety risks and increasing build efficiencies“.* This optimism is reflected in its projected growth for the sector (Figure 1.19).



	2012	2013	2014	2015	2016	2017	2018e	2019f	2020f	2021f	2022f
Value £M	36	35.3	37.5	40.3	42.8	39.7	38.5	40.3	43.6	49	53.6
% Change		-1.9	6.2	7.5	6.2	-7.2	-3	4.5	8.2	12.3	9.4

Fig. 1.19. Non-domestic timber frame construction market UK 2012-2022 by value (MTW Research, 2018)

1.5.3.4. Technologies

Modern wooden construction technologies which are to be considered include:

- Glue laminated timber (Glulam).
- Cross laminated timber (CLT).
- Factory made pre-fabricated structural and infill panels.

2. NATIONAL TECHNICAL REQUIREMENTS FOR DESIGN AND CONSTRUCTION OF PUBLIC WOODEN BUILDINGS

2.1. LATVIA

National technical requirements for design and construction of public wooden buildings are shown in Table 2.1.

Table 2.1. National technical requirements for design and construction of public wooden buildings in Latvia (developed by the authors)

No.	Topic	Explanation of the requirements
1	Mechanical resistance and stability	1) Cabinet of Ministers Regulation No.331 Riga, 30 June 2015 (prot. No. 30, 50th) Regulations on the Latvian Construction Standard LBN 208-15 "Public Buildings". Accepted: 30.06.2015. Entry into force: 01.07.2015. Published: Latvijas Vēstnesis, 125 (5443), 30.06.2015. OP number: 2015 / 125.6 2) Cabinet of Ministers Regulation No.793 Riga, December 23, 2014 (prot. No. 72, §§ 2) Regulations on the Latvian Construction Standard LBN 206-14 "Design of wooden building structures" Accepted: 12.24.2014. Effective: 01.01.2015. Published: Latvijas Vēstnesis, 257 (5317), 30.12.2014. OP number: 2014 / 257.32 3) Adopted 19 August 2014 General Construction Regulations. Issued pursuant to Section 5, Paragraph one, Clause 1 of the Construction Law Adoption: 19.08.2014.Entry into force: 01.10.2014.Publication: "Latvijas Vēstnesis", 191 (5251), 26.09.2014. OP number: 2014/191.3
2	Fire safety requirements	1) Cabinet of Ministers regulations Nr. 238 Riga, 19 April 2016 (Section 10 of Law No 19) Fire safety Regulations Accepted: 19.04.2016. Entry into force: 01.09.2016. Published: Latvijas Vēstnesis, 78 (5650), 22.04.2016. OP number: 2016 / 78.5 2) Cabinet of Ministers Regulations No.333 Riga, June 30, 2015 (prot. No. 30, 53rd) Regulations on the Latvian Construction Standard LBN 201-15 "Fire safety of buildings" Accepted: 30.06.2015. Entry into force: 01.07.2015. Published: Latvijas Vēstnesis, 125 (5443), 30.06.2015. OP number: 2015 / 125.8
3	Energy efficiency requirements	1) Law On the Energy Performance of Buildings Adoption: 06.12.2012. Entry into force: 09.01.2013. Theme: Energetics. Publication: "Latvijas Vēstnesis", 201 (4804),

		21.12.2012. OP number: 2012/2 Republic of Latvia Cabinet Regulation No. 348 Adopted 25 June 2013 Methodology for Calculating the Energy Performance of a Building Adoption: 25.06.2013.Entry into force: 11.07.2013.Publication: "Latvijas Vēstnesis", 132 (4938), 10.07.2013. OP number: 2013/132.2 2) Republic of Latvia Cabinet Regulation No. 383 Adopted 9 July 2013 Regulations Regarding Energy Certification of Buildings Adoption: 09.07.2013.Entry into force: 19.07.2013.Publication: "Latvijas Vēstnesis", 138 (4944), 18.07.2013. OP number: 2013/138.3
4	Sustainable use of natural resources	1) Environmental Protection Law. Adoption: 02.11.2006.Entry into force: 29.11.2006. Theme: Environmental rights. Publication: "Latvijas Vēstnesis", 183 (3551), 15.11.2006., "Ziņotājs", 24, 28.12.2006. 2) Natural Resources Tax Law. Adoption: 15.12.2005.Entry into force: 01.01.2006. Theme: Taxes and duties, Environmental rights. Publication: "Latvijas Vēstnesis", 209 (3367), 29.12.2005., "Ziņotājs", 2, 26.01.2006.

2.2. LITHUANIA

Currently in Lithuania there are no separate technical requirements for design of wooden buildings. There are two technical requirements which regulate structural timber design:

1. Lithuanian local document issued by the Ministry of the Environment STR 2.05.07:2005 “Technical regulations for construction. Design of timber structures” (Lithuanian: Statybos techninis reglamentas. Medinių konstrukcijų projektavimas).

2. European document Eurocode 5 “Design of timber structures” with Lithuanian national annexes.

For national technical requirements for design and construction of public wooden buildings refer to Table 2.2.

Table 2.2. National technical requirements for design and construction of public wooden buildings (developed by the authors)

No.	Topic	Explanation of the requirements
1	Mechanical resistance and stability	These requirements are regulated by Technical regulations for construction and Eurocode 5. The limit states method is used to ensure mechanical resistance and stability of timber structures.
2	Fire safety requirements	There are general technical requirements for calculation of fire loading value for the buildings (Lithuanian technical regulation). The structural safety is ensured by structural calculations according to Eurocode 5 – Design of timber structures, Part 1-2: General rules – Structural fire design.
3	Energy efficiency requirements	This technical requirement is ensured by "STR 2.01.09:2012 Lithuanian technical regulation for construction. Energy efficiency of buildings. Energy efficiency certification". Currently, the minimum energy efficiency class for all new buildings is **A+**, which are being built in Lithuania.
4	Sustainable use of natural resources	According to the Lithuanian Forestry Act (1994), cutting areas are reforested within two years after final felling. All silvicultural measures are aimed at the establishment of productive and resistant stands and protection of biologic and genetic diversity in forests. While carrying out reforestation, planting is successfully combined with natural forest regeneration. About one-third of cutting areas are left for natural regeneration. Forestry and Forest Industry Development Programme has been approved by the Government in 1994 and updated in 1996. This programme is closely related to Lithuanian national sustainable development strategy. The Action Plan, which is annexed to the program, foresees the actions to be undertaken up to the year 2023. In this Programme and Action Plan the principles of sustainable forest management were introduced in a broader sense.
5	Other	-

The case of Finland is described further.

2.3. FINLAND

In Finland national technical requirements for design and construction of public wooden buildings are based to Land use and Building act (Land use and Building act 132/1999). Under this act there are decrees to complement this. In these decrees there might be guides to use Eurocodes. Technical requirements are present in different degrees as are in table 5.

There are some requirement for public buildings, but there are no special requirements for public wooden buildings. Only special thing considering wooden building is on energy efficiency requirements. Public buildings made by massive timber, requirements for energy efficiency number (E-value) can be 10 % bigger compared to other buildings with other materials.

For Public buildings there are special requirements for accessibility for children, elderly and people with disables. National technical requirements for design and construction of public wooden buildings are shown at Table 2.3. Public building should be suitable for everybody's use.

Table 2.3. National technical requirements for design and construction of public wooden buildings in Finland (developed by the authors)

No.	Topic	Explanation of the requirements
1	Mechanical resistance and stability	(Degree of the Ministry of the Environment on load bearing structures 477/2014)
2	Fire safety requirements	(Fire safety of building decree 848/2017)
3	Energy efficiency requirements	(Degree of the Ministry of the Environment on the Energy Performance of New Buildings 1010/2017) and (Government Degree on the numerical values of coefficients for form of energy used in building 788/2017)
4	Sustainable use of natural resources	No special requirements. Some are inside energy efficiency requirements.
5	Moisture performance of buildings	(Degree of the Ministry of the Environment on the moisture performance of building 782/2017)
6	Indoor air Climate and Ventilation	(Degree of the Ministry of the Environment on the indoor air climate and ventilation of new buildings 1009/2017)
7	Acoustic Environment of buildings	(Degree of the Ministry of the Environment on the Acoustics Environment of buildings 796/2017)
8	Accessibility of building	(Government degree on accessibility of building 241/2014)

There was a big change in legislation in beginning of year 2018. There became quite many new decrees to replace old building regulations. Probably biggest change came to moisture performance requirement. After a change we have to make moisture control statement of a construction project (Degree of the Ministry of the Environment on the moisture performance of building 782/2017, s.4). These new requirement bring flexibility but also difficulties to building physical design.

Fire safety requirements

Fire design in Finland is table based in fir class P1,P2 and P3. Fire classes are presented in Table 2.4.

Table 2.4. Fire classes according to Paloturvallinen puutalo 2017-guide

P0	Project-specific fire protection concept required, no specific building types
P1	Buildings that are not allowed in classes 2 and 3 NB: intended use-specific definition of fire load class.
P2	max. 8-story healthcare facility/ assisted living facility max. 4-story building with high occupation density
P3	max. 1-storey healthcare facility/assisted living facility max. 2-story building with high occupation density

Example of table-based fire design is presented in Figure 2.1. below.

P1	Building type	Primary use	Fire loading group	Sprinklers	Fire cell [m²]	N of storeys	Frame
	Daycare (day use), school	High occupation density	under 600 MJ/m²	-	≤ 2400	1...2	R 60
				mandatory	≤ 24000	1	R 60
				mandatory	≤ 12000	2	R 60
	Library	High occupation density	600 - 1200 MJ/m²	-	≤ 2400	1...2	R 90
				mandatory	≤ 24000	1	R 60
				mandatory	≤ 12000	2	R 60

P2	Building type	Primary use	Sprinklers	Gr.fl. area [m²]	Fire cell [m²]	Height [m]	N of storeys	N of people	Frame
	Daycare (day use), school	High occupation density	-	no restrictions	≤ 2400	≤ 9	1	no restrictions	R 30
			mandatory	no restrictions	≤ 9600	≤ 9	1	no restrictions	R 30
			-	no restrictions	≤ 2400	≤ 9	2	≤ 250	R 30
			mandatory	no restrictions	≤ 4800	≤ 9	2	≤ 500	R 30
			mandatory	≤ 12000	≤ 1200	≤ 14	3...4	≤ 1000	R 60
	Library	High occupation density	-	no restrictions	≤ 2400	≤ 9	1	no restrictions	R 30
			mandatory	no restrictions	≤ 9600	≤ 9	1	no restrictions	R 30
			-	no restrictions	≤ 2400	≤ 9	2	≤ 250	R 30
			mandatory	no restrictions	≤ 4800	≤ 9	2	≤ 500	R 30
			mandatory	≤ 12000	≤ 1200	≤ 14	3...4	≤ 1000	R 60
	Assisted living	Healthcare	-	no restrictions	≤ 800 overnight accn ≤ 1600 others	≤ 9	1	≤ 100	R 30
			mandatory	no restrictions	≤ 1200 overnight accn ≤ 2400 others	≤ 9	1	≤ 200	R 30
			-	no restrictions	≤ 800 overnight accn ≤ 1600 others	≤ 9	2	≤ 25	R 30
			mandatory	no restrictions	≤ 1200 overnight accn ≤ 2400 others	≤ 9	2	≤ 50	R 30
			mandatory	≤ 12000	≤ 800 overnight accn ≤ 1200 others	≤ 28	3...8	≤ 150	R 60

Fig. 2.1. General fire requirement by fire class, according to Paloturvallinen puutalo 2017-guide

P3	Building type	Primary use	Sprinklers	Gr.fl. area [m²]	Fire cell [m²]	Height [m]	N of storeys	N of people	Frame
	Daycare (day use), school	High occupation density	-	≤ 2400	≤ 400	≤ 9	1	≤ 500	-
			mandatory	≤ 4800	≤ 1200	≤ 9	1	≤ 1000	-
			-	≤ 1600	≤ 400	≤ 9	2	≤ 50	-
			mandatory	≤ 2400	≤ 600	≤ 9	2	≤ 50	-
	Library	High occupation density	-	≤ 2400	≤ 400	≤ 9	1	≤ 500	-
			mandatory	≤ 4800	≤ 1200	≤ 9	1	≤ 1000	-
			-	≤ 1600	≤ 400	≤ 9	2	≤ 50	-
			mandatory	≤ 2400	≤ 600	≤ 9	2	≤ 50	-
	Assisted living		-	≤ 2400	≤ 400 overnight accn ≤ 400 others	≤ 9	1	≤ 10	-
			mandatory	≤ 2400	≤ 600 overnight accn ≤ 1200 others	≤ 9	1	≤ 25	-

Fig. 2.1. General fire requirement by fire class, according to Paloturvallinen puutalo 2017-guide (continued)

2.4. DENMARK

National technical requirements are provided in Table 2.5.

Table 2.5. National technical requirements for design and construction of public wooden buildings in Denmark (developed by the authors)

No.	Topic	Explanation of the requirements
1	Mechanical resistance and stability	Executive ordern on Building Regulations 2018 (BR18) (*Bygningsreglementet, 2018*)
2	Fire safety requirements	Executive ordern on Building Regulations 2018 (BR18) (*Bygningsreglementet, 2018*)
3	Energy efficiency requirements	Executive ordern on Building Regulations 2018 (BR18) (*Bygningsreglementet, 2018*)
4	Sustainable use of natural resources	-
5	Other	-

Examples of national wooden public buildings are described in the next subpart.

2.5. UNITED KINGDOM

National technical requirements are as follows:

- BS EN 1995 (Eurocode 5) for structural design
- UK Building Regulations:
  Part A: Structure
  Part B: Fire safety
  Part C: Site preparation and resistance to contaminants and moisture
  Part D: Toxic substances
  Part E: Resistance to the passage of sound
  Part F: Ventilation
  Part G: Sanitation, hot water safety and water efficiency
  Part H: Drainage and waste disposal
  Part J: Heat producing appliances and Fuel storage system
  Part K: Protection from falling, collision and impact
  Part L: Conservation of fuel and power
  Part M: Access to and use of buildings
  Part N: Glazing - Safety in relation to impact, opening and cleaning
  Part P: Electrical safety
  Part Q: Security - Dwellings
  Part R: Physical infrastructure for high-speed electronic communication networks
  Regulation 7: Materials and workmanship

- National Structural Timber Specification (NSTS): a new document that guides the specification process of timber structures.

3. EXAMPLES OF WOODEN PUBLIC BUILDINGS

3.1. LATVIA

Construction of the roof of the open public skating ring in Jelgava can be found at Fig.3.1.

Fig. 3.1. Construction of the roof of the open public skating rink, Jelgava (Latvian Builder Association, 2018)

Address: Pasta sala 1, Jelgava
Customer: Jelgava City Municipality
Project author: Ineta Buka
Main contractor: Igate Būve Ltd., leading member of the supplier association IBK
Construction supervisor: "Jurēvičs un Partneri" Ltd. - Martins Birini
Designer - Constructor: Arturs Strižnovs
Main contractors: SIA "Rodentia", SIA "IKTK".

According to the awards in the *Annual Construction Award* by Latvia State Forests, the following information on wood public buildings is provided. Client center in Dundaga, Latvia is shown at Fig.3.2.

Fig. 3.2. Wooden building - 1st place for client center in Dundaga, Latvia, year 2016. Source: Latvia State Forests, 2017.

According to the Latvia State Forests (2017), ,,LVM North Kurzeme Client Center, a building in Dundaga, which is proud of the prudent use of natural resources, was recognized as the best wood construction in 2016. Building structures are made of exposed glued wood, insulation made of wood fiber, walls, ceilings and floors - made of wood materials. The heating and cooling of the building are provided by ground heat pumps, the building's ventilation system is built with air quality control and air heat recovery, glazed structures are created with extremely high thermal resistance.

The building project in 2016 in the competition "The Most Sustainable Building and the Project" received the 2nd place in the "Sustainable Project" nomination.

Gintars Dardets, project manager of the construction company "Selva būve", owner of LVM Client Center building in Dundaga, 2nd place in the competition "Construction Engineer of the Year in Latvia 2016" in the 2nd place in the nomination "Project Manager of the Year"".

Reconstruction of the engineering structure – 3rd place for the bridge of Menčupīte, Latvia (year 2016) is shown at Fig. 3.3.

Fig. 3.3. Menčupite bridge in the Kocenu district. Source: Latvia State Forests, 2017.

,,The 3rd place was awarded to the renovated Menčupite bridge in the Kocenu district in the competition "The Year of Construction of the Year in Latvia 2016" in the category "Reconstruction of Engineering Structures". This is Latvia's first prestressed glued wooden construction bridge for construction, which uses two natural building materials - stone and wood. In addition, the bridge-rebuilding preserves the heritage-historic broken limestone supports. The bridge span is made of tensile glued wooden structure, the carriageway structure - from a double board deck. What is also used in the rest of the bridge construction - glued wooden bridge rails, wooden barrier in the access area of the bridge, road signboards of plywood, road sign poles.

"Timber producers and producers of Latvia are able to provide quality work in a short time using wood. Any such object using renewable natural resources – wood – contributes to the development of forestry. "Using glued and bent wooden structures can be constructed more quickly and cheaply than with classical methods, while ensuring durability, durability and other essential requirements," says Andrei Domkins, Director of the Forest and Wood Products Research Institute (MeKA)"(Latvia State Forests, 2017).

Wood construction - 3rd place LVM Kalsnava arboretum cashier's house (2016) is represented at Fig. 3.4.

Fig. 3.4. LVM Kalsnava arboretum cashier's house. Source: Latvia State Forests, 2017).

,,The new building of the LVM Kalsnava arboretum car park and cash desks "Slodas" in Madona district, which is appreciated especially by the guests of the arboretum, has also received a great attention in the competition. At the beginning of the summer, thousands of people arrive at the arboretum on the traditional Peonies Festival, which will take place on June 18th. Every year, celebratory guests have the opportunity to watch and enjoy the glamorous blooming peonies, buy them as newstates at the marketers, and take part in the auction, trying to get rare and exotic vegetable plants" (Latvia State Forests, 2017).

3.2. LITHUANIA

Football sports hall in Marijampolė city, Lithuania

The football sports hall is Marijampolė city was built in 2009. The completed building is shown in Fig. 3.5.

Fig. 3.5. The football sports hall in Marijampolė city, in Lithuania (SDV, 2018)

This building has the longest clear span in between supports, made of timber structures, in Lithuania. The clear span in between supports is about 84 m. The structural system is three hinged arch, as shown in Fig. 3.6. The load bearing element is made of glued laminated timber (Glulam), as shown in Fig. 3.6. The construction process is shown in Fig. 3.7.

Fig. 3.6. The load bearing structure – three pinned glulam arch (SDV, 2018)

Fig. 3.7. The construction process

One more example is described further.

Catholic Church in Dubingiai city, Lithuania

Catholic Church was built in 2012 in Dubingiai city, in Lithuania. The final view of the building is shown in Fig. 3.8.

Fig. 3.8. Catholic Church in Dubingiai, Lithuania (WeloveLithuania, 2018)

The load bearing structure of this church is also glued laminated timber. All elements are curved axis, varying cross-section with an aim to reduce the cross section of the element on top of the structure. The view of the whole glulam load bearing elements is shown in Fig. 3.9.

Fig. 3.9. The load bearing glulam structure of the church in Dubingiai

For stability of separate arches, the horizontal and vertical bracing system elements are included. Glulam frame elements are connected to the foundation using welded steel details which are anchored to the foundation. The distance between foundation and glulam element is 30 cm.

Horse riding building near Utena city, Lithuania

The horse riding building is built in 2013, near Utena city, in Lithuania. This is the largest dome building built in Lithuania using solid timber frame structure. The final view of the building is shown in Fig. 3.10.

Fig. 3.10. The horse riding building near Utena city, in Lithuania (INFOMOLĖTAI, 2018)

The load bearing structure is shown in Fig. 3.11.

Fig. 3.11. The load bearing solid timber structure of the horse riding building (Makalius, 2018)

This dome type building is built using only solid timber elements which are connected together using punched-in metal plates. The clear span in between supports (diameter of the solid timber roof structure) is 35 m.

3.3. FINLAND

Examples of the public buildings are provided below.

Fig. 3.12. Tuupala timber school

Location: Kuhmo

Wooden school building

First CLT massivewood element build school in Finland

Ready: 2018

Fig. 3.13. An apartment building block in Latokartano, Viikki

Location: Viikki
5 wooden apartment building wooden complex

3-4 floors high buildings from premade elements

Ready: 2018

Fig. 3.14. The Pudasjärvi Log campus (school building)

Location: Pudasjärvi

Log made schoolbuilding

Largest log building in the world (2015)

Ready: 2015

3.4. DENMARK

Examples are provided in Tables 3.1 and 3.2.

Table 3.1. Ny hovedindgang til Den Gamle By

Photo: Cubo Photo: Cubo

Name	Ny hovedindgang til Den Gamle By
Description	The main entrance to Den Gamle By is a large main entrance foyer which covers many people at the same time under the large roof construction that forms an umbrella. Building costs: Non data DKK/m^2 (before tax)
Architect & Client	Cubo Den Gamle by
Location	Aarhus, Denmark
Competition won Year of construction	2018 2020-2021
Building system	The building will be built up in a column frame of glulam and steel (hybrids) The roof will be steel and wood (hybrids)
Number of stories	3 and access to basement
Floor area	1000 m^2

Table 3.2. Sønder Otting school

Name	Sønder Otting school
Description	The school will be built in wood and will be one of the first wooden schools in Denmark, which, together with several other initiatives, will make the school a very low carbon footprint. Expected building costs: 14.000 DKK/m2 (before tax)
Architect & Client	Arkitema Architects Haderslev kommune
Location	Sønder Otting, Denmark
Competition won Year of construction	 2019-2020
Building system	The bearing systems will be built up in a column frame of glulam. The roof is plan to be made by roof cassettes of wood.
Number of stories	2
Floor area	5,800m^2

3.5. UNITED KINGDOM

Rievaulx Abbey Visitor Centre and Museum, Rievaulx, Helmsley, Yorkshire. 2017

The visitor centre, designed by Simpson and Brown (Fig. 1) stands adjacent to the ruins of Rievaulx Abbey, one of the great medieval abbeys of England. Designed for English Heritage, using timber to create its principal space, a light-filled arcaded hall of tall glulam arches, the building reflects the characteristic columns and pointed arches of the Gothic ruins. The visitor centre hall gives visitors a taste of the Abbey's history with exhibition area, contains a seating area to the café and offers a view through the glazed eastern gable wall to the abbey ruins beyond.

The glulam arches, consist of spruce glulam columns and rafters connected by epoxy bonded-in rods and concealed steel flitch plates. They are connected together at the eaves by pairs of glulam eaves beams; the spaces between these beams act as conduits for concealed lighting and services. The arches are structurally connected at roof level by a deck of 42mm thick cross-laminated timber (CLT) panels supporting an insulated zinc sheet roof covering. A series of 42mm thick CLT panels extend at the eaves to create a deep tapered overhang to the roof; they are fixed back to the main structure with profiled steel T-brackets.

Although consistent in pitch and height, the glulam arches (Fig, 2) vary in size as they run from the west end of the building to the east. At the west end gable wall the end arches, reducing in size to 64 x 240mm, create a 1.92 metre wide narrow glazed box, a showcase for the ancient carved stone urn. The central arches of the main hall are 80 x 400mm in size and span 4.378 metres; as they near the east end gable they are set closer and splay at ever increasing angles.

The glulam arches are stained with a translucent white coating (Fig. 3), chosen to unify the timber and the adjacent internal finishes while still allowing the natural appearance of the frame timbers to be appreciated. The CLT roof panels are exposed where possible and stained to match the glulam structure.

Fig. 3.15. Rievaulx Abbey Visitor Centre and Museum: a) Exterior view of the visitor centre (RIBA, 2017); b) Interior view of café (RIBA, 2017); c) white glulam arches (RIBA, 2017); d) Splayed glulam arches project beyond the glazed east gable (TRADA, 2019)

Sunderland Aquatic Centre, Sunderland, Tyne and Wear. 2008

Designed by Red Box Architecture, the £19.8 million Aquatic Centre, the largest in the North East, is the first phase of a development of sport and educational facilities for Sunderland.

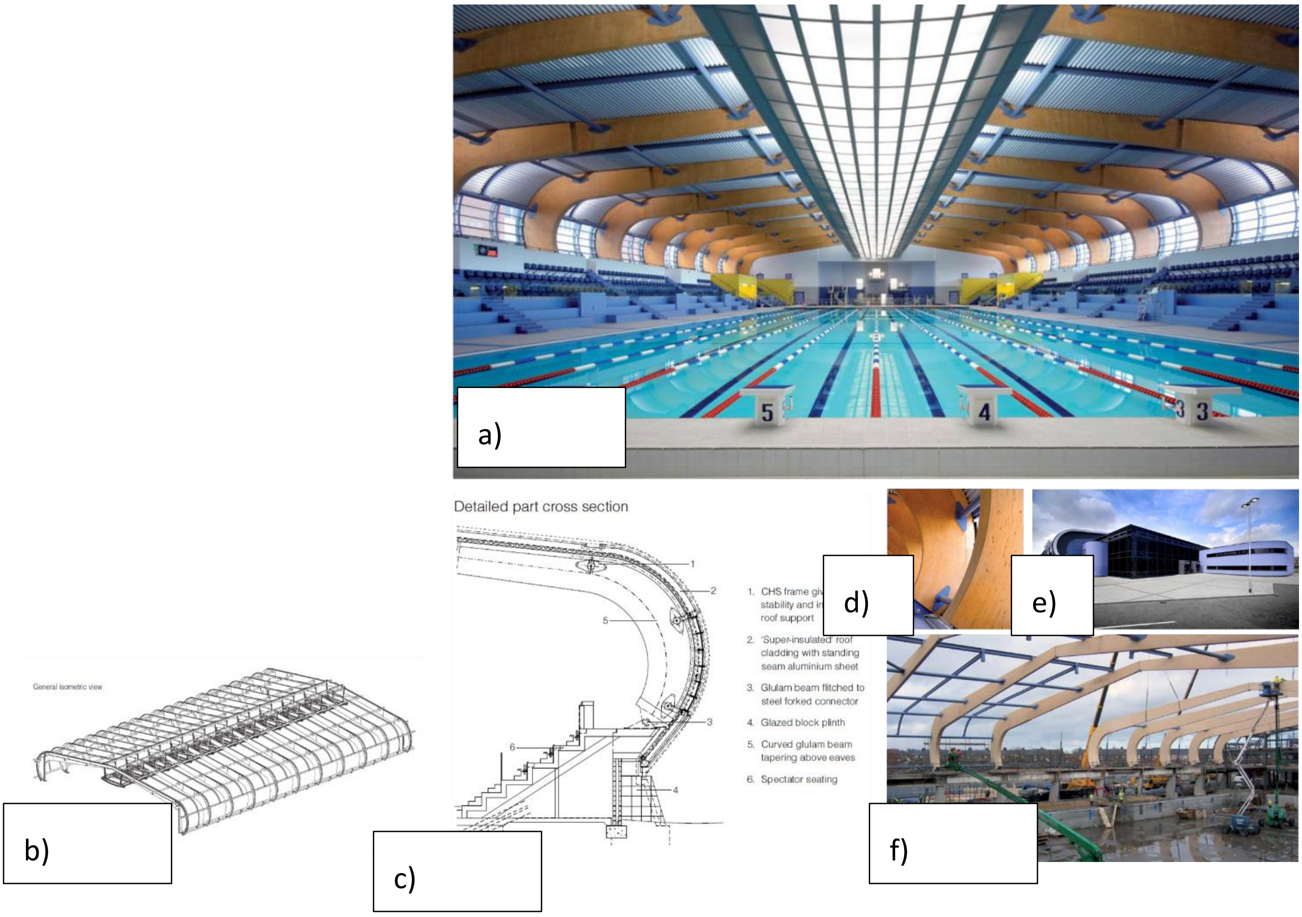


Fig. 3.16. Sunderland Aquatic Centre: a) Interior of Aquatics Centre (TRADA, 2019); b) Detailed part cross section (TRADA 2019); c) Each Glulam Beam Is fixed to A Steel Plate (TRADA, 2019); d) Entrance to Aquatics Centre (E-Architect, 2008); e) General isometric view (TRADA, 2019); f) The glulam beams are craned into position (TRADA, 2019)

The building houses a 50 metre competition pool, 25m wide with 10 lanes, a moveable floor and a moveable boom; a 25 m multi-purpose diving tank with moveable floor and a variety of double-width diving boards; seating for 500 spectators and a wide variety of changing facilities to meet the needs of disabled and other groups with specific needs.

The structure had to span 50 m to cross the 25m width of the swimming pool together with the spectator and competitor seating on either side. A standard 3 pin connection was unable to be used due to the shape of the truss which was required to take into consideration a number of factors including spectator sight lines. According to the structural engineer Arup, “The final roof structure consisted of straight beams which inclined from apex to eaves and then curved around the eaves to the base supports, which lie at the back of the spectator seating. This meant that the frame started to work more as a portal frame with large bending moments around the eaves. The large forces at the eaves were the key determinant for the size of the frames and resulted in a glulam section at this point of 2m deep by 440mm wide.” (TRADA, 2019)

City Of London Freemen's School Swimming Pool, Ashtead, Surrey. 2017.

The swimming pool designed by Hawkins/Brown utilises timber to create an elegant cathedral-like structure for a swimming pool, a structure that is corrosion-resistant, resilient and carbon-neutral. The 25 metre competition pool building stands within a Green Belt on the campus of City of London Freemen’s School, a co-educational private school for approximately 800 pupils. In response to its sensitive location, the architect created an exterior with minimal impact, a simple form with dark copper-coloured standing seam zinc panels to compliment the historic features of the school’s Grade II* listed Main House.

‘The glulam portal frames form a continuous section profile for the stanchions and rafters of 1020mm deep by 220mm wide. The depth of these sections was selected to translate to the natural fabrication size of the timbers, which are formed of a series of 41 mm thick laminas bonded together to form the desired depth. During the early design phase, the portal frames were set further apart meaning a greater span was required and a less readily available grade of timber available. As a result, it was suggested that the overall building size be reduced; however the architects considered that if the frames, at the same sizes, were set closer together, they would create a stronger visual presence. This added benefit of overall cost savings, as it allowed a lower grade of timber to be used and meant restraint struts and steel cross bracing were omitted. The timber frames are braced by the CLT skin which wraps around the building roof and walls, acting as a rigid diaphragm, tying the frames together in both directions. Overall stability is provided by moment connections between the stanchions and rafters and at the ridge (BM TRADA 2019).

Fig. 3.16. Swimming Pool (Hawkins Brown, 2018)

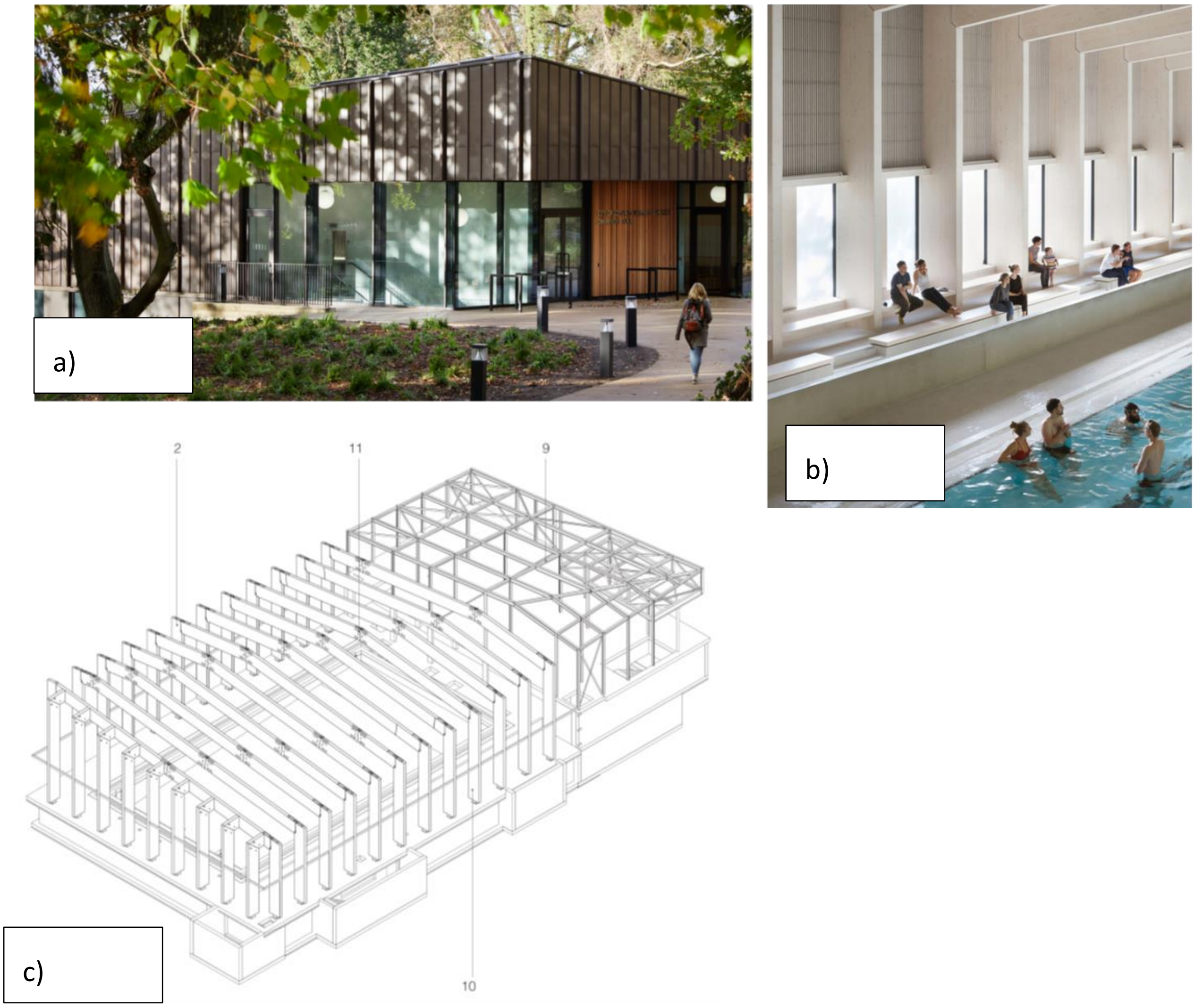


Fig. 3.16. City Of London Freemen's School Swimming Pool: a) Building is clad with dark copper-coloured zinc panels. (Hawkins Brown, 2018); b) The white-stained glulam frames and CLT panels create a light and spacious pool; c) Isometric view of pool structure (Hawkins Brown, 2018)

Anglesey Abbey Visitor Centre, Lode, Cambridgeshire. 2008.

Anglesey Abbey is known for its gardens with superb vistas and an impressive collection of plants. Visitor numbers to this National Trust property have risen to over 180,000 per year and in recent years this has placed a strain on the visitor facilities which led to the design of the new visitor centre designed by Cowper Griffith Architects.

There were many design challenges to consider simultaneously in terms of the glazing / wall details, such as:

- General architectural appearance. An important factor in achieving a well formed design of the glazing and shading. The client wanted visitors to enjoy garden views from the centre but did not want others in the garden to be distracted by the building
- Light and energy performance.
- Long term appearance durability and maintenance.

Louvred screens providing ‘filtering layers’ were used in various locations. The first is a wooden louvred system constructed in the gable ends of the east and west facing elevations, which was used in combination with other solid and glazed elements in the gable. The second is an external sliding louvred wooden panel arrangement installed in front of three aluminium sliding door sets on the south elevation.

The Design detail chosen was a Gable steel framework. The slender and virtually non-visible steel framework, into which the timber louvred panels are seated, allows the whole system to be supported back to the four aluminium structural upright members using only six fixings. The steel framework simply comprised mm thick ‘L’ and ‘T’ sections, with a grey powder coat finish matching the aluminium to prevent staining of the timber from contact with the steel. To connect it to the aluminium members, simple cleats with bolt holes were welded to the back with similar partner members, secured via cut-outs in the cover caps, to the vertical aluminium structural supports. The framework can be removed reasonably easily if necessary, for example if replacement glass units are required (TRADA, 2019).

Fig. 3.17. Entrance towards the Visitors Centre from Car Park (Detail, 2009)

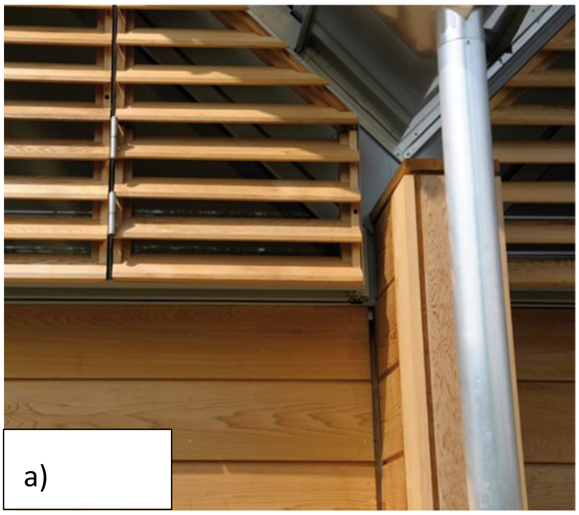


Fig. 3.18. Anglesey Abbey Visitor Centre: a) Close up of hinged louvre detail on elevation (TRADA, 2019); b) View inside restaurant (Detail, 2009)

The Savill Building, Windsor Great Park, Windsor, Royal Berkshire. 2006.

The Savill Building, designed by Glenn Howells Architects was a new visitor centre set in the historic Windsor Great Park 14,000 acre forest and woodland park to the south of Windsor.

The latest technology and engineering expertise are combined with traditional craft skills to create the grid shell roof, a flowing organic shape that mirrors the forest skyline. The three-domed double curved structure, 90 x 25 metres on plan, is the largest grid shell roof in the UK.

A grid shell structure is created on the naturally strong structure of a seashell, with the structure concentrated into strips. It is a light, efficient and immensely strong structure and can be made of timber, steel or concrete. Concrete grid shells are cast in-situ, metal grid shell components have to be prefabricated, repetition of structural elements is limited and the result in both cases can be complex and expensive. During construction these timber components are flexible, allowing the structure to be laid flat then raised or lowered before being locked into the final curved form desired.

The Savill grid shell is consists of 80 x 50 mm larch laths in a regular 1 metre grid. The two bottom rows of laths are bolted together, with 50 or 75 mm deep shear blocks separating the top rows of laths, screwed together with stainless steel screws; there are no direct fixings between the upper and lower slats. The entire roof structure is clad with two layers of 12 mm plywood which supports the roof cladding, provides essential stiffness to the structure and acts as the visible internal finish to the ceiling. The plywood supports an insulated standing-seam aluminium roof, to which was fitted a rainscreen cladding of oak boards. Oak bearers were fixed to the aluminium using modified seam clips, onto which 100 x 20 mm oak boards were fixed at 135 mm centres.

Green Oak Carpentry's Site Manager, Steve Corbett, said "there were genuinely no real problems with the construction", which he attributed to the architect commissioning Burro Happold and Green Oak Carpentry early in the design phase so that procurement, engineering and construction issues were addressed as part of the design from the start. Coordinating many skilled craftsmen in a simultaneous fashion required the creation of an on-site training academy where everybody involved was trained to carry out specific tasks.

Fig. 3.19. Innovative visitors Centre (GHA 2019)

Fig. 3.20. a) Grid shell Structure (Bolger, 2016); b) Inside the Visitors Centre (GHA, 2019)

3.6. Examples of wooden public buildings worldwide

Smart Material Houses. WOODCUBE. International Building Exhibition BTA Hamburg

Specification:
Beginning of construction: November 2012
Completion: May 2013
Gross floor area: 1,479 square metres
Storeys: 5
Residential units: 8
Sizes of residential units:
90 – 190 square metres
Energy standard: efficiency house 40
Energy supply: photovoltaic, living area ventilation with heat recovery
PRIZES AND AWARDS: AIV Building of the year 2013
Prize award 'BDA Hamburg Architektur Preis' 2014, honourable mention.

WOODCUBE house can be found at Fig. 3.21.

Fig. 3.21. *Smart Material Houses. WOODCUBE*. Source: *International Building Exhibition IBA Hamburg (2018)*

„**The Use of Wood throughout the Building.** WOODCUBE, a five-storey apartment building, consists almost entirely of wood; neither glue nor any type of protective coating has been used. Slab-like balconies jut out of the untreated, naturally ageing wooden façade, and are a marked feature of the building's design. Inside, wood forms just as conspicuous a feature of the building as it does on the outside: ceilings, outer walls, and floors all have wooden surfaces. One utterly novel feature is the bare solid wood casing around the massive staircase, which eschews layering or adhesives. In addition to forming the structure of the building, the 32 centimetre-thick solid wood walls also provide complete insulation" (International Building Exhibition IBA Hamburg, 2018). **The Energy Benefits of Using a Renewable Natural Resource.** The objective behind the WOODCUBE was to build a house that would emit no greenhouse gases whatsoever throughout its life cycle and be totally bio-recyclable. All building materials in the house were examined for their CO2 potential and their safety in building biology terms. The WOODCUBE is built to KfW 40 energy efficiency standards and dispenses as far as possible with the use of non-renewable raw materials. Power and heating are derived from renewable sources and are CO_2 neutral. In terms of building and running the WOODCUBE, its zero-sum CO_2 balance reveals the potential for solid wood construction in the field of climate-neutral building and of meeting energy requirements from renewables in the inner-city environment. Thanks to its monolithic, natural construction style, the Woodcube's consumption figures are comparable with those of a passive house (18 kWh/m²a heating requirement). Looking at its entire life-cycle, however, the materials used give it considerably better values so that it is more sustainable than any traditionally built passive house. The house therefore makes an important contribution to climate protection that can, at present, hardly be bettered by any other style of building´´ (International Building Exhibition IBA Hamburg, 2018).

Thompson Exhibition Building / Centerbrook Architects and Planners

Fig. 3.22. Thompson Exhibition Building / Centerbrook Architects and Planners.

Source: https://www.archdaily.com/802115/thompson-exhibition-building-centerbrook-architects-and-planners/585c3a6ce58ece38950001b0-thompson-exhibition-building-centerbrook-architects-and-planners-photo

Architects: Centerbrook Architects and Planners
Location: Stonington, CT, United States
Architect in Charge: Chad Floyd, FAIA; Charles G. Mueller, AIA, ALA
Area: 21.681 ft2
Project Year: 2016
Photographs: Jeff Goldberg / ESTO Photographics, Derek Hayn
Source: https://www.archdaily.com/802115/thompson-exhibition-building-centerbrook-architects-and-planners

Mjøstårnet tower in Brumanddal, Norway

The Mjøstårnet tower in Brumanddal is the tallest high rise building in the world which is constructed only using timber based engineering products. The total height of the building is 84 meters, 18 floors. This building is being built now; the date of completion is 2019.

The net area is 11300 m^2, and there will be offices, hotel, apartments, restaurant and a roof terrace. Next to the tower there will be a large indoor swimming arena. The exterior view of the building is shown in Fig. 3.23.

“Mjøstårnet” is Norwegian and means “The tower of lake Mjøsa”. The initiative to build Mjøstårnet comes from Arthur Buchardt. His vision is that the project will be a symbol of the green shift, and a proof that tall buildings can be built using local resources, local suppliers and sustainable wooden materials (Abrahamsen, 2017).

Fig. 3.23. Mjøstårnet tower (The Skyscraper Center, 2018)

The view of load bearing timber structure during construction process is shown in Fig. 3.24.

Fig. 3.24. The load bearing glulam and CLT structure Mjøstårnet tower (Byggeindustrien, 2018)

The load bearing structure of the building is glued laminated timber for columns, beams, bracing elements and cross laminated timber panels are used for elevator and staircase shafts.

Öster arena in Vaxjo city, Sweden

The football arena was built in 2012, in Vaxjo city, in Sweden. Varying cross section glued laminated timber beams were used for the rood structure, as shown in Fig. 2.12. The length of glulam beam is 22 meters which is supported on steel ties from top of the beam (see Fig. 4.5.).

The service class of the glued laminated timber elements is III according to Eurocode 5, EN 1995-1-1. The structure is in the open air where ambient humidity is more than 85 %.

a)

Fig. 3.25. The view of Öster arena in Vaxjo city, Sweden (StadiumDB, 2012)

Richmound speed skating rink

Richmond Olympic Oval
Location: Richmond, Vancouver, Canada
Glued laminated timber beams (100m)
*200m*100m.*
2010 Vancouver Olympic games.

Fig.3.26. Richmound speed skating rink

Varennes library
Location: Varennes Canada
Net-zero library, wood used in exterior and interior materials and partly in frame of building. First net-zero library on Canada.

Fig. 3.27. Varennes library

The Globe at CERN, Geneva

The Globe, designed by Groupe-H: Hervé Dessimoz, is the tallest timber domed structure in the world, roughly the size of the dome of Saint Peter's Basilica in Rome. Despite its great size, this timber structure was always intended to be relocated.

The Globe was originally conceived as a pavilion known as Le Palais de l'Equilibre (The Palace of Equilibrium) for the Swiss Expo 2002 at Neuchâtel, held 10 years after the United Nations Conference on Environment and Development (The Earth Summit) at Rio de Janeiro. The competition brief was to plant the idea of sustainability in the minds of visitors.

The Globe is a sphere, 40m in diameter, 27m tall and made primarily of wood; it represents the Earth's future by combining science with innovation. Its structure is reminiscent of the shape of the planet, while it is made of the most ecological of all building materials, wood. The outer shell, resembling a finely spun cocoon, is designed to protect the building from the sun and the elements, just like the Earth's atmosphere.

The outer shell includes glulam compression braces lls each comprise 18 glue-laminated cylindrical arcs of 600mm diameter. The inner shell is clad in curved and steel rod tension braces, supports louvre panels. Two spiral pedestrian ramps wind their way between the outer and inner shells.

Five species of timber were used in the Globe's construction: Scots pine, Douglas fir, spruce, larch and Canadian maple all grown locally. The Swiss forests produce about 700m³ of timber per hour;

hence, the 2,500 m³ of timber in the structure represents three-hour's production. This timber is a significant carbon sink for as long as the timber is preserved (TRADA, 2019).

Fig.3.27. The Globe at CERN: a) A relocatable exhibition pavilion made entirely of wood; b) The interspace between outer and inner domes; c) The Globe at night

4. GAPS IN EDUCATION AND RESEARCH ON DESIGN AND CONSTRUCTION OF PUBLIC WOODEN BUILDINGS

4.1. LATVIA

Gaps may exist between the education and knowledge of architects, engineers, economist, working in the same area, when interdisciplinary knowledge is necessary. At the same time design process became important as never (Larsen, 2016). Design questions are also related to the results in energy efficiency. Changes in the technologies that can vary between regions, and technological development in general, questions related to the competition within the industry, can be considered as challenges as well.
Construction sector is a rather inert branch of industry in Lithuania, therefore many professions are classical (e. g. civil engineer) and almost unchanging in the course of time. However, the developing supply of new building materials and technologies, the growing level of automation of activities, the increasing globalization determine the need for new skills.

4.2. LITHUANIA

Civil engineering students often lack understanding about sustainable construction because education on sustainability is not sufficiently included in curricular of bachelor study programmes. Moreover, education on design and construction of wooden buildings is very limited. In bachelor study programmes *Civil Engineering* and *Construction Technologies and Management* delivered by VGTU there is only one subject of 6 ECTS “Steel and wooden structures”. In the second biggest technological university of Lithuania – Kaunas Technical University – subjects on wooden design and construction are not included to the curriculum of *Civil Engineering* studies at all.

Timber structures are less popular between students because there is lack of modern technical literature on timber structures in Lithuanian and English. Especially there is lack of literature in Lithuanian with guidelines on using Eurocodes for the design of timber structures.

In Lithuania most of the building are designed and constructed using steel and concrete, so fewer students choose timber structures as their final projects in bachelor and master studies. Students should be encouraged to choose timber structures for their final projects, as this is one of the fastest growing branches in the construction.

The acoustic, thermal, environmental (including carbon capture) and economic performance of wooden buildings are also fields without significant research in Lithuania.

In summary major gaps are as follows:

– insufficient general awareness of students, teachers and wider society about sustainable construction;
– no particular attention on modern wooden construction in higher education;
– lack of literature on modern wooden public buildings’ design and construction;

- lack of statistical data on wooden manufacturing and construction in Lithuania and abroad;
- engineers lack creativity, analytical skills, work in a team and the knowledge in new technologies and technological processes;
- wood industry specialists lack personal qualities, i.e. language skills, manufacturing organisation, quality management and initiative taking skills to promote wooden construction.

4.3. FINLAND

There is need for improve education, research on design and construction of public wooden building according many research. According one research in 2008 there is need for construction managers (Kivistö et al. 2008) with special knowledge on wooden construction technologues. In Finland government make decision to stop educating construction managers in the 1990s. But they have to start educate construction managers again in year 2007. Also according Kivistö (Kivistö et al. 2008) there is also need to improve education in design of wooden structures, wood material knowledge, construction technology, quality control, co-operation skills, knowledge in research and development. There was also was expected that PBL (Problem based learning) might be good teaching method where student can solve authentic problems in construction field.

At the beginning of the year 2018 there was a lot of changes in legislation. Because of this, there is lack of study material with new degrees. Some study material are in time, despite of this. One example in a textbook made in HAMK in 2014 (Ilveskoski 2014).

There is also need for education how to calculate carbon footprint. In Finland this is coming to legislation near year 2020 (Kuittinen 2018). Ministry of Environment has presented that there is coal to get carbon footprint based requirement in building legislation.

In research Finnish federation wood works Industries 2015 has goal to improve process with energy, material and work, improve knowledge with sustainable material, improve technical and visual properties of wood product and make final wooden product more suitable to many kinds of use in building.

In Finland Government has in the government plan to promote wooden construction (Heino 2017). Goal is to increase use of wood in building. Goal spots are to promote national wood buildings, to get regional knowledge for wood technology, to develop legislation, information, research-project and International cooperation.

Finnish wood industry has to need to develop standardised runkoPES and halliPES systems to new versions runkoPES 3.0 and halliPES 2.0. (Hakkarainen Jouni 2015)

Finnish wood industry organisation Puutuoteteollisuus ry did a clarification about educational and research needs (Puutuoteteollisuus 2019). According that there are worries about education about wood technologies in University of applied Sciences in Finland. Also there are some new important knowledge needs. Most important new knowledge needs is robotics. They estimate that robots will come very soon to wood industry in large scale.

4.4. DENMARK

We have interviewed several engineers who has worked on big scale wooden building projects.

"The biggest challenges have been calculations with the new materials. They have used German calculations, in lack of Danish ones. So they could wish for a test facility in Denmark where wooden materials could be researched, and where they could experiment with how large recesses they can make in the different wooden constructions, or analyse different construction joints." Says Kenny C. Holm.

Acoustic Requirements

"It is a challenge to prevent noise levels from exceeding specific Danish compliance requirement, without the wooden constructions being combined with other materials." Says Bo Lautrup.

Fire Requirements

"There are also challenges in complying with the Danish fire requirements, without the wooden constructions being combined with other material, or a fire simulation being made." Says Mads Valentin.

"Generally, more experience is necessary in the field of wooden building construction, especially when designing buildings that are not cottages or single-family houses." Says Kenny C. Holm.

Education

Students from the professional bachelor programme in Architectural Technology and Construction Management and HEIs students of Architecture are becoming more aware of the qualities of wooden buildings and the evident climate benefits of building with wood. However, the students can only be introduced to examples and textbooks on the subject. Students cannot achieve insight into best practice in wooden constructions and the latest knowledge from research. Partly because teachers themselves have to gain insight first.

Several Danish study programmes in Engineering offer bachelor courses on wooden constructions. However, they lack the Master courses that give the students in-depth insights and the core competencies to calculate larger and complex wooden structures. The result is that newly graduated construction engineers enter the business world without the necessary skills to build with wood (Thybring, E. i.a., 2019).

4.5. UNITED KINGDOM

According to the Construction Skills Network (2019) "the uncertainty over the final terms of leaving the European Union has had a knock-on effect on two key construction areas: investment and skills." This is evidenced in an estimated UK construction growth rate per annum of 1.3% in the 2019 – 2023 period, which is lower than the forecast UK GDP growth of 1.6% for the same period. Nevertheless, demand for construction jobs has risen. "In fact, construction employment is expected to reach 2.79 million in 2023, just 2% lower than its 2008 peak." (CSN, 2019)

Egan Consulting (2016) identifies that there is an ongoing skills shortage within the UK construction industry. It also states: "*Timber frame construction remains a relatively niche trade within overall building industry and suffers from a lack of young apprentices training up on relevant skills in timber construction and joinery. Furthermore there remains an ageing workforce with limited young people choosing timber or carpentry as a career option. This has been exacerbated by a limited selection of further education courses, apprenticeships and craft qualifications available".* Therefore the further development of this sector is required. Nevertheless, a continuous growth in number of employees in the sector is predicted.

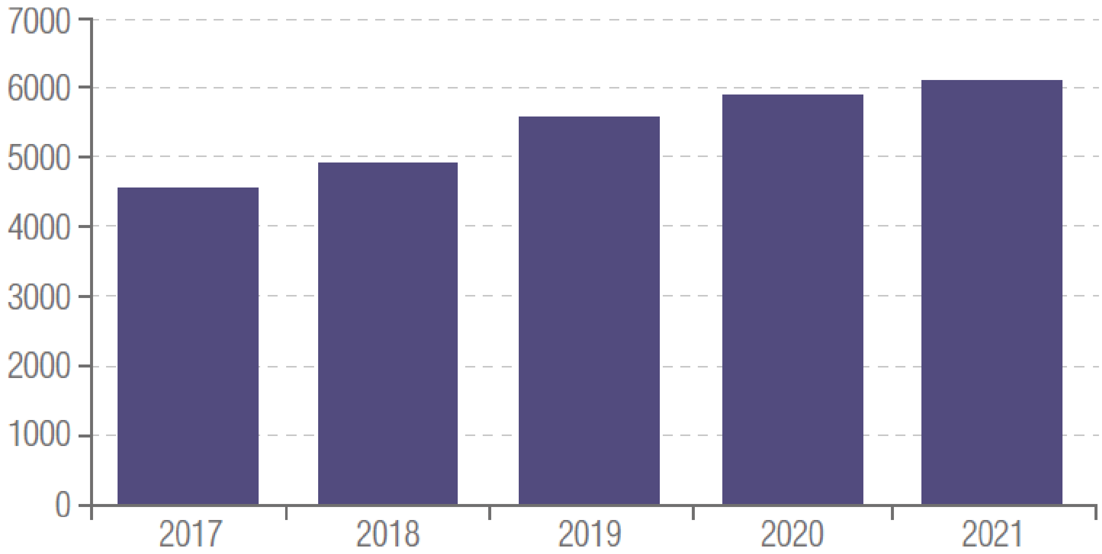


Fig. 4.1. Number of employees in direct manufacturing employed in the timber frame construction sector (Egan Consulting, 2016)

CONCLUSIONS AND RECOMMENDATIONS

Latvia

The development of the economic situation and construction industry in general can be considered as a positive. Construction market is affected by variety of factors, and includes many stakeholders, which make the processes within the industry more complicated. This aspect also highlights the significance of the construction industry, its role for the public, private sectors.

The question, how entrepreneurs will react to the challenges. As the solution of economic, environmental and social conflicts, the usage of wood products in construction can be a good solution for Latvia, because of its climate, and other environmental and economic characteristics.

According to Cabinet of Ministers Regulation No.331. Riga, 30 June 2015 (prot. No. 30, 50th), public building is ,,a building in which more than 50% of the total area of the building is public spaces or premises for the provision of public functions or engineering structures intended for public use (such as public stage, stadiums)".

The industry has the opportunities for the usage of wood, and, by increase of knowledge in this area by minimization of gaps in education, suppliers risks etc. Questions related to the affordability of such housing are important as well.

Wood construction is widely developed in Latvia. This case of Latvia represents just some examples and tendencies, not including, for instance, the case of resort city of Jurmala, and other cities and territories, located closer to the sea, which can be a separate object of the research.

Construction industry always searches for new opportunities, and, at the same time, the role of public objects is high. The usage of wood materials in public construction can be considered as a interesting and, with correct application, also an environmentally friendly solutions which could positively affect the development of a particular object and, in case of wider application, the development of industry in general.

Lithuania

Macroeconomic outlook revealed that forecasts for development of the Lithuanian economy are positive, however purchasing power is substantially lower compared to developed European countries. Modern buildings in Lithuania are mostly constructed from steel and concrete as use of these materials is cheaper compared to wood. Therefore sustainable wooden construction is still not affordable for majority of the Lithuanian public institutions and enterprises that build large public buildings for their activities.

Analysis revealed that construction market recovered from the crisis, however, it is forecasted that it will slow down considerably up until 2020 due to the limited opportunities on the domestic market. Lithuanian construction companies are highly qualified to design and build (or be subcontracted to build) public and private housing, as well as industrial and commercial property, throughout Europe and Scandinavia. As the construction of the public buildings needs public and/or private sector investments and wooden construction is expensive, it can be predicted that more opportunities for construction of public wooden buildings exist in the markets abroad, i.e. Scandinavian countries.

Lithuania has strong wooden building traditions. Most (~90%) of the buildings constructed in Lithuania before the year 1940 were built of wood. According to Centre of Registers, there are 21,971 registered public wooden buildings in Lithuania, however, majority of these buildings were built many years ago.

Forests cover more than 33% of the territory in Lithuania. Therefore, the wood industry is by tradition one of the largest and strongest in Lithuania, however around 2/3 of production is exported to more than 90 countries around the world. Construction of the modern wooden public buildings is still limited. Wood is mostly popular in residential construction (family houses), construction of recreational facilities (rural tourism homesteads), traditional food restaurants and bathhouses. Producers of wood houses export about 75% of their products to Scandinavian and Western European countries. In Lithuania innovative ways of wooden structures are applied fragmentally and inadequately to the use of wooden architecture in the past.

There is insufficient general awareness of students, teachers and wider society about sustainable construction in Lithuania, no particular attention on modern wooden construction is given in higher education, and therefore civil engineering specialists are not adequately prepared for future labour market needs.

Recommendations:

1) To close the gap in civil engineering education, new bachelor study module on design and construction of sustainable public buildings shall be developed and integrated to existing study programmes as a new subject or elective element. Content of the module at least shall include general understanding of sustainable construction, use of wood as sustainable building material, modern wood design technologies, technical requirements, and best practices examples from abroad.
2) Students should be encouraged to choose timber structures for their final projects, as this is one of the fastest growing branches in the construction around the world.
3) Engineers lack creativity, analytical skills, work in a team and the knowledge in new technologies and technological processes, therefore innovative education methods, i.e. project-based learning, blended learning, case studies shall be used for education of the future specialists. Best practices from advanced higher education institutions shall be adopted, competences of teachers improved.
4) Information on the wood manufacturing and wooden construction is very limited in Lithuania. There is a lack of information on modern wooden buildings designed and constructed abroad. To close this gap database on public wooden buildings shall be developed. Database shall contain at least information of public wooden buildings' projects in Lithuania and abroad, information on education, research in this field, networks and other significant data.
5) Public awareness about modern sustainable wooden construction is minimal in Lithuania. Therefore wide range dissemination and promotion activities are necessary. "Pub-Wood" project has to contribute to these activities; moreover, major national associations shall be involved.

Finland

In Finland, there are a long traditions and a lot of experiences of wooden buildings. Wood is the most popular and used frame material in single family houses (88%). Wood is not a common construction material in block houses and not generally in public buildings.

Wood has many advantages as a construction material. Wood is a renewable material, wood has a high strength compared to its weight, thermal conductivity is low and wood is easy to modify to a different kind of product.

To term “Public building” there is no official definition. According to Neuvonen (2017) “public building” is a building that is open for everybody and is owned and maintained by public sector. There are also “semi-public buildings” which do not fill these requirements. They are usually commercial and collect for example entrance fees.

Right now economic situation is good at construction sector. Wood has a 29% share in the market. Share has been almost the same in the resent years, but amount has risen.

For public building sector, there is some pilot project with massive wood buildings. For example, school building in Pudasjärvi, largest log building in the Word.

Study about education and research needs for design and construction of wood buildings in Finland was published lately (Puutuoteteollisuus, 2019). According to that, they are worried about educational situation about wood construction technology. They mentioned many different points to improve in education. One important new further educational need concerns use of robotics.

Lately there has been lot of changes in legislation and because of that, study material should be updated soon. There is clear understanding that there should be more cooperation. Universities need industry and vice versa.

Denmark

The present situation is problematic for the future of the Danish construction industry, where wood should be used on an equal footing with other materials. Therefore, higher educations have to act now and focus on attracting wood scientists to do research within the subject and develop relevant teaching materials.

United Kingdom

The UK economy was strongly affected by the 2008 recession. The construction sector struggled to recover. Employment in the construction industry has also taken some time to recover fully. Housing has been the sector that has performed the strongest since. Brexit has affected investment in the sector, it has affected particularly the non-housing sector, which is performing badly for other post-recession reasons. The timber frame construction sector has been growing steadily, particularly in the housing sector, and has increasingly a larger section of the market. Timber frame construction in the non-housing sector has not performed quite as well, and has exhibited little overall growth, but this is possibly due to the overall weakness of the non-housing sector overall. The timber frame construction industry is optimistic about the future including the non-housing sector. The UK’s construction industry in general, and the timber frame sector in particular, project a growth in employment and need increased skill-training.

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GLOSSARY OF ABBREVIATIONS

n.d. – no date

n/a – not available

yoy – year on year