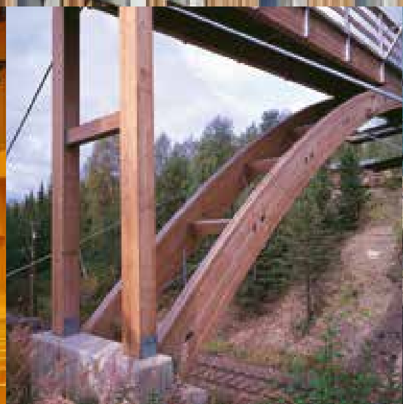
“Tackle climate change: build with wood”



Build with wood - reduce CO_2 emissions

Wood and wood-based industry is part of the solution to a competitive low carbon economy.

The European woodworking and furniture sector plays an essential role in the development of a green economy using wood, a natural renewable raw material. Using a renewable material with low carbon footprint and improvements of energy performance of buildings to reduce emissions provide low-cost and short term opportunities to reach the policy goals. The main opportunities are the storage of carbon in wood and wood products, the potential offered by the substitution of other (energy or carbon intensive) materials and the efficient eco-cycle of wood products.

It is cost efficient to build with wood and wood also offers a great potential to modernizing existing, older buildings.

Numerous international scientific studies have found that wood in constructions involve lower GHG emissions. This booklet shows some results using standard methods to calculate the environmental impact of using wood in constructions.

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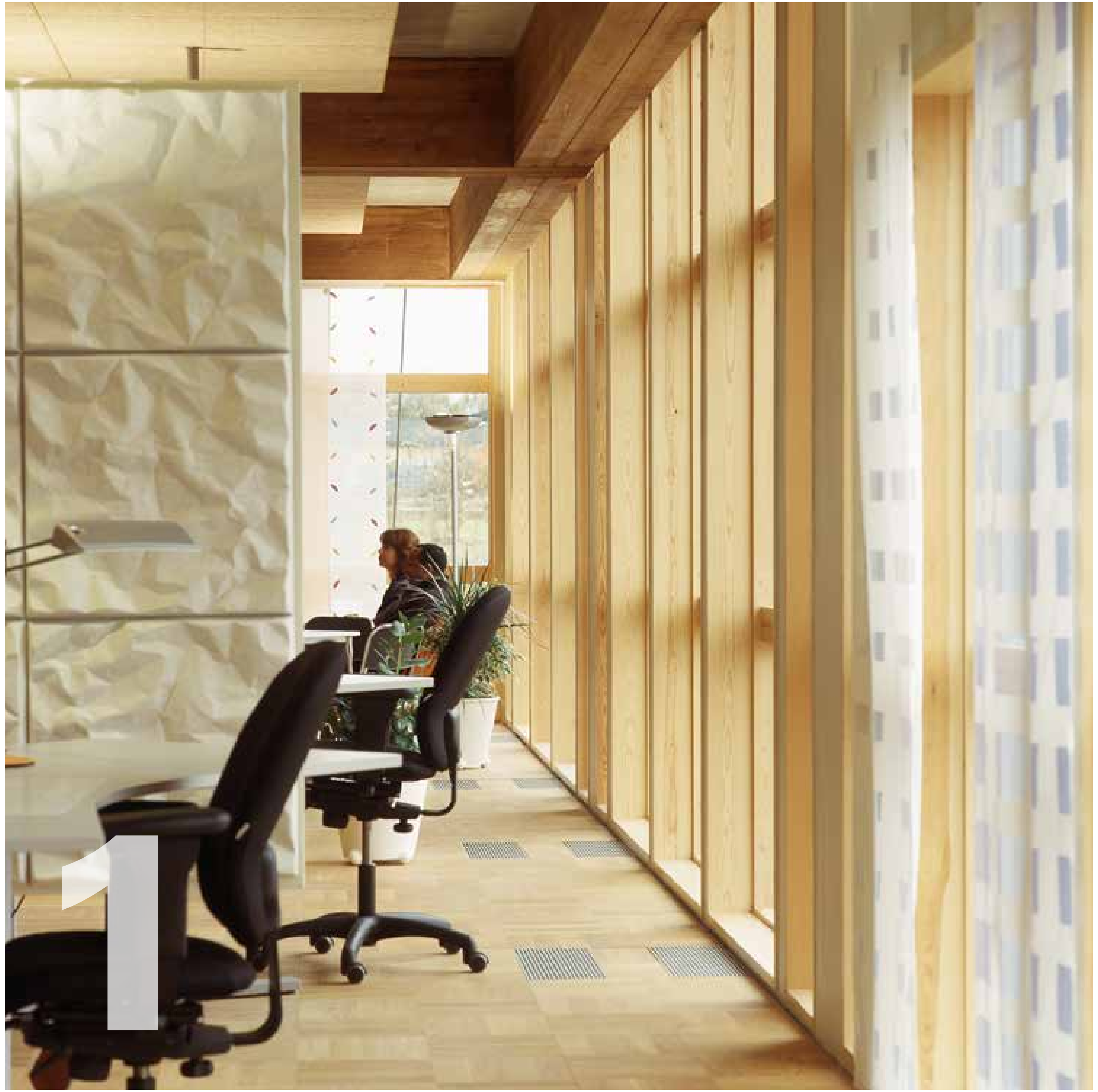
Large cover photo:
Building: School of Architecture Umeå, Sweden.
Nominated in the The Timber Prize 2012. The Timber Prize is a prize of honor endowed by the Swedish Forest Industries Federation.

Content



Introduction

The construction sector is responsible for a great deal of the resources used. In Europe the building sector accounts for 40% of the energy demand, 36% of greenhouse gas emissions, 40% of material consumption and 33% of generated waste[1]. The environmental issues are therefore getting more and more important in building planning.

In March 2011, the Commission published a Communication entitled, "A Roadmap for moving to a competitive low-carbon economy in 2050"[2]. This Roadmap builds on the Europe 2020 flagship initiative for a resource-efficient Europe as part of a series of long-term policy plans in areas such as transport, energy and climate change. The Communication sets out key elements that should shape the EU's climate action helping the EU become a competitive low-carbon economy by 2050.

The aim of Roadmap 2050 is to cut greenhouse gas emissions by 80-95% of 1990 levels by 2050 in order to keep climate change below 2°C.

The EC Roadmap 2050 also points to the role of the built environment in achieving the 80% reduction target. The built environment provides low-cost and short-term opportunities to reduce emissions, first and foremost through improvement of the energy performance of buildings. The Commission's analysis shows that emissions in this area could be reduced by around 90% by 2050, a larger than average contribution over the long-term. This underlines the importance of achieving the objective of the recast Directive on energy performance of buildings stating that new buildings built from 2021 onwards will have to be almost zero-energy buildings.

Efforts will need to be strengthened significantly over time. Today, new buildings should be designed as intelligent low- or zero-energy and carbon-efficient buildings. Wood and wood-based products have a specific role to play in this context. Indeed, there is a strong development potential for woodbased construction in structural and non-structural applications, both for new buildings and for renovation purposes.

[1] COM (2007) 860 final
[2] COM (2011) 0112 final

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Wood and climate change

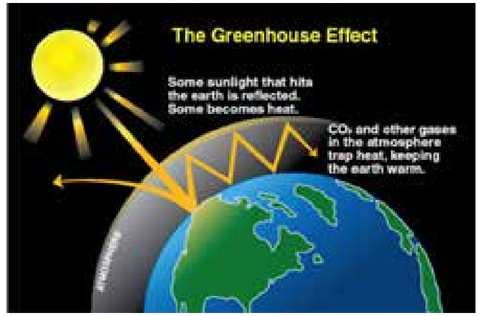
2.1
Climate change – is happening NOW

“Climate change is happening now and affects all aspects of our society”

Climate change has long-since ceased to be a scientific curiosity, and is no longer just one of many environmental and regulatory concerns. Global warming is the major, over-riding environmental issue of our time. It is affecting our society in economic, health and safety, food production, security, and other aspects.

Shifting weather patterns, for example, threaten food production through increased unpredictability of precipitation, rising sea levels contaminate coastal freshwater reserves and increase the risk of catastrophic flooding, and a warming atmosphere aids the pole-ward spread of pests and diseases once limited to the tropics.

Figure 1:
The Greenhouse effect



Solar radiation at the frequencies of visible light largely passes through the atmosphere to warm the planetary surface, which then emits this energy at the lower frequencies of infrared thermal radiation. Infrared radiation is absorbed by greenhouse gases, which in turn re-radiate much of the energy to the surface and lower atmosphere. The mechanism is named after the effect of solar radiation passing through glass and warming a greenhouse.

There is alarming evidence that important tipping points, leading to irreversible changes in major ecosystems and in the planetary climate system, may already have been reached or passed. Ecosystems as diverse as the Amazon rainforest and the Arctic tundra, for example, may be approaching thresholds of dramatic change through warming and drying. Mountain glaciers are in alarming retreat and the downstream effects of reduced water supply in the driest months will have repercussions that transcend generations. Climate feedback systems and environmental cumulative effects are building across Earth systems, demonstrating behaviours we cannot anticipate.

The potential for runaway greenhouse warming is real and has never been more present. The most dangerous climate changes may still be avoided if we transform our fossile fuel based energy systems towards renewable energy sources and renewable materials such as wood.

2.2 Climate change – a political challenge

“Climate change requires quick and profound political actions to reach EU's climate targets ”

As 85% of the energy necessary to run our societies comes from fossil fuels, a reduction in emissions of this order would involve politically unarchievable cuts in our energy consumption. In short, the efforts necessary to stabilize the concentrations of greenhouse gases within the required time frame of roughly 100 years are not consistent with our current vision of development based on a steady increase in global consumption.

The Europe 2020 Strategy for smart, sustainable and inclusive growth includes five headline targets that set out where the EU should be in 2020[3]. One of them relates to climate and energy: Member States have committed themselves to reducing greenhouse gas emissions (GHG) by 20%, increasing the share of renewables in the EU's energy mix to 20%, and achieving the 20% energy efficiency target by 2020. The EU is currently on track to meet two of those targets, but will not meet its energy efficiency target unless further efforts are made.

[3] COM(2010) 2020 final

The document describes the cost-effective pathway to reach the EU's objective of cutting greenhouse emissions by 80-95% of 1990 levels by 2050 in order to keep climate change below 2°C.

The EC Roadmap 2050 mentioned in the introduction (Chapter 1) points to the role of the built environment in achieving the 80% reduction target. As a matter of fact the built environment provides low-cost and short-term opportunities to reduce emissions, first and foremost through improvement of the energy performance of buildings. The Commission's analysis shows that emissions in this area could be reduced by around 90% by 2050, a larger than average contribution over the long-term. This underlines the importance of achieving the objective of the recast Directive on energy performance of buildings, that new buildings built from 2021 onwards will have to be almost zero-energy, carbon-efficient buildings.

Political efforts will need to be strengthened significantly to ensure both that the building stock becomes energy efficient and that the potential of selecting building material with low-carbon emissions and the potential of storing additional carbon in buildings can develop fully.

2.3 Multiple climate benefits of using wood to mitigate climate change

“There are significant CO_2 savings to be made by using timber in the construction of housing and other buildings, both in terms of GHG emissions and in terms of embodied energy and in energy efficiency. At the end of their service life, wood products can in most cases be recycled, thus extending the carbon storage effect, and/or be used as a carbon neutral fuel in cascade use, substituting fossil fuel sources ”

Due to the unique combination of renewability and biogenic origin, wood and wood-based products have the potential to play a key role in transforming our economy from an unsustainable fossil fuel driven society towards sustainable development.

There are two ways to reduce CO_2 in the atmosphere: either by reducing emissions, or by removing CO_2 from the atmosphere and storing it - reducing 'carbon sources' and increasing 'carbon sinks'. Wood has the unique ability to do both.

2.3.1
Increasing carbon sinks

Figure 2 :
Sustainable forestry carbon cycle

(Source: CEI-Bois, Tackle climate change, 2009)

Trees absorb CO_2 during growth via photosynthesis. The carbon is locked in the wood and stored in the wood product until the carbon is released again as CO_2 during combustion processes or natural decay. Then, the carbon cycle of sustainable forestry is closed. In addition, wood has the potential to be a substitute for other, more energy intense materials, whilst it can be a substitute for fossil fuels when combusted, either as bioenergy from forest biomass or residual wood from wood at the end of its service life.

The carbon cycle

Carbon is present in our environment in a variety of different carbon reservoirs: dissolved in oceans; in the biomass of plants or animals, whether living or dead; in the atmosphere, mostly as CO_2; in rocks (limestone, coal…); etc. This carbon is being exchanged continuously between the different carbon sources and sinks in a process called the 'Carbon Cycle'.

The imbalance between current CO_2 emissions from the combustion of fossil fuels, and the required reductions from a climate perspective, is so acute that it will not be enough just to reduce CO_2 emissions. Carbon sinks will also have to be increased, and one of the simplest ways to increase carbon sinks is to increase the use of wood.

Forests as a carbon sink

Thanks to photosynthesis, the trees in a forest can trap large amounts of CO_2 and store it in wood. Some 0.9 tons CO_2 is trapped in every cubic metre of wood. Sustainably managed forests ensure a stable or even increased carbon storage effect, while most of the CO_2 of the trees harvested from a managed forest continues to be stored throughout the life of the resulting wood product.

Wood products as a carbon store

Wood products are carbon stores. They play an important role in enhancing the effectiveness of forest carbon sinks, both by extending the period that the CO_2 captured by forests is kept out of the atmosphere and by encouraging increased forest growth.

According to recent estimates, the average life of wood products varies between 2 months for newspapers and 75 years for structural wood. The longer the better for the environment, not least because it makes better use of forest resources. As long the CO_2 remains stored in the wood, any increase in the global volume of 'wood storage' will reduce the CO_2 in the atmosphere. So increasing the use of wood from sustainable sources is one simple way of reducing climate change.

2.3.2
Reducing emissions of carbon dioxide

Substitution of other materials

There is no other commonly used building material that requires so little energy to produce as wood.

Thanks to photosynthesis, trees are able to capture CO_2 in the air and combine it with the water they get from the soil to produce the organic material, wood. This process of photosynthesis also produces oxygen; all the oxygen we breathe and on which all animal life relies comes from the photosynthesis activity of plants and trees. So, from every molecule of CO_2, photosynthesis produces two key components essential to life: carbon, around which all living materials are built, and oxygen, on which all animal life relies.

Not only is the production and processing of wood highly energy-efficient, giving wood products a very low-carbon footprint, but wood can often be used as a substitute for materials like steel, aluminium, concrete or plastics, which require large amounts of energy to produce.

In most cases the energy necessary for processing and transporting wood is less than the energy stored by photosynthesis in the wood. Every cubic metre of wood used as a substitute for other building materials reduces CO_2 emissions to the atmosphere by an average of 1 to 2.5 t CO_2[4].

[4] Bafu (2007), Werner & Richter (2007), Sathre & O'Connor (2008), Albrecht et al. (2009), Lundmark et al. (2014)

2.4
The role of wood products in supporting forests

"A forest that pays is a forest that stays; sustainable forest management ensures carbon-neutral long-term wood supply"

Contrary to the commonly held belief that there is a direct causal link between using wood and the destruction of forests, increasing the use of wood makes a positive contribution to maintaining and increasing forests. Clearly there is a distinction to be made between tropical or sub-tropical forests, and temperate forests.

In the former, forest cover is indeed being reduced for a number of reasons linked to population growth, poverty and institutional deficiencies. However, in many cases increasing wood use is not a primary contributing factor. On the contrary, it creates a market value for forests, which is a powerful incentive to preserve them. The saying that 'a forest that pays is a forest that stays' may be a simplification, but it illustrates a simple truth: a forest's survival depends, broadly speaking, on its value to the local community. As noted during the Earth Summit of Rio in 1992, conserving tropical forests is more often considered by the countries concerned as an obstacle to their own development than an ecological necessity. In providing energy, arable or pasture land, or simply more space, deforestation is frequently seen as a solution rather than a problem. Developing a market for wood helps owners and governments to see forests in a different way and to recognize their contribution to local and national economies. As soon as the prosperity of a local community is seen to be associated with the presence of a forest, the principles of sustainable management begin to be respected.

In all European regions, forest area has increased since 1990. Europe is the only region to have a positive net change in forest area for the past 20 years. Europe has gained 5.1 million ha of forest and other forest land since 2005 and 16.69 million ha since 1990. The total standing volume in Europe in 2010 amounted to 96,252 million cubic metres, of which 21,750 million cubic metres are in 27 EU countries. The net annual increment within the EU 27 is estimated at 620 million cubic metres. In practice, however, just 64% of the net annual increment is harvested[5].

The European forest-based sector is well aware that its own future is linked to the future of its forests. This, together with regulations requiring the reforestation of harvested trees and the development of certification schemes, gives the stability needed in order for the forests to continue to thrive.

[5] SWD(2013) 342 final

2.5
The contribution of the woodworking sector to mitigate climate change

"Already today, the European wood industries provide workable solutions that limit the emission of greenhouse gases and contribute to achieving the ambitious policy goals of the EU. Wood and wood-based products are, therefore, a first choice for the future EU society"

The role of wood and wood-based products in providing solutions to EU policy goals has meanwhile been recognized by the European Economic and Social Committee, EESC. An own-initiative opinion entitled, "Opportunities and challenges for a more competitive European woodworking and furniture sector", (CCMI/088) and approved in October 2011, recognizes that the European woodworking and furniture sector (as well as the pulp and paper industry) mainly uses a natural renewable raw material, wood, and plays an essential role in the development of a green economy.

The contributions of the woodworking sector to mitigate climate change are manifold:

Role of Forest carbon pools

- The role of forests in climate change mitigation is outstanding due to their potential to sequester carbon in tree biomass. Between 2005 and 2010, about 870 million tonnes of CO_2 have been removed annually from the atmosphere by photosynthesis and tree biomass growth in European countries. This corresponds to about 10% of the greenhouse gas emissions in 2008 of these countries that have been emitted in other parts of the economy[6]. In addition forests provide bio-materials that can act as temporary carbon stores (harvested wood products) or as "carbon substitutes", replacing carbon intensive materials and fuels[7].

Extending the carbon storage effect by using more wood

- Current use of wood extends the pool of carbon sequestered in wood products by roughly 53 megatons CO_2 per year[8]. Using more wood has the potential to substantially increase this beneficial effect of carbon stored in wood to mitigate climate change.

[6] *Ministerial Conference on the Protection of Forests in Europe (Ed.), 2011*
[7] *SWD(2013) 342 final referring to the Communication on Accounting for land use, land use change and forestry (LULUCF) in the Union's climate change commitments COM(2012)94*
[8] *FCCC/TAR/2011/EU, value proposed as reference level by the European Union*

Energy efficiency

- Energy efficiency is one of the main elements of the Europe 2020 Strategy for smart, sustainable and inclusive growth. Energy efficiency is "one of the most cost-effective ways to enhance security of energy supply and to reduce emissions of green house gases and other pollutants".

  The energy performance of buildings is key to achieving EU climate and energy objectives in the short and long term. Wood's naturally good thermal insulation makes it the material of choice in both cold and hot climates. Due to its technical performance as a structural material in combination with its unique property as an insulation material, wood is the preferred building material for energy efficient construction.

Cascade use of wood: reuse, recycling and energy recovery

- Wood products can be reused, recycled into other wood products and finally be used as fuel for a energy recovery. Residues from production processes of sawn timber products can be used for the production of other wood-based products such as wood-based boards. The more often by-products and recycling products are used, the higher the cascade factor gets, which allows not only increasing the available amount of wood for material use, but also extends the effect of carbon storage in wood products. Currently, wood extracted from forests is used roughly 2.43 times as a material (paper and panel products) on average before being used energetically[10].

Substitution of more GHG-intense materials

- Numerous international scientific studies have found that wood buildings involve lower GHG emissions than their steel and concrete-framed counterparts. Furthermore, in the residential sector, steel and concrete-framed homes consume considerably more embodied energy and release more air pollutants than a wooden house[11]. The sector can thus play a major role in supporting the EC's Roadmap 2050 goals to achieve an 80% reduction in GHG emissions by 2050.

[10] Mantau 2012 when increasing the cascade use of wood, care should be taken that the cascade remains eco-efficient.
[11] Werner & Richter (2007), Albrecht et al. (2009), Sathre & O'Connor (2008), Kuittinen et al. (2013)

Substitution of fossil fuels

- When wood cannot be re-used or recycled, it can still produce energy through combustion, following the principle of cascade use of wood. The energy produced is effectively stored solar energy. As the amount of CO_2 emitted from combustion is no more than the amount previously stored, burning wood is carbon neutral, a fact well understood by the wood industry which derives up to 75% of the energy it uses to process wood from wood by-products.

- European forests are the largest reservoir of biodiversity compared to other terrestrial ecosystems, while providing over 50% of the renewable energy in Europe. Households accounted for the largest share (61.3%) of the EU´s final energy consumption of wood and wood wastes in 2008, followed by paper manufacturing and printing (19.8%)[12].

All in all, encouraging the use of wood products is the greenest choice: by using the full potential of wood in buildings, Europe could reduce emissions of CO_2 by 300 million tons[13] every year.

Despite these obvious advantages of wood and its potential to mitigate climate change, there are still legislative barriers or obstacles as regards perception, which are hampering an enhanced use of wood and wood-based products in residential buildings in the EU. Ad hoc initiatives should be undertaken at national level to enhance local and regional authorities' knowledge of wood as a construction material. Moreover, the lack of appropriate education, training and skills, not only in the wood-based industries but also in key related occupations (construction engineers, architects, etc.), is one of the most significant barriers preventing the increased use of wood for construction.

[12] SWD(2013) 342 final
[13] European Economic and Social Committee EESC (2012)

3

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Methodology for the quantification of carbon-efficient buildings

3.1 CEN TC 350 – harmonized approach for the environmental assessment of buildings

> **“Harmonized methods are available for the quantification of carbon-efficient buildings. Environmental product declarations support the assessment of the environmental performance of buildings, including carbon footprinting by providing the relevant information for construction products”**

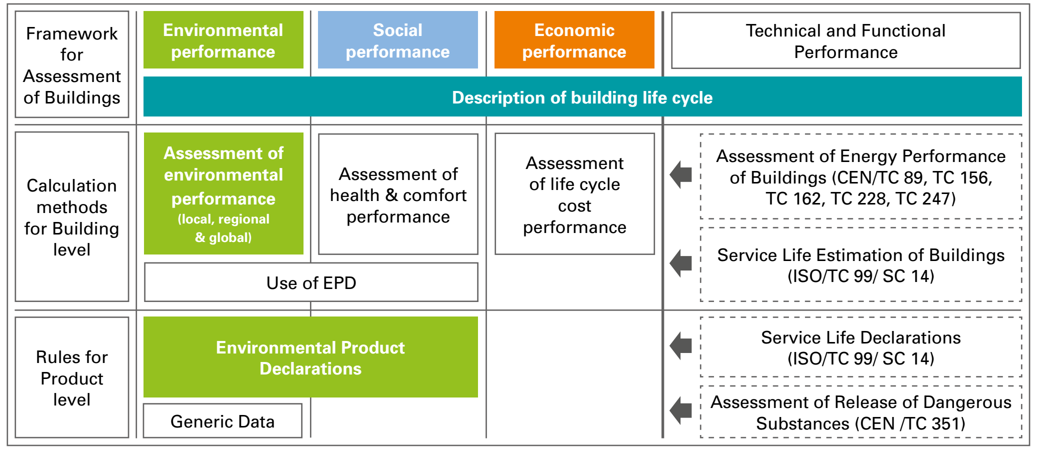
Product-related environmental information of construction products has constantly been gaining importance during the last 10 years. Companies are increasingly confronted with various enquiries about the environmental impacts of their products by architects, developers, legislators and consumers.

Not only the demand but also the complexity of environmental information has been increasing. Years ago, planners tried to minimize operational energy use as the reduction of thermal energy losses whereas today more and more integral environmental assessments of buildings are required, e.g. in the context of tenders, architectural competitions or building certification schemes.

Construction products are semi-finished products in complex interactions within a building. Their environmental performance can only be reasonably assessed in the context of the whole building and considering its entire life cycle from production, construction, usage, disposal and eventual recycling and energy recovery.

Traditional environmental labels may be suitable for the communication of environmental characteristics of consumer goods, but are insufficient considering the complex inter-dependencies of construction products in a building. This means that product-related environmental information has to be provided transparently and in a structured way, based on commonly agreed rules and consistent with the applicable building assessment scheme.
During the last ten years, several EPD programmes and related building assessment schemes have been developed for construction products and buildings with differing rules and requirements. To avoid barriers to trade, the European Commission has mandated the European standardization organization CEN to harmonize the sustainability assessment of buildings. CEN has, for some years, been working on sustainable construction within CEN/TC 350. It is responsible for the development of voluntary horizontal standardized methods for the assessment of sustainability aspects of new and existing construction works, and for standards for environmental product declarations of construction products. The standards can be generally applied to all construction products and are relevant to the assessment of integrated performance of buildings over their life cycle. The standards show how to calculate and present the economic, environmental and social aspects of sustainability, but do not specify any target values or benchmarks.

Figure 3:
Structured approach of CEN TC 350 to quantify sustainability aspects on product and building level



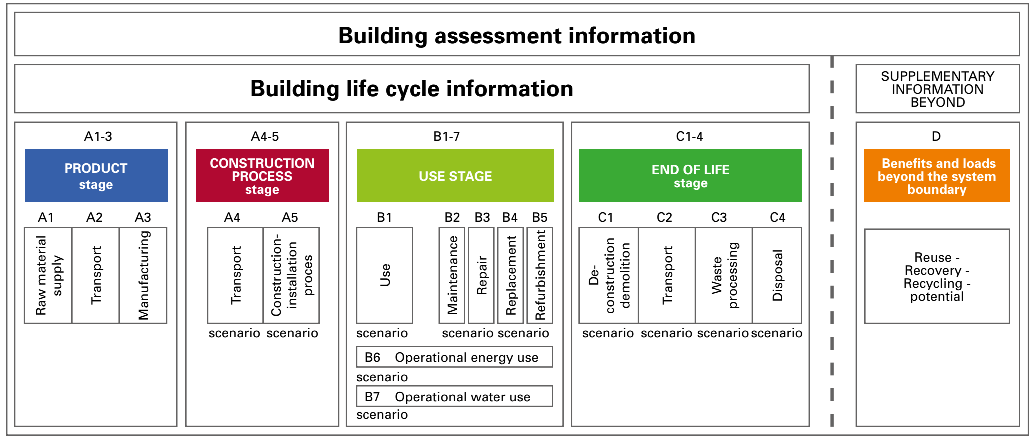
In 2011, the standard EN 15978 Sustainability of construction works, assessment of environmental performance of building, and in 2012, EN 15804, Sustainability of construction works, Core rules for the product category of construction products, were published. Whilst EN 15978 details the rules for the quantification of environmental aspects of buildings - among them the global warming potential relevant to the carbon footprinting of buildings - EN 15804 provides the rules on how to quantify and structure the environmental information relevant to the building level. Within this framework product-related environmental information is compiled in a structured way to serve at building level for the quantification of the environmental performance of buildings, including carbon footprinting.

3.2 Quantification of the environmental performance of buildings according to EN 15978

The following bullet points summarize the basic principles of an assessment of environmental performance of a building according to EN 15978, with a focus on carbon footprinting:

- The assessment covers the GHG removals and emissions over the whole life cycle of the building.
- The life cycle of a construction product is divided into "product", "construction", "use" and "end-of-life" stages. These modules are further subdivided to specifically address all relevant phases of the life cycle of a building.

Figure 4:
Modular structure of environmental information over the building life cycle



- An additional optional module can contain information on "burdens and benefits beyond the life cycle of the building". In this module, substitution effects can be reported, such as energy substitution effects associated with energy recovery from wood replacing fossil fuels.
- The assessment therefore covers both the GHG emissions and removals related to the materialization of the building, including maintenance, repair and refurbishment, but also the GHG emissions related to the operational energy use. This allows quantifying the total energy balance of a building and depicts eventual trade-offs between GHG emissions related to the materialization of the building and the resulting operational energy use.
- The building is assessed over a specific reference study period in line with EUROCODES and ISO 15686-1 on service life planning.
- Comprehensive guidance is provided on how to specify the building model and the scenarios for the construction, use and disposal phase for the purpose of the assessment. Comparisons of buildings or design options can only be made based on functional equivalency of the options to be compared.

The assessment of the environmental performance of buildings according to EN 15978 contains a broad variety of indicators on environmental aspects and impacts of a product, one of which is the Global Warming Potential, GWP_{100} (kg CO_2-eq).

3.3 Environmental Product Declarations according to EN 15804

As outlined above, a building assessment requires a huge amount of information on building products to be provided in a structured way to meet the needs of the building assessment scheme. Environmental Product Declarations (EPD) according to ISO 14025 are the ideal means to convey product-related environmental information for construction products.

Environmental Product Declarations show the environmental performance of a product based on an independently verified life cycle assessment (LCA) in a transparent and credible way. As outlined above the data is used as input for evaluating the whole building.

An Environmental Product Declaration (EPD) is generated by the manufacturer of a construction product based on so-called product category rules. The new European harmonized standard EN 15804 sets core rules for the creation of Environmental Product Declarations for building products and materials.

This standard gives the basis for a uniform calculation and declaration of product-related environmental information all over Europe. Nevertheless, individual materials have to specify the core rules for EPD outlined in EN 15804 to make them applicable to their specific circumstances.

3.4 Specific rules for wood products

Wood industries have been the frontrunners in specifying the core rules of EN 15804 for their products. Regarding wood, CEN TC 175 has developed the wood specific standard EN 16485, Product Category Rules for wood and wood-based products for use in construction, which were acknowledged by CEN TC 350 to be fully in line with EN 15804. The Wood PCR are the first product category rules that have passed the Formal Vote, while all other construction products are still preparing their own PCR.

This step is very important because of the acceptance of specific wood rules in EPDs, in particular on biogenic carbon as a material inherent property of wood. These rules allow depicting the temporal storage carbon storage effect in wood and wood-based products as part of the quantification of the global warming potential (GWP) not only on product level but also on building level.

The potential of wood in carbon-efficient construction

> **"Using wood provides low-cost and short-term opportunities to mitigate climate change."**

Using renewable materials with low-carbon footprints and improvements in energy performance of buildings to reduce emissions provides low-cost and short term opportunities.

The main opportunities are the storage of carbon in wood and wood products, the potential offered by the substitution of other (energy or carbon intensive) materials and the efficient eco-cycle of wood products.

Wood's naturally good thermal insulation makes it the material of choice in both cold and hot climates. There are thus significant CO_2 savings to be made by using timber in the construction of houses and other buildings, both in terms of embodied energy and in-use energy efficiency.

At the end of their service life, wood products can, in most cases, be recycled, thus extending the carbon storage effect, and/or be used as carbon neutral fuel, substituting fossil fuel.

Timber and wood-based products are not only the first choice for the construction of new buildings as timber offers great potential for changing and modernizing existing, older buildings which are often constructed from concrete. It is primarily a matter of extensions to roofs and storeys. This offers a great potential for big cities to increase the number of dwellings on existing grounds.

Due to unique technical properties and biogenic origin, wood and wood-based products have a huge potential in carbon-efficient construction over the whole life cycle of a building:

A Production of building, materials and the construction phase

- ***Wood is the most widely used natural renewable material***
  Europe´s forests are sustainably managed and growing – meaning increasing carbon stocks in European forests. An endless, carbon-neutral source of renewable raw material, properly managed.
- ***Local sourcing***
  Timber is often locally sourced which means short transport distances and low GHG emissions associated with transportation.
- ***Little energy is needed to produce sawn timber***
  Wood has the lowest GHG emissions of any building material when compared on a functionally equivalent basis.
- ***Highly eco-efficient technical performance***
  Wood is a flexible, strong building material that can be easily manufactured to different dimensions, easily assembled and easily combined with other materials. Steel is the most commonly used material for fittings in wood construction and ideal to be recycled many times.
- ***No waste***
  During production and construction, little waste is generated as all industrial residual wood can either be recycled or used as bioenergy.
- ***Eco-efficiency via prefabrication***
  Using prefabricated modules and elements, the construction site becomes more of an assembly site, reducing noise and dust, whilst leading to an eco-efficient manufacture of wooden elements with low associated CO_2 emissions.
- ***Wood products store carbon***
  Properly managed forests are a carbon sink and the carbon continues to be stored in the wood products during their whole service life. Some 0.9 t CO_2 is trapped in every cubic meter of wood. Thereby, wood products are an important part in enhancing the effectiveness of the forest sinks, both by extending the period that the CO_2 captured by the forests is kept out of the atmosphere, and by encouraging increased forest growth.
- ***Innovative wood construction offering new and intelligent areas of application***
  There are new techniques developed for multi-storey buildings, extensions on existing buildings and renovations. Timber offers great potential for changing and modernizing existing, older buildings which are often constructed from concrete.

It is primarily a matter of extensions to roofs and storeys. The simplest method is to fit the old building with a new roof designed so that a number of apartments can be built into the attic space. The space can also be used for placing installations for improving energy efficiency and heat exchangers for ventilation. As timber structures are light, there are often margins for building additional storeys. In such cases, the use of prefabricated components is often suitable. Naturally the design must be checked so that there is a margin for absorbing the additional vertical loads and ensuring horizontal stability.

Last but not least, it is cost efficient to build with wood. The cost of the wood frame is about 30-35% lower than that of a concrete frame. The total cost is about 10-15% lower for wood buildings. Using prefabricated modules the total cost is 20-25% lower[14].

B Use phase

- ***Flexibility in use***
  As a light-weight material that can easily be processed, wood is the ideal material for renovation and refurbishment, allowing high flexibility for inhabitants and users in wooden construction for adjustments of the building to their specific needs.

As outlined above, using wood for renovation and refurbishment ensures the use of a low-carbon material with high material substitution potential and, with a high energy recovery and substitution potential, and leaves practically no construction waste.

- ***Fire and acoustics***
  There are the same requirements on wood buildings as for other building systems. Unlike any other materials, wood behaves predictably in fire, forming a charred surface which provides protection for the inner structure, so that wood elements can remain intact and fully load-bearing during a fire. Modern timber buildings readily comply with sound insulation standards through using a layered structure of different materials. Even more demanding standards can be met using a number of different design solutions, setting no limits to carbon-efficient construction in wood.
- ***Insulation***
  Wood's naturally good thermal insulation properties make it the material of choice in both cold and hot climates. There are thus significant CO_2 savings to be made by using timber in the construction of houses and other buildings, both in terms of embodied energy and in-use energy efficiency, and associated GHG emissions.

[14] *Independent source*

C End-of-life stage

- ***Easy dismantling and no waste***
  Wood constructions are fairly easy to dismantle. The wood can be reused, recycled into panels and finally recovered as energy, leaving almost no waste for disposal.
- ***Easy recycling of further components***
  Steel fittings can be recycled in established recycling systems.

D Recovery of building materials

- ***Cascading wood multiplies material substitution and energy substitution effects***
  The inherent properties of wood as a material and biofuel make it ideal to be reused, recycled and finally used as a biofuel. These unique properties, in combination with the cascade use of wood, lead to multiple substitution effects related to the material use of wood as well as to energy substitution at the end of service life. Using wood in cascade increases the availability of wood as a raw material and is associated with the same beneficial climate mitigation effects as related to the direct use of wood from forests.

The following case studies provide practical examples on the unique properties of wood in carbon-efficient construction.

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Case studies

Comparative research shows that using wood constructions in buildings instead of a concrete or a brick one is good for the climate. The following case studies provide good information for this.

5.1
Case study 1: Passive houses and zero energy buildings in Austria

5.1.1
Description of the buildings

The Austrian case studies analyse primary energy input and CO_2 emissions over the life cycle of high energy efficient residential buildings (Passive houses and Nearly Zero Energy Buildings - NZEB). Three existing buildings that represent typical residential buildings according to the Austrian building typology (developed within the EU project TABULA) have been chosen for this analysis.
However, the wood construction systems they incorporate are quite innovative and not yet common in Austria.

Table 1:

Key parameters of the three buildings used as case studies in Austria

Multi-storey Building Mühlweg (Vienna)	Terraced house Steinbrechergasse (Vienna)	Single-family house Schönkirchen (Lower Austria)
Gross floor area 2 052 m^2	**Gross floor area** 668 m^2	**Gross floor area** 290 m^2
Living area 1 565 m^2	**Living area** 531 m^2	**Living area** 161 m^2
Gross volume 5 269 m^3	**Gross volume** 2 143 m^3	**Gross volume** 885 m^3
Net volume 4 269 m^3	**Net volume** 1 335 m^3	**Net volume** 760 m^3
Nr of occupants 50 persons	**Nr of occupants** 20 persons	**Nr of occupants** 4 persons
Planned service life 50 years	**Planned service life** 50 years	**Planned service life** 50 years
Operational energy use 74 320 kWh/a 36,2 kWh/m^{2}a	**Operational energy use** 40 240 kWh/a 60,3 kWh/m^{2}a	**Operational energy use** 2 923 kWh/a 13,9 kWh/m^{2}a
Heat generation Ventilation system, solar/gas heating, system radiator	**Heat generation** Central heating pellet boiler	**Heat generation** Ventilation system, Heat pump
Heat distribution Ventilation system, radiators	**Heat distribution** Ventilation system, radiators	**Heat distribution** Ventilation system
Energy generation -	**Energy generation** Photovoltaics	**Energy generation** -
Air tightness 0,3 h-1	**Air tightness** 0,6 h-1	**Air tightness** 0,11 h-1
Energy class Passive house	**Energy class** Passive house	**Energy class** Passive house

Multi-storey building Mühlweg (Vienna)

The first building presented is a multi-storey residential building located in Mühlweg, Vienna. The apartment complex consists of four blocks comprising 70 flats for approximately 200 inhabitants in total. The project was the winner of a developer and architect contest launched by the City of Vienna and Holzforschung Austria (HFA). It was built within the financial means of the social housing fund. The residual heat is provided by a combined solar/gas heating system. All apartments are supplied with fresh air by a central ventilation system. The basement, the staircase and the load-carrying system of the first floor are made of concrete; the three upper floors and the attic floor show a solid wood construction. The characteristic structure of the building is a cross laminated timber (CLT) construction. External walls are made of a prefabricated crosslaminated wood construction with mineral wool between wooden lathes as insulation material. The exterior side of the wall is covered with wood or plastered wood wool panels.

Terraced house Steinbrechergasse (Vienna)

The second presented building is a row house with a gross floor area of 668 m² and a net floor or living area of 531 m², considering all five housing units. All units are equipped with a basement below the entire ground floor. The whole settlement is located in Vienna, Austria, in green surroundings with single-family houses. The whole building originally was designed as a Low Energy House with an average heating demand according to Austrian building regulations. Since one of the fundamental goals of the research project was to determine the environmental impact of Nearly Zero Energy buildings, the whole existing construction was adapted and transferred to a passive house structure with the additional application of PV cells on the roof. Therefore all exterior elements (roof, walls, windows and ground floor slab) were thermally improved by raising the thickness of insulation material. Moreover, the building had to be equipped with a ventilation system with heat recovery.

The row house is equipped with a basement on an insulated ground slab.
External walls are a prefabricated post and beam structure with glass wool in the cavities and an external thermal insulation composite system made of polystyrene.

The single pitch roof is partly prefabricated and also a wooden beam structure with mineral wool insulation in the cavities and a rear ventilated aluminium roof covering.

Single-family house Schönkirchen (Lower Austria)

The third building is a single-family house with a gross floor area of 290 m². The building has no basement, but about 80 m² of the mentioned area is used as a garage and storage room. The remaining 70% is used as living area. The garage and the living area are connected and accessible via a central porch. The living area of the building was built as a solid wood construction with stone wool used as insulation material. The garage is a brick construction of only one floor and not conditioned.

The external walls of the residential building are built as a solid wood construction with stone wool insulation. The external walls of the garage consist of 16 cm of bricks. The share of the external garage walls to the total external walls is about 40%. The internal walls are built as lightweight timber constructions with a rendering loam on reed matting and the inner ceiling is made of cross laminated timber panels. The roof of the residential building consists of timber rafters and stone wool.

5.1.2 Results

Production phase

For all three buildings, the basement or foundation has the largest impact in terms of primary energy and GHG emissions, followed by floors and interior ceilings, the roof and exterior walls. However, the energy input for the basement is almost entirely non-renewable, while the other elements store significant amounts of carbon and include a higher share of bonded energy, which can be recovered at the end of the life cycle.

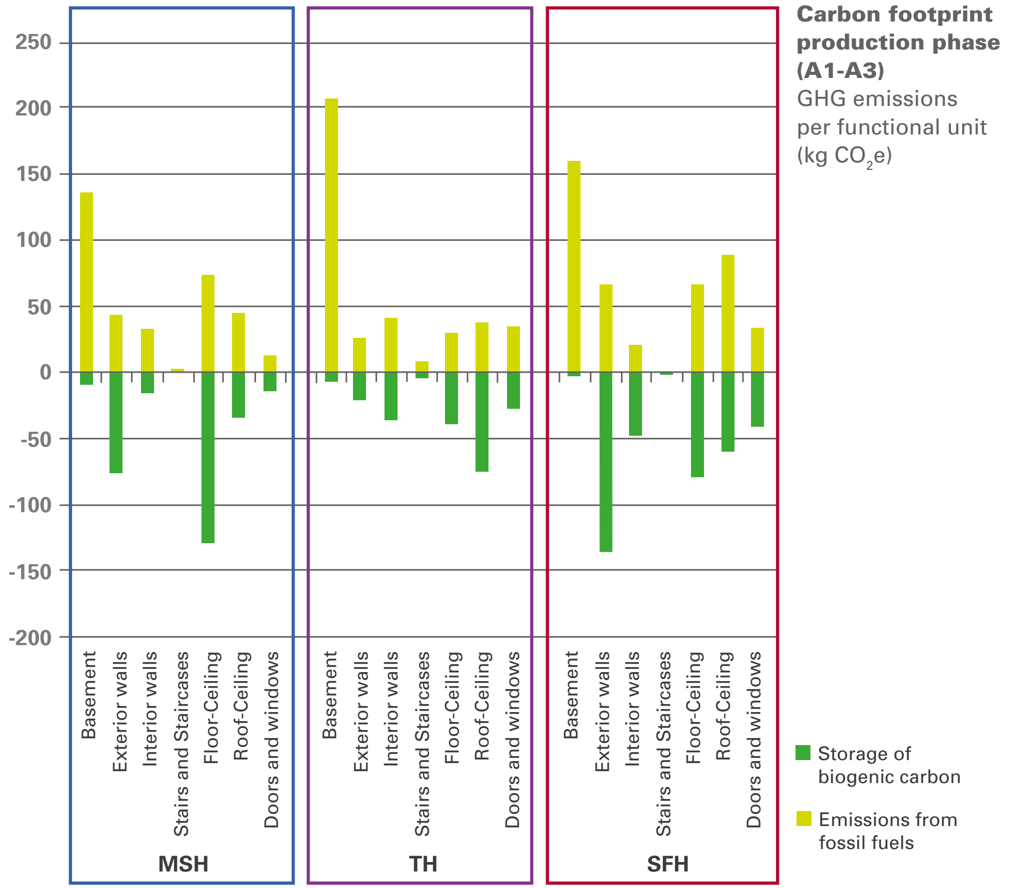
Generally more carbon is stored in the solid wooden constructions of the multi-storey building and the single-family house than in the wooden frame structures of the terraced house. In all three buildings, the non-renewable primary energy use and the GHG emissions caused by the walls and roofs are higher due to the use of mineral or glass wool and polystyrene as insulation materials. This is especially important for the wooden frame structures since the cavities are filled with glass wool. Alternative insulation materials like cellulose fibres could improve these indicators.

Building service installations are not significant in case of the multi-storey building (gas and solar heating, central ventilation system) and the single-family house (heat pump, central ventilation system).

In case of the row house, the PV plant (consisting of a 151 m² collector, inverter, electric installations and fastening system for the roof) has an impact of almost 30% of the total primary energy input in the production phase. However, so far there is little data available for building service installations and their ancillary materials. Therefore results are subject to large uncertainties. More reliable information on building service installations could significantly improve knowledge about the impact of that part of the building's life cycle.

When comparing the building concepts of a multi-storey building, row house, and single-family house in terms of primary energy demand per m² in the production (and also maintenance) phase, it is obvious that the dense concept of multi-storey buildings is the most efficient one.

Figure 5:
Carbon footprint of the production phase of the multi-storey house (MSH), the terraced house (TH) and the single-family house (SFH) in Austria



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Maintenance phase

Due to the assumption of a 50-year service life, the replacement of materials covered in phase B4 is not very significant. This is due to the assumption that only windows, outside sealing and surface coverings, floor covering and heating, ventilation and air conditioning get replaced once in this period. For all other materials and elements an assumed service life of 50 years and longer is foreseen.
Maintenance is therefore most significant for the row house as the energy intensive produced PV plant is exchanged once within the 50-year period.
An assumed service life of 100 years significantly increases the primary energy input and GHG emissions for phase B2-5 to a higher level than the production phase (A1-A3). In that case, the production and maintenance phase together may become more important than the energy use of the building. This is a strong indicator that building materials have to be a focus of energy efficient building concepts in the future.

Energy use

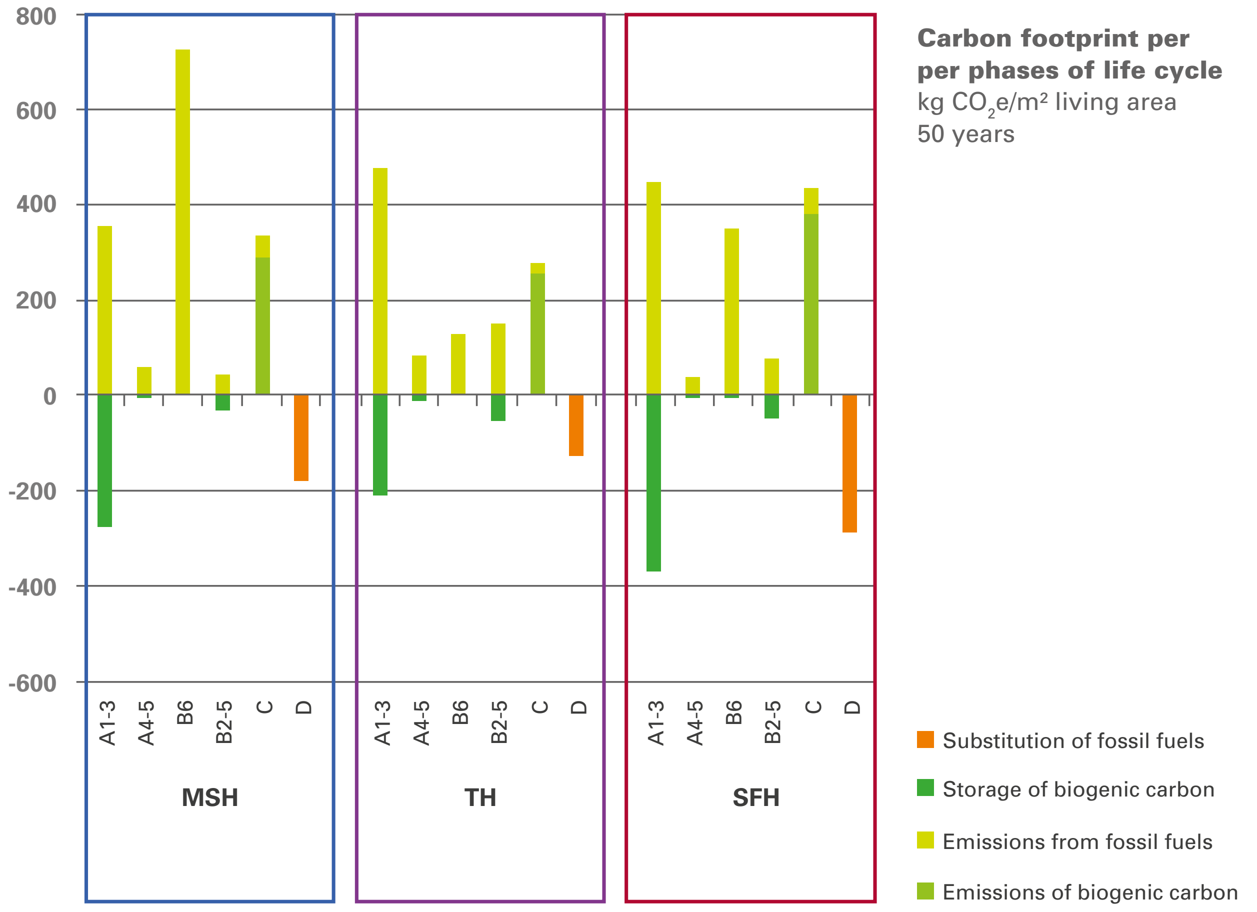
The three buildings are equipped with different building service systems. This has a significant impact on phase B6 (energy use) of the life cycle. The multi-storey building is equipped with a central gas boiler and a solar thermal system, which reduces the demand for gas.

Nevertheless the non-renewable primary energy demand is quite high compared to the other buildings. The single-family house is heated by a heat pump.

The row house has been designed as a Nearly Zero Energy Building (NZEB) according to Austrian definitions. The PV plant has therefore been designed to cover most of the non-renewable primary energy demand of the building for heating, ventilation and household appliances. Nevertheless the total primary energy demand (largely renewable from pellets) for heating and sanitary hot water production is quite high compared to the other buildings.

This is due to the seasonal efficiency of the small scale pellet boilers used for heating and sanitary hot water production. On the contrary, GHG emissions in phase B6 are significantly lower for the row house. This again adds to the future importance of building materials and construction methods (represented in phases A1-3 and B2-5).

Figure 6:
Carbon footprint of the multi-storey house (MSH), the terraced house (TH) and the single-family house (SFH) in Austria over their life cycle (for abbreviations of life cycle stages, see Figure 4)



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5.2
Cases study 2: pre-fabricated wooden building in Mietraching, Germany

5.2.1
General

This building is part of a redevelopment site for a zero-energy model city and is a pilot project for a prefabricated building system for residential buildings in wood.

The building is a four-storey apartment located approximately 50 km south-east of Munich. The building consists of six flats and an external staircase with elevator. The building has a gross floor area of 726 m² and a living area of 488 m².

Wood as primary construction without any concrete reinforcement for walls and ceilings was selected because of ecological aspects, high level of prefabrication and short construction period. Specific detailing was necessary for solutions in fire safety and sound protection.

The building is a simple box shape with balcony made of laminated veneer lumber (LVL). All building elements were prefabricated in factory as walls, floors and ceilings. The on-site assembly of prefabricated elements took just four days. The energy performance of building was 50% better than the energy regulations required at the time. Operational energy use was assumed as 31.83 kWh/m² and year for district heating and 31.31 kWh/m² and year for electricity use in the whole building.

For the conditioning of the indoor climate, a heat recovery ventilation system and radiation connected to the district heating system are used.

5.2.2
Construction

Foundation and floors
The basement is made in concrete and on top of it mineral wool, cement screed and parquet flooring. The intermediate floors consist of gluelam panel, gravel fixed by latex, mine al wool, cement screed, parquet flooring.

External walls
Walls consist of sawn timber panel covered by gypsum board on both sides, vapour barrier, mineral wool, wind barrier, spruce batten and larch cladding.

Roof
Roof elements are composed of six layers; gypsum board, spruce batten, vapour barrier sheet, cellulose fibre I-joist, softwood plywood. Above PVC waterproof sheet and finishing of ceiling (plywood) have been installed on site.

All wooden building elements were prefabricated. The prefabrication work in factory was in about one month. Every wood waste from prefabrication process was burnt in factory's biomass boiler. The generated heat was utilized for drying wood and for the space heating of the factory. Non-renewable primary energy could be substituted.

On-site construction work was mainly assembly of the prefabricated elements, which was done in three weeks. After that, interior finishing and water-proofing work were done.

5.2.3
Results

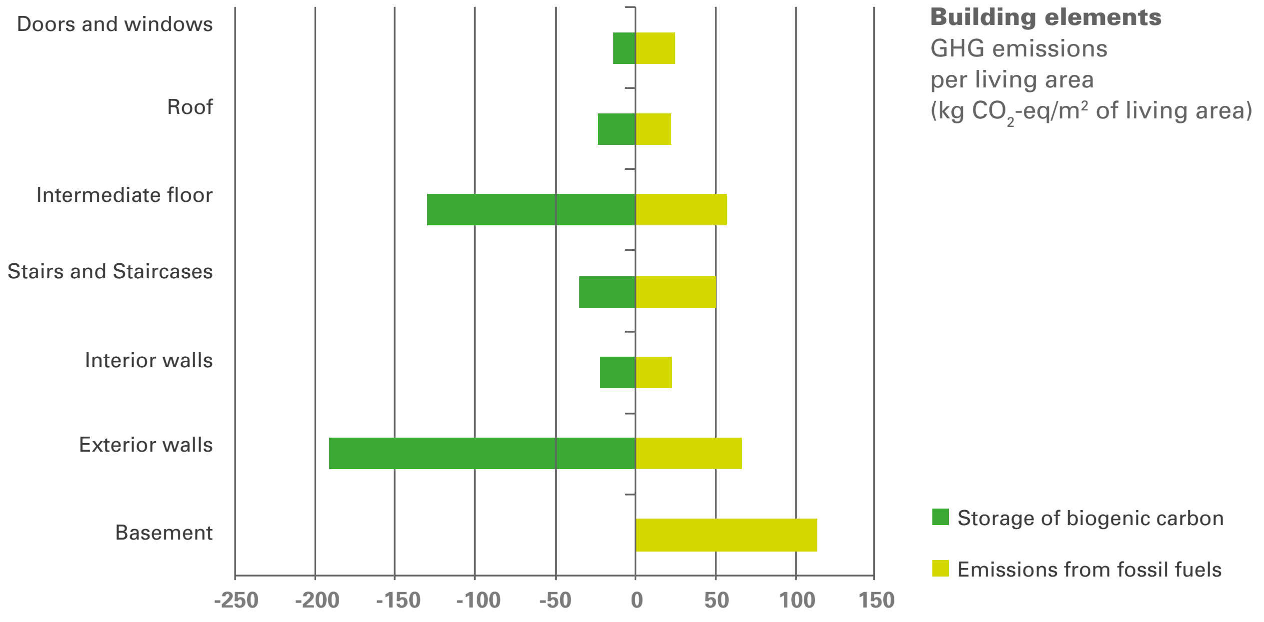
Greenhouse gas emissions and carbon storage

The whole building stores 208.9 t CO_2-eq. per m² or 428 kg CO_2-eq. per m² living area.

Greenhouse gases emissions are 767 t CO_2-eq. per building or 1572 kg CO_2-eq. per m² living area.

Carbon footprint shows the same trend in the primary energy balance. 75% of GHG emission originates in module B6, and production phase emits about 20% of the total. Carbon storage capacity is about 428 kg CO_2-eq./m² of living area which corresponds to more or less the same amount of GHG emission from module A. This means that the carbon stored in construction is around the same height as GHG emissions used to produce the building.

Figure 7:
Carbon footprint of various building elements used for the building in Mietraching



In terms of building elements, the basement is dominant regarding carbon footprint due to its volume and mass for the material production phase (A1-3). In addition, the basement is used as storage and machine room which is not included in living area. Therefore, the result normalized by m² of living area shows relatively high value for the production phase.

Also high GHG emissions come from exterior walls and floors. On the other hand exterior walls and floors are the elements which have a high amount of carbon stored.
Primary structure for buildings out of wooden material increases the carbon storage of building significantly.

Primary energy balance

Operational energy during the use phase, module B6, accounts for 77% of total primary energy consumption for module A and B6. This means 23% of total primary energy consumption is allocated to erection of the building. This percentage would even be increased if energy efficiency of the use phase was improved. In the erection phase (module A) construction process (module A4-5) has a minor impact, about 5% of the total. The energy content of the material is about 4.000 MJ/m² of living area, which can cover all energy consumption for construction phase.

5.2.4 Conclusions

An LCA has been conducted covering material production, construction, and the operational phase of the building. Based on the collected data the relevance of the construction phase was assessed as compared to the production phase of the construction products. It turned out that further research is needed to fully understand the environmental impact associated with the construction phase.

Accuracy of inventories for the assessment of module A1-3 is also an important feature of this study. The amount of each on building component was taken from the detailed drawings and material order information given by the constructor as precise as possible. Therefore, detailed inventories could be made.

In this study, all building service equipment is not included due to lack of the information. Building service equipment would have significant influence on the life cycle environmental impact, especially due to its maintenance. This issue needs to be investigated more.

5.3 Case study 3: residential house in Joenssun Elli (FI)

5.3.1 General

Joensuun Elli is a residential housing area for students in the city of Joensuu, the capital of Eastern Finland. The project consists of six separate apartment buildings, each with 16 student apartments. The area of one building is 730 m^2 gross and 548 m^2 living area. Joensuun Elli was built during 2012-2013. The studied life cycle modules were production phase (A1-3), construction phase (A4-5) and operational energy use (B6), which was based on energy certificate. System boundary was drawn to include the frame of the building, whereas building services, furniture, and landscaping were excluded. Studied indicators include fossil greenhouse gas emissions, biogenic carbon storage and primary energy demand.

5.3.2 Construction

The building is made of wall panels that have cross-laminated timber (CLT) as load bearing frame. The roof structure consists of horizontal CLT panels over which roof truss made of laminated veneer lumber (LVL) with 550 mm of cellulose fibre insulation is attached.

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External walls are made of CLT panels that are insulated with 225 mm of mineral wool from outside. Internal gypsum boards have been used for additional fire safety. The façade cladding is made of sawn timber. Base floor structure is made on site from concrete, 200mm of polystyrene insulation and gravel fill.

All CLT-based elements were prefabricated. Thermal insulation, sheathing, façade cladding, doors and windows were installed before transport to building site. On-site work included foundations, installation of roof truss elements, balconies and canopies.

The building reached energy class A, which is the best in the Finnish classification system. The structures have better U-values than required in the national building regulations: 0.07 W/(m^2K) for the roof, 0.14 W/(m^2K) for the walls and 0.16 W/(m^2K) for the floor. The operational energy use, estimated from the energy certificate, are 32 W/(m^2K) for heating and 27 kWh/m^2 for electricity. All energy is provided from local CHP plant that uses 50% biomass for fuel.

5.3.3 Results

Greenhouse gas emissions and carbon storage

The emissions from production, construction and operational energy use for 50 years reach 1.000 kg CO_2e/m^2. Half of these emissions come from operational energy use and half from production and construction. The wooden building parts store over 237 tons of CO_2e from the atmosphere, more than 430 kg per every m^2 of living area. This carbon storage almost offsets the emissions from production and construction phases.

Figure 8:
Carbon footprint of various building elements used for Joensuun Elli

Most of the emissions and primary energy use are related to the production and construction of intermediate floors. However, they also have the second largest carbon storage. The largest carbon storage is in the exterior walls, which store over 150 kg CO_2-eq for each m^2 of living area. The same trend applies for the dominance of primary energy demand.

Primary energy balance

The primary energy demand of the building is roughly 12 GJ. Half of the energy goes into production and construction phases and the other half for operational energy use for 50 years. Thanks to the wooden components, there is a significant renewable primary energy content in the building. If the wooden parts would be burnt after being recycled in a cascade, they can provide over 2 GJ of bioenergy, more than 4150 MJ per m^2.

5.3.4 Conclusions

Because the Joensuun Elli building has a high level of energy efficiency, a large share of emissions is linked to the production and construction of the building. Therefore the emissions from the production construction materials need to be optimized. In this case the carbon storage of construction materials is almost the same as the emissions their production caused. Furthermore, the energy content in wooden materials is double the energy consumption during construction work. Transportation consumed three times more energy than the actual construction work.

If compared to the German case study building in Mietraching, the results differ in only one aspect: The emissions from the operational energy use are smaller, because of different energy mix. Especially the use of woody biomass in the district heating lowers the emissions.

The good energy performance of the building increases the importance of choosing materials that have low embodied carbon footprint. Joensuun Elli is a good example of the potential of CLT in carbon-efficient construction.

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Prefabricated volume element

Conclusions

The construction sector holds a significant potential for lowering greenhouse gas emissions. As new buildings are becoming more energy efficient, the energy demand and carbon footprint of construction materials seem to become increasingly important. Wood-based building materials have several direct and indirect climate related advantages. However, strong political actions will be needed in order to utilise this potential for the mitigation of climate change.

Environmental assessment of buildings and building products

- Holistic understanding of environmental impacts during the full life cycle of a building is required in order to include all important aspects into political decision making. Utilising the carbon flows of European forests and the substitution potential of bio-based products is essential for meeting our climate goals.
- Simplified practical assessment boundaries are required for designers and authorities. The present European standard for the assessment of environmental performance of buildings (EN 15978) is not practical for being used iteratively in the design and procurement phases of construction projects.
- Country-specific and geographic factors have a considerable impact to the carbon footprint of construction products. Different energy sources lead into differing carbon footprint of similar production processes. Country-specific data should be made available to overcome this problem.

Carbon footprint of building elements

- Foundations and ground works have the largest impact to the carbon footprint of the building. The higher the building, the smaller the impact. The impact increases along with underground spaces, excavations and piling.
- The carbon storage of buildings increases along with the amount of sustainably sourced wood in the building. Also the indirect benefits of the wood construction chain, secondary products and carbon neutral bioenergy increase, if massive wood structures, such as cross-laminated timber, are used.
- The mitigation of climate change requires urgent action within next decades. Therefore it is not sufficient to focus only on building zero energy buildings. The payback time of carbon emissions from the production of building materials should be taken into account. Certified wood-based products keep the carbon sink in the forests active and keep atmospheric carbon stored in buildings for even centuries.

Construction, maintenance, deconstruction and recycling

- The environmental impacts of the construction work seem to be small when compared to manufacturing of construction materials.
- The role of maintenance is vital in order to optimise the service life and carbon footprint over the full life cycle.
- Thick insulation layers of zero energy buildings require careful design and construction. The environmental net effects of the insulation materials depend on the ratio of the capacity for saving energy and the energy and emissions associated to the manufacturing of the insulation layers.
- Wood-based construction materials can be reused and recycled in a cascade several times. This enables a long storage time for the sequestered atmospheric carbon within wood material.

Recommendations for decision makers

- Environmentally friendly and carbon-efficient construction should be made the most desirable form of construction. Tax reductions are one path to this goal. However, the conditions of the building site and the use of the building should be taken into account when instruments for encouraging low-carbon construction are made.
- The estimation of carbon footprint, primary energy demand and the amount of renewable materials of construction products should be included in building permission processes and green public procurement.
- Authorities need reference values of the carbon footprint of different building types. With the help of such values, maximum emission levels may be set for each building type and are in city plans.
- In addition to the existing E-value (energy efficiency), a new C-value should be added into building permission process. This value should show the carbon footprint of the production of construction materials.
- If renewable construction materials are not used in a building, the choice should be explained and examined in the building permission process.
- European raw materials should be prioritised. Around 90% of all wood used in Europe comes from local, sustainably managed forests. Supporting European raw materials has significant positive impacts on climate change. Local carbon sinks, local ecosystem services and local economy are all kept active.
- The certificate of the sourcing of construction materials should cover all raw materials, not just wood-based products. This would improve the reliability of environmental information, e.g. land-use related impacts.

The over-all goal is, by showing the environmental benefits and technical possibilities of using wood in constructions to increase the use of wood. For this purpose, CEI-Bois advocates among other points for the following actions:

- Legal requirements for a certain amount of wood in buildings;
- Better harmonized building regulations;
- Recognition of the positive role of wood in housing in the green building rating schemes which are currently in operation.

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