How can wood construction reduce environmental degradation?

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THE EUROPEAN CONSTRUCTION SECTOR

- Based on long-term averages, the overall annual building construction volume in the EU27 totals 240 million m^2, or more than 2 million housing units.
- Including the whole lifecycle of buildings, the sector accounts for 42% of total energy consumption, 35% of total greenhouse gas emissions, 50% of extracted materials and 30% of water consumption.
- It represents 10% of GDP, and employs more than 12 million people in the EU.
- Changes in the construction sector take a long time, due to slowly changing standards, norms, perceptions, education programmes and building culture.

WOOD CONSTRUCTION: the environmental benefits

- Wood construction refers to any form of construction in which the load-bearing structural frame is partly made from wood-based products.
- Wood construction can reduce energy consumption and CO_2 emissions from the manufacture of construction products, as well as reducing the overall material use and thereby the amount of waste.
- For each ton of wood products used instead of ordinary Portland cement, an average of 2 tons of CO_2 emissions are avoided due to substitution, i.e., avoiding larger emissions from the production of other materials, and the storage of carbon in wood products.
- Due to the multiple times lower weight of wood compared to concrete, a wood-based structural frame can cut the total material consumption of construction by half.
- A hypothetical 100% market share of wood construction would require a maximum of 400 million m^3 of roundwood in the EU per annum, translating to 50% of the annual forest growth. With realistic assumptions, the impact of increased use of wood in construction on the demand for wood resources would be relatively small.

POLICY IMPLICATIONS

- Construction is identified as a key sector in the EU Circular Economy Strategy, the Resource Efficiency Strategy, and the Lead Market Initiative. Reaching a significant reduction of environmental degradation in building construction will require a rapid and widespread uptake of both modern wood construction techniques and advanced concrete and steel technologies.
- The public sector could introduce stricter norms for construction and facilitate new business opportunities.
- A level playing field should be created by removing the unnecessary regulatory and cost burdens of wood construction in national construction regulations.
- New and updated education and R&D programmes would also be needed to facilitate a transition to more sustainable construction.

The European construction sector

The European building construction sector has large economic and social significance and a major environmental impact.

Looking at average figures in the 2000s, the overall annual construction volume in the EU27 totals around **0.24 billion square metres**[1]. Approximately 75% of all construction in Europe is residential[2]. Each year, around **2 million housing units**, or approximately 1 million flats and 0.9 million detached houses, are completed in the 19 largest European countries.[A] The construction sector accounts for around 10% of GDP and employs more than 12 million people in the EU[3,4].

The health impacts of buildings are also important, as people spend 90% of their time indoors.

The construction industry is more risk-averse and fragmented than most other economic sectors[5]. Established building practices are favoured over alternatives due to existing norms, institutions, infrastructure and expertise[6]. These characteristics can make businesses unwilling to accept new practices, which from their point of view potentially cause extra work and associated costs in the short-term[5]. Partly for these reasons, the commercialisation of new products, processes or business models in this sector typically takes several decades. However, the sector has significant potential for cost-effectively reducing the environmental impact of the global economy[7].

What are the environmental impacts of construction?

Currently, the global construction and building sector accounts for:

- **42% of total energy consumption**
- **35% of total greenhouse gas emissions**
- **50% of extracted materials**
- **30% of water consumption**[2].

These figures include the **whole lifecycle** of buildings, from the manufacture of construction products to their decommissioning. Most of the emissions are caused by heating and cooling in the period when a building is in use. As the European building stock is relatively old, and is renewed only at a rate of 1% annually, building renovation is important particularly when attempting to reduce the energy consumption of the sector[8].

Steel and cement production, together with aluminium, are responsible for the largest share of energy consumption and CO_2 emissions in the manufacture of building products[9].

- Steel production releases 2 tons of CO_2 per 1 ton of steel produced on average[10].
- 1 ton of cement produced releases around 1 ton of CO_2.

In the EU, the annual cement consumption was on average 200 million tons in the 2000s[11]. The cement industry accounted for almost 5% of the annual EU CO_2 emissions in 2014[12].

A Euroconstruct association countries: AT, BE, CH, CZ, DE, DK, ES, FI, FR, GB, HU, IE, IT, NL, NO, PL, PT, SE, SK

The EU consumed between 1,200 and 1,800 million tons of construction materials per year for new buildings and refurbishment between 2003 and 2011[9]. Construction and demolition are responsible for approximately 850 million tons of waste per annum in the EU[9].

What is wood construction?

Wood construction refers to any form of construction in which the **load-bearing structural frame is partly made from wood-based products**.

It is essential to note that a **building always consists of a mixture of materials**, and the largest material input comes from foundations and earthmoving. In the EU, concrete, aggregate materials (sand, gravel and crushed stone) and bricks make up 90% (by weight) of all materials used, while wood, the largest biotic fraction, currently accounts for only 1.6%.

Wood has traditionally been used in single family buildings: around 8-10% of single family buildings have a wooden frame in the EU[13]. However, this varies regionally from above 80% in the Nordic countries to near zero in a number of southern European countries[14]. With the emergence of engineered wood products (EWP) such as glued laminated timber (glulam) and cross-laminated timber (CLT) in recent decades, wood has increasingly been used also in large-scale construction, such as multi-storey residential buildings, office buildings, schools, hospitals, and industrial and sports halls.

Wood is a renewable material with natural variation. EWPs are able to overcome this natural variation in the raw material, as the random weaknesses created by knots are removed by gluing pieces of wood together in various arrangements. EWPs can withstand a given level of stress and meet demanding regulations[15], and can therefore directly compete with steel and concrete.

There are typical misperceptions about wood as a building material, including fire hazards and issues with strength and durability. However, as with any form of construction, wood construction needs to conform to construction regulations which aim to prevent these hazards. A case in point is the tallest wooden building under construction (at the time of writing), in Vienna, which will be 24 storeys high. Negative perceptions about fire hazards are likely to be based on experiences with outdated wood construction techniques – they may even originate from historic city fires. However, these perceptions are not in line with modern wood construction standards. The behaviour of massive wood under fire is highly predictable: it burns roughly at a pace of 1 mm per minute, and forms a protective layer of char on the surface. Some EU Member States require the installation of sprinklers in large wooden constructions, effectively preventing human casualties.

Its beneficial strength-to-weight ratio and ease of handling make wood well-suited for industrial prefabrication. Industrial wood construction could address many of the pressures faced by the construction sector, including:

- efficiency (productivity, time of construction, overall construction costs)
- environmental impact (less construction waste, less disturbance for the surroundings of the construction site, for example less need for special traffic arrangements and lower dust and noise emissions)
- the safety and convenience of workers (standardized working conditions).

Wood as a material has a number of further possible benefits, including fitting accuracy, tremor safety (for earthquake-prone areas) and good insulation, as well as the possible beneficial impact of bare wooden surfaces on the indoor air quality and human health (humidity buffering, soft acoustics, stress-relieving atmosphere). However, for some of the latter benefits, it is difficult to show conclusive scientific evidence, due to the wide array of objective and subjective factors affecting human health.

The economic competitiveness of wood construction varies between regions and market segments[14]. In wood-frame multi-storey markets, wood-based building practices are still on average a few per cent more expensive when compared to established methods. This is still partly due to national construction regulations which treat materials unequally. However, in future one can expect wood construction to become cost competitive, due to learning-by-doing through an accumulating number of pilot projects and ultimately the standardization of modern wood construction techniques.

How can wood construction reduce environmental degradation?

A significant body of literature recognizes the possible environmental benefits of substituting the most common building materials with wood-based products. Research on the environmental impact of wood construction invariably concludes that wood-based construction practices cause less environmental burden compared to established practices[14,16,17,18]. In particular, wood construction can reduce the energy consumption and CO_2 emissions related to the manufacture of construction products, as well as contribute to reducing the overall material use and thereby the amount of waste.

Reducing CO_2 emissions

Wood-based products contribute to climate change mitigation by two main mechanisms: carbon storage and substitution. First, substituting wood for steel, concrete, and other products that use more energy in their manufacture avoids larger fossil fuel consumption and consequent CO_2 emissions (**substitution**). The use of sawmilling residues for bioenergy recovery also improves the energy balance of wood products. Second, trees sequester CO_2 in standing forests through photosynthesis (see Figure 1), and store the carbon in wood-based products for the duration of the life cycle of the product (**storage**).

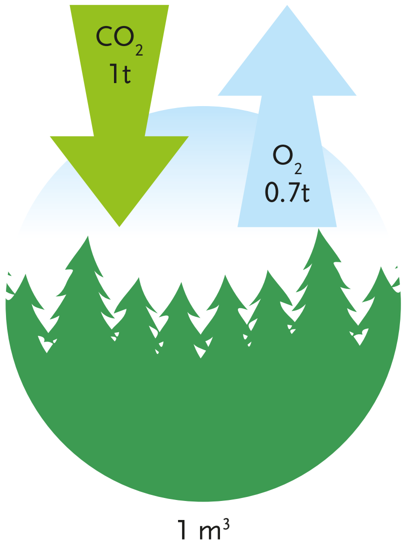

Figure 1: Trees sequester CO_2 through photosynthesis. When a tree is cut and used for building, the carbon contained in wood is stored away from the atmosphere for decades, if not for centuries. In the meantime, another tree has grown in its place, and sequestered the amount of carbon that will eventually be emitted when the building is decommissioned. Modified from Puuinfo.

Most of the emissions from buildings are caused by their use, particularly due to heating and cooling. While the choice of building material has no decisive impact on the energy efficiency of buildings, wood-based solutions exist, for example, for energy façade renovations. However, with stricter energy efficiency requirements and a possibly changing fuel mix in energy generation in the future, the relative importance of the CO_2 emissions of the manufacture of building products is likely to rise.

Meta-analyses for the average impact of using wood instead of concrete suggest an average reduction of 2.1 tons of CO_2 emissions per 1 ton of wood products used, though the estimates for this impact vary significantly (from a maximum of 15 to a minimum of -2.33)[14,16]. So, according to best estimates, **for each ton of wood products used instead of non-wood products, there is an average emissions reduction of approximately 2 tons of CO_2**. If all new buildings were constructed with approximately 50% by mass of wood, this would offset the CO_2 emissions caused by producing the cement used for the building sector (3.5% of total EU emissions).

According to the figures above, the increased use of wood in construction is unlikely to have a conclusive impact on the total CO_2 emissions in the EU. However, it could be notable compared to the current emissions from cement production, and should therefore not be overlooked.

It is difficult, however, to guarantee the reliability of estimates on an EU scale, due to regional differences in building regulations and practices and climate conditions. There are significant uncertainties related to, for example, the assumed share of wood of all material used in building (in practice this can be as low as 10–30% in terms of weight, even if the structural frame is made of wood products)[19], as well as the point of comparison (whether wood is being compared to ordinary Portland cement or advanced building materials with significantly lower emissions). Reaching a significant reduction of emissions in building construction will require a rapid and widespread uptake of **both** modern wood construction techniques and advanced concrete and steel technologies.

Reducing material use and waste

Construction is one of the most significant sectors causing the depletion of natural resources. The resource intensity of construction means that circular thinking will have to become increasingly acknowledged in the sector. A ‘circular economy’ aims for a closed system by:

- maximizing the circulation of product, component, and material flows by reducing material input and waste, recycling, reuse, and sharing
- maximizing the value of materials (€/kg)[20].

These aspects are partly interrelated, since the higher the value of waste, the more incentives there are for recovering it. The high costs of recycling coupled with a low value of waste material may partly explain why efficient recycling systems are only common for high-value metals.

The circularity indicators currently available are typically applied to short-lived consumer goods, instead of buildings and infrastructure[21]. This means it is not possible to claim that one material or building practice is more circular than another, as it always depends on the perspective and system boundary definition. However, the renewability (biodegradability) of wood means that demolition wood can eventually be combusted, and the emissions are reabsorbed to growing forests[22], which could justify the use of wood being characterised as a circular process.

In terms of reducing material input and thereby waste, wood construction has benefits. From a ‘waste hierarchy’ perspective (see Figure 2), prevention of waste is the best option. Substituting a wooden frame for a concrete frame significantly reduces the total material input of a building, i.e., it avoids greater material use and waste due to the four to five times lower weight of wood compared to concrete. A wood-based structural frame can cut the total material consumption of construction by half and the weight of the structural frame by 70%[19]. A lighter structural frame also allows reduced material input to the foundation. Industrial prefabrication provides an efficient way of minimizing waste at the construction site. The residues from the manufacture of wood products (e.g., for use in construction), such as chips, sawdust and bark, are used for producing wood-based panels, bioenergy and biochemicals that can substitute for fossil-based raw materials.

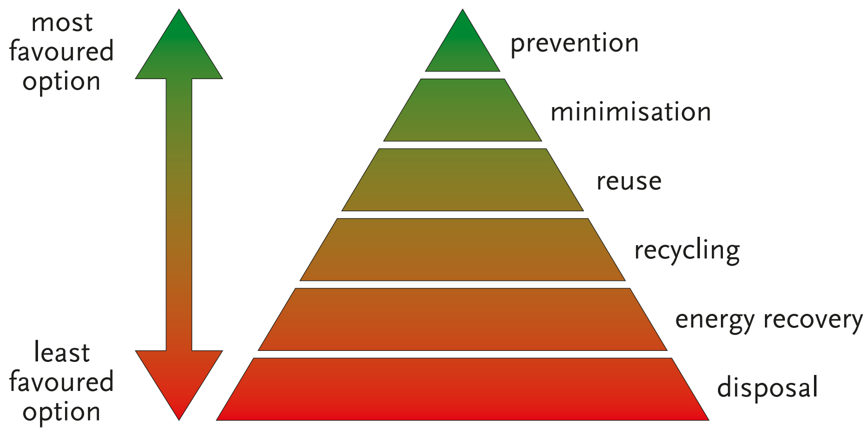

Figure 2: A waste hierarchy based on Waste Framework Directive 2008/98/EC.

The most significant waste streams are created in renovation and at the decommissioning of the building. The EU Waste Framework Directive (2008/98/EC) stipulates that 70% of non-hazardous construction and demolition waste must be prepared for re-use, recycled or undergo other material recovery by 2020. At the time of the Directive's introduction, the recycling rate of construction waste in the EU27 was on average 63%, and for wood 30%[23], with significant differences between countries.

One third of demolition wood is used directly for energy production, which from the waste hierarchy perspective is regarded as the least favourable option. Finding more efficient recycling options for demolition wood will be a challenge, due to the chemical impregnation of wood or the use of oil-based glues, paints and other material mixes. One important aspect will be cascading[24], which means extending the lifetime of wood material in the production loop before combusting it, for example in the following sequence of applications: Beam > floor board > window frame > oriented strand board > fibreboard > combustion.

Better design of buildings and building products will have to be emphasised, both in terms of guaranteeing the flexibility and modularity of buildings to support the extension of their lifetimes, and in terms of making building products more cost-efficient and convenient to maintain, reuse, refurbish, or remanufacture[25].

Impact on forests

Wood sourcing in the EU builds on the principles of **sustainable forest management**[26]. Wood construction is in no way linked to global deforestation, which is primarily caused by competing land uses in developing countries.

As the majority of forest owners' revenues from selling wood comes from large diameter logs, increased wood construction may provide incentives for active forest management and maintenance as a long-term carbon sink. The raw material impact of the possible increase of wood construction can remain moderate – a 100% market share of wood construction of all building in Europe would translate to a maximum direct annual demand of 400 million m^3 of wood. This is equivalent to around 50% of the annual growth of EU forests, or 50 million m^3 more than the industrial roundwood produced in the EU in 2015 .[B] With realistic assumptions, the impact of increased wood construction on the demand for wood resources remains relatively small – e.g., with a 20% market share and equal use of massive and light frames the annual demand for roundwood would be around 50 million m^3 in the EU.

B The EU building stock is renewed at a 1% annual rate – an area of 240 million m^2 is built annually[1]. The wood use intensity of wood construction can be assumed to vary from 0.2 m^3/m^2 (light frame) to 0.6 m^3/m^2 (massive frame). Thus, a simple calculation suggests that 100% of the European construction markets could be covered with 45–145 million m^3 of wood products, translating to around 100-400 million m^3 of raw wood (the conversion factor to roundwood equivalent (RWE) ranging from 2.0 for sawnwood to 2.8 for cross-laminated timber (CLT)). As the increment in forests available for wood supply was 769 million m^3 in 2010 in EU27 (Eurostat), a 100% market share of wood construction in Europe would require a maximum of 53% of the annual growth of European forests.

Conclusions and recommendations

The use of wood has the potential to reduce the environmental impact of construction, particularly in terms of reducing greenhouse gas emissions and the overall material use of construction. However, achieving significant reductions in the environmental impact of construction will also mean reducing the impact of the most common building materials (concrete and steel).

There is a range of policies at EU and Member State level to enhance the sustainability and resource efficiency aspects of the building sector. These could directly or indirectly support the use of less environmentally burdensome materials, such as wood, in construction. However, the first step needs to be the creation of a level playing field for construction markets, by removing the unnecessary regulatory and cost burdens of wood construction in national construction regulations.

The public sector could facilitate the reduction of the environmental impact of construction by creating new business opportunities and stipulating the use of materials and practices with less environmental impact. A unified assessment framework, which overcomes the current fragmentation of schemes for the environmental impact of construction, is also a priority. Objective information from such a framework could be used for green public procurement to facilitate the market uptake of new, more sustainable and efficient building practices. New and updated education and R&D programmes would also be needed to facilitate a transition to more sustainable construction.

Due to historical and cultural reasons, wood construction has had mainly regional significance. It remains to be seen, if it could trigger more competition throughout the construction sector also outside the Nordic countries, Central Europe and the UK. Increasing competition could yield more options, reduce the costs, improve the quality, and ultimately reduce the environmental impact of construction.

Glossary

Cross-laminated timber (CLT): A massive wood product, consisting of multiple layers of sawnwood, which are glued crosswise in every second layer. Similar idea as with plywood, but thick enough to be used as a load-bearing structure in multi-storey buildings and for example bridges.

Engineered wood products (EWP): In an EWP, layers of wood, either sawn or peeled, are glued together to improve the dimensional stability and mechanical performance of the product compared to solid wood. The term 'engineered' refers to manufacturing the wood-based products to withstand a given level of stress and to meet demanding building regulations. Some of the most common EWPs include glued laminated timber (glulam), laminated veneer lumber (LVL), I-joists, and cross-laminated timber (CLT).

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