

ID: WOOD

Clustering knowledge,
Innovation and Design in
the SEE Wood Sector

n.4 Thematic Dossier
Construction

WP5: Transnational knowledge clustering

www.idwood.eu

index

Foreword	4
Multi-storey wooden buildings as a great opportunity in residential and public construction.	5
Introduction	5
Positive Energy Balance - How to use timber for construction and actively eliminate CO2	6
Measures to improve the energy performance of timber buildings. (Manja Kitek Kuzman)	11
1. Introduction	11
2. Energy-efficient improved buildings bring economic benefits	13
3. Measures to reduce energy consumption in buildings	14
3.1 Legislation	14
3.2 Energy Performance Certificate	14
3.3 Green Public Procurements	15
3.4 Raising environmental awareness among people	15
3.5 Financial support	16
3.5.1 Loans with low interest rates	16
3.5.3 Subsidies	16
3.6 The development of different methods - Certificates	17
4. Environmental Impacts of Primary Wood Products	18
5. Conclusion	19
6. References	20
Restoration of Existing Structures (DI Frank Lattke)	22
Restoration of Existing Structures – Potentials for timber engineering	22
Continuing Development – a Metamorphosis of Architecture	23
Prefabricated Building Envelops for Upgrading Existing Buildings	24
Conclusion	25
Calculations for multi-storey residential timber constructions - assessment criteria used in construction management and construction economics (Jörg Koppelhuber / David Zügner / Detlef Heck)	26
1. Introduction	26
2. Initial state of affairs of multi-story residential timber construction	26
2.1 Residential multi-storey timber building market	26
2.2 Technical aspects of the initial state of affairs	27
3. Calculation	28
3.1 Assessment Criteria used in Construction Management	28
3.2 Economic aspects	29
4. Conclusion	29

Fire Safety in Timber Buildings (Martin Teibinger)	30
1. General introduction	30
2. Fire stages	31
2.1 Reaction of construction materials to fire	31
2.2 Fire Resistance	32
2.2.1 General	32
2.2.2 Dimensioning of the load-bearing capacity R of timber frame components	33
2.2.3 Dimensioning of the load-bearing capacity R of x-lam elements	33
2.2.3.1 Charring rate β_0 for cross-laminated timber with unprotected surfaces	33
2.2.3.2 Charring rate values β_0 for cross-laminated timber with initially protected surfaces	34
2.2.3.3 Structural design of load-bearing capacity R of cross-laminated timber elements	35
2.2.4 Dimensioning of the separating function EI of timber-constructions	35
3. Constructive recommendations for elements	35
3.1 Laying of electrical installations in partition walls in timber frame constructions	35
3.2 Penetration through partition walls	36
3.3 Interspace in double-shell partition walls	36
4. Connection details for fire compartment-forming components	37
4.1 Basic technical rules	37
4.2 Connection of the fire compartment-forming partition wall to the exterior wall	37
5. Vertical Distribution	38
5.1 Type A shaft	38
5.2 Type B shaft	39
6. References	41



foreword

With a surplus of quality forest resources and a strong tradition in woodworking, the SEE area has yet to take advantage of the significant potentials in the wood sector. The development dynamics of the sector have not been homogeneous, and the area is characterized by a dual spatial pattern - some of the territories have managed to develop their potential to excellence levels, whilst others are still struggling to fine tune the right support approach to the sector. Considerable disparities in terms of innovation and technological capacity hamper trade and investment flows.

The main objective of the **ID:WOOD Project** is to foster the innovation and competitiveness of SMEs in the wood manufacturing sector in the SEE area by networking and sharing technical and organizational know how in order to enable local support organizations (wood clusters, wood technology centres and RDAs) to address the organizational and technical deficits in the production sector. Pooling the experiences and know how of territories which have reached levels of excellence in the wood sector, and promoting cooperation between support organizations and local knowledge poles (universities and design centres) should accelerate the catching up process in terms of innovation capacity and human resources development.

A transnational network of wood sector support centres/experts which has been set up within the framework of the ID:WOOD Project is bestowing a synergic approach in order to promote the sharing, integration and transfer of the necessary know how. This approach should not promote simply cooperation, but also the complementarities and synergies between the territories in order to prevent any unnecessary overlapping of initiatives and investments in support structures which do not appear to be very rational in times of increasing budget constraints.

The present **Thematic Dossier** is part of a series of 5 technical dossiers produced by the wood sector experts involved in the ID:WOOD Project: 3 dossiers are each dedicated to one of the sub-sections of the wood sector (Sawmill, Construction Material, Furniture), 1 is dedicated to organizational aspects of the sector (Clustering), and 1 is dedicated to the transnational technical assistance provided to partners and SMEs by international experts. The aim of the dossiers is to provide partners, stakeholders and SMEs with an insight into some of the relevant technical aspects for the sector, and to strengthen the knowledge flow between the different reference centres, the stakeholders and the SMEs.

Paolo Panjek

INFORMEST
WP5 Coordinator



Multi-storey wooden buildings as a great opportunity in residential and public construction.

Source: **ProHolz**

Introduction

In recent years, wood has rapidly developed into a high tech construction material. Wood is now used for constructions of hitherto unimaginable dimensions, even for multi-storey buildings, and is increasingly used in cities. It also has unique ecological qualities and, like no other construction material, fulfils the growing demand for the efficient use of resources in the construction process.

Building with wood in dense, urban areas

Wood has gained importance as a building material that would have been unthinkable a couple of years ago. Developments in recent years have revolutionised wood constructions. Technical research has brought about big improvements in fire safety and noise protection. Computer-aided calculation and production methods have made new design shapes possible. Material and product innovations have opened up completely new areas of application for building material wood. It can increasingly be used for bigger projects. New dimensions in space and height are being achieved. Wood, as a building material, is finding its way back into the urban areas from which it has long been pushed out.

Wood brilliantly fulfils all the requirements of domestic architecture in dense urban areas with many additional benefits. The building elements are prefabricated under weather-independent conditions at the production site. A high degree of prefabrication means extremely short erection times of only a few months and the construction sites are low-noise and clean. All of these benefits make wood the preferred construction material in densely inhabited areas. It is not only suitable for residential buildings, but is also particularly useful for the construction of kindergartens, schools, and for special care and nursing homes.

Wood construction has unique qualities when it comes to building redevelopment. One of the big challenges of the future is to adjust old buildings to new ecological, functional, energetic and aesthetic requirements. Wood does not weigh much and has a high load-bearing capacity as well as good insulation properties. It is thus especially suitable for renovation and redensification. Growing cities that suffer from a lack of space profit especially if, for example, additional storeys are built on top of existing buildings using wood as an ecological construction material, which doubles the space and reduces CO₂ pollution dramatically.

Wood-based construction as a form of active climate protection

Climate protection is one of the most pressing questions of our time and requires different ways of thinking, including in the area of building and construction. Buildings for the smart cities of the future need to be resource



efficient and low in CO₂ emissions. Therefore, the kind of construction materials used will be very important in the future. When it comes to environmental credentials, wood is clearly superior to conventional building materials.

Trees remove the greenhouse gas CO₂ from the air as they grow. With the help of sunlight, they convert it to carbon and oxygen. Carbon is stored in wood. Approx. one tonne of CO₂ per cubic metre of wood is bound up and prevented from entering the atmosphere until the wood rots or is burnt. Building with wood maintains the climate-protecting carbon reservoir for decades and gives rise to a secondary forest of buildings.

The renewable construction material wood contributes to CO₂ reduction in multiple ways. Timber buildings not only expand the reservoir of stored carbon that exists in forests, every harvested tree creates additional space for new trees and increases the carbon reservoir. Furthermore, since wood replaces other building materials, the CO₂ emissions that they generate are avoided.

Europe has a big stock of wood and is able to sustainably build with wood. At the moment, less than two thirds of the annual regrowing capacity is used. Only 490 million cubic metres of the 776 million cubic metres that are regrowing in European forests are harvested.

The growing, green cities of tomorrow have a high demand for resource efficiency, smart densification, energy efficient renovation, and the smart creation of living spaces. Wood provides appropriate solutions which are not yet well known or which cannot be used yet due to unsuitable conditions.



Residential building in Wagramer Straße, Vienna.



Murray Grove, London.

Timber Used in Buildings – Caring for People and the Environment

All of those political decision-makers who promote timber as a construction material exert, in this way, a direct influence on people and the environment. Their responsibility for the economy and society also incorporates plans to shape a future with a culture of building that relies on construction methods that meet the technical requirements of today, and also positively impacts on the mid- and long-term development of a society's economy and its environment.

There are many arguments in favour of timber and its more widespread use: it does not harm the environment, it is available and sustainable, and it provides optimal energy balance and advantages to humans.

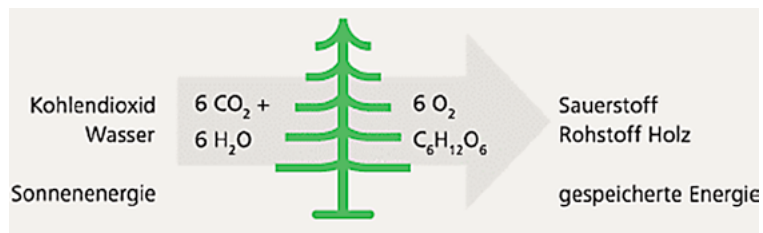
POSITIVE ENERGY BALANCE – HOW TO USE TIMBER FOR CONSTRUCTION AND ACTIVELY ELIMINATE CO₂

Source: proHolz Austria Edition 09, Holz und Klimaschutz

1 cubic metre of wood stores 1 tonne of CO₂

How does wood lock in CO₂? By photosynthesis. During its growth, a tree absorbs carbon dioxide from the air and nutrients from the water in the soil to produce organic material - wood. In the next stage of the process, light helps to split the low energy carbon dioxide molecule into a high energy carbon atom and a high energy

oxygen molecule. Oxygen (O) is released back into the atmosphere. Carbon (C), on the other hand, is used for the tree's organic composition and remains stored in the tree for its entire life cycle.



Kohlendioxid=Carbon dioxide

Sauerstoff=Oxygen

Wasser=Water

Rohstoff Holz=Feedstock wood

Sonnenenergie=Solar energy

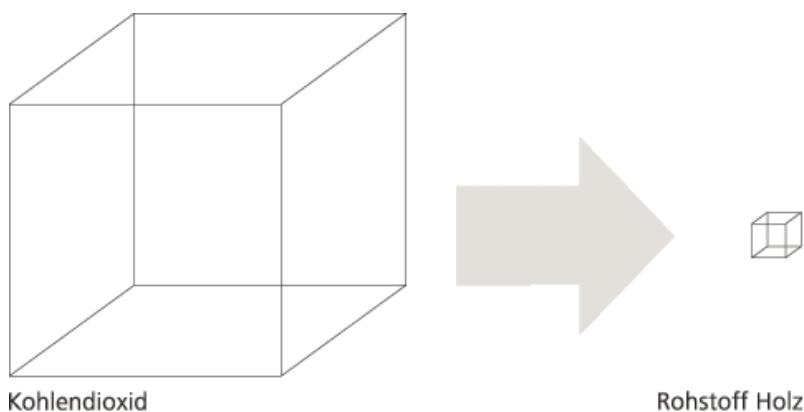
gespeicherte Energie=Stored energy

The magic C-formula: How do you calculate the C storage capacity of wood?

$$250 \text{ kg C/m}^3 \text{ wood} \times 3.67 \text{ kg CO}_2 = 917 \text{ kg CO}_2$$

One cubic metre of wood stores carbon from 1 tonne of CO₂; wood is made up of 50% carbon (C). If we take a mean value of 500kg (dry weight) per one cubic metre of wood as a starting point, the result is that 1 m³ of wood contains 250 kg C. When C gets converted (oxidises) into CO₂, 0.9 kg of carbon produces some 3.7 kg of carbon dioxide.

This means: 250 kg C/m³ of wood x 3,67 kg of CO₂ produces 917 kg i.e. 1 tonne of CO₂ per 1 m³ of wood.



Kohlendioxid=Carbon Dioxide

Rohstoff Holz=Feedstock wood

Source: Arno Frühwald, Hamburg University

1 cubic metre wood (Atrö) contains:

250 kg carbon

215 kg oxygen

30 kg hydrogen

5 kg various other elements

A modern vehicle emits some 1.5 tonnes of CO₂ in a year.

(EU benchmark: 120g CO₂/ km; Annual mileage of a personal vehicle: 11.400 km.)

The same amount of CO₂ is stored in a modern single family timber house as its occupants emit over 40 years of mobility.

Positive Energy Balance

Products made out of timber store more energy than is needed for their production. More than 50% of stored solar energy is further delivered for other consumption purposes to close the cycle in the form of heat or power.

Timber as Feedstock

Timber is used as feedstock in a number of products. However, it can be used even more often as there are so many opportunities where it can replace synthetic materials. Synthetic materials are not only produced from fossil fuel – mineral oil, but the CO₂ that is emitted during their production and combustion contributes considerably to global warming. Furthermore, it is not that unusual to see synthetic materials which have not been properly disposed of, but have simply been dumped in landfills or in bodies of water. Only small amounts of synthetic materials get recycled. For example, no more than 1% of the 14 million tonnes of polystyrene produced annually is recycled! Timber is a perfect substitute for such material.

Synthetic materials are most widely used in the following three fields:

- packaging (33%)
- construction (25%)
- electronics and electrical engineering (25%)¹.

Polystyrene as a packaging material can be quite easily replaced by wood or wood shavings. Wood is an almost ideal material for use in the production of textiles and articles for every day use such as furniture, cooking utensils and toys. If just one fraction of the more than one million tonnes of synthetic materials used in Austria annually was replaced by wood, it would be such a huge contribution to the protection of the climate and the environment.

Embodied Energy

“Embodied energy” – an item that we tend to forget about so easily when calculating the CO₂ balance sheet for many types of construction materials and feedstock types. “Embodied energy” is the cost incurred in extraction, production and transportation of construction materials and feedstock. Even timber has its share of “embodied energy”. However, its amount is much lower than for steel, aluminium, bricks or concrete. Why is this so? It is quite obvious: a tree grows nearly entirely by itself. Except for the rain and energy from the sun, it presents no costs at all in life cycle assessment, no other “costs” are incurred. The energy required for forest management and wood harvest is small when compared with mining, electrolysis, blast furnaces and combustion plants. Not to mention transportation costs, as roads for wood transportation are, in most cases, regional and therefore short. Furthermore, wood stores carbon captured from the CO₂ in the air during its entire life cycle.

CO₂ Substitution

If timber is used raw or as a building material instead of any of the said feedstock, like steel, aluminium, bricks or concrete, one cubic metre of wood replacing any of the said feedstock would not generate the 1.1 tonnes of CO₂ otherwise emitted in the production, since the share of “embodied energy” is much smaller in case of wood.

Significant CO₂ reduction

As it is today, the building sector, by applying conventional building methods (steel-concrete construction), uses 25–40% of the feedstock and energy resources available worldwide. Of course, we must all have housing space, but because of the rapidly growing population, it is high time to consider alternative building materials. When we also take into account the fact that solid building materials generate 30–40% of entire global waste, this necessity becomes even more obvious. Directly or indirectly, the building sector accounts for some 30–40% of global CO₂ emissions. It is therefore in the interests of all people and of every individual to build in a way that maximises energy and resource savings. In this respect, collective interests such as the protection of the climate and the environment go hand in hand with personal benefits – from money saved due a better indoor climate to the carbon footprint that an individual makes. There are so many things to start with. It starts even

¹ Plastic-Planet.at

before a building is erected, i.e. with the selection of construction materials and the CO₂ balance sheet for the production and transportation of the construction material selected. The space needed for a building and the sealed surface area it requires should be taken into account. In terms of facility management (the energy needed for heating, cooling and other purposes, and maintenance costs), durability and functionality, timber is clearly ahead of other construction materials. To build by applying energy-saving methods is not only a matter of using the right materials. First and foremost, it depends on proper planning and competence to deal with the given prerequisites.

It makes sense to use timber in buildings

There is plenty of wood in this country: it is a natural and sustainable feedstock that continually grows in more quantities than is needed. In Austria, enough trees grow every 40 seconds to build a wooden house. The research done by Hamburg University shows that one single wooden house can store up to 30 tonnes of CO₂. Bearing in mind that Austria's goal since 2008 has been to eliminate 30 million tonnes of a CO₂ a year, it soon becomes clear that timber is the only sustainable building material.

Modern construction

Timber is not only used to build houses, but also for multi-storey business buildings, and leisure facilities and halls with gigantic width spans. Timber is the lightest building material even for bridges as it exhibits, when good heat insulating properties are provided, such a high strength that it may be used for supporting parts. All this makes timber a first choice building material from both environmental and economic points of view. Using timber for construction makes it possible to maintain a low CO₂ balance sheet for a building over all three life cycles.

CO₂-saving stage 1

The energy expenditure (the so-called "embodied energy") required for production – also for "harvesting", processing (sawing, finishing, assembly, etc.) and transportation to the construction site – is considerably lower than that of other materials. No other building material requires less energy for its production, therefore it emits lower CO₂ quantities. Already, in this early stage, it can be demonstrated to what extent timber as a building material contributes to the CO₂ reduction. A house wall in a wooden frame construction, for example, saves up to 50% of the primary energy demand over the course of its production compared with a brick or concrete wall.

Not to mention that, in order to obtain wood, only the energy of the sun is needed. In terms of actual figures, this means that a brick wall or a concrete block emits 5 tonnes of CO₂ per 50 square metres, while a wooden frame construction of the same surface area with formwork made of softwood emits only 1.5 tonnes of CO₂. A 3.45-tonne reduction in CO₂ is possible in case of a 50-square metre surface.

CO₂-saving stage 2

If timber is used as a construction material, considerable savings in energy and reductions in emissions can be made during the entire useful life of a building (energy consumption, thermal properties and maintenance included). The specific cell structure of wood is responsible for its extraordinary proofing and insulation properties and, consequently, for lower energy consumption over the entire life of a building. According to ÖNORM B 2320, the useful economic life of such a building is at least 100 years.

Long-term CO₂ storage

Construction experts know that timber used for building has a life exceeding 250 years. Timber used according to the rules of the trade is extremely durable and in many cases, especially if installed under the roof or in a building's interior, requires no chemical protection against external impacts. Due to the natural strength and stability of different types of wood, timber constructions may have a useful life of more than 100 years.

CO₂-saving stage 3

Each piece of timber used in buildings binds CO₂ as a carbon. In this way, its release back into the atmosphere is delayed until the timber reaches the final stage of its life cycle when it is converted into thermal energy. Most importantly, when a timber house is dismantled after decades or even centuries of use, it is not unrecoverable debris that is left behind, but useful timber. Single construction elements such as beams can be reused and the remaining timber can be used to generate energy. Only the amount of CO₂ that is locked in the wood is released during combustion. The natural carbon cycle comes to a close.



Timber is unbeatable

There are so many advantages of timber, not just its CO₂ balance sheet. Timber is a resource that is locally available in sufficient quantities, and it “gets produced on its own”. No other feedstock or construction material requires anywhere near as low amount of energy for its production as timber. This also holds true for storage and processing. Timber and semi-finished timber products such as sawn timber can often easily be stored outdoors all year round – there are no expenses incurred for this purpose.

For wood drying and processing, the required energy is generated mostly from water power or from its own biomass with only limited CO₂ emissions. Therefore, the total energy balance for the production of construction timber is much lower than for other construction materials. Even the transportation of timber consumes less (fossil) fuel: timber is lighter than concrete, steel or bricks, so larger quantities can be loaded. Furthermore, nearly all timber is processed in local factories, which shortens transportation routes considerably. This aspect of timber utilisation also contributes greatly to CO₂ elimination.

Timber buildings to break the skyline

We already have the first taster of the building of future: Life Cycle Tower is a project that has reached the production phase. It shows how it is possible to safely build 20-storey timber buildings. The CO₂ balance sheet of such a building speaks for itself: 822 tonnes of CO₂ is produced during the development of a 20-storey Life Cycle Tower that is made out of timber, as compared to 10,375 tonnes for an equivalent 20-storey steel - concrete building².

CO₂ storage: going up and redensification

With its small mass compared to other building materials, timber represents an ideal building material for adding additional storeys because strengthening of the bearing structure is often not required. Due to its natural heat insulation, its small space requirements (10% more dwelling space when compared to solid construction), its good fire protection properties, and not least its pleasant indoor climate and aesthetic qualities, besides being durable timber is an ideal building material for multi-storey structures and extensions i.e. for redensification.

² PE International on behalf of Rhomberg Bau



Measures to improve the energy performance of timber buildings



Manja Kitek Kuzman¹

Assistant Professor



University of Ljubljana
Biotechnical Faculty, Department
of Wood Science and Technology,
Jamnikarjeva 101
1000 Ljubljana - SLOVENIA
manja.kuzman@bf.uni-lj.si
www.bf.uni-lj.si / www.lesena-gradnja.si

ABSTRACT

Over the past decade, a variety of measures have been implemented in the EU to improve the energy performance of buildings: tightening legislation, awareness-raising, education and promotion, state financial aid, and demonstrating the above-standard quality of components and buildings through certification. Increasing energy demands, environmental pollution and the consequent legal requirements present some of the main reasons for energy-efficient timber construction. In the European Union, the building stock is responsible for about 40% of primary energy consumption and about 25% of CO₂ emissions, which shows that there is a relatively high potential for a reduction in the energy consumption and GHG emissions caused by buildings. The advantages of wood as a construction material are lower embodied global warming potential and embodied carbon which is positively associated with well-being, aesthetic qualities, eco-friendliness, and realistic end-of-life disposal options.

1. INTRODUCTION

Based on existing facts describing the energy consumption of buildings, many authors [1-3] have pointed to the need for energy-efficient construction. Passive houses offer a viable option for meeting the remaining energy demand using only renewable sources. Consequently, it is necessary to lower energy consumption and oil consumption in the EU and other countries because of GHG emissions and the continuation of the current trends in oil production and price levels which are likely to continue posing great challenges for systems which cannot reduce their petroleum requirements in kind [4]. It should be emphasised that more research and development is needed to tackle the energy problem and to reduce emissions for a reasonable standard of living in our world [5]. At present, the world energy situation is getting grimmer, and China's energy supply pressure is also growing [6]. It should be pointed out that energy demands have doubled in the last 10 years, while current energy resources have not met market requests. This situation has put more pressure on scientists and communities to work harder to increase the use of renewable energy and to achieve the greatest efficiency from each resource [7].

¹ Manja Kitek Kuzman has a Ph.D. in architecture from the Faculty of Architecture at the University of Ljubljana (2007), and started as an Assistant Professor in the Department of Wood Science and Technology of the Biotechnical Faculty in 2010. Her teaching and research work focuses primarily on the advances in timber construction and the potential of the innovative use of wood and wood furniture design. Her contributions have been featured in national and international journals. She recently published three scientific monographs on timber construction and design. She is currently working on the preparation of scientific monographs for the Springer- Series entitled "Green Energy and Technology" and "Contemporary Slovenian Timber Architecture for Sustainability".

The European Union, like all developed parts of the world, is grappling with increasing energy needs. Only a small portion of its energy products are domestic, with the majority coming from various countries outside of Europe [8]: natural gas from the Russian Federation (34%), Algeria (14%), and more than 10% from Qatar, Libya, Nigeria and Egypt. Crude oil comes from OPEC (35%), the Russian Federation (33%) and 9% from Kazakhstan and Azerbaijan. Securing an uninterrupted supply of raw sources involves increasing difficulties and even extortion. Given that energy products come from politically unstable regions, similar difficulties can be expected in the future.

The EU's dependence on energy imports is therefore constantly growing (Fig. 1). Currently, more than 50% of energy needs are covered by imports, placing it at the top on a global scale. If the envisaged measures are not introduced and observed, by 2030 this share could rise to 67% [9]. Energy dependence represents an economic, social and environmental risk.

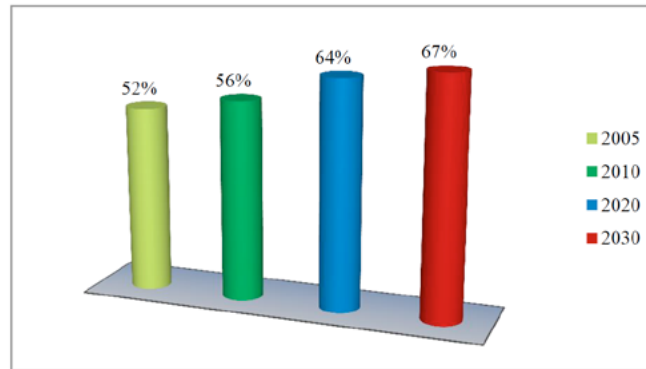


Figure 1: The EU's energy dependence on imports 2005 – 2030 [9]

The import dependence of Member States varies (Fig. 2).

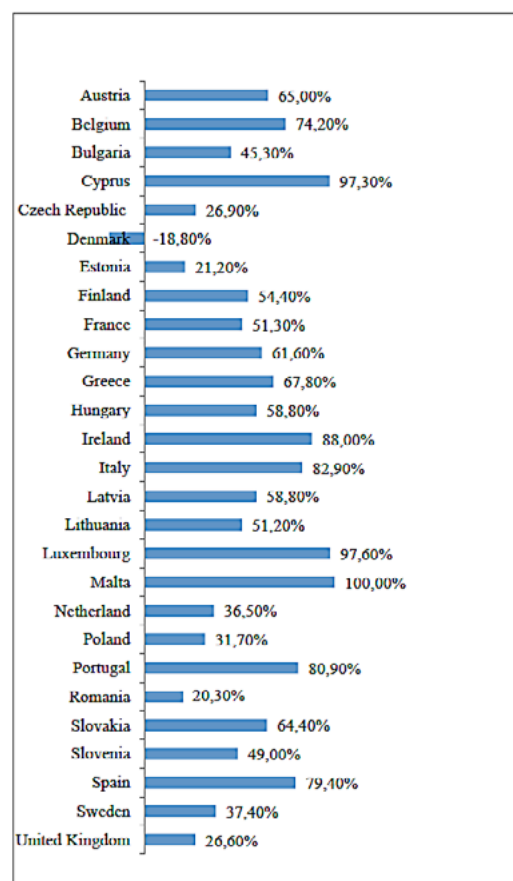


Figure 2: Energy import dependence of EU Member States [8]

Ensuring the necessary quantities of raw sources for power generation is not the only problem with fossil fuels. Their combustion involves emissions of greenhouse gases which cause global climatic warming.

There are 16 EU Member States that do not exceed the agreed quotas (Figs. 3, 4).

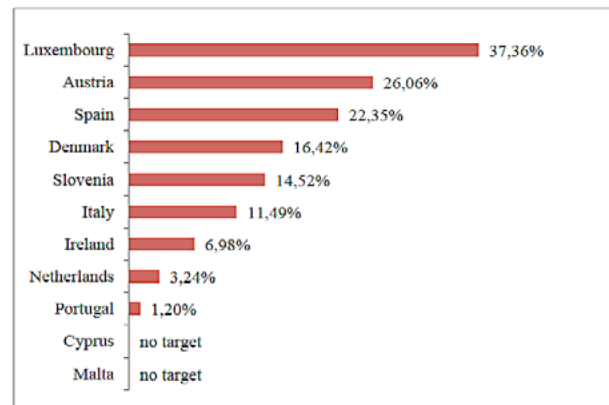
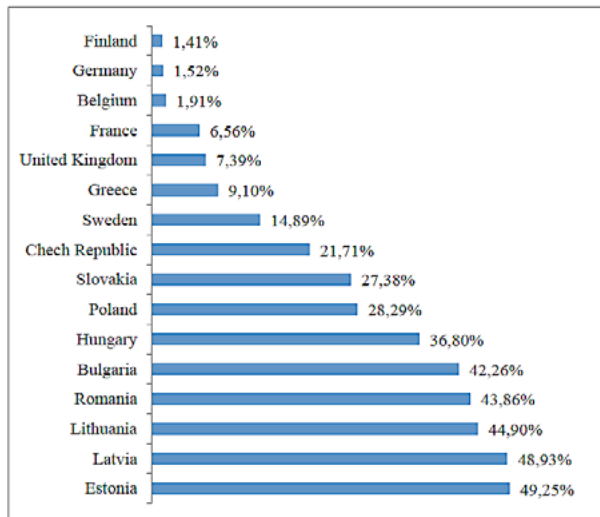


Figure 3: EU Member States UNDER Kyoto target 2012 [8] - Figure 4: EU Member States ABOVE Kyoto target 2012 [8]

A large proportion of the energy obtained is used in European households. Total final energy consumption in EU households amounted to 307 Mtoe in 2010, or 26.6% of the total. Heating accounts for 70% of energy consumed and contributes around 14% of the total emissions of greenhouse gases [11].

2. ENERGY-EFFICIENT IMPROVED BUILDINGS BRING ECONOMIC BENEFITS

Energy-efficient or improved buildings bring economic benefits with regard to lower future costs. Operating energy represents by far the largest part of energy demand in a building during its life cycle [12]. It has been shown that it is important to reduce the energy demand of a building. Research has shown that the costs of heat energy and distribution can be reduced by the construction of energy-efficient buildings [3]. An inspection of eleven existing apartment buildings established that the most economically efficient building in Switzerland was a low-energy house; it has been shown that, taking into account initial investment costs and costs for heating over a 20 year period, low-energy houses cost 4% more than standard houses, and that passive houses are 16% more expensive (Audenaert et al. [13]). This higher value of energy-efficient buildings on the real estate market was also found during a study in Romania [14] where energy-efficient buildings were 2-3% more expensive than similar energy-wasteful buildings. Investing in a passive house is justified and the results have shown that investment in timber passive houses can be assimilated into standard brick-concrete buildings in 10 years time taking into account the initial investment and energy consumption costs. The term 'passive house' refers to a construction standard that can be met through a variety of technologies, designs and materials such as solid (masonry, concrete and aerated concrete) and wood structures. The following considerations are particularly important when choosing the material and construction type: the construction type should be standardized; the construction system should be based on natural and environmentally friendly materials; the thermal envelope should meet the standards of a passive house; the construction should be windtight, airtight and diffusion open. In order to design and implement a high-quality passive house project, attention should be paid to the materials used. Initial investment in a passive house is 15% higher than in a standard one [15]. The most economically efficient insulation thickness for Tunisia's climate and the investment refund period in façade insulation were studied by Daouas et al. [16], and it was ascertained that the most economically efficient façade thickness was 5.7 cm with regard to life cycle cost analysis over 30 years. In Greece, thermal insulation and low-infiltration strategies have reduce energy consumption by 20-40% and 20% respectively [17]. For different types of walls and their impact on energy use in different energy zones, it has been ascertained that a correct building envelope must be designed in such a way as to take into account the climatic zone in which it is built [18]. It has been concluded that building envelopes should be designed to enhance energetic performance relative to local climate conditions. The optimal envelope composition with regard to costs and the optimal thermal insulation levels for floors, roofs or ground floors were found by Gieseler et al. [19] with the help of a model for Germany's climate. It is necessary to pay attention to glazing surfaces. Considering daylight optimisation at an early design stage can be referred to a way of designing architectural forms that take advantage of the prevailing urban context, such as existing shadow masks, in order to achieve a comfortable interior environment while minimising energy use and reliance on artificial lighting systems [20]. In order to achieve better energy efficiency, it is necessary to be up to date with the latest technology and to make

comparisons between energy-efficient buildings [21]. An energy-efficient building has to feature the correct architectural design which enables passive building strategies, such as solar loads, natural ventilation and other climatic conditions [15], in order to reduce the energy demand and the use of low-energy materials (wood).

3. MEASURES TO REDUCE ENERGY CONSUMPTION IN BUILDINGS

In the EU, as much as 40% of final energy consumption is tied to buildings which are responsible for as much as 35% of CO₂ emissions into the environment [4]. Energy saving measures in the construction sector are therefore logical, necessary and, above all, extremely effective. The trend of promoting energy efficiency began more than a decade ago in the EU through various measures and mechanisms [22]:

- more stringent statutory restrictions,
- promotion and education of professionals and lay public,
- financial support for energy-saving technologies, and
- highlighting and demonstrating successful cases of energy-saving technologies and state-of-the-art certified buildings.

3.1. Legislation

The European Commission has adopted an Action Plan for Energy Efficiency (2007-12) which includes measures to improve the energy performance of products, buildings and services, to improve the yield of energy production and distribution, to reduce the impact of transport on energy consumption, to facilitate financing and investments in the sector, to encourage and consolidate rational energy consumption behaviour, and to step-up international action on energy efficiency [23].

Energy consumption to heat buildings is limited by EPBD Directive 2002/91/EC [10] and particularly by the recast EPBD Directive 2010/31/EU [11] which lays down further significant structures on certain requirements:

- 20% reduction in greenhouse gas emissions (relative to the base year, 1990)
- 20% reduction in primary energy consumption through increased energy efficiency
- 20% share of renewable sources in the primary energy balance.

The two directives envisage restrictions on energy consumption for the entire building which, in addition to the building shell, includes specific technical systems in buildings such as ventilation, heating, air conditioning, cooling, hot water and lighting.

The recast EPBD Directive 2010/31/EU envisages an increase by 2020 in the energy performance of buildings, and introduces the concept of the nearly zero-energy house:

- by 31st December 2020 – all new buildings must be nearly zero-energy
- by 31st December 2018 – all new publicly-owned buildings must be nearly zero-energy since they must serve as models for others.

The anticipated results of the recast EPBD Directive 2010/31/EU are a 5% to 6% reduction in the EU's end-use energy, 160 Mt – 210 Mt a year in CO₂ savings, and 280,000 to 450,000 new jobs by 2020 [24].

3.2. Energy Performance Certificate

Directives EPBD 2002/91/EC and EPBD 2010/31/EU lay down the introduction of the Energy Performance Certificate which will show the energy consumption in an individual building. The Energy Performance Certificate (EPC) must be made available to the new owner or prospective buyer/tenant when a home is sold or let. Essentially a tool of communication, the EPC must not only state the amount of energy consumed during standard use of the building, but, most crucially, must also include cost-effective recommendations suggesting how energy performance might be improved [25].



3.3. Green Public Procurements²

The European Commission defines Green Public Procurement (GPP) in its communication COM (2008) 400 "Public procurement for a better environment" as a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared with goods, services and works with the same primary function that would otherwise be procured. The European Commission (EC) achieved a 50% implementation of the share of best GPP performances countries in the EU. Since this commitment was required, many administrations at national, regional or local levels have included GPP in their policies or assumed the engagement required in this field. In Slovenia, the Decree of Green Public Procurement (GPP) was published in 2011. The authorities responsible for the preparation, monitoring and continuous improvement of National GPP are primarily the Ministry of Finance, the Ministry of Agriculture and the Environment, the Ministry of Economic Development and Technology, and the Ministry of Public Administration. National GPP guidelines are available on the Ministry of Finance's web page and within the Public Gazette of the Republic of Slovenia.

GPP in the construction sector in Slovenia is primarily affected and regulated by the technical specifications and award criteria for buildings, as specified in Annex 7 of the Decree Amending the Decree on Green Public Procurement (2011). In the buildings category, it is generally required that 30% of in-built material (by volume) must be wood or wood-based (50% of this – 15% of the total volume – can be substituted by products with EcoLabels I or III). Furthermore, an award criterion gives additional credits if the 30% minimum threshold is exceeded. According to Annex 8 of the Decree on Green Public Procurement, furniture is generally required to contain at least 70% wood and wood-based materials. However, in Slovenia, GPP is currently unmonitored, limiting the ability to assess the success of its implementation.

Although National GPP rules are in place, there are several barriers to their successful implementation. The main barriers are a lack of public funding, a fear of increased procurement costs due to GPP, resistance from industries traditionally reliant on public procurement, and the lack of trained/experienced purchase managers and project evaluators. However, it is believed that National GPP in the construction sector could have a considerable impact on the market. By promoting and using GPP, public authorities can provide incentives for the industry to develop green technologies and products.

It is expected that the Slovenian GPP for buildings (Annex 7 of GPP) will be changed in the future. The Construction Products Regulation states that, where a European standard exists, it must be used. In addition, it states, "For the assessment of the sustainable use of resources and of the impact of construction work on the environment, Environmental Product Declarations should be used when available." Furthermore, the new GPP criteria for buildings will also almost certainly be influenced by the new public procurement Directives which were approved on January 15th 2014 by the European Parliament. The new provisions affirm that contracting authorities may introduce social and environmental considerations throughout the procurement process, as long as these are linked to the subject matter of the contract. Additionally, public authorities can differentiate what they purchase on the basis of process and production methods which are not visible in the final product. It will be easier for them to rely on labels and certifications as a means to prove compliance with the sustainability criteria which they have set. The new Directive allows public authorities to give preference to bidders that offer better working conditions for their workers, favour the integration of disabled and disadvantaged workers, and offer sustainably produced goods [29].

3.4. Raising environmental awareness among people

In addition to the progress made possible by scientists through the invention of ever new energy-saving technologies, a particularly important factor is the level of education and awareness of all citizens regarding the importance of environmental responsibility. The tendency towards greater energy efficiency is gradually becoming part of the personal behaviour of individuals who adopt this through the education system (Bologna process, E-Learning, joint curriculum development) and through legislation more than through technological advances. Environmental education on technology, programmes and strategies at all levels (including education for children, adults, experts, and so on) yields rewards [26].

The fact is that environmental education has to be incorporated as an effective part of environmental

2 More: Kitek Kuzman M., Kutnar A. Slovenian Contemporary Timber Architecture for Sustainability, Springer (2014) 170 p.

management programmes. Also, on an international scale, there are various examples showing growth in such a trend [27]. Agenda 21 suggests that all students and their teachers should be exposed to concepts and methods of ecologically sustainable development as part of their formal education.

Environmental awareness is continually growing among people. In the Eurobarometer survey, which included almost 27,000 people from all EU Member States, a full 95% of respondents stated that environmental protection was important to them (58% very important, 37% important). The survey included 1,047 Slovenians. As much as 80% agreed that, for them, environmental protection was very important, and 18% that it was quite important, giving a total of 98%. The survey results showed that their environmental awareness was even greater than the overall European result [28].

3.5 Financial support

The technologies that enable the greater energy performance of buildings are more expensive than conventional technologies, so they take a long time to breakthrough into the market. One method of promoting environmentally friendly technologies is to tax outmoded, energy-wasting technologies that cause pollution. Numerous writers have analyzed the effect of the Pigouvian Tax [30] and taxing market activities that negatively impact the environment (Pollution Tax, Carbon Tax etc.). Many writers oppose them [31] since supervising and punishing companies is problematic and, in particular, very expensive. They see greater sense in state aid.

Certain countries in Europe are increasing the energy performance of buildings by encouraging investors or buyers of conventional technologies to buy more energy-efficient technologies through measures that make them more price competitive – through low interest loans or subsidies.

3.5.1 Loans with low interest rates

For example, in Slovenia, investors can build passive and very low-energy houses with loans from two banks with interest rates that are lower than for other forms lending in the market. In addition to these two banks, lower interest loans are also offered by the Eco Fund which has an even more prominent role in this [32]. Loans are intended for the construction or renovation of passive or very low-energy houses or for partial measures (installation and replacement of solar collectors, biomass boilers, heat pumps, ventilation with recuperation, external building fixtures, or heat insulation of the façade and roof).

From 2008 to 2011, the Eco Fund allocated 21,832,400 Euros in soft loans. This led to savings of 85,262.7 MWh in energy and 12,875.3 t CO₂. An important fact is that, in recent years, funds have been increasingly limited. The reduction in the amount of loans allocated is therefore not a reflection of reduced interest, but of limited possibilities (Table 1).

	Amount 1,000 Euros	Energy savings MWh	Savings of CO₂ t
2008	12,164.6	37,536.7	5,681.1
2009	5,531.9	22,658.1	3,410.5
2010	2,365.6	10,608.1	1,598.6
2011	1,730.3	14,453.0	2,184.1
Total	21,832.4	85,262.7	12,875.3

Table 1: Effects of loans with low interest rates [33]

3.5.3 Subsidies

Subsidies are incentives in the form of grants which are intended to reduce barriers to the introduction of new technologies which improve the environment and increase the energy performance of buildings. These technologies are more expensive than conventional ones, and are therefore not commercially attractive enough to be left to the laws of the market, so subsidies are needed. The level of subsidies is set so that they stimulate those buying conventional technologies to opt for more expensive but more environmentally friendly technologies. Financial aid in the form of subsidies usually comes from the state budget, but can also

be allocated by individuals or non-governmental organisations. Subsidies improve the environmental quality of products. It is highly suitable for wealthy governments to use this tool because it requires sufficient financial support. If financial support is insufficient or if the subsidy rate is too low, governments need to use a minimum environmental quality standard as a supplement [34].

3.6 The development of different methods - Certificates

In recent decades, several methodologies have been developed to assess the quality of buildings: in the UK, there is BREEAM (BRE Environmental Assessment Method [35]), in France HQE (Haute Qualite Environnementale [36]), the USA has LEED (Leadership in Energy and Environmental Design [37]), Germany has DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen [38]), and so on. These certificates demonstrate the environmental and energy indicators of buildings, as well as the economic, socio-cultural and technical aspects of construction.

The first widely used building assessment method was the BREEAM method which was developed in 1990 in the UK. It focused above all on the assessment of the building's influence on the environment and on the use of energy. It belongs to the methods of the first generation. The Green Building Challenge 98 also belongs to this group. It was the first attempt to develop a comprehensive assessment method from which the GBTool method was later developed. Another important first generation method is the American LEED which is globally the most widespread; then there is the Japanese CASBEE, the Australian GREEN STAR, and the French HQE. A building assessed with the help of first generation methods is defined as a so-called green building.

Second generation assessment methods (LEnSE, DGNB), which have been developed in recent years, deal with the building during its entire life cycle and also include economic, socio-cultural and technical aspects. With the inclusion of more aspects in the assessment process, the building is defined as a so-called sustainable building (Fig. 5).

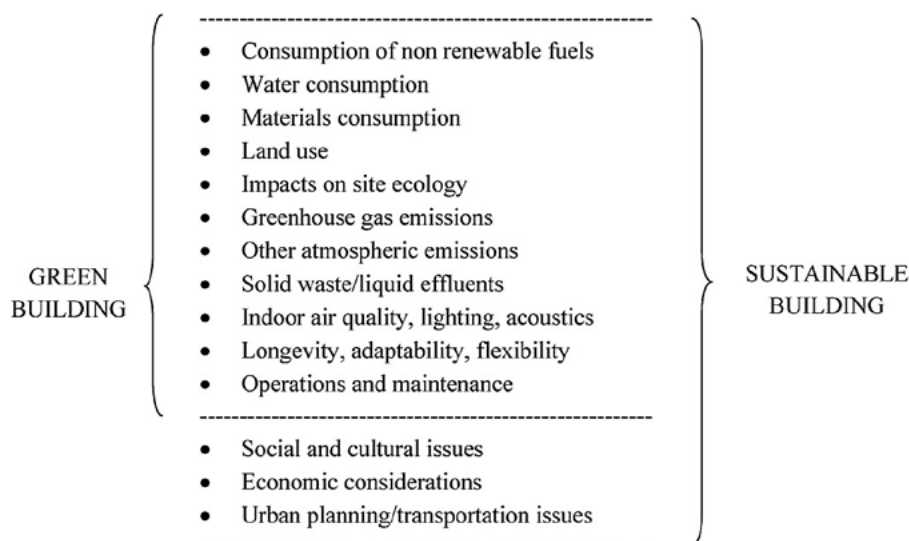


Figure 5: Aspects of assessment in first generation green building methods and in second generation sustainable building methods [Lowe & Ponce, 2008:39].

Most building assessment methods are based on already existing methods which have been upgraded or adapted to the circumstances and regulations in individual countries. Methods are adapted to the countries in which they have been developed as they follow national legislation, climatic conditions, level of development and economic status, as well as other characteristics. There are large differences between them, so the use of a method outside its home country is usually limited [40].

An overview of the development of building assessment methods in the current situation is presented in the form of a table (Fig. 6). The methods that have been developed on the same basis are marked with the same pattern. The name of the country in which the building assessment method was developed and is in use is written on the left-hand side. The coloured bands feature the names of the methods with the dates on which they were first used and the years in which the methods underwent important updates. For some methods,

the names of the countries in which the basic method was adapted for use in the assessment of buildings are listed under the band.

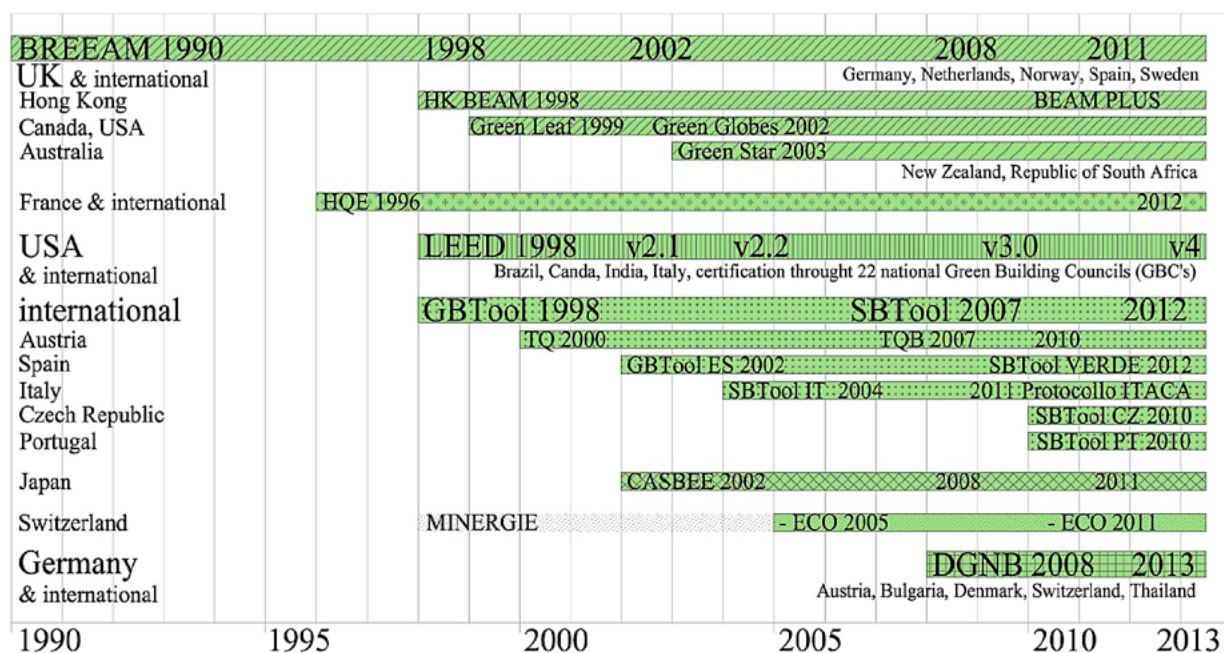


Figure 6: Table showing the development of building sustainability assessment methods.

During the building assessment process, individual criteria are given points, thereby producing a comprehensive final score that is simple to understand. On the basis of the final score, the building is classified in a certain class of demands that have been met, and it is given a simple and recognisable certificate: e.g. a golden sign. The final presentation of the assessment result is important, from the point of view of the building's promotion for the investors, as a quality guarantee for customers or users, for verification of the fulfilment of assessment demands for researchers and planners, as well as for determining the value of the property [41]. The use of assessment methods and the certification of a building are usually done on a voluntary basis. In some countries, buildings that have been publicly financed must be certified. In Germany, a method has been developed with the purpose of assessing new public buildings, and this has helped improve their quality.

4. ENVIRONMENTAL IMPACTS OF PRIMARY WOOD PRODUCTS

As sustainability becomes a greater concern, the environmental impact of construction and furnishing materials should be included in planning by considering the life cycle and embodied energy of the materials used. Therefore, Life Cycle Assessment (LCA) should be used to reveal the environmental and energy performances of the materials used throughout their whole life cycle.

The carbon footprints of selected primary wood products are presented in Fig. 7, calculated using the IPCC 2007 GWP 100a V1.02 method which was developed by the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change 2007). This method includes the climate change factors of the IPCC with a time frame of 100 years.

The products with the lowest carbon footprints are air-dried sawn timber and glued laminated timber. This is unsurprising because these products are processed less than wood-based composites. The glued laminated timber has a higher carbon footprint due to adhesives, but it is still negative. Wood has a negative footprint because of the carbon dioxide fixed by the original living tree. The emissions associated with harvesting, transporting and processing sawnwood products are small compared to the total amount of carbon stored in the wood. This means that even when the energy used for harvesting, transportation and processing are taken into account, sawnwood still has a negative footprint. Wood-based composite production requires additional energy inputs to process raw materials, to manufacture by-products, and to recycle wood into the desired form, as well as adhesives and other additives to form the composite matrices which considerably increases

the carbon footprint of these wood products. The highest carbon footprint among the products compared is plywood for outdoor use, followed by MDF and particleboard. Among the wood-based composites compared, oriented strand board has the lowest carbon footprint [20].³

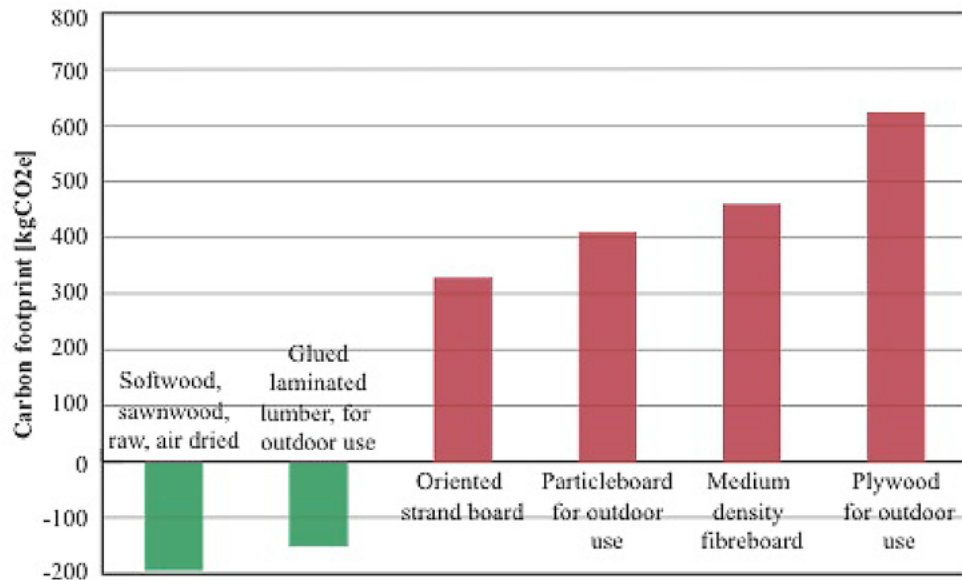


Fig. 7 Carbon footprint of 1 m³ of selected primary wood products from Ecoinvent 3.0 (2013).

5. CONCLUSION

The fact is that reducing dependence on fossil fuels is essential, and that a large proportion of energy savings can be made in the buildings sector. The efficient use of energy in buildings is required both by European and by national legislation. In recent years, various measures and mechanisms have been set up to promote the energy performance of buildings. These involve statutory limits on energy consumption in the form of rules and directives, promotions and education, financial support, and the certification of high-quality technology. Each of these measures has its own share in the current situation and a number of successful projects. The hierarchical distribution of these measures by success is most probably different in each country – depending on the strictness of law enforcement, the financial capacity of the country, the intensity of promotion and education of target audiences, and the success of adherence to the systems of certification in the market.

Considering the growing importance of energy-efficient building methods, timber construction will play an increasingly important role in the future. The positive trend towards wooden construction is dictated by international guidelines in which a wooden building is an important starting point, not only for low-energy, but also low-emission buildings with exceptional health and safety aspects.

³ More: Kitek Kuzman M., Kutnar A. Slovenian Contemporary Timber Architecture for Sustainability, Springer (2014) 170 p.

6. REFERENCES

- [1] Clift R. Climate change and energy policy: the importance of sustainability arguments. *Energy* 32 (2007)4:262-8
- [2] Feist W., Schnieders J., Dorer V., Haas A. Re-inventing air heating: convenient and comfortable within the frame of the Passive House concept, *Energy Build* 37 (2005)11: 1186-203
- [3] Jakob M. Marginal costs and co-benefits of energy efficiency investments - the case of the Swiss residential sector, *Energy Policy*, 34 (2006)2:172-87
- [4] Hallock Jr JL., Wu W., Hall CAS, Jefferson M. Forecasting the limits to the availability and diversity of global conventional oil supply: validation, *Energy* (2014) 64:130-53
- [5] Olabi AG. Developments in sustainable energy and environmental protection. *Energy* 39 (2012)1:2-5
- [6] Geng J., Ji Q. Multi-perspective analysis of China's energy supply security, *Energy* (2014)64:541-50
- [7] Olabi AG. State of the art on renewable and sustainable energy. *Energy* (2013)61:2-5
- [8] Europe's Energy Portal, <http://www.energy.eu/#top> (Accessed September 2013)
- [9] Europe's dependence, <http://www.energetska-ucinkovitost.si/energetska-odvisnost/evropska-odvisnost/> (Accessed August 2014)
- [10] Eurostat, Energy balance sheets 2009-2010, Statistical books, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-EN-12-001/EN/KS-EN-12-001-EN.PDF (Accessed August 2014)
- [11] Market Observatory for Energy, Report 2009, Europe's energy position – markets and supply. doi: 10.2768/20104
- [12] Sartori I., Hestnes AG. Energy use in the life cycle of conventional and lowenergy buildings: a review article. *Energy Buildig* 39(2007) 3):249-57
- [13] Audenaert A., De Cleyn SH., Vankerckhove B. Economic analysis of passive houses and low-energy houses compared with standard houses, *Energy Policy* 36 (2008)1:47-55
- [14] Popescu D., Bienert S., Schutzenhofer C., Boazu R. Impact of energy efficiency measures on the economic value of buildings. *Appl Energy* 89 (2012)1:454-63
- [15] Sorsak M., Žegarac Leskovic V., Premrov M., Goričanec D. Economical optimization of energy-efficient timber buildings: Case study for single family timber house in Slovenia. *Energy* (2014) 0360-5442
- [16] Daouas N., Hassen Z., Aissia HB. Analytical periodic solution for the study of thermal performance and optimum insulation thickness of building walls in Tunisia. *Appl Therm Eng* 30 (2010) 4:319-26
- [17] Balaras CA., Drousa K., Argiriou AA., Asimakopoulos DN. Potential for energy conservation in apartment buildings. *Energy Build* 31 (2000)2:143-54
- [18] Pulselli RM., Simoncini E., Marchettini N. Energy and emergy based costbenefit evaluation of building envelopes relative to geographical location and climate. *Build Environ* 44(2009)5:920-8
- [19] Gieseler UDJ, Heidt FD, Bier W. Evaluation of the cost efficiency of an energy efficient building. *Renew Energy* 29(2004)3:369-76.
- [20] Zegarac Leskovic V., Premrov M. *Energy-Efficient Timber – Glass Houses*, Springer (2013)177p.
- [21] Liu L, Zhao J, Liu X, Wang Z. Energy consumption comparison analysis of high energy efficiency office buildings in typical climate zones of China and U.S. based on correction model. *Energy* 65 (2014) 221-31
- [22] Cansino J.M., Pablo-Romero M. del P., Roman R., Yniguez R. Promoting renewable energy sources for heating and cooling in EU-27 countries, *Energy Policy* 39 (2011) 3803-3812
- [23] Action Plan for Energy Efficiency (2007-12), http://europa.eu/legislation_summaries/energy/energy_efficiency/l27064_en.htm (Accessed August 2013)
- [24] Energy efficiency, <http://www.energetska-ucinkovitost.si/energetska-ucinkovitost-v-stavbah/evropske-direktive/> (Accessed September 2013)



- [25] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings. Official Journal of the European Union, L1/65:168-173
- [26] Leal Filho W. Integrating environmental education and environmental management, Environmental Management and Health 8/4(1997) 133-135
- [27] Leal Filho W. (ed.) (2011). World Trends in Education for Sustainable Development, Peter Lang, Frankfurt am Main, Berlin, Bern, Bruxelles, New York, Oxford, Wien.
- [28] Eurobarometer (2011): Attitudes of European Citizens Towards the Environment http://ec.europa.eu/environment/pdf/ebs_365_en.pdf
- [29] Kitek Kuzman M., Kutnar A. Slovenian Contemporary Timber Architecture for Sustainability, Springer (2014) 170 p.
- [30] Baiardi D. Pigouvian tax, abatement policies and uncertainty on the environment. Journal of Economics (2011), Vol. 103 Issue 3, p221-251-251
- [31] Jian-bing, H., (2008). Tax/subsidy Model of Environmental Differentiation Competition of Products. <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4669083>
- [32] Eco Fund, Slovenian Environmental Public Fund, <http://www.ekosklad.si> (Accessed August 2014)
- [33] Eco Fund, Slovenian Environmental Public Fund, Annual Reports 2008, 2009, 2010, 2011, 2012, 2013
- [35] BREEAM, <http://www.breeam.org/> (Accessed August 2014)
- [36] HQE, http://www.interfaceflor.co.uk/web/sustainability/green_building/hqe (Accessed August 2014)
- [37] LEED, <http://www.usgbc.org/DisplayPage.aspx?CategoryID=19> (Accessed August 2014)
- [38] DGNB, <http://www.dgnb.de/> (Accessed August 2014)
- [39] Lowe, C., Ponce, A., 2008, UNEP-FI / SBCI'S Financial & Sustainability Metrics Report. An international review of sustainable building performance indicators & benchmarks, BRE / CSTB, http://www.unepfi.org/fileadmin/documents/metrics_report_01.pdf,
- [40] Cole, R. J. Building Environmental Assessment in a Global Market. SB10 Seoul: (2010) 124-127
- [41] Lützkendorf T. et al. Next generation of sustainability assessment – top down approach and stakeholders needs. 2011 WSBC Helsinki 2011.



Restoration of Existing Structures



DI Frank Lattke¹

Academic

Fachgebiet Holzbau,

Faculty of Architecture, Technischen Universität München



Technische Universität München
Fakultät für Architektur

lattke@tum.de

RESTORATION OF EXISTING STRUCTURES – POTENTIALS FOR TIMBER ENGINEERING

The use of timber and biogenic materials to upgrade buildings offers many solutions for an efficient reduction in total energy consumption, the purpose of which is to attain climate protection goals. Densely populated towns have hardly any extra space for new development. Existing buildings in nucleated towns present a great potential for building upgrading and subsequent redensification.² Most of the existing structures, especially residential buildings, are costly to maintain, inadequate in terms of energy savings, and do not meet the needs of their users.

These facts offer great possibilities for building engineering because the condition and insufficient energy-saving properties of such buildings in the first place call for a comprehensive and integral upgrading method.

One major contributions to a reduction in the emission of CO₂ into the atmosphere is a decrease in the thermal heat requirements of existing buildings by significantly improving the insulation of the building envelope. When it comes to thermal heat requirements, the majority of existing buildings need between 250 and 350 kWh/m², which significantly exceeds statutory benchmark values not to mention the efficiency of a passive house which stands for the best available technology.

The methods currently applied to improve the energy efficiency of the building envelope originate from the field of new construction, and are not specific enough for this task. Non-ergonomic working methods and the use of insulating and building materials that are not environmentally friendly also have just as negative an impact as cutting and processing on-site, and there are also the ensuing high dust and noise emissions, high waste and pollution levels, disturbance of the residential environment, and uncontrollable flow of materials to and from the construction site to consider. The embodied energy share that is already present in each building material increases additionally for the entire building due to such inefficient working methods.

Insulating materials made of mineral fibre or PUR foams are most commonly used to improve the energy efficiency of the building envelope. Such materials contain a large share of the embodied energy during the entire life cycle. The issue of an environmentally acceptable way to disposal of them still remains outstanding. In this respect, prefabricated systems and the use of feedstock that will grow again constitute only a marginal exception.

When compared to other building materials, timber offers huge advantages for the restoration of existing structures because prefabricated timber elements reduce construction time, their weight is much lower, and the CO₂ balance sheet and ecological profile are more positive.

In terms of full energy cycles, biogenic materials, wood, and its many by-products in particular, could gain true importance only if appropriate building systems were available.

¹ Frank Latte

Born in 1968, from 1989 to 1992 apprenticed as a cabinet maker, then studied Architecture at Technischen Universität München (Germany) and Escuela Técnica Superior de Arquitectura de Madrid (Spain).

In 2000 flew to Brisbane/Australia, where he worked as an architect at Donovan Hill Architects. In 2001 he came back to Europe and opened his own business in Augsburg, Germany.

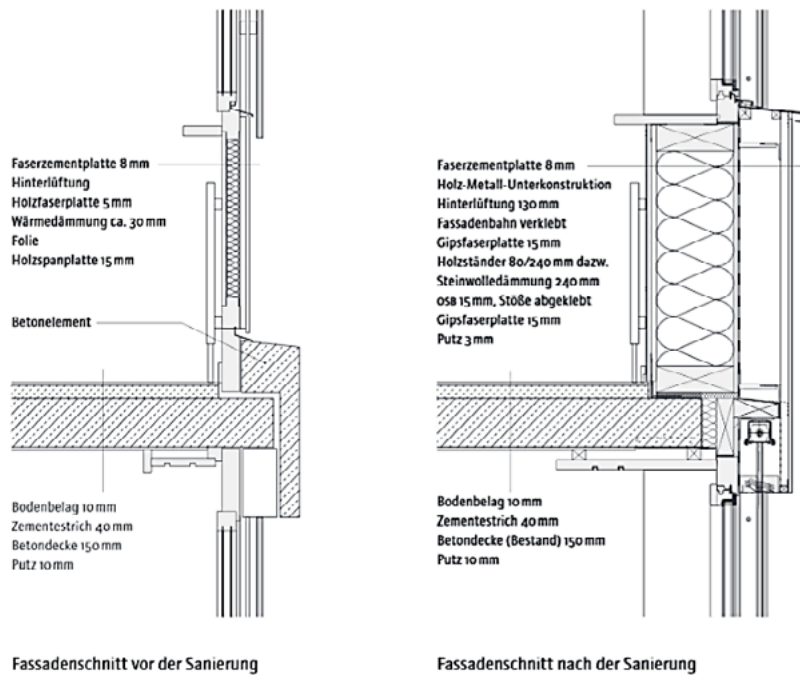
Since 2002 he also has been working in Research and Teaching at Fachgebiet Holzbau (directed by Prof. Hermann Kaufmann), at the Faculty of Architecture of TU Munich.

Project coordinator in the international research projects TES EnergyFacade (WoodWisdom-Net, 2007-2010) and smartTES (WoodWisdom-Net, since 2010), he is currently involved in the implementation of E2ReBuild and leanWOOD Projects.

² Definition of domestic architecture in a study: single-family house, multi-family house, annexes and renovation.



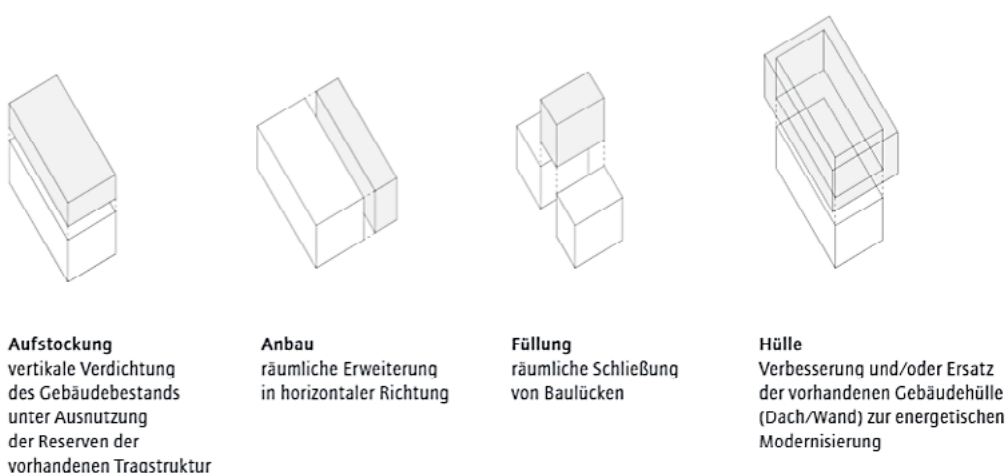
Existing structures require retrofit methods that are cost-effective and that can be applied quickly, precisely and without too much disturbance. With different levels of prefabrication, timber engineering provides solutions to that effect. The manufacturing process relies on precision and efficiency; fabrication processes are standardised, optimised and fully controlled to ensure a high level of quality.



CONTINUING DEVELOPMENT – A METAMORPHOSIS OF ARCHITECTURE

Any intervention in existing structures is always a change of a building's external appearance. Naturally, there are also building regulations to be followed, and the economic and technical targets of an extensive refurbishment exercise. This is an opportunity to add new value to the existing structures by applying solutions that are highly demanding in terms of design. It is a task for which timber, as a material for lighter building methods, can be used in many ways – as a replacement for individual construction elements to annexes and extensions with modules.

With respect to the requirements of building regulations and the design itself (fire protection, earthquake protection, noise protection, stability of the existing structure, foundation soil/settlement, building class/building law, distance space, parking lots), a distinction can be made between the following interventions in existing structures:



PREFABRICATED BUILDING ENVELOPS FOR UPGRADING EXISTING BUILDINGS

High insulation timber elements can be quickly mounted on-site. For this reason, they are an interesting alternative to the more common methods of improving the energy efficiency of the building envelope (composite heat insulation systems made from polystyrene or mineral rock wool, aluminium or steel unitised façades). A maximal level of prefabrication is a requirement for the production of ever-larger elements that react differently to building geometry and spatial structure, from high insulation panels to extension modules.

Different stages of prefabrication determine the degree to which an element will be completed so that it can leave the shop and be assembled on-site.

Different completion stages can be distinguished for load-dispersing and statically active structural elements (beams, plate), from binding together individual elements to the production of non-insulated panels and finished walls, ceilings and roof units that contain all structural layers and fenestration. Modules are units with a high level of prefabrication that are first assembled from ceiling and wall elements in the shop, and then transported to the construction site as ready-to-mount elements where the assembly process is completed. The selection of the completion stage depends on the construction project and the technical specifications.



Zunahme der notwendigen Präzision

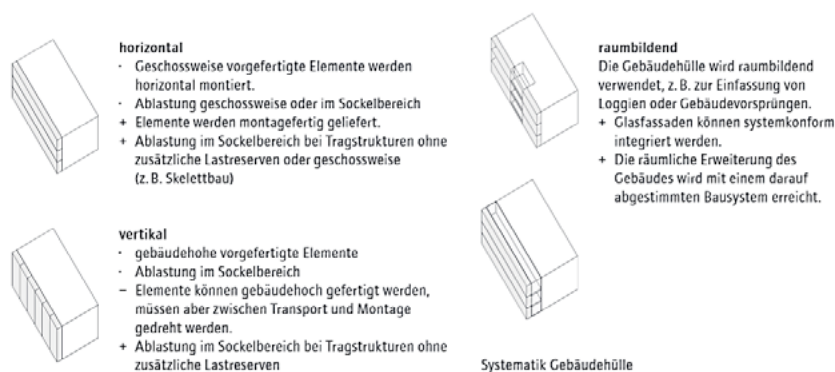
The use of prefabricated building elements saves construction time on-site, and consequently causes less disruption to work or home activities. Besides residential buildings, public buildings such as schools, kindergartens and administrative buildings often have to be rehabilitated without closing them for works. This is a decisive argument for the use of fully prefabricated elements.

In general, a distinction can be made between horizontal and vertical wall elements, and elements for spatial partitioning, depending on the dimensions and assembly directions.

Similar to timber frame or panel construction, the elements for upgrading energy efficiency of the building envelope are composed of a statically active bearing structure (e.g. KVH, BSH or joist), an insulation base, a panelling (e.g. statically active and/or active fire protection), an air- and/or wind tight layer, and a cladding layer.

The load-dispersing structure allows additional loads (e.g. balconies) and the use of different cladding systems and materials (timber, engineered wood, glass, metal, etc.).

The same as with new buildings, there are fire protection regulations to be observed that allow the use of timber and engineered wood for buildings type 4 and 5 provided that general protection requirements are met. In this respect, it is crucial to avoid cavities and to have a superstructure with an appropriate fire resistance rating in order to prevent any danger from large sections falling in the case of fire.



Windows, posts and beam façades, or some extra special elements such as active solar façades (Lucido ®, gap solution) or components (photovoltaic, solar energy), can be easily incorporated as their use is compatible with timber building methods taking into account the size of each module and the applied orthogonal design system. Thus, they integrate well in a prefabricated building envelope.

To what extent the integration of these elements in the prefabrication is justified depends on the specific set of circumstances. A prefabricated panel with integrated components and ready top surfaces requires a higher level of precision, more control of the application of engineering tolerance, and more opportunities for corrections. Decades of experience in the division between fabrication and on-site assembly have resulted in the extraordinary quality of modern timber constructions.

Prefabricated timber units have to be made dimensionally stable and accurate to fit perfectly. The outer and window edges in particular have to be nearly identical. The more such elements match, the less time- and money-consuming on-site work is needed. An accurate and precise drawing of the existing building is of paramount importance.

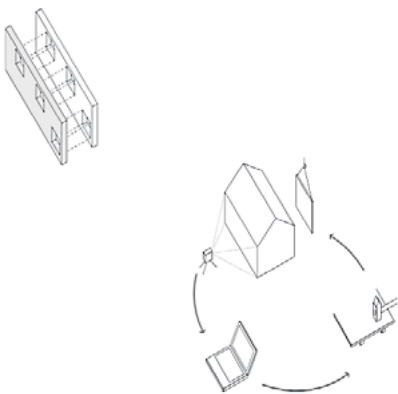
New measuring techniques (photogrammetry, laser scanning) record and deliver precise data about a building to create a 3D model to serve as the basis for planning, prefabrication and assembly.

In an age of digital and three-dimensional planning, the smooth transfer of data is the basic requirement for a proper interaction between all stakeholders in a construction project.

CONCLUSION

Timber engineering offers various solutions for the tasks to be undertaken in the future: the upgrading and further energy efficient retrofit of existing buildings. From simple basic elements to integrated technical components and complete modules for new storeys or annexes, the advantages are easily adaptable building elements, short construction time on-site, and less disruption in running operations and at the construction site.

There are still untapped opportunities for timber engineering – first, it has to be convincing by delivering quality and precision and by transferring the level of expertise in new developments to projects upgrading existing buildings.



TES EnergyFacade³ is an international research project (2008-2014) at the Technical University in Munich with the aim of showing opportunities for applying the advantages of a prefabricated timber building in order to improve the energy efficiency of the building envelope. The project has produced a detailed catalogue containing fundamental principles of design and a digital, uninterrupted process chain from data capturing (by means of photogrammetry, tachymetric and 3D laser scanning), planning and prefabrication to assembly. Over the course of the project, a systematic overview of the application of prefabricated timber construction for upgrading energy efficiency will be prepared and illustrated by already existing buildings. It is intended to be for designers and timber craftsmen alike. Download: www.tesenergyfacade.com

.....
³ TES EnergyFacade (timber-based elements system for improving the energy efficiency of the building envelope) is a European research project, the call for proposals was launched by WoodWisdom-Net, supported by BMBF, project management TU Munich, 2008/2009.

Calculations for multi-storey residential timber constructions - assessment criteria used in construction management and construction economics

Jörg Koppelhuber / David Zügner / Detlef Heck

Graz University of Technology, Institute for Construction Management and Economics

In the last 20 years, modern timber construction has been recorded as a positive trend in the construction sector due to new technological discoveries and developments. What was hard to imagine with timber as a building material only a few years ago is possible today with new building materials obtained from timber as a raw material. Systems are made with the help of the latest technology materials that make it possible to eliminate the statistical restrictions of a linear building material, and to compensate by means of surface application. This makes building multi-storey buildings in timber possible, which has so far been subject to considerable restrictions because of legal framework requirements, not because of the properties of the material itself.

1. INTRODUCTION

As experience shows, arguments for the use of timber for the construction of multi-storey residential buildings are mainly to be looked for in the environmental aspects of modern building materials, not in terms of financial assessments and comparability to traditional building materials. In contrast to many considerations, often not based on research, timber offers the possibility of a cost-efficient and comparable building material in the case of multi-storey residential buildings. This should be proven and verified.

The paper below presents an analysis of a project study which includes an objective and comparable cost analysis of multi-story residential buildings made of different building materials. The issue concerning the results of using timber as a building material for multi-storey residential buildings is clarified from the point of view of production costs.

2. INITIAL STATE OF AFFAIRS OF MULTI-STORY RESIDENTIAL TIMBER CONSTRUCTION

Assessing the initial state of affairs in the field of multi-storey residential timber construction with regard to it as a whole, and to its economic impacts in, detail requires some explanations beforehand.

2.1 Residential multi-storey timber building market

Building multi-storey timber houses has a long tradition in central Europe. Five or more storey timber buildings were already the dominant form of dwelling centuries ago. Strict fire protection regulations and the mass-production of other building materials led to an almost complete expulsion of this building material from the residential construction sector. The development of new timber products in the last twenty years, such as cross-laminated timber for example, has enabled multi-story timber construction to gain a foothold again. The market share of this construction technique in the entire Austrian building industry is actually small.



The figure below shows the timber construction share in the entire residential construction sector in Austria on the left, and details relating to multi-family houses on the right.

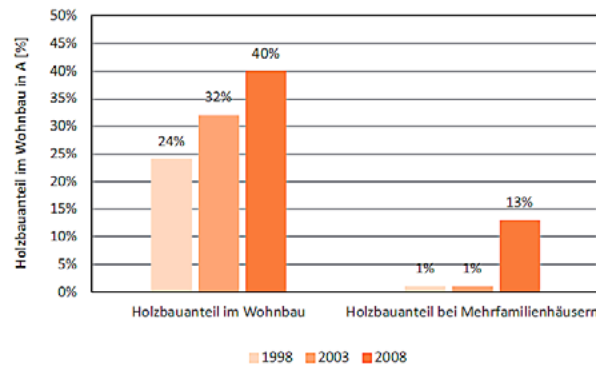


Figure 1

Holzbauanteil im Wohnbau in A [%] = timber construction share in residential construction in Austria [%]

Holzbauanteil im wohnbau = timber construction share in residential construction

Holzbauanteil bei Mehrfamilienhäusern = timber construction share in the case of multi-family houses

The data shows that, in 2008, four out of ten approved building projects in the Austrian residential construction sector were carried out using timber, and that the share was very small when it came to the construction of multi-storey residential buildings. However, the currently observed trend points to an apparent increase in the timber construction share in Austria as far as multi-storey residential buildings are concerned.

Due to latent ambiguities about the interpretation of legal regulations and much stricter guidelines relating to fire protection, timber construction is for the most part regarded as a "special solution". As a result, planners and builders have it difficult when making a decision about the building material.

In spite of these reservations, many outstanding projects have emerged in Europe in the last few years. These include, for example, the newly built eight-storey Murray Grove residential building and Bridport House in London, the nine-storey Via Cenni residential building in Milan, the planned construction of the 13-storey Treet residential tower in Norway, and the world's highest residential timber building at the moment, Forté Living in Melbourne which has 10 storeys.

Although the technical know-how and timber products for such structures originate in Austria, their implementation in Austria is falling behind. Nevertheless, there are positive tendencies in this respect, judging from the efforts of individual architects, timber construction companies, developers and manufacturers of cross-laminated timber.

2.2. Technical aspects of the initial state of affairs

Thanks to the development of laminar timber building products, cross-laminated timber (CLT), the possibility of building multi-storey buildings had changed fundamentally by the end of the 20th century. Cross-laminated timber is a timber product consisting of at least three layers of solid wood laid on top of each other at right angles and glued together. The crosswise arrangement and gluing result in a material with a diaphragm and slab action that may be used as a laminar wall, ceiling or roof building element. In timber construction, this enables planar-like or monolithically designed architectural concepts to be put into practice, similar to mineral solid construction, as cross-laminated timber elements also have a stiffening function in load-bearing systems as well as a load dispersal function. Another positive aspect can be found in the visible quality of a prefabricated surface area for interior design¹.

The world cross-laminated timber market is constantly growing thanks to the previously mentioned properties of this product, and its special suitability for multi-storey buildings. In 2012, for example, two thirds of the world cross-laminated timber production came from Austria. This corresponds to a volume of 432,000 m³ a year².

Restrictions on the use of timber for construction are strongly influenced by diverging building regulations. In

¹ See Informationsdienst Holz, Bauen mit Brettsperrholz (2012) 4

² See Schickhofer, Holz-Massivbauweise in Brettsperrholz (Präsentation Kolloquium ETH Zürich 2011) 12.

Austria, according to the building regulations currently in force, four-storey timber buildings may be erected pursuant to building type IV of OIB Guideline³. From building types V and upwards – more than four storeys – a 90-minute fire resistance is required for all building components. This regulation also includes a non-combustible top surface (Euro-class A2). For attaining the required protection goals, a fire protection concept may serve to compensate for these requirements, which can be done by implementing structural measures such as lining with mineral materials or by means of systems engineering measures like automatic fire extinguishing systems. In the light of current research concerning the fire and protection issue and the discoveries made over the last years, a question arises concerning the adjustment of the regulations in force according to OIB so that the building material may become fully appreciated. Such measures significantly influence the production costs of multi-story timber constructions⁴.

3. CALCULATION

In order to illustrate the building materials and the impact of the number of storeys as well as construction costs, we have compared three-storey (abbrv.:G3) and eight-storey residential towers (abbrv.:G8) made of cross-laminated timber as examples of the solid timber construction technique with towers made of armoured concrete and brick as examples of the solid mineral construction technique.

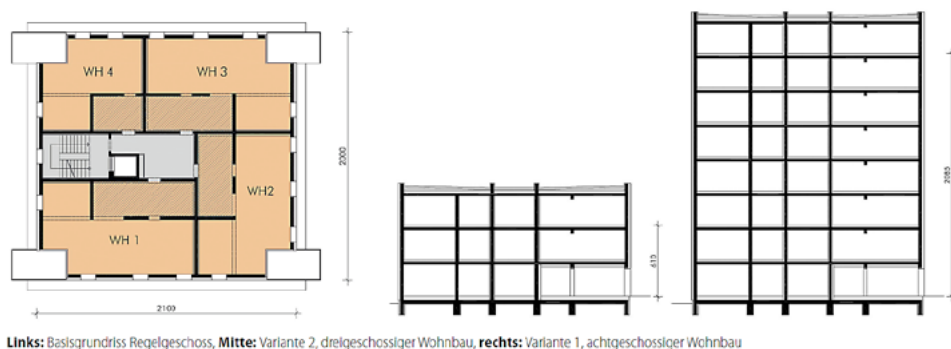


Figure 2

Left: basic floor plan, typical storey;
middle: variant 1 three-storey residential building;
right: variant 2 eight-storey residential building

3.1. Assessment Criteria used in Construction Management

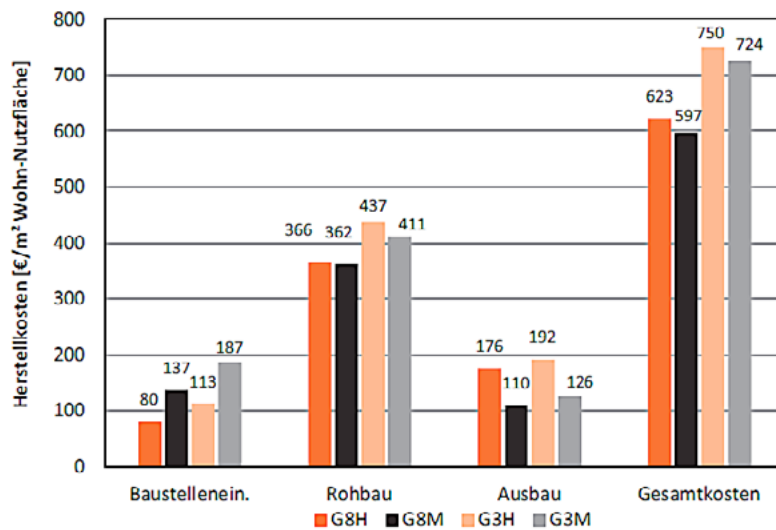
For creating a comparable structural and physical foundation, we have calculated the production costs of the so-called shell construction/Edelrohbau/, structured as building site equipment, shell and finishing (plasterwork, dry lining and ETICS-works) for both building materials and for both building heights. These construction costs, calculated according to Önorm B 2061 standard, are presented in the figure below in relation to the respective usable surfaces. Accordingly, the production costs of the shell construction for the solid mineral construction technique in case of three- and eight-storey residential buildings are lower by some 7%. This figure would further decrease when considering total construction costs (proportional shell construction/total construction costs). The costs of the shell construction for the solid timber construction technique and the solid mineral construction technique are about the same.

The big advantages exhibited by timber construction include shorter construction times and the lower costs of building site equipment. Finishing represents an important cost driver, with its high wages and its materials share in terms of the dry lining required to comply with fire protection regulations according to OIB-Guideline 2.

³ Technical Guidelines of the Austrian Institute for Structural Engineering /Österreichisches Institut für Bautechnik/ (OIB).

⁴ Teischinger/Stingl/Zukal, Holzbauanteil in Österreich (2011) 12.

Figure 3: Comparison between the production costs of shell construction in relation to usable surfaces divided into individual finishing stages



Herstellkosten [Eur/m² - Wohn-Nutzfläche] = Production costs [Eur/m² - usable surface]

Baustellenein. = Building site

Rohbau = shell equipment

Ausbau = finishing construction

Gesamtkosten = total costs

3.2 Economic aspects

Usable area: the slight wall thickness of the solid timber construction creates 3% more living and usable area, provided that the façade alignments remain the same. This increase in usable area can bring additional income from renting and sales revenues that can compensate for the expected higher construction costs of a timber building.

Cubature: the use of cross-laminated timber for the bearing structure reduces the weight of the structure by 80 to 90%. The achievable reduction in the number of truck trips may be set at a factor of 1:10. It is also connected to lower emissions.

Shortened construction time: dry lining, a high degree of prefabrication and the quick assembly of the shell of a building contribute to a reduction in construction time by 40 to 50%.

4. CONCLUSION

Costs incurred in the construction of a building shell using solid timber are only slightly higher than those incurred when using mineral materials. However, they can be converted into a financial benefit provided that basic planning guidelines, optimal ground plan design and consistent project implementation are taken into account. Timber construction companies have to engage in research and development in order to take full advantage of solid timber. It is necessary to bring the statutory requirements regarding fire protection in line with the latest research results. Efficient production with a high degree of prefabrication results in shorter construction times, higher quality, and thus profitability.

Furthermore, construction management and planning require the application of far-reaching norms, and the development of complete construction systems that provide full solutions. In future, all of these issues will be more intensely tackled by timber construction companies and prime contractors alike in close cooperation with architects and urban planning experts.

Source:

Zügner, D.: Die Holz-Massivbauweise im mehrgeschossigen Wohnbau - Ein kalkulatorischer Vergleich zur mineralischen Massivbauweise. S. 1ff;

Hohensinn, J.; Strobl, M.; Zinganel, P.: Timber in Town – Masterplan Konzepte. Report. S. 92

bl, M.; Zinganel, P.: Timber in Town – Masterplan Konzepte. Report. S. 92

Fire Safety in Timber Buildings

Martin Teibinger

1. GENERAL INTRODUCTION

Parts of the population still consider that ensuring fire protection when using combustible construction methods is not realizable, or realizable only with difficulty. The evolutionarily established fear of fire and the collective memory of historical fire catastrophes are too great. Thus, extensive fire catastrophes have represented a risk for centuries, above all in cities. Talking about these catastrophes today, scarce development within fortifications, the carefree handling of open fire, the missing or simple fire-fighting measures, and the combustible roof coverings, which represented the essential reasons for the emergence and fast expansion of the fires, are hardly considered. On the part of the authorities, specifications with regard to preventive fire protection were established step by step in order to eliminate the causes of fire outbreak.

Several research projects on the fire safety of timber constructions have proven the safety of timber houses. New fire design concepts and models have been developed based on fire testing. Many European countries have started to revise their regulations to allow multi-storey timber houses. European research projects, e.g. the wood wisdom project “Fire In Timber”, have identified major differences between national regulations in terms of the number of permitted storeys and the possibility of using visible wooden surfaces, see Figure 1. Some countries, e.g. Sweden and Italy, have no limitation on the number of timber storeys allowed. However, there is an economic and practical limit for pure timber constructions of between eight and ten floors in height. In combination with concrete supporting structures, this limit may even be higher.

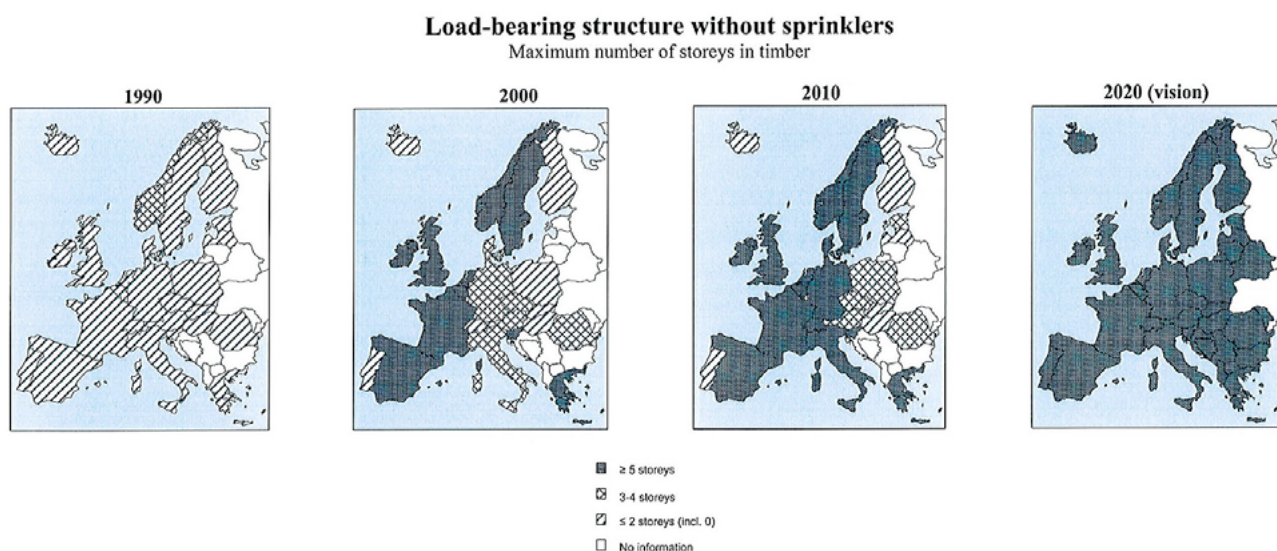


Figure 1: Restrictions on the use of timber structures for higher buildings set by national prescriptive regulations have been eased in Europe over the last decades. A further increase in permitted use is expected. [Östman et al, 2010]

2. FIRE STAGES

In principle, a fire can be subdivided into two stages, see Figure 2. At the incipient fire stage, slow, low temperature increases occur. This stage can be further subdivided into ignition and smouldering fire phases. At this stage, the fire behaviour of claddings and coverings used is decisive (construction material behaviour), since this can contribute to a fire spreading. At the time of the so-called flashover, there is a sharp increase in temperature. Any combustible substances and gasses in the fire compartment suddenly ignite. A flashover must be reckoned to be between seven and fifteen minutes following the emergence of a fire, depending on the fire load and ventilation conditions. In natural fire tests under "optimal" conditions, flashovers have been generated after only 30 seconds. From this time onwards, a fully developed fire is assumed which can be subdivided into heating and the cooling phases. This stage concerns the component behaviour. Requirements are made of the fire resistance of the components.

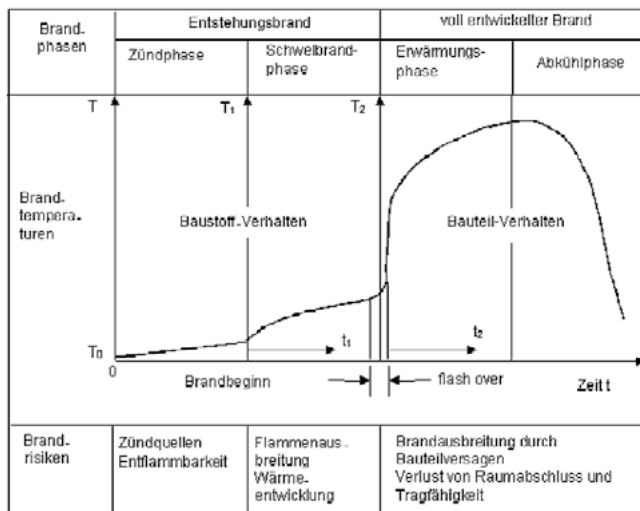


Figure 2: Fire stages, source: [Schneider, 2009]

Mixing the requirements, for example R30 or A2, means that a combustible component must have a fire resistance of 30 minutes, while there are no requirements for the fire resistance of a non-combustible component. Due to the different protection targets according to the fire stages shown in Figure 2, this requirement is not expedient.

2.1 Reaction of construction materials to fire

Flammability, combustibility, flame propagation and smoke development, as well as charring speed, represent essential properties for the assessment of construction materials in respect to their reaction to fire. Since these properties depend on numerous factors, standardized tests are performed to compare the fire behaviour of the individual construction materials. The standard for construction products was withdrawn and replaced by [EN 13501-1].

The classification of construction materials, with the exception of floor coverings, is undertaken according to [EN 13501-1] as follows:

Table 1: Classification of reaction to fire classes according to EN 13501-1.

Fire behaviour	Smoke development		Dripping off and/or falling off
A1, A2	Non-combustible	s1 Smallest portion	d1
B, C, D, E, F	Combustible	s2	d2
		s3	d3

In order to reduce the resulting required testing and classification effort, the European Commission offers the opportunity to apply classifications without further testing (cwft) for construction materials with known reactions to fire and defined material properties. In compliance with the decision of the European Commission 2003/43/EC, construction timber for use as wall, ceiling, roof or special components must be allocated to the Euro class D-s2-d0 according to [EN 13501-1].

A summary for timber and timber materials can be found at www.holzforschung.at and the complete list at www.eur-lex.europa.eu. Error: sorgente del riferimento non trovata shows the fire behaviour of selected construction materials by way of example.

2.2 Fire resistance

2.2.1 General

Requirements for fire resistance are always applied to the entire component. Considered by itself, plaster cladding normally cannot provide sufficient fire protection.

For fire protection classes R, E and I, contrary to former fire resistances (F classes), a distinction can be made between load-bearing and/or fire compartment-forming components.




Abbreviation	Requirement	Figure
R	Load-bearing capacity	
E	Separating function	
I	Thermal insulation	

Table 2: Designations for fire resistance according to ÖNORM EN 13501-2 (extract), figures from [Östman et al., 2010].

Designation	Requirement	Component example
R 30, R 60, R 90	Load-bearing component	Column, wall, girder
EI 30, EI 60, EI 90	Thermally insulating component with separating function	Non-load-bearing, separating components, shaft walls, penetration seals, glazing
REI 30, REI 60, REI 90	Load-bearing, thermally insulating component with separating function	Load-bearing, separating component

Table 3: Examples of designations for fire resistance.

For substantiation, classification reports according to [EN 13501-2] on the basis of fire resistance tests according to EN 1364 or EN 1365 can be used.

For timber components, there is also the possibility of performing calculations according to [EN 1995-1-2] in combination with the respective national application documents. Calculation examples for timber components can be found at [Östman et al., 2010].

2.2.2 Dimensioning of the load-bearing capacity R of timber frame components

The dimensioning of timber structures in the case of a fire is undertaken according to EN 1995-1-2 in combination with the national annexes, wherein the dimensioning of the load-bearing capacity of timber frame components can be calculated according to Appendices C and D of EN 1995-1-2. The rules apply up to a maximum fire resistance time of 60 minutes under standard fire load. Appendix C is used for fully insulated (mineral wool) and Appendix D for non-insulated timber frame components. In general, the calculative load-bearing capacity of a timber frame structure must be equated with the falling off of the boarding (failure time t_f can be determined according to ÖNORM B 1995-1-2). In the case of a timber frame structure insulated with rock wool, Appendix C permits the calculation of a residual timber cross-section and thus the verification of the load-bearing capacity. However, it must be ensured that the insulation is secured against falling out, otherwise there will be no further calculation, even with a structure insulated with rock wool. If the rock wool is not secured against falling out, failure of the component must be assumed with the failure of the boarding.

Buckling analysis takes place around the strong axis, i.e. out-of-the-plane. It is assumed that the boarding remains intact on the side facing away from the fire and thus the bracing effect is maintained, which prevents buckling around the weak axis. Similarly, for exterior walls, the strength of the external cladding (especially in the case of directly clad composite thermal insulation systems) must be tested. Details of the calculations of fire resistance according to the standards and an outlook on possible changes can be found at [Östman et al., 2010].

When using alternative insulating materials as infillings, the classification reports of the producers or those at www.dataholz.com are commonly used as verification.

2.2.3 Dimensioning of the load-bearing capacity R of x-lam elements

2.2.3.1 Charring rate β_0 for cross-laminated timber with unprotected surfaces

The charring rate value of coniferous wood is 0,65 mm/min according to [EN 1995-1-2]. This value may be used for the top layer. Due to temperature influences, a softening of the glue line may occur if polyurethane adhesives are used, which may result in the carbon layer coming off in small structures. Until a carbon layer of about 25 mm is formed from the nearest layer exposed to fire, the charring rate is doubled [Frangi et al. 2008; Östman et al 2010]. These combustion rates have been confirmed based on experimental investigations [Teibinger and Matzinger 2010].

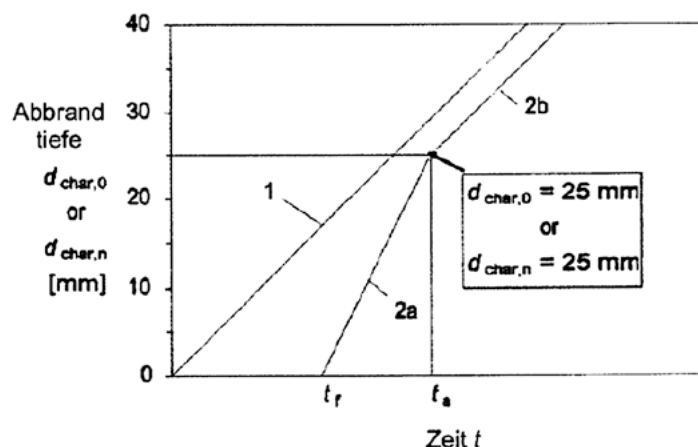


Figure 3: Representation of increased burn-off of another layer if the carbon layer of the top (2a) falls off, reduced combustion if a carbon layer of 25 mm is formed (2b), and constant burn-off without flaking off of the carbon layer (1), source: [EN 1995-1-2].

The charring rate values shown in Table 4 were determined through loaded large-scale fire tests [Teibinger and Matzinger 2010] and have to be used in the calculations. If deviation value rates are available that have been determined through large-scale fire tests, these may be used for calculations. Charring rates determined from small-scale fire tests cannot be compared with values determined from large-scale fire tests.

Ply	Component	Carbon layer of top ply comes off?	β_0 [mm/min]
Top ply	Wall Ceiling or roof	---	0.65
Further plies	Ceiling or roof	yes	1.3
Further plies	Ceiling or roof	no	0.8
Further plies	Wall	yes	0.9
Further plies	Wall	no	0.7

Table 4: Charring rate values β_0 for cross-laminated timber elements depending on the bonding of individual plies.

2.2.3.2 Charring rate values β_0 for cross-laminated timber with initially protected surfaces

When the surfaces of cross-laminated timber elements are initially protected from fire, the starting point of combustion behind the planking t_{ch} and the failure time of the planking t_f are crucial.

With wooden composite boards and type A and H gypsum boards, according to [EN 520], failure time t_f is equated with the start of combustion of the wooden construction t_{ch} . The standard states the formulae for calculating t_{ch} for individual fire protection claddings. After the start of combustion and the falling off of the planking, which is equated with the former, an increased rate of combustion (twice as high according to the standard) occurs on the basis of a charcoal layer that does not form until the point of time t_a . After a burn-up depth of 25 mm, the usual rate of combustion returns again. This corresponds to the course of combustion with delamination occurrences of the top ply, see Figure 4.

With type F gypsum plasterboards, according to [EN 520], the combustion rate is reduced from the start of combustion until the fire protection cladding fails; subsequently, a double and then a constant rate of combustion occurs until a 25 mm thick carbon layer has formed, see Figure 4. The start of combustion is calculated according to [ÖNORM EN 1995-1-2] where the thickness of the external cladding and 80 % of the internal cladding thickness are used for multilayer cladding.

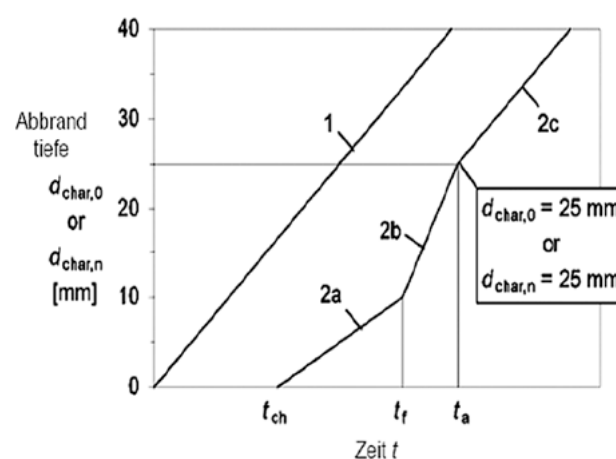


Figure 4: Representation of burn-up depth as a function of time for $t_f > t_{ch}$ for type F gypsum boards and DF or GKF planked woods, source: [EN 1995-1-2].

For gypsum plaster fire protection boards (GKF) and gypsum fibreboards, no failure time points t_f (boards coming off) were available, thus dimensioning was possible only within limitations. Based on investigations by

Holzforschung Austria [Teibinger and Matzinger 2010], the following failure times were included in [ÖNORM B 1995-1-2] for these boards:

Wall:	$t_f = 2,2 \cdot h_p + 4$
Ceiling:	$t_f = 1,4 \cdot h_p + 6$
t_f :	Failure time [min]
h_p :	Cladding thickness [mm]

Values were determined from experimental results using clad timber frame elements. These are to be used for cross-laminated timber elements with suspension or facing shells. In the case of directly clad cross-laminated timber elements, these values may be used when distinctly higher failure times are expected. Single experiments have shown that the failure time t_f for cross-laminated timber elements directly clad with GKF may be higher by up to 200% than those with timber frame components.

2.2.3.3 Structural design of load-bearing capacity R of cross-laminated timber elements

The mechanical properties of wood are diminished in the temperature range between 25°C and 300°C when wood is heated. For this reason, two simplified methods of calculation – the reduced cross section method and the reduced properties method – are shown besides a detailed calculation in [EN 1995-1-2]. The use of the reduced cross section method with a factor of $k_0 \cdot d_0$ for the determination of the ideal burn-up depth has taken root in Austria. The value for d_0 stated in the current standard and taken from the simplified method of calculation of the reduced cross section method is currently under international discussion.

2.2.4 Dimensioning of the separating function EI of timber-constructions

The separating function EI for timber elements can be verified according to the model stated in [ÖNORM B 1995-1-2], which was elaborated by [Schleifer, 2009]. Contrary to the calculation method according to Appendix E [EN 1995-1-2], the model shows the possibility of expandability with other materials, as well as a wider range of calculable build-ups. The model was designed for fire resistance durations of up to 60 minutes, and has also been included in the standard with this limitation. Validation calculations with large-scale fire tests performed within the scope of [Teibinger and Matzinger, 2010] show that the model can also be applied in an engineering manner for 90 minutes.

3. CONSTRUCTIVE RECOMMENDATIONS FOR ELEMENTS

3.1 Laying of electrical installations in partition walls in timber frame constructions

In principle, for partition walls in timber frame constructions, it is recommended to assemble the electrical installations in facing formwork. Upon laying in the load-bearing infill, compensation measures, e.g., the use of tested fire protection sockets or enclosures of the cavity sockets with non-combustible panels (variants 2 and 3 in *Erre: sorgente del riferimento non trovata*5), are required. Using a plaster bed as a compensation measure is not recommended for practical construction reasons. If the infill insulating material is mineral wool with a melting point ≥ 1000 °C, a minimum raw density of 30 kg/m³ and a minimum thickness of 5 cm, the compensation measures stated can be omitted. In this case, the distance of the installations to the timber upright for load-bearing components should be higher than 15 cm (variant 1 in Table 5).



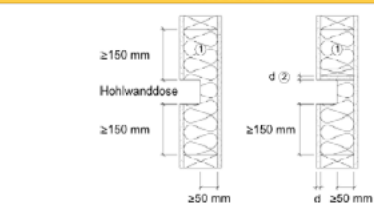

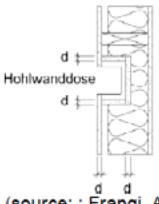
No.	Compensation	Illustration
1	Rock wool	 <p>1) Melting point $\geq 1000\text{ }^{\circ}\text{C}$, raw density $\geq 30\text{ kg/m}^3$ secured against displacement/falling out 2) No requirement with non-load-bearing components (source: Frangi, A. et al., 2007)</p>
2	Hollow wall socket with Intumescent materials	 <p>(source: http://www.baulinks.de/webplugin/2006/1272.php4)</p>
3	Plaster enclosures	 <p>(source: : Frangi, A. et al., 2007)</p>

Table 5: Compensation possibilities for the direct installation of electrical installations in partition walls

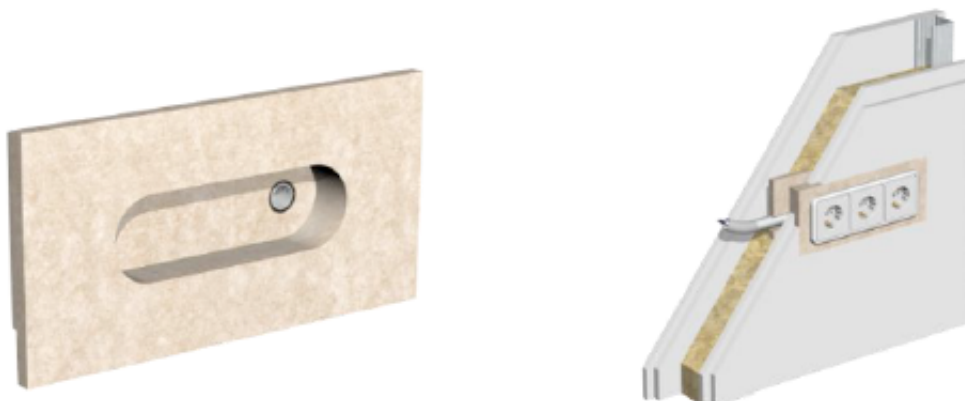


Figure 5: Examples of the installation of power outlets with plaster enclosures, source: company Air Fire Tech.

3.2 Penetration through partition walls

In principle, penetration through partition walls should be avoided. If it cannot be avoided, the penetrations must be sealed off with certified systems. Details based on fire tests are given in [Teibinger, Matzinger, 2012]

3.3 Interspace in double-shell partition walls

The interspace in double-layer partition walls must be insulated with mineral wool in any case. A continuous air layer is not admissible for technical fire protection and sound insulation reasons (due to the possibility of connection). By increasing the distance of the two walls or by using asymmetrical build-ups, the sound insulation coefficient can be optimised.

4. CONNECTION DETAILS FOR FIRE COMPARTMENT-FORMING COMPONENTS

4.1 Basic technical rules

In the following, the structural details for fire compartment-forming timber components are explained in an overview. The developed details were derived from exploratory small fire tests of wall and ceiling connections in timber frame and solid timber constructions, according to the standard temperature-time curve, which were performed within the scope of a research project by Holzforschung Austria [Teibinger, Matzinger, 2008]. Here, investigations of the connections for a fire resistance of 60 minutes were undertaken, wherein any variants in timber frames and in solid timber constructions fulfilled the requirements in the area of the connecting joint, too. With respective build-ups, detailed designs of up to 90 minutes are likewise possible. Thus, for example, in the course of a further research project by Holzforschung Austria on the fire resistance of timber structures [Teibinger, Matzinger, 2010], amongst other things, 33 stressed large fire tests of timber frame walls were performed. For load insertion, an auxiliary ceiling structure in cross-laminated timber construction clad with plasterboards was fastened to the wall elements with a screw distance of 500 mm in all cases. In the area of the joint between the auxiliary ceiling and the wall, no additional technical fire protection measures were provided. There was not a single case where there was increased charring in the connection area or a failure in the area of the joint when the test duration varied between 30 and 120 minutes.

4.2 Connection of the fire compartment-forming partition wall to the exterior wall

With respect to the detailed design, the basic rules stated in the section 4.1 Basic technical rules apply. In addition, the joint between the two walls must be completely filled with mineral wool.

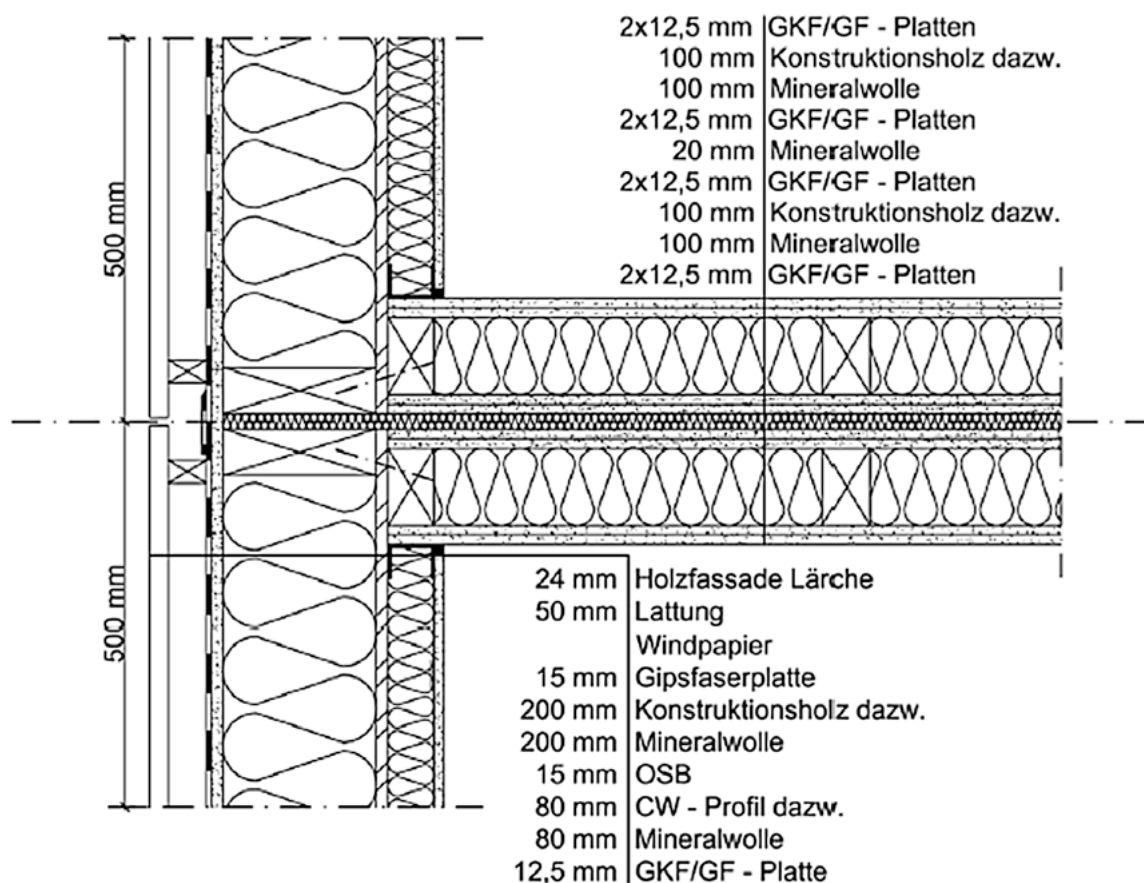


Figure 6: Connection of a fire compartment-forming partition wall to an exterior wall. 0.5 m from the axis of the fire compartment-forming wall, the exterior wall should have a fire resistance of 90 minutes. No electrical installations must be installed into the partition wall without compensation measures or facing formwork. Source: [Teibinger, Matzinger, Dolezal, 2014]

More Details are given in [Östman, et al, 2010], [Teibinger, Matzinger, 2013] and [Teibinger, Matzinger, Dolezal, 2014].

5. VERTICAL DISTRIBUTION

Shafts are used for the vertical distribution of the installations across the individual utilisation units or fire compartments. With respect to the position of the sealing measures of penetrations, there is a distinction between a type A shaft and a type B shaft.

5.1 Type A shaft

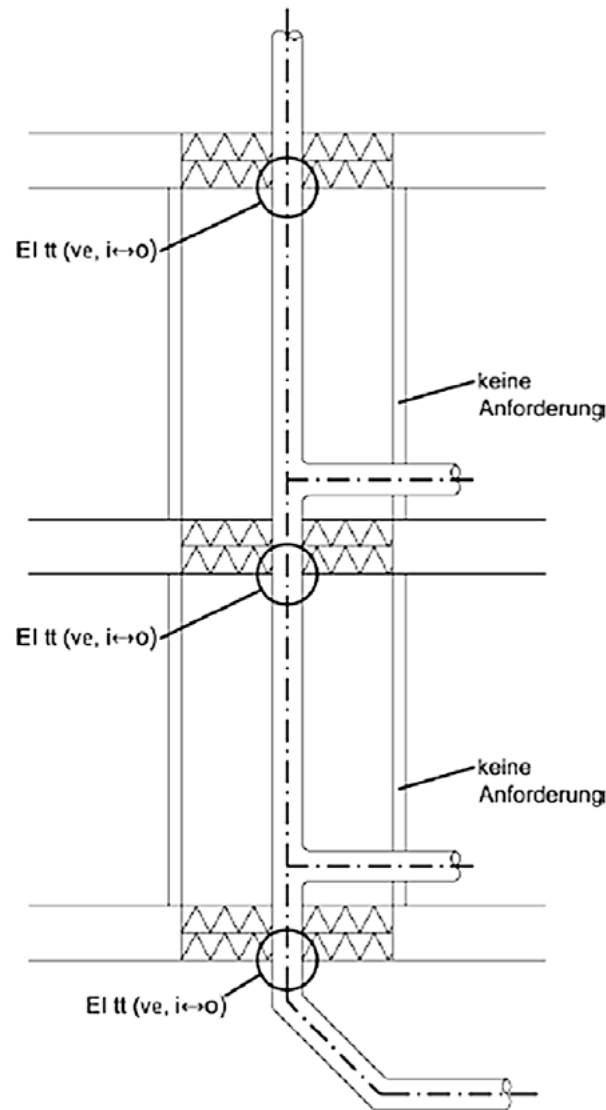


Figure 7: Schematic diagram of a type A shaft, source [Teibinger, M.; Matzinger, I. 2012]

For a type A shaft, the fire resistance requirements are applied to the shaft walls and their penetrations. The requirements are applied from the outside to the inside, as well as from the inside to the outside, since, for e.g. in the case of revision work, a fire could occur in the shaft.

The shaft must be sealed off horizontally between the first above-ground floor and the basement floor, as well as between the topmost floor and the undeveloped attic. Plasterboard stud structures are normally used as shaft walls. These must be classified and executed according to requirements, likewise so must the sealing systems of the penetrations through the shaft wall. For revision openings, tested and classified revision flaps are likewise available from the manufacturers.

Shafts are frequently erected in corners or in interior walls. When the circumferential shaft walls are erected in timber constructions, these are provided with non-combustible cladding on the inside of the shaft, and must fulfil the fire resistance requirements of shaft walls.

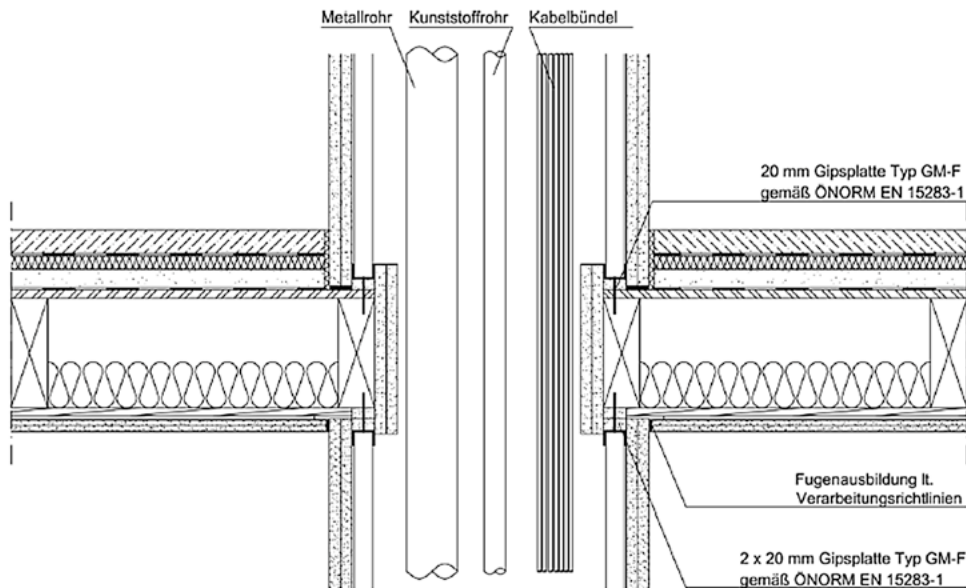


Figure 8: Exemplary design of a penetration of a type A shaft with a timber frame ceiling. Source: [Teibinger, M.; Matzinger, I. 2012]

The reveal of the ceiling opening must be clad in a non-combustible manner to allow for 60 minutes of fire resistance, plasterboard fire protection panels of at least 2 x 12.5 mm must be used. It must be ensured that the plasterboard reveal cladding rests on the timber over the entire surface. Otherwise, the timber surface and the joint between plaster and timber must be coated with an intumescent product. Upon thermal stress, intumescent products effect the closure of residual openings by foaming, and thus prevent the penetration of smoke and toxic gasses.

Should the corners of the opening not be sharp-edged due to production, then the edges of the plasterboards must be adjusted and the joint likewise coated. In the area where the tested and classified shaft wall connects with the timber elements, two strips of type GM-F plasterboard with a width of 50 mm and a thickness of 20 mm, according to [EN 15283-1], must be fastened to the timber ceiling on the shaft's inside.

5.2 Type B shaft

For this type, no fire requirements apply to the shaft walls. Storey by storey, the shaft is sealed off horizontally according to the requirements of ceiling fire resistance. Soft or hard seals in combination with fire protection pipe sleeves, strand insulation and the like can be used as sealing systems.

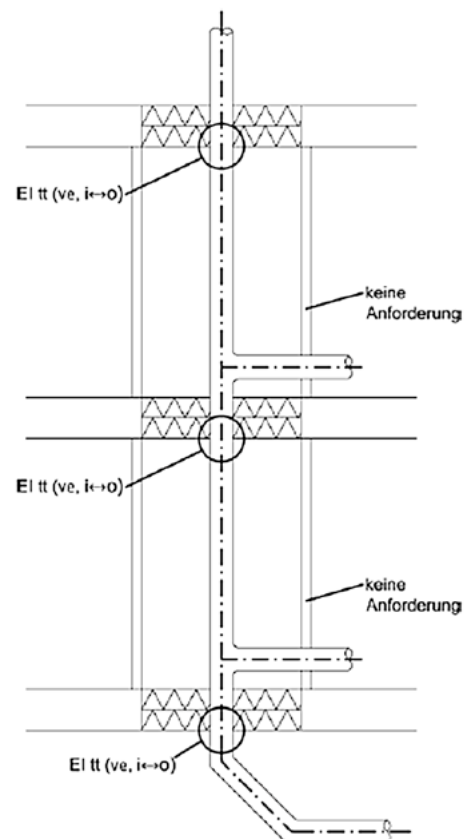


Figure 9: Schematic diagram for type B shaft, source: [Teibinger, M.; Matzinger, I. 2012]

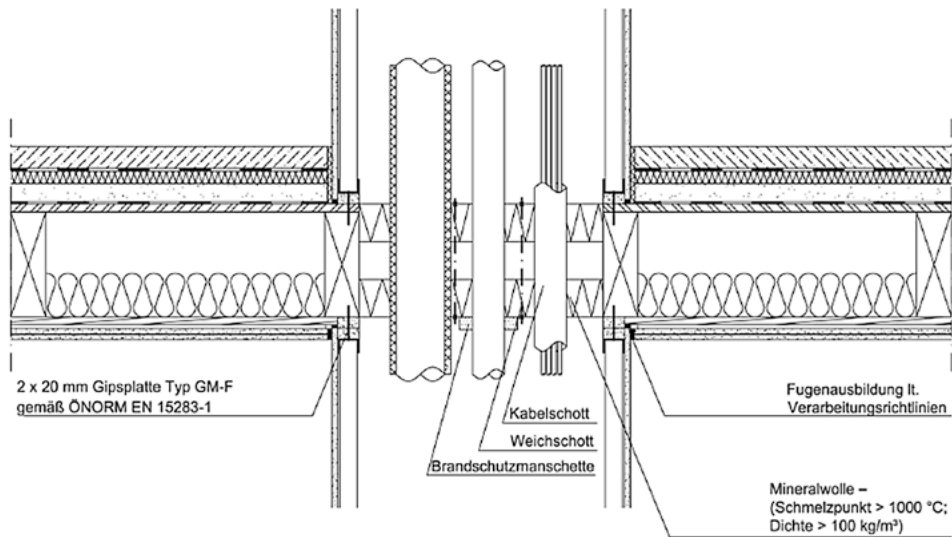


Figure 10: Exemplary design of a horizontal sealing in the area of a timber frame ceiling (type B shaft). Source: [Teibinger, M.; Matzinger, I. 2012]

On the bottom of the ceiling, two strips of type GM-F plasterboard with a width of 50 mm and a thickness of 20 mm, according to [EN 15283-1], must be fastened to the timber ceiling on the shaft's inside, see Figure 10. In the area of the penetration seal, the ceiling reveal must not be clad. Exposed timber surfaces in the shaft must be clad in a non-combustible manner.

For type B shafts, no fire protection requirements apply to the shaft walls, which is why these may also be executed single-layered. In order to fulfil sound insulation requirements, it is recommended to execute them multi-layered or to insulate the shafts.



6. REFERENCES

- EN 1366-3, 2009-05-01: Fire resistance tests for service installations – Part 3: Penetration seals.
- EN 1995-1-2, 2011-09-01: Eurocode 5: Design of timber structures – Part 1-2: General – Structural fire design (consolidated version).
- EN 13501-1, May 2007: Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests.
- EN 13501-2, 2012-02-15: Fire classification of construction products and building elements – Part 2: Classification using data from fire resistance tests, excluding ventilation services.
- EN 15283-1, 2009-10-01: Gypsum boards with fibrous reinforcement – Definitions, requirements and test methods – Part 1: Gypsum boards with mat reinforcement.
- Frangi, A.; Fontana, M.; Knoblauch, M. (2008): Fire Behaviour of Cross-Laminated Solid Timber Panels. Herausgegeben von ETH Zürich. Institute of Structural Engineering.
- ÖNORM B 1995-1-2: 1/9/2011: Eurocode 5: Design of timber structures - Part 1-2: General – Structural fire design - National specifications concerning ÖNORM EN 1995-1-2, national comments and national supplements. Austrian Institute for Standardisation
- Östman, B.; et al. (2010): Fire safety in timber buildings. Technical guideline for Europe. Published by SP Trätekt. Stockholm.
- Schleifer, V. (2009): Zum Verhalten von raumabschließenden mehrschichtigen Holzbauteilen im Brandfall. Dissertation. Supervised by M. Fontana, A. Frangi and J. König. Zurich. Federal Institute of Technology Zurich, Institute for Building Physics and Construction.
- Teibinger, M.; Matzinger, I. (2010): Grundlagen zur Bewertung des Feuerwiderstandes von Holzkonstruktionen. Endbericht. Holzforschung Austria. Vienna.
- Teibinger, M.; Matzinger, I. (2012): Fire-resistant Sealing in Timber Construction. Planning Brochure. Holzforschung Austria. Vienna.
- Teibinger, M; Matzinger, I. (2013): Construction with Cross-laminated Timber in Multi-Story Buildings – Focus on Building Physics. Planning Guide. Holzforschung Austria. Vienna.
- Teibinger, M; Matzinger, I.; Dolezal, F. (2014): Timber Frame Construction in Multi-Story Buildings – Focus on Building Physics. Planning Guide. Holzforschung Austria. Vienna.



LEAD PARTNER

Slovenian Forestry Institute, Slovenia

PROJECT PARTNERS

- ▶ INFORMEST, Italy
- ▶ Wood Industry Cluster, Slovenia
- ▶ Technological Pole of Pordenone, Italy
- ▶ Wood Cluster Styria, Austria
- ▶ Regional Development Agency Centru, Romania
- ▶ Agency for Sustainable Development and Eurointegration - ECOREGIONS, Bulgaria
- ▶ Zala County Foundation for Enterprise Promotion, Hungary
- ▶ Local Development Agency PINS, Croatia
- ▶ Development Association NERDA, Bosnia and Herzegovina
- ▶ University of Belgrade, Faculty of Forestry, Serbia

ASSOCIATED PARTNERS

Friuli Venezia Giulia Autonomous Region

Central Directorate for Education, University, Research, Family, Associations and Cooperative Entrepreneurship,
Service for Education
University and Research, Italy

Ministry of Agriculture and the Environment
of the Republic of Slovenia, Slovenia

Ministry of the Economy
of the Republic of Slovenia, Slovenia

Tuzla Canton, Ministry of Agriculture, Forestry and Water Management,
Bosnia and Herzegovina



