Discussing Timber Myths:

a dialogue between our ambitions and the facts

Design: SeARCH
Picture: Lior Teitler for Moso International

BUILT BY NATURE

AMS AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

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introduction

The transition we need...

The building industry has a huge impact on the environment, both in terms of greenhouse gas (GHG) emissions and resource consumption. It therefore requires a major transition towards more circular and climate-proof building practices. A key piece of the puzzle may come from an unexpected corner: mass timber systems.

For centuries, humankind has built with timber and other renewable, biobased building materials such as straw, reed, hemp and bamboo. A look at the centres of our medieval cities shows the historical importance of these building materials. However, since the industrial revolution in the 19th century, timber has been largely replaced by non-renewable, abiotic alternatives such as mineral materials (i.e., concrete and masonry), metals (i.e., steel and aluminium) and later on plastics as well (i.e., polyvinyl chloride (PVC) or polyurethane (PUR)). This replacement was the result of high levels of industrialisation, which allowed for the improved and more uniform technical performance of these new materials.

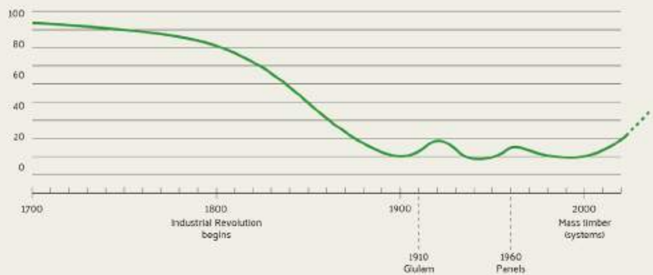
While the high-performance building materials of the industrial revolution have—quite literally—brought us to great heights (think about steel-concrete skyscrapers), they come at a price for our planet. As a whole, the building industry is responsible for 39% of global anthropogenic GHG emissions. The production of abiotic building materials is responsible for nearly a third of this amount—about 11% of global anthropogenic emissions.

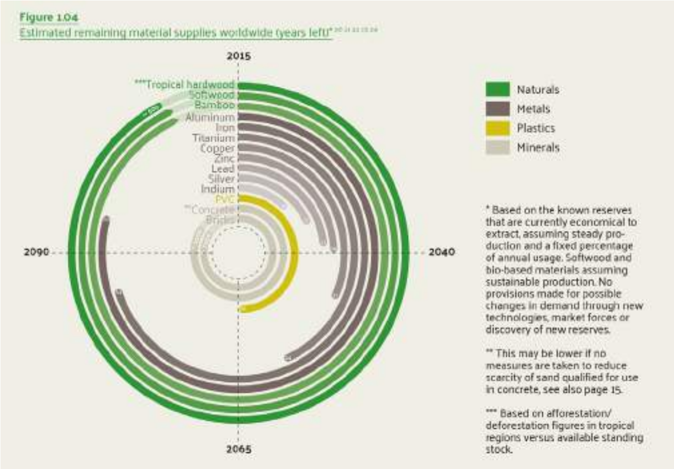
In addition to its contribution to climate change, the building industry is responsible for 44% of global material consumption. Considering the current 'circularity gap'—just over 7% of global materials extracted

Historically, timber has been the main building material. However it was largely replaced during the industrial revolution (01).

Figure 4.02
Historic timber usage

Use of timber as building material in Northern and Central Europa as percentage of all building materials (years indicate commercial introduction, not invention).





By the end of this century it is expected that feedstocks for production of metals and plastics will be depleted (01).

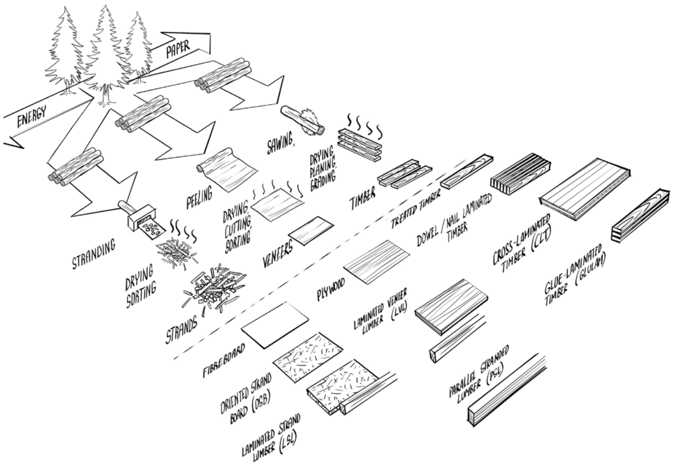
are cycled back into the economy (02)—this means that by the end of this century, our reserves of economically extractable ores used in the production of metals, as well as oil for plastics, might run out.

As we improve in delivering extremely energy-efficient, sometimes even net-zero buildings, the relative importance of operational energy use decreases in the carbon footprint of buildings. This makes it even more important to focus our attention on the energy and carbon embodied in the construction phase of these buildings, where the increased use of sustainably sourced timber offers an alternative with a considerable positive impact.

Timber partly caught up with abiotic materials in the 20th century as a result of its industrialisation. The development of glulam technologies and engineered panel products such as plywood, medium-density fibreboards (MDF) and oriented strand boards (OSB) allowed a more effective use of trees—by utilising residual flows like wood chips and sawdust—and made the output of the forestry sector more efficient as a result. Increased sustainable forest management and reforestation efforts have also allowed the sustainable timber feedstock in Europe to grow steadily since 1900. Finally, the introduction of automated methods to determine the strength of timber planks (for example, based on laser scan technology) improved the uniformity of sawn timber in various strength classes.

This resulted in an increase in timber frame construction practices in the second part of the 20th century.

The last two decades have also shown an upsurge in timber adoption through the invention of large-scale, engineered timber products with high performance and consistent mechanical properties, such as Cross Laminated Timber (CLT) and



Various timber products suitable for mass timber systems. In Europe, at the moment, 47% of harvested wood is used for products in the building industry (or ‘long cycle’ products) and 53% for ‘short cycle’ products (21% pulp for paper and 32% for energetic purposes including pellets) (01,03).

Laminated Veneer Lumber (LVL). These materials can span large distances and carry large weights, and have the potential for mass-scale adoption. Because of their high and uniform technical performance, mass timber systems can directly substitute load-bearing structures traditionally made from abiotic materials such as concrete and steel, even in high-rise buildings up to 20 stories. This is a complete paradigm shift.

Instead of focusing in a carbon-intensive source of finite resources, the combinaton of forests (including soil) and urban system should become a carbon store strategy, lowering atmospheric carbon, while increasing terrestrial carbon sinks. Mass timber systems are also typically light and easy to work with. As a result, they are extremely suitable for prefabrication. Prefabrication (also known as offsite or industrialised construction) results in less transport and quick, on-site assembly time of large-scale elements, with considerably fewer emissions and less nuisance compared to traditional construction. Mass timber systems are a very promising, low-carbon alternative to solve housing problems in European metropoles—be it through the erection of new high-rise buildings, topping up existing structures, or even developing floating housing systems—as densification plays a crucial role in minimising the number of built surfaces in natural areas. Mass timber and timber frame systems are also very suitable for low-rise construction. Through this evolution and rising opportunities, it seems there is a momentum for timber to become a cornerstone of the transition that the construction sector needs to go through.

Timber building requires paradigm shift

Since the 20th century, construction methods have been mostly standardized based on fossil building materials such as metals, plastics and minerals. This means that the construction value chain, including key stakeholders such as contractors, architects, engineers and developers, in general have far less experience with building in timber. Given the conservative attitude of the building sector, this means that new mass timber products are often ruled out. Or if timber is chosen (often in a late stage, based on a design optimized for concrete and steel), sometimes the wrong design and organizational approach is taken, which could lead to a more expensive project or a project with mediocre building quality

Designing and building with mass timber requires a fundamentally different approach in which the key stakeholders in the building process, including the mass timber supplier, work together, e.g. in a building team approach. This is the only way in which the many advantages of mass timber construction can be utilized.

This requires learning by doing and increased adoption of timber engineering and design in academic curricula for engineers, architects and advisors, as well as labourers onsite.

Also, the perception of the final user, who often holds many prejudices against mass timber with respect to durability, strength and fire safety, needs to change.

For example, an extensive literature study about the perception of wood products shows that end-users see fire safety, quality and lack of durability leading to high maintenance as main disadvantages of timber construction (04).

This highlights the importance of a comprehensive communication campaign to take away (unsubstantiated) worries and show the benefits of timber construction. This booklet aims to partly fill this void.

Timber building consumer perception in the Netherlands

A very recent, large consumer survey in the Netherlands came to similar results regarding the need for knowledge of end-users. Of the over 1000 random adult respondents with intentions to move houses, almost 2/3 was not aware of the possibility of timber houses (62%). About half of the respondents (48%) mentioned a neutral position towards a timber house, 31% had a positive attitude, and 21% had a negative attitude. Of these with a negative or neutral position, the main reasons/perceptions as to not wanting a timber house were: fire danger (37%), higher maintenance / lower durability (36%) and expected noise problems (24%). For those with an interest in living in a timber house, the main reasons were the sustainability (44%), the natural look (41%) and quicker construction (36%).

Based on the intention to consider a timber house for rent or purchase, the results of the survey show that the market potential of timber building is 35% of the population with an intent to move. If myths regarding timber building can be taken away, the market potential can increase substantially (05).

Notes from interviews with individual members of the Steering Group (2022).

The transition we want...

Although the momentum clearly shows the opportunity to discuss the timber transition in a diversity of contexts in the world, it seems extremely important to understand how this transition could happen, what the missing elements are and who should be involved during the process.

In 2021, responding to this momentum, and in relation to the success of the Dutch publication 'Houtbouwmythes Ontkracht: het onderscheid tussen fabels en feiten', the intention grew to explore how this Dutch booklet could be internationalized, opened up to the European context, and discussed in the context of a diversity of cases.

In order to do so, AMS Institute, with the support of Built by Nature Foundation (BbN), has set up a collective effort towards opening up a discussion on Mass Timber transition, the Myths & Facts defining the narrative, and the next steps in pushing forward this transition.

The project started with generating a steering group representing different European expertises and contexts. The members were first interviewed individually, after which they collectively joined a workshop to discuss directions, next steps, and ambitions for the transition.

This publication goes beyond the original Dutch booklet by not only debunking myths, but also opening up a dialogue on the diverse positioning of these myths and the topics addressed, ultimately weaving together a narrative around timber construction in Europe.

Therefore, this booklet becomes an honest reflection of the dialogue between the very different perspectives on themes as a way to kick off the conversation from a community of experts and promotors of mass timber.

This booklet's goal is a factual response to the myths and an open conversation about the themes and knowledge under development.

With this approach, the booklet aims to become the kickoff and call for the contribution of an ecosystem of key stakeholders promoting the mass timber transition in the next years.

Who are the key contributors to this booklet?

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how to read

On the white pages, the reader will find the myths description with the facts as arguments. On the colored pages, the reader will always find a parallel debate on the theme and myths from a more open and diverse perspective.

This booklet is rooted in a collaborative process, meaning that it expresses and reflects the diversity of opinions, ideas and ideologies on this topic. This level of contextualization and nuance is a humble approach from the authors to avoid deterministic and categoric messages.

We are aware of our blind spots. As much diversity as we tried to engage with the steering group, we know there are areas, cultures, topics, issues, and opportunities we might be missing.

Therefore, we decided this booklet demanded this duality on the debate to be transparent in the reading format.

We will guide you through the myths and themes with colours and a dual reading approach.

If you are reading this from the printed version, please get ready to have fun flipping the booklet and having the experience of reading two booklets in one!

how to read

Facts and fiction

Despite the many advantages of building with timber, the mass adoption of timber as a building material is evolving at a rather slow rate.

This is due in part to the many misconceptions about building with timber, or common 'timber myths'. This publication dispels the most persistent of these myths. Information in this publication and on the BbN website (where this publication lives) is derived from the international book 'Tomorrow's Timber' and complemented with the latest research insights on this topic, added as references in the final annex.

Although the BbN website focuses on the use of mass timber for residential buildings, the information in this publication is also largely applicable to other building types, such as utility buildings, and partly to other timber systems as well, such as timber frame constructions.

The into myths are divided into four themes:

- **Building quality & performance**
- **Environment & climate**
- **Forestry & wood availability**
- **Economics**

building quality & performance

timber structure will never comply with other materials standards as it has its own quality and standards...

Myth 01: timber buildings are unsafe and weak

Facts in a nutshell:
Timber has one of the best strength-to-weight ratios of all materials, and with fully standardized and strength classified mass timber elements, even high-rise buildings can be safely constructed.

...a purist or pragmatic embrace?

Members of the steering group seem to prefer one of two different approaches.

A more purist approach advocates for understanding how we could exclusively design and build with biobased materials, where we manage to phase out abiotic materials. As Torero remarks: “For the foundations and core, you do not always need to use concrete and steel when you can achieve the exact same objectives through carving stone and developing your foundations in those terms” He continues: “However, in the case of a high rise building, perhaps concrete is indeed the ideal solution. High rise timber could become inefficient. You need to look at the multiple dimensions, weight and height demands. Then analyze gains and compensation on using concrete or other complementary materials.”

This points to a more pragmatist approach consisting of embracing hybrid building systems, where traditional materials like concrete and steel complement timber and biobased materials there where entirely timber-based systems would become too expensive. Such hybrid systems require careful design, where materials from the techno-cycle are not mixed with those of the bio-cycle.

As Garcia mentioned: “It is important to understand the use of wood for the right purposes, especially where it brings value and it makes sense. Cities often ask: I want to understand where it makes sense to build with timber, and where should I be using other traditional bio-based materials.”

FACTS

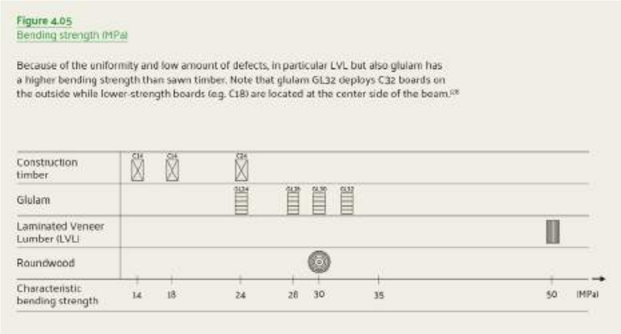
Strength grading (laser eye) of incoming spruce boards in the CLT factory of DERIX in Westerkappeln.

Efficient strength

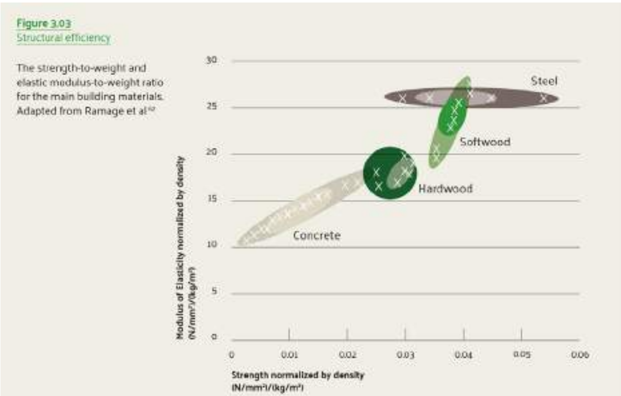
Wood is a natural and anisotropic material. That means that its strength differs according to the direction it is loaded, with far higher strength in longitudinal direction parallel to the fiber. It follows that each board may have different properties.

In the past, this non-uniformity of timber made for large-scale replacement with fossil materials in the industrial revolution. However, with the introduction of (often automized) strength grading, each board intended for structural use is graded following EN 14081 and classified in strength classes following EN 338.

Actually, because of its lightweight and relatively high strength, (engineered) timber is one of the most efficient building materials available on the global market from a structural perspective, with mechanical properties such as strength or stiffness that can easily meet European building regulation requirements.



Bending strength of various mass timber products compared to 'normal' structural timber (01).



Timber performs very well both in terms of strength per weight and stiffness per weight (elasticity) (01,06).

This applies even more to mass timber products, as during their production, weak components in the boards are taken out, and the often fault-free boards or veneers (LVL) are then glued together to form a very strong component, far stronger than the individual boards.

Additionally, timber buildings have lightweight and elastic structures—allowing them to bend under shock loads—making them more resilient to earthquakes (07). Building with wood is therefore often preferred in earthquake-prone areas.

Choosing materials on a fit for purpose basis

This consistent mechanical performance also makes mass timber suitable for high-rise buildings. Globally, the tallest timber building as of October 2021 is the 18-story multi-functional building Mjøstårnet in Norway at an impressive height of 85.4 meters. The complete load-bearing structure of this building was erected in mass timber, with a glulam mega frame, LVL cassette flooring systems, CLT walls and thermally modified cladding. Throughout Europe, various multi-story mass timber buildings are being developed for various uses.

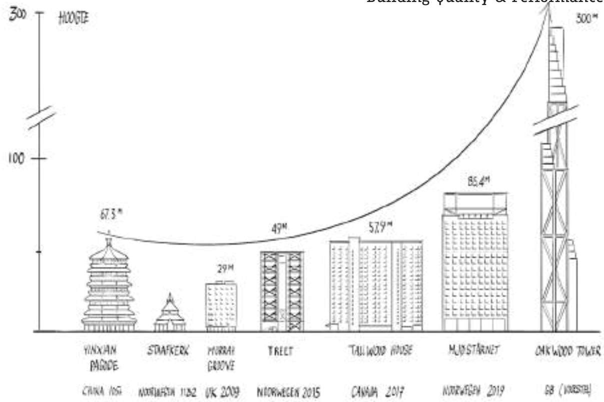
Most of these buildings, especially those over 10 stories high, feature a considerable amount of concrete (e.g. for foundations, elevators shafts) and/or steel

Patch 22, a hybrid timber building features a glulam post beam structure with a demountable prefab concrete flooring system.
Design: FRANTZEN et al.
Picture: Luuk Kramer

(e.g. for bracing). We believe this is a good development, as this way, the unique strengths of these materials (e.g. concrete: compression and water resistance, steel: tension) are capitalized upon.

This leads to a durable building that is efficient in material use.

The provision would need to be that these fossil materials are manufactured (e.g. fully made of secondary materials) or designed (dry, demountable connections) to be truly circular. Regretfully, this is more exception than common practice.



The evolution of tall timber buildings is taking off with the introduction of mass timber systems (01).

Sara Kulturhus in Sweden features over 10.000 m3 of timber including CLT elevator shafts.
Design: White Arkitekter
Picture: Martinsons/Jonas Westlin

Design for the multi-functional building Dutch Mountains (120 meters high) in Eindhoven, the Netherlands, which should be ready around 2025.
Design: Studio Marco Vermeulen

wood is one of the most ancient building materials...

Myth 02: timber buildings do not last long

Facts in a nutshell:
If a timber building does not last long, there has been a design or construction mistake. As long as a timber structure remains dry, it can last indefinitely. Also, on the outside, timber can last extremely long if detailed well and if the right timber products are chosen.

FACTS

Picture: Micha L. Rieser

Picture: Quistnix

Durability classes

The durability of wood as a building material (or its natural resistance to fungi or insects) is defined through the EN 350 standard, with durability class 1 being the highest standard a material could achieve (a lifespan of at least 25 years in direct ground contact) and class 5 being the lowest (a lifespan of at least 5 years in direct ground contact). Thus, the durability of wood, in combination with the use class, will define the lifespan in various circumstances, both interior and exterior.

Well-constructed and designed timber buildings last for ages, as these examples from Scandinavia (stave churches from the 12th century), the Netherlands (medieval windmill) and China (Hori-yu temple from 607 AD, the oldest known timber structure in the world) show (01).

Durability of bearing structures (interior)

Load-bearing structures in mass timber, as well as timber frame structures, are usually made from softwood species with lower durability classes. This, however, does not jeopardize their technical lifespan. If designed well, indoor timber structures remain dry and will not be susceptible to decay or fungi, borer or termite attacks. As a result, a timber structure can last indefinitely. This also applies to mass timber structures. Although CLT has not yet been around for long enough to show old case studies, there are several case studies of glulam constructions of over 100 years old in perfect condition (08).

Semi-outdoor timber structures can also last long, as long as the timber structure is able to ventilate and dry after exposure to moisture.

It is perfectly okay for non-durable timber to get wet for a short period of time, as long as it gets the opportunity to dry properly through sufficient ventilation.

The moisture sensitivity of (especially) softwood, does mean that (mass) timber should not be exposed to moisture for too long during the construction process. Through prefabrication of mass timber elements and modules, the potential time of exposure can be greatly reduced if the right additional preconditions are taken (covering up, or, in case the elements did get wet, enabling drying before final installation).

Durability of skin (exterior)

The use of timber for the exterior of a building—for example, for facades, window frames, decking or shutters—is often associated with high maintenance. However, with the right detailing (especially when it comes to managing exposure to moisture, i.e. facilitating ventilation) and with the right choice of wood species (more in Myth 09) and finishing, maintenance does not have to be more of an issue than with abiotic materials.

Several highly durable tropical hardwood species and modified wood products (such as acetylated wood, furfurylated wood or thermally modified wood—whose molecular structures have been altered in a non-toxic way to significantly increase the biological durability and dimensional stability) actually perform better compared to their abiotic counterparts in terms of durability and related maintenance, making them very suitable for use for the exterior of a building.

Non-durable wood species may also be applied, provided they are maintained with a solid, high-performance coating system. From a precautionary principle, it is instead to advised to apply durable wood species or products instead (minimum of durability class 2).

In this process, it is also very important to to manage expectations with respect to colour change (greying of timber) of cladding and decking as a result of UV degradation. This is perfectly normal and does not affect the durability or quality. However, final users should be informed about this natural phenomenon. If this is not desirable for aesthetical or other reasons, the boards can be maintained (e.g. with oil application) or another finish could be chosen (painting, or other treatments such as charring the outer layer).

Thermally modified compressed bamboo as applied at the Grotius residential towers in The Hague.
Design: MVRDV
Picture: MOSO International

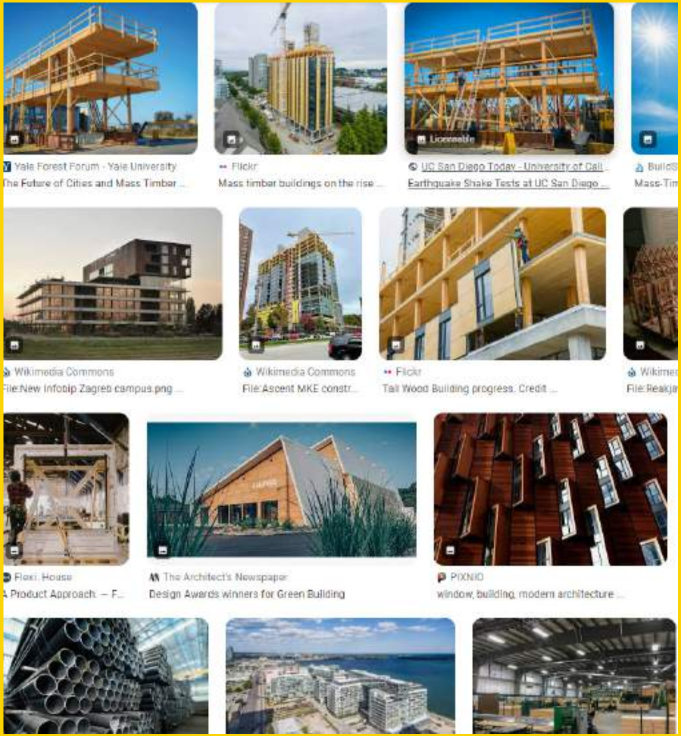
considering durability beckons the topic of adaptive design

If a timber building that was intended to be permanent does not last long, a design or construction mistake has been made. As long as a timber structure remains dry, it can last indefinitely. Bear in mind the centuries-old timber structures in our historic city centres.

The steering group pointed to the importance of awareness and skill amongst all involved stakeholders—from architect to contractor—about how timber buildings can be built for several generations. Yet, the needs of our built environment are constantly evolving and timber buildings can and should serve or change accordingly. This would demand a new understanding of how mass timber can play a role in changing spatial demands and the practice of adaptive design.

...how will mass timber buildings perform in 100 years?

Screenshot from google search on most visited web for “mass timber buildings”



...we are missing a shared European conversation about fire safety [...]

Myth 03: timber buildings are not fire safe

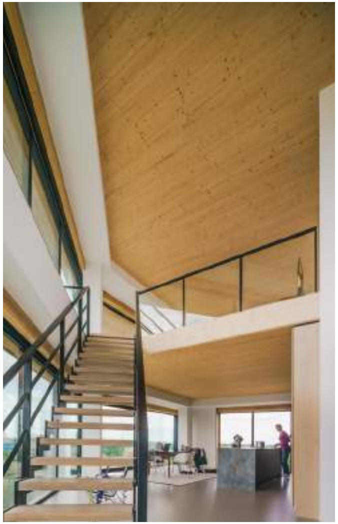
Facts in a nutshell:
Although timber is combustible, mass timber behaves very predictably in case of fire, and many measures can be taken to safeguard fire safety in a timber building.

[...] we need knowledge exchange

The Steering Group agrees that many measures can be (and are) taken to ensure fire safety in timber buildings. As Torero explains: “these myths about fire hazards are unfounded, and exist mostly because the industry does not want to educate itself. There is a lack of knowledge and a lot of misinformation, which results in either too much checking, or no checking at all. There is no shared European conversation about fire safety. We need facilitation of this conversation and stimulation of knowledge exchange. For lots of topics, there is a need for more diversity in narratives. But when it comes to fire safety, a more homogeneous narrative (between European countries) is crucial”.

FACTS

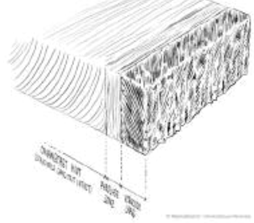
Sprinklers were placed on to the CLT ceiling reduce the probability of significant damage in the 73m tall HAUT building in Amsterdam.
Design: Team V Architectuur
Picture: Jannes Linders



Various strategies for securing fire safety

Mass timber systems have a very predictable fire behaviour: under fire, mass timber will char and form an outer coal layer, protecting the inner layers and leaving them with a predictable structural capacity. The rate of charring can be well characterized, which makes it possible to guarantee the fire safety of mass timber structures through adequate design. Considerations such as delamination and the evolution of the timber's mechanical properties are necessary but not out of reach for competent engineers.

In addition to their predictable charring rate, mass timber structures can be prevented from igniting by cladding their surface with non-combustible materials such as gypsum boards, also referred to as



When timber burns, it will form a char layer at the surface, behind which the timber will retain significant structural capacity (01).

'encapsulation'. As this can negatively affect the aesthetic and moisture regulating qualities of mass timber, it is often desirable not to cover all surfaces, in which case additional demonstration of performance might be necessary. This performance will focus on attaining the self-extinction of the non-encapsulated timber.

It is possible to use existing performance assessment such as Fire Resistance testing. This was the case for the Mjøstårnet tower, the tallest timber building worldwide. Large-scale testing experiments were executed by SP Firetech and Sweco to gain confidence on the fire safety performance of the timber structural elements.
Picture: Sweco Norway

let us focus
on what
timber is,
rather than
what it is
not (concrete
or steel)

In the 10 story Brock Commons mass timber building (design: Acton Ostry) an encapsulation strategy was chosen to meet the 120 min fire resistance requirements (01).

Adjustment of building legislation

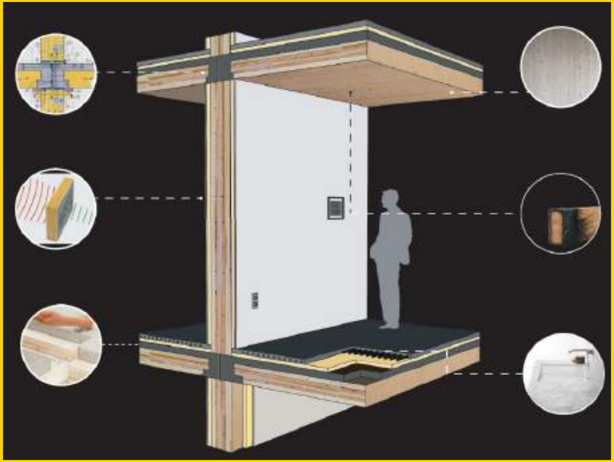
While fire safety can be engineered well by a holistic design approach in which one or more of the strategies mentioned above are combined, national and European building legislation and standardization systems are not yet fully synchronized with mass timber building systems. This has to do with the potential higher fire burden that mass timber systems can bring and the risk of increased inflammation after delamination of boards in a laminated construction (e.g., glulam or CLT), which is an important field of research in institutes across Europe. This is expected to lead to additional design rules in Eurocode 1995-1-5 and, in various countries, an adjustment of the relevant building codes. For example, the Dutch Normalisatie Institute (NEN) is investigating altering norms NEN 6068 and NEN 6069.

This is expected to lead to more stringent legislation and requirements for timber buildings above 30 meters tall (09).

design is a crucial factor to achieve proper sound performance

Myth 04: timber buildings have poor acoustics

Facts in a nutshell:
Due to the lightness of mass timber, especially contact noises can form a challenge in multi-story residential buildings. With good design measures however, acoustic requirements can be met.



In the HAUT building in Amsterdam a concrete screed floor is poured in the factory on the CLT floor to make a combined hybrid flooring element. Although this increases structural and acoustic quality, it significantly weakens the circularity potential of the floor element in End of Life.
Design: Team V Architecture

There is an interest and demand from the Steering Group to keep researching and looking for more data-based backup. As Torero mentions: "if you keep in mind qualities for sound that apply to other materials when designing a timber-based system, then the performance will not be adequately or properly assessed."

FACTS

Acoustic design measures

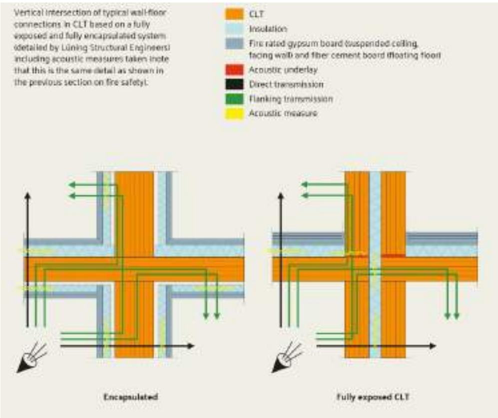
Because of their light weight, timber structures do not absorb sound or contact vibrations as well as heavy building materials do.

This especially applies to contact sounds in the lower frequencies. This proves a challenge, particularly for structural floors in multi-story residential buildings, where mass timber elements often need to be acoustically decoupled and mass needs to be added. Several acoustic measures are often combined to reach high acoustic comfort in multi-story timber buildings, such as the application of elastomers between wall and floor slabs, the introduction of cavities between mass timber panels, the addition of mass (e.g., screed floors) and the adoption of suspended ceilings and facing walls on battens. The key challenge here is to strike the right balance between structural integrity, acoustic decoupling and circularity (reuse potential) of the building.

For example, instead of permanently fixating a concrete screed floor with anchors onto a CLT floor, it is preferable to add a mass layer that can be removed in end-of-life (e.g. gravel) or use a more efficient mass-spring system. In any case, involving an experienced acoustic engineer is essential, especially for multi-story residential buildings.
When the right balance is achieved, residents and users of (exposed) timber buildings often have a higher appreciation of the acoustics of timber environments, which often exhibit lower reverberation compared to stony materials.

Elastomers added under CLT slabs and metal connectors.

Various acoustic measures combined in an exposed and an encapsulated standard floor-wall detail in a residential timber building (01).



what are the aesthetics of mass timber?

Myth 05: timber buildings look like log cabins

Facts in a nutshell:
With mass timber, a new architectural form language is possible, both in complex 3D parabolic and rectangular forms. And although it is perhaps a lost opportunity, a building with a complete timber shell, can still resemble an 'ordinary' concrete building.

...what is the mass timber design imaginary?

Besides the agreed need to develop competence and capacities for the technical requirements, it is essential to also tackle the design process as it is one of the most crucial steps when decisions come together and will define whether the building will perform and feel like a successful outcome.

On this note, during the brainstorm session, many members of the steering group agreed that design considerations should largely be discussed at the European level. Both from the practitioner side and from the education on design disciplines.

We refer to architectural design, as well as design in the broader sense. From the urban, to the process design, and from architectural composition to the most interior design detail: design matters.

An imaginary requires a more "moving forward" approach to this myth than exclusively talking about timber versatility. This requires activating a collective understanding of challenges and opportunities for integrated and interdisciplinary mass timber design in order to construct an imaginary of where we can and would like to go.

Here is when contextualization in the discussions, in the diversity of countries, design approaches and execution capacities are crucial. All of it through an integrated and interdisciplinary ecosystem open to debate of where, how and what we are aiming for with the mass timber transition.

FACT

The Swatch and Omega headquarters (Shigeru Ban architects) in Switzerland features a marvellous curved mass timber bearing structure.
Design: Shigeru Ban Architects
Photo during construction: (c)Philip Zinniker
Interior photo: (c)Didier Boy de la Tour

Timber could be as architecturally versatile as any other material

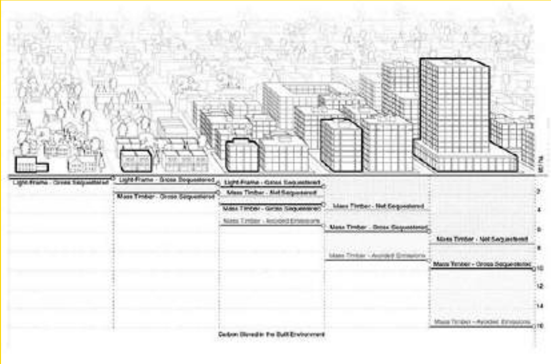
There are sometimes concerns that a mass timber building will inevitably look like a log cabin—in other words, that the amount of exposed wood will be 'overkill'. This, however, is generally not the case: while most architects and users do appreciate the look and feel of exposed wood, this is often only applied to a select amount of surfaces, and sometimes it is not shown at all.

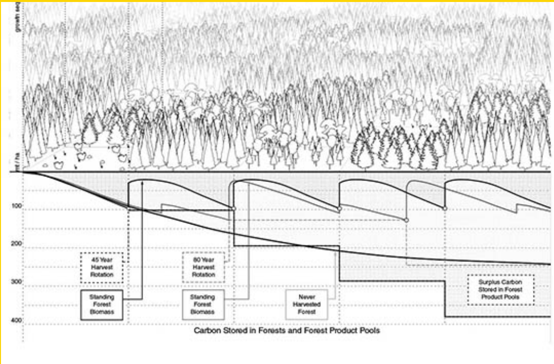
When kept in sight, CLT panels are usually finished with a higher quality top layer compared to regular CLT panels, which typically come in 'industrial' visual quality and often include knots and scars. Visible CLT panels can also be finished with a top layer of a more luxurious wood species such as oak, silver fir or even engineered bamboo.

Besides this more traditional thinking—using timber to replace fossil materials in mainstream architecture—it should be stressed that the lightweight consistency and workability of mass timber offers many opportunities for parametric modelling. This way, huge 3D-formed and even curved elements may be prepared offsite with extreme precision, based on robotic manufacturing to design and construct extraordinary structures. The Japanese architect Shigeru Ban is one of the pioneering star architects developing a new form language in timber construction, taking advantage of these specific qualities.

what if we would look at the multi-escalar and metabolic dimension of mass timber?

Extraction illustrations from the book Wood Urbanism, published in 2021 from Daniel Ibañez.





BEAT Barcelona Stage. IAAC led the design of a sustainable and unique proposal that recreates the Barcelona coastline from Besòs to Llobregat, featuring some of the city's most important landmarks.

environment& climate

the mass timber sector is becoming a crucial player reducing the carbon footprint of our built environment

Myth 06: Harvesting and processing make the forestry and wood sector a huge carbon emitter

Facts in a nutshell:
The European forests are a net carbon sink, and building with mass timber can actually substitute carbon intensive building materials and store carbon in buildings, making the built environment an additional carbon sink.

Design: SeARCH
Picture: MOSO International

Hotel Jakarta in Amsterdam was built using 2500 cubic metres of mass timber and engineered bamboo, leading to 1995 tons of Construction Stored Carbon and 2394 tons of avoided CO_2 emissions—a combined benefit of 4389 tons of reduced CO_2 emissions. Building with wood alone allowed to compensate for the CO_2 emissions of 655 European citizens (who, on average, account for 6.7 tons of emissions per year), the equivalent of driving an efficient car 1004 times around the equator! As a bonus, a large amount of oxygen was also produced: 3500 tons in total. For reference, an adult human being consumes about 0.75 tons of oxygen per year.

The amount of timber required for this building was sustainably produced by the European forestry industry in less than 14 minutes (03).

FACTS

How it works - The Forestry Construction Pump

The IPCC states in its latest assessment report that timber derived from sustainably managed forests and used in the construction industry, can considerably improve the carbon balance, both in terms of carbon storage and as substitution (10).

The Forestry Construction Pump was coined by climate expert Professor Hans Joachim Schellnhuber. It explains the 3 levers through which timber construction from sustainably managed forest can mitigate climate change (05).

1. Capturing CO_2 in forests
2. Storing CO_2 in the built environment
3. Avoiding emissions associated with CO_2-intensive building materials

Forests

First, forests act as important carbon sinks in Europe, absorbing about 10% of Europe's Greenhouse gas emissions (more info below). During the photosynthesis process, trees absorb CO_2 from the atmosphere and, powered by solar energy, convert it to glucose—a building block for wood molecules—and oxygen. As a result, about half of the dry weight of wood consists of biogenic carbon. This is carbon stored in biological materials through the photosynthesis process.

PEFC and FSC certification guard the balance between harvesting and growing forests (see M9).

Buildings as carbon sinks

Second, timber buildings can store carbon for as long as the timber components remain in use. When designed and used following circular principles, timber buildings and components can last for decades, if not centuries— and so does their carbon storage.

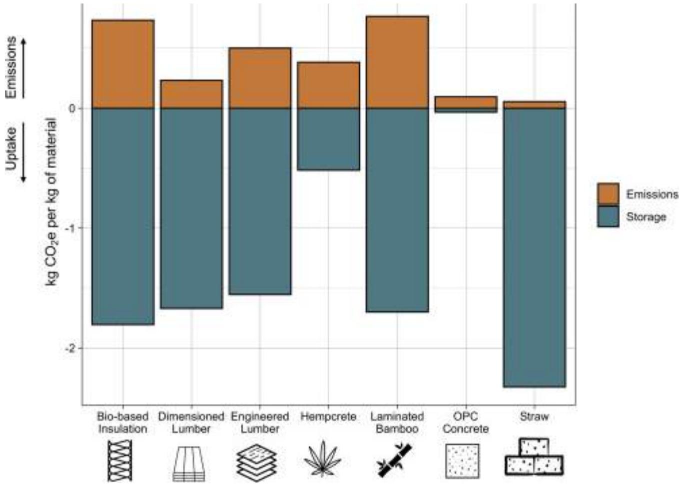
Building with wood can, when combined with sustainable forestry, thus result in higher carbon sequestration than when leaving forests untouched.

This storage of biogenic carbon is not (yet) taken into account on a cradle-to-grave basis in environmental impact calculations such as EN 15804. However, it is reported in the latest version (+A2) of the standard as a separate category, which is a step in the right direction (12).

As we improve the circular reuse of timber components and buildings (see M7), not accounting for construction-stored carbon increasingly becomes an omission.

We notice some change on this front, where both the Dutch Environmental Product Declaration (EPD), the French RE2020 and the Finish “Carbon Handprint” are looking to or already do take biogenic carbon storage into account (06). On a country level, the carbon stored in Harvested Wood Products (HWP) is reported following IPCC tier 1 guidelines.

The amount of carbon stored in a project can be calculated with a rather simple formula published in the END 16449 standard, and is also referred to as “Construction Stored Carbon) (13, 14).



When based on sustainable production, the carbon storage in biobased materials is far larger compared to the CO_2 emissions during production. Note that these numbers are per kg, explaining the low emissions for concrete (which per m3 is about five times higher compared to mass timber) (11).

The substitution effect

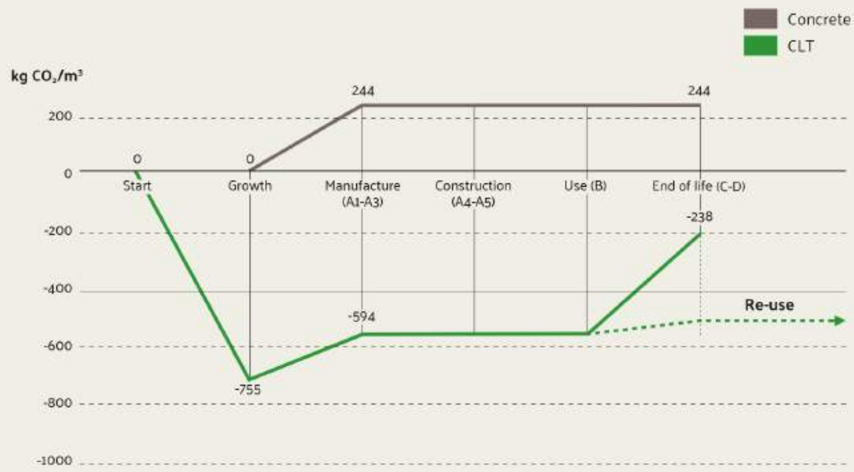
Third, by building with wood, the emissions normally produced during the manufacturing of CO_2-intensive abiotic materials are also avoided. The CO_2 material pyramid, based on the CO_2 emissions during production as reported in the EPD for various materials, gives a neat overview of the large difference in the carbon footprints of abiotic and biobased building materials. This overview of the carbon stored in biogenic building materials is included, explaining the negative values.

The CO2 Material Pyramid (15).

The largest impact of the embodied carbon of a building is related to the bearing structure, and in particular the structural flooring (01).

Figure 2.18
Life-cycle carbon comparison CLT and concrete

The CO_2 emitted during production of CLT is many times smaller compared to the amount of CO_2 locked in for the lifetime of the product. Although this CO_2 is emitted again, e.g. in case of burning for energy in the end-of-life phase, this still leads to a negative CO_2 value over the full life cycle because of the substitution of high CO_2 intensive fossil fuels in a country's energy mix. If the CLT is reused after a shaving round (marginal CO_2 emissions), the CO_2 is locked in for another lifetime, which can be further extended through cascading. The figures below are based on generic sector-based EPDs for CLT and concrete (C35/45, excluding CO_2 emissions of steel reinforcements) published in the German IBU EPD database.[108 109]



The carbon footprint of 1 m3 CLT compared to 1 m3 of concrete (still excluding steel reinforcements), set out over the life cycle of building material. The total CO_2 emissions for 1m3 for CLT are negative as a result of incineration for energy production (providing a credit as a result of replacing the German energy mix), although reuse is preferred both from carbon and material use perspective (01).

Production emissions far lower than carbon stocked

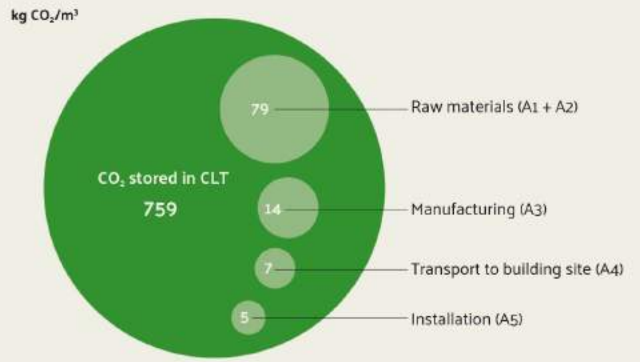
As a rough rule of thumb, a ton of CO_2 in timber instead of abiotic materials, represents 1.2 tons of avoided CO_2 in the built environment (13,16).

During the harvesting, transport, manufacturing—including glue and energy use—and construction of mass timber, CO_2 is emitted as well. However, the amount emitted is five to ten times lower compared to the amount of CO_2 locked into the timber. This is a result of the light weight of the timber and its short, low energy-intensive production process (17).

Considering all steps, from harvesting to production, CLT and glulam are associated with 118 to 132 kg of CO_2/m3, more than five times lower than the 750 to 800 kg of CO_2/m3 they store.

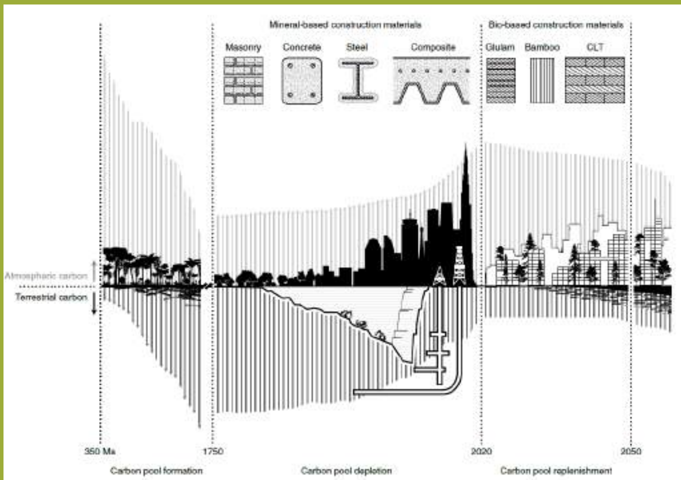
Figure 2.11
CLT as a carbon store

The CO_2 emitted during production of one cubic meter of CLT is many times smaller compared to the amount of CO_2 locked in for the lifetime of the product (based on EPD of Derix Group).[131]



The carbon emissions (cradle to gate) for the production of 1 m3 of CLT (DERIX group) are considerably lower compared to the CSC (01).

Carbon emissions and storage over time (18).



Potential impact of a global timber transition

Looking ahead, it is expected that by the year 2100, about 80% of global citizens will live in a city (currently, this is over 50%).

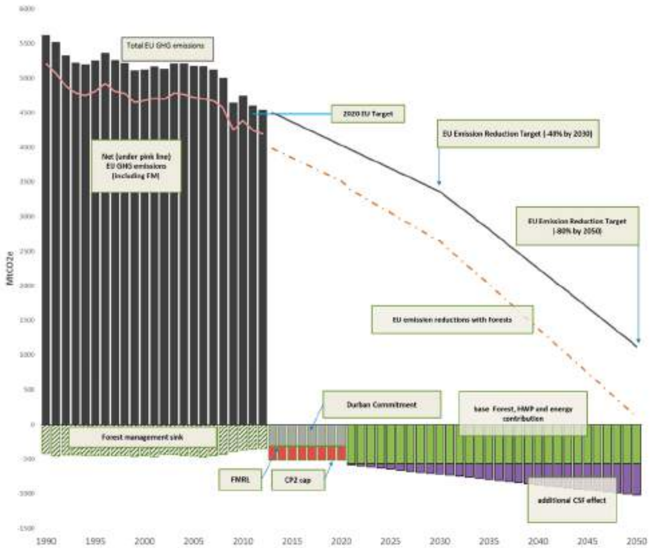
Several studies have modelled the consequences if, worldwide, future construction would be executed largely in mass timber.

For example, UK think tank The Royal Society found that the large-scale increase of timber may yield a cumulative carbon decrease of up to 20-50 Gt CO_2 by 2100, i.e. about 5 -12% of the 400 Gt CO_2 carbon budget identified to stay within an increase of 1.5 degrees Celsius.

This study did not incorporate the substitution effect of replacing abiotic building materials or model the land-use impact of the increased demand for timber, which could have both a positive (e.g. reforestation) and negative (e.g. overexploitation) effect.

A recent study published in Nature, based on the global land system model MAgPIE, found that a wide-scale transition (90%) to mid-rise wooden buildings in cities worldwide is achievable in terms of land use, in particular through the establishment of forest plantations. This would lead to a saving of 106 Gt CO_2 (more than 25% of the carbon budget to stay within the 1.5-degree climate change parameter). This scenario would require an additional plantation area of 149 Mha (only 4% of the current global forest area) based on fast-growing species. Modelling this additional plantation need in MAgPIE showed that this is possible without jeopardizing agricultural production, although strong governance is crucial in this scenario for biodiversity conservation (18, 19, 20, 21, 22).

(23)



So what does this mean at a large scale?

In 2015, the carbon sequestration capacity of forests represented about 10% of European CO_2 emissions (435 Mt CO_2 per year). If the carbon storage and substitution effect of timber products are also taken into account (levers 2 and 3), the complete EU forest mitigation effect totals 13% of European CO_2 emissions (569 Mt CO_2 per year).

The carbon sequestration benefit of European forests could increase to over 20% in 2030, at a 78% lower cost than right now. In order for this to happen, high-value-added applications of wood (such as for mass timber in construction) have to be increased. This carbon sequestration capacity is still excluding the potential use of fibres from biobased materials through cultivation (e.g., hemp, flax, etc.) and the use of residual streams from agriculture (22, 23, 24).

...design for dissassembly is paramount to achieve circularity

Myth 07: Timber buildings are incinerated at the end of their life

Facts in a nutshell:
A building which has been designed through circular principles will last for ages, and when designed for disassembly, it can be very easily taken apart and rebuilt.

FACTS

Circular building strategies

Circularity is a hot topic. And rightfully so: worldwide, only 7.2% of materials are being recycled. The other 92.8% is burnt or ends up in a landfill.

As the built environment is responsible for 44% of raw material consumption, the building sector can play an important role in closing this gap (02).

In a circular economy, resources are reused so as to avoid wasting them at the end of a life cycle (01).

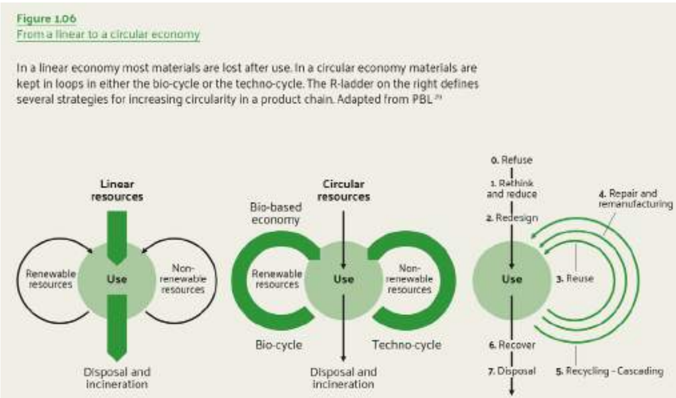


Figure 1.06
From a linear to a circular economy

In a linear economy most materials are lost after use. In a circular economy materials are kept in loops in either the bio-cycle or the techno-cycle. The R-ladder on the right defines several strategies for increasing circularity in a product chain. Adapted from PBL[29]

A useful tool in defining priorities when adopting circularity strategies is the so-called R-ladder, which is also adopted by the European Commission. It is a very useful tool when setting priorities for building (or for not building: the highest level of the decision ladder is to not build at all or to transform existing buildings). If building is necessary, renewable materials are preferred over finite, abiotic materials.

Furthermore, the end-of-life phase needs to be taken into account in order to facilitate high-end reuse of materials. This means designing for adaptability (e.g. flexible floor plans facilitated by Open Building concepts) and disassembly (i.e. dry, demountable connections) (25, 26).

When materials can be recycled, a cascading strategy should be adopted (see M9). In general, biobased building systems (including mass timber) are easier to recycle than traditional fossil materials because of their low weight and good workability.

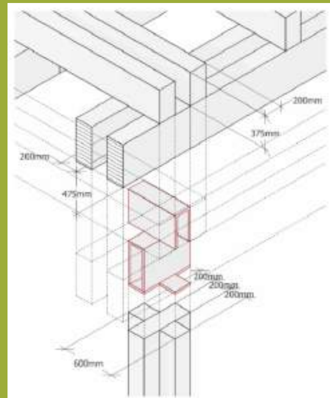
Suitability of Mass Timber for Circular Building

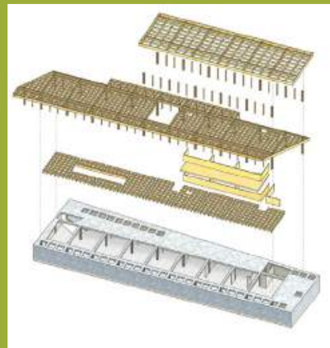
In contrast to most traditional building materials, mass timber is a light material that is easy to work with. This makes it well-suited for use in 'dry' building methods. The demountable, separable connections are perfect for adaptable and dismountable circular buildings. As load-bearing structures have the longest lifespan and represent the largest material volume in a building, reusing shell elements provides the largest environmental gain. For building functions with a lower lifespan, it is important to take dismountability and repairability into account, following the 'Layers of Brand' (27). By designing these demountable shell elements or modules for disassembly from the start, they can be more easily 'harvested' from buildings that have reached the end of their functional lifespan. This is particularly relevant for large solid elements such as CLT and glulam, which, if kept dry, can be reused after just a sanding round.

"The Epos", a school in Rotterdam, was built with a very tight budget and is designed to be disassembled again. The building consists of demountable modules made from mass timber. The plan is to disassemble and rebuild the school in another location in five years.
Design: SeArch
Picture: Ossip van Duivenbode for SeArch

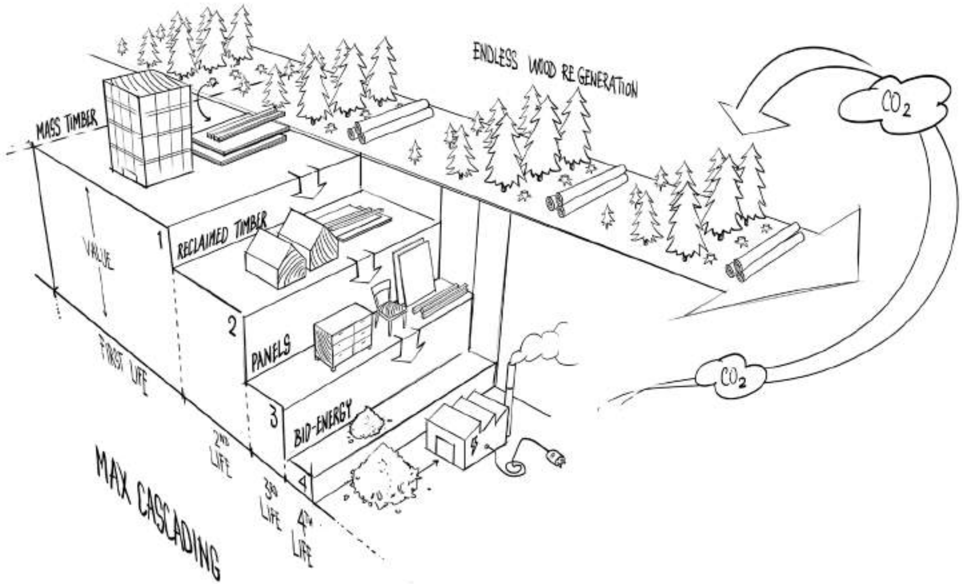
The recycling of old structures, including the increased recycling of post-consumer wood, is already happening within some projects. It is expected to become more popular, partly because of the economic (residual) value that these large mass timber elements (CLT slabs or glulam beams, for example) represent. In fact, some mass manufacturers have already implemented a take-back system (28) or are in the process of doing so.

In the Circl pavilion in Amsterdam, completely modelled in BIM, including a material passport, the glulam beams are designed to be disassembled. The beams are made of slightly oversized timber, enabling their re-use at end-of-life in commercially attractive dimensions. Mass timber supplier Derix has already guaranteed to take back the glulam elements for reuse. This will be an interesting case study: the pavilion will need to move as the ground was sold by ABN AMRO to another owner in 2022.
Design: de Architecten Cie
Picture: Ossip van Duivenbode





In the headquarters of architectural firm 3XN in Copenhagen, the centuries old wooden beams, harvested from old warehouses in the neighbouring harbour, have been reused one on one in the post-beam load-bearing structure featuring traditional connections with bolts and carvings.



Cascading of timber products; the more often we reuse timber, the longer CO_2 is stored, whilst forests can regenerate several times in the meantime (01).

Cascading stores carbon for longer

When mass timber components are reused, the attached carbon is stored longer. Forests are able to regenerate during the lifespan of the building, sometimes several times.

After a second or third useful high-end life, it makes sense to 'break' the timber components and chip them for use in panel boards such as particle boards, MDF or OSB. In a fourth or fifth life, these elements can be used for bio-energy production from biomass, biochar (soil improvement) or biochemistry: their final destination. Note the contrast with 'grey' biomass, which uses newly harvested logs directly for the production of energy (e.g. for pellets).

Grey biomass is often a result of counterproductive subsidies, some of which are provided by the EU.

Currently, most LCA and EPDs are still based on a scenario in which timber will eventually be incinerated for energy production. However, with the EU having to meet certain environmental guidelines before 2050, it is expected that incineration of existing timber constructions will not happen anymore—most of the existing timber constructions have functional lifespans of more than 50 years.

It is therefore very likely that after 2050, even more effort will be made to reuse biobased materials and that the current practice of incineration for energy production (without capturing the CO_2) will no longer be accepted or might even be prohibited.

If a mass timber EPD is based on a circular scenario, i.e. with reuse of the elements, then the results in terms of environmental impact and carbon footprint are considerably lower than the already low cradle-to-grave impact.

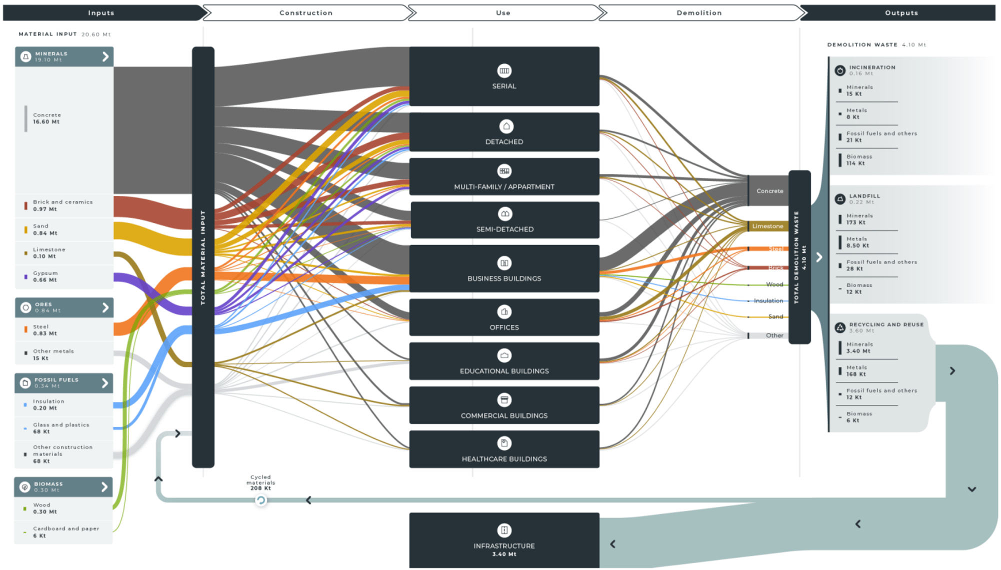
Use of post-consumer wood in Europe

While several projects incorporating the added value of post-consumer wood are being erected all over Europe, the “Wood Circularity Gap” is still far too high. On a European level, of the more than 55 million m3 of wood waste, 36% is landfilled, 31% is burned for energy production and 33% is recycled for (panel) materials.

In some countries, where the demand for biomass to fuel large biomass energy plants is high, the recycling percentages are even lower. For example, in the Netherlands, 86% of post-consumer wood / biobased material is incinerated for energy production, and only 5% is recycled (29, 30).

A crucial component in multi-story residential timber buildings is to adding mass in particular to absorb vibrations (footfall). Typically this is done by pouring concrete on top of a CLT floor, often connected with anchors. However, this largely damages the circularity potential of the combined CLT-concrete floor. A better development, as shown in this apartment building in Belgium, is to use a dry solution, in which the tubes and wires are attached to the CLT floor, and a layer of gravel/sand/chalksplit is added on the CLT floor, which is covered by foil. Using a dry method facilitates the high-end reuse of the CLT slabs at end-of-life.
Picture: CLT-S

Whilst this project might not look that special, it is actually a perfect example of circular timber use, 90% of the timber structure, windows and cladding comes from a neighbouring project (01).
Design: Rothuizen Architecten en Adviseurs BV



On the other hand, the processing residues during the industrial production of wood (at 188Mm3, a far higher amount than post-consumer wood) are almost entirely used for panel board production or for heat/energy production, usually in the same production facilities (29).

The material flow analysis of the built environment in the Netherlands shows that timber (green flow) represents only a marginal amount in the current material use, which is largely dominated by concrete. Only 9% of secondary materials are being reused; most ends up downcycled as road beddings. Most timber is incinerated for energy production at the end of its life (02).

the adhesive becomes a crucial factor in the end of life of the building…

Myth 08: The glue used in mass timber negates its environmental benefits

Facts in a nutshell:
The most commonly used glues have considerable environmental impact. Yet, amounts are very low, hardly affect indoor emissions, end-of-life reuse or reuse, and non-toxic alternatives are under development.

FACTS

Various sizes of Dowel Laminated Timber.
Picture: Holz 100

Glues cause some environmental harm

Most mass timber products (CLT, glulam, LVL) require some kind of adhesive to bind the boards or veneer layers. Although this aspect receives a lot of negative attention, the amount of glue (dry weight) in mass timber products is very low: 1% for CLT, 1-2% for glulam and 3-6% for LVL.

The most commonly used glues in mass timber are melamine (urea) formaldehyde, polyurethane and phenol formaldehyde.

These glues are indeed based on fossil resources, making them less compliant with the bio-cycle, and some are slightly toxic. However, several of these adhesives are so well-advanced that their indoor emissions are extremely low. For example, volatile organic compounds (VOC) emissions tested for CLT revealed a TVOC score of less than 10% than the European threshold levels.

So, from a health perspective, there is no reason for concern.

On the other hand, while the amount of glue is very low, it does have a considerable impact on the environmental burden of the wood. For CLT based on MUF, the glue is only 1% of the weight but creates almost 20% of the complete environmental burden (based on the EPD by DERIX in the Dutch NMD database). This shows that choosing a different glue system can make a difference.

There are several glue systems on the market that are formaldehyde-free and are Cradle-2-Cradle (C2C) certified at the Gold level. There is even a CLT manufacturer with an overall C2C Gold level certificate, and a Material Health (measuring toxicity) at Platinum level, the highest level possible (31, 32, 33).

One should remember that, in general, these glues (also the MUF) do not limit the end-of-life reuse possibilities of mass timber. As they are assessed as A-grade timber, post-consumer mass timber may be reused, and can safely be incinerated for bio-energy production.

Non-toxic, non-fossil alternatives

There are two alternatives to fossil based glues.

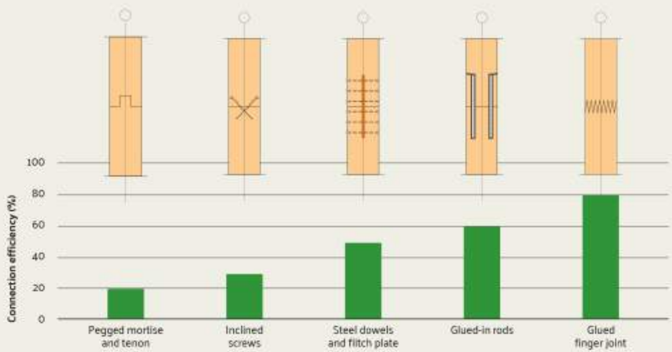
First, there are glue systems that are (at least partly) biobased, for example on lignin, soy or furfural. There are some experimental systems on the market as well. So far, their adoption has been slow due to price, performance, availability, and processing requirements. But, technology develops fast with such high demand.

A second route is a glueless mass timber system. Products such as Dowel Laminated Timber (DLT) or Nail Laminated Timber (NLT—hardly known in Europe, more common in North America) do not contain any glue. DLT uses hardwood dowels with low moisture content that expand upon insertion in the softwood boards, connecting them and forming a multi-layered panel. But, these methods are less efficient and may require a significant amount of additional material to be used as an exact replacement for CLT.

Glued connections offer a larger strength than dowel and screw connections (01).

Figure 4.10
Connection efficiency

Efficiency of connection in terms of the strength of the connection divided by the strength of the connecting member, based on experience Lūning Structural Engineers.[141] Adapted from Ramage et al[62]



...could we find innovative alternatives to glue?

During a focus discussion in the Steering Group, the use and future of synthetic glue was discussed. As Kutnar mentions: "Adhesive is used, and yes, it could be harmful. Therefore, communication about its impact and the research about adhesives matters. Although the glue makes up only 1% of the mass, the environmental impact is much bigger.".

Pomponi agrees that the use of glue has its limits but adds that "It should not be a concern, as technological solutions with biobased materials will change the current discourse.".

While it is important to do more research and gain an understanding of the impact of the glue that is currently used, the research into the (biobased) future of glue should not be forgotten.

In the case of adhesive discussions, the Steering Group has brought up "the end of life" as a linked discussion on adhesive management. These statements intrinsically look at the potential reusability of used timber, and with that at the impact that adhesives might have. If thinking about adhesive and its end-of-life management is incorporated from the initial design thinking of the building, then adhesive would become less of an impactful consideration.

The office of Geelen Counterflow has the highest BREEAM score worldwide (99.94%) and features a bearing structure based on DLT.
Design: ARCHION bouwmeesters & architecten-Roermond
Picture: John Sondeyker Architectural Photography

forestry & wood availability

how to deal with forest management and certification skepticism?

Myth 09: Building more in timber will destroy forests worldwide

Facts in a nutshell:
The key is to only buy timber from sustainably managed forests—the lion's share of European forests, which also have additional capacity. For tropical timber, the amount of certified forest still needs to increase, as paradoxically, using certified tropical timber can prevent tropical deforestation, but careful nuance is required.

FACTS

The forest map of Europe showing that the continent is largely covered in forest (34).

As a result of increased sustainable forest management as well as afforestation, the forest area of Europe has increased significantly in Europe the past 30 years, while in tropical areas deforestation continues– however, not as a result of increased demand for tropical timber (01).

The timber industry does not threaten primeval forests

Less than 1% of Europe's forest qualifies as primeval and another 2% to 3% is older than 150 years. These old-growth forests are protected and the area of protected woodland is increasing over time under the new EU biodiversity strategy.

Timber for construction is sourced from young production forests, and its use hence does not endanger primary forests.

Moreover, while old forests have a higher carbon stock than younger forests, these younger ones have a higher annual absorption rate if managed well.

Wood from sustainably managed forests is a renewable material

Wood from sustainably managed forests is a renewable resource in that it may grow back several times in the lifespan of a building, especially if product lifetime extending cascading principles are taken into account (see M7). This is even more relevant for short-cycle biobased materials such as hemp, straw or bamboo. As such, sustainably sourced wood is an endlessly renewable resource. Sustainably managed forests maintain a careful balance between the amount of wood harvested and the amount that grows again each year. This guarantees that, by definition, no net deforestation has taken place upon harvesting. Furthermore, several social and environmental requirements must be met in these forests.

Sustainable and varied forest management is guaranteed through the national forestry legislation of member states. These rules are closely upheld. In many cases, data and statistics about management, trade, and certification are compiled in independent databases of the Food and Agriculture Organization of the United Nations (FAO) and the EU itself. In Europe, usually even more stringent sustainable forestry guidelines are adopted along the entire value chain (Chain of Custody) based on voluntary certification from the Forest Stewardship Council (36) or the Programme for the Endorsement of Forest Certification (35). These schemes safeguard carbon storage, biodiversity, water storage capacity and many other ecosystem services (35, 36). Maintaining biodiversity is a key component in both schemes both for natural forests and plantations. Biodiversity should at least be maintained but should preferably increase over time on landscape, ecosystem, species and genetic level by taking specific management measures, including allocating specific buffer zones for biodiversity purposes (37, 38, 39). They also cover social aspects, including the well-being and safety of forestry workers and rights of indigenous peoples.

Climate smart forestry

Climate Smart Forestry is a methodological forest management strategy to build locally adapted, healthier and more resilient forests based on a variety of management styles and tree species. These include more deciduous species, which can yield various of durable wood products (41, 42).

CSF has become acutely relevant in the face of increased natural disturbances caused by climate change; at 46%, most damages since 1950 were related to more severe storms and winds, followed by heatwaves and related forest fires at 24%, and droughts and related beetle outbreaks at 17%. These have damaged, on average, 52 Mm3 per year, a number which has risen to 80 Mm3 in the past 20 years. This equals no less than 16% of the total European roundwood harvest. Particularly worrisome is the increase in tree mortality as a result of bark beetle infestation, which has doubled in the past 20 years and threatens the 7 billion m3 of growing stock of Norway Spruce (>25% of the European growing stock).

Partly as a result of climate change, partly as a result of increased harvesting for biomass energy products, the carbon sink capacity of European forests has declined over the past few years (43, 44).

80% of global deforestation is driven by agriculture—especially beef, soy, and palm oil.

As described in Cities4forest website: "...urban populations are disconnected from these forests, and often unaware of their importance. Forests once covered over 50% of the world's land area. Today, they cover about 30%, and many remaining forests have and are rapidly losing species diversity. Tropical forests in particular play a key role in regulating climate and conserving biodiversity, but are also cleared at much higher rates than other forests. And consumption in cities is largely responsible: nearly 80% of global deforestation is driven by agriculture—especially beef, soy, and palm oil. Mining, timber, and fossil fuel extraction also drive deforestation and pollute forest habitat. Most of these products are consumed in cities, where residents are unaware of their origins and impact" (47).

Certified forests in Europe

National legislation should guarantee sustainable management for all European forests. Currently, almost two-thirds is certified following FSC or PEFC schemes. This is reflected in, for example, an increasing amount of tree species.

Furthermore, almost one quarter of European forests is located in protected areas, and this protected area is increasing by almost 65% in the past two decades.

Although the area of certified forests grows each year (with 3.5 Mha between 2019 and 2020 to an all-time high of 436 Mha in 2020), this is still only a little more than 10% of the global forest area. Especially in tropical areas, forest certification is lagging behind (45-46).

About 75% of forests in the five largest wood-producing countries in Europe comply with certifications (48). In Europe, there are many relatively small owners that meet all the PEFC and FSC criteria but are not certified because of the associated costs of certification, so these percentages are an underestimation. Over 95% of the sawn timber produced in the largest wood-producing countries is coniferous. This coniferous wood is used as input to produce mass timber products such as CLT, glulam and LVL.

It is expected that the share of certified mass timber products in Europe is at least as high as the amount of certified sawn timber produced in Europe (at least 70%) (49).

What about tropical hardwood?

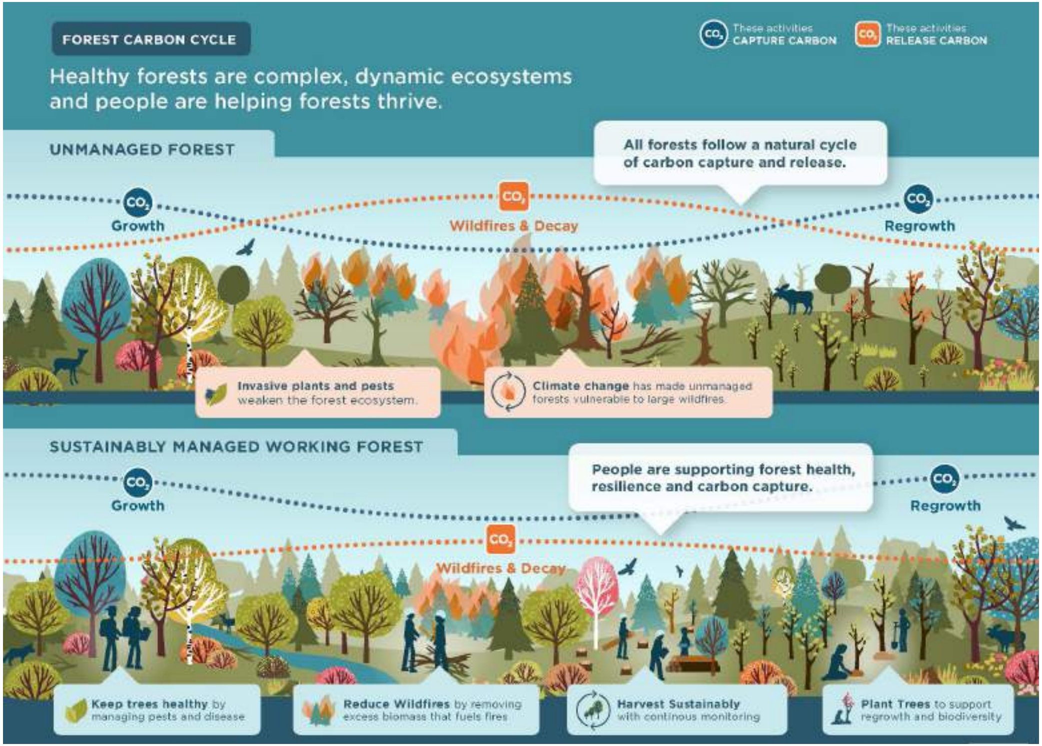
Tropical deforestation is not driven by the demand for tropical hardwood in construction—this in itself is a persistent myth. Rather, it is the result of land conversion for large-scale soy and palm oil cultivation, as well as grazing land for cattle, infrastructure and, ironically, mining for construction materials (25). Putting a complete stop to the use of tropical hardwood in construction to halt deforestation does therefore not hold true unequivocally; the debate requires careful nuance. Conversely, and perhaps counterintuitively, the use of more tropical hardwood in Europe from sustainably managed, certified sources actually helps to provide forest owners with a business case and prevent them from clear-cutting for other land uses. Considering the crucial role tropical forests play in the world's carbon balance, this requires a radically sustainable approach, as well as stringent certification and enforcement. This holds particularly true in the face of the fragility of tropical forests, and their threatened existence reaching 'tipping points' after which unrestorable damage to the ecosystem may occur. The remote location of these communities complicates guaranteeing correct management. Current certification schemes may hence not suffice, and a more involved bilateral relationship between user and supplier may be required.

Even though the use of tropical timber in construction is relatively low in Europe, the share of certified imported hardwood is only 31% to 36% and requires urgent improving (50, 51, 52).

forestry management can reduce risks and improve existing ecosystems in our forests

Myth 10: It is always better to leave forests alone

Facts in a nutshell:
While in the short term, there might be more carbon storage in a conserved forest, in the long term, the combined carbon benefit of managed forests producing durable timber products substituting carbon-intensive materials has a larger benefit. Managed forests are less susceptible to natural disturbances such as wildfires that inflict extensive damage to biodiversity and cause carbon emissions.

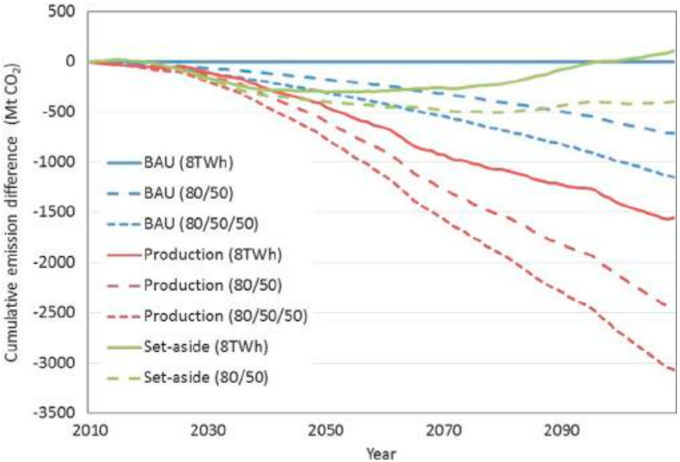


Graphic presentation of the carbon benefits of a managed forest versus an unmanaged forest (53).

FACTS

Active management improves carbon storage, reduces wild fires and improves climate resilience of forests

Various scenarios for Swedish forestry schemas show that compared to the current scenario, the conservation scenario might be beneficial in terms of carbon sequestration in the beginning. Over time, the production scenario (based on sustainably managed forests) with the highest production efficiency provides the most significant climate benefit (54).



There is no consensus among forestry practitioners and ecologists whether active forest management leads to more carbon sequestration than the more passive conservation approach. Evidence points to active management yielding better carbon storage benefits (55).

Various studies in different temperate European regions (Sweden, other Nordic Countries, the Netherlands) show that whilst in the first years a conservation scenario brings about temporary additional carbon storage in the forest, this situation quickly turns around (54,56, 57).

Active management, moreover, reduces the likelihood of forest fires, including the related biodiversity loss and CO_2 release. In Nordic countries with more intensive forest management practices, forest areas were 50 to 60 times less affected by wildfires compared to low-intensity managed forests in Russia and Canada (56). Improved management may indeed prevent and counteract the impact of disturbances (58).

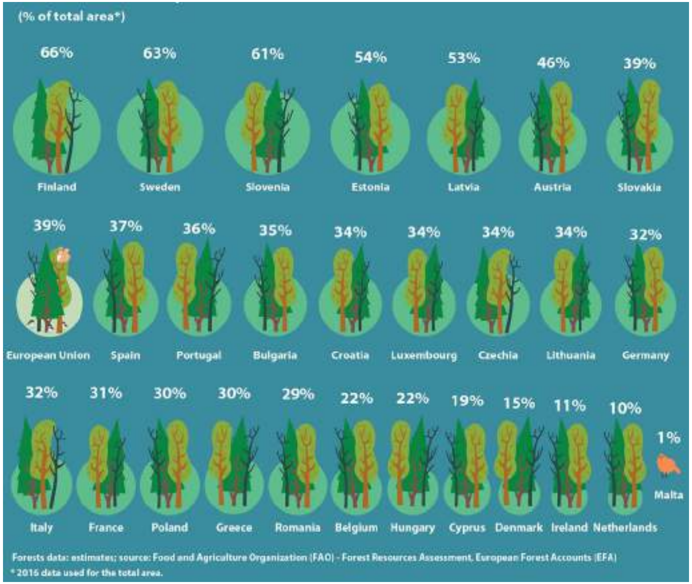
Furthermore, active management includes Climate Smart Forestry measures, improving the climate resilience of the forests.

the question needs to shift from if there is enough wood towards if there is enough production capacity

Myth 11: There is not enough wood in the European Forests to meet housing demand

Facts in a nutshell:
There is a need to balance the current built environment material logics as there is still additional capacity in the European forests to build more with timber. This is especially possible if we add more value to forest harvests, increase reuse and recycling percentages, make our forests more climate resilient and keep increasing the forest area as it has happened for decades in Europe.

FACTS



Area covered by forests in 2020 (59).

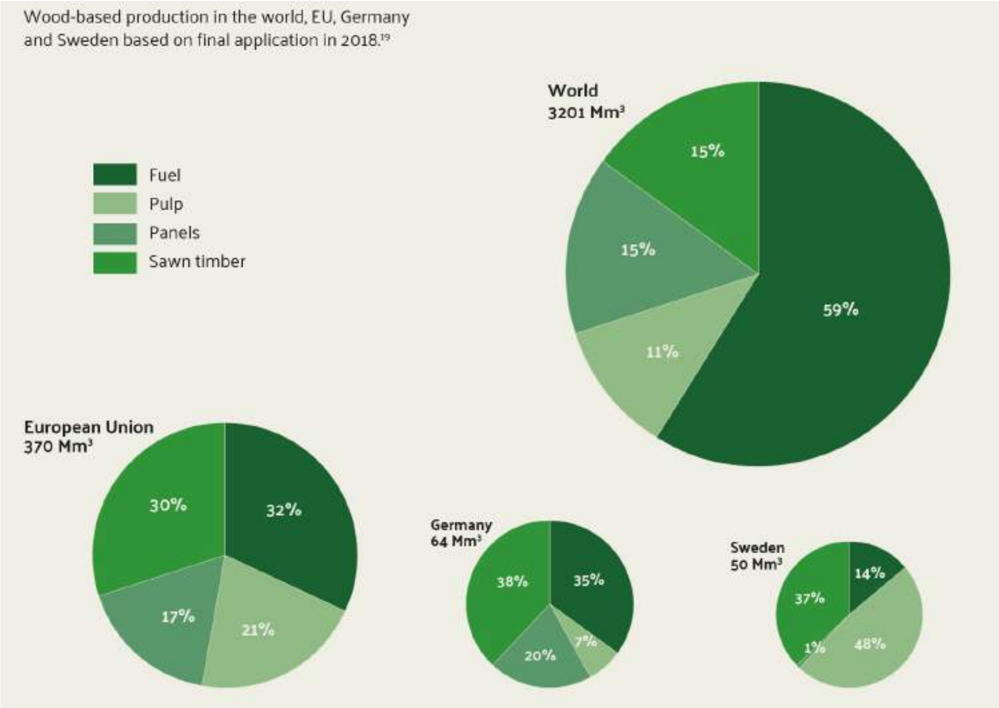
European Forestry sector

In 2020, the EU had an estimated 159 million hectares of forest. Forest coverage differs greatly across Europe, with the highest and lowest shares in Northern Europe, Ireland, and the Netherlands, respectively (59).

European forest area is steadily growing, with an increase in forest area of about 10% since 1990. This corresponds to an annual growth rate of 0.75 million hectares, or over 1 million soccer pitches.

European timber industry

The European forest products industry is unmatched in terms of efficiency and productivity. While the forests cover only 4% of the global forest area, almost one quarter (23%) of all sawn timber is produced in the EU (22). Almost half of all wood-based products manufactured in Europe are durable products such as sawn timber and panel materials, a lot higher than the global average, which lies at 30%. Roughly a third of wood-based products are, still used for fuel production. As fuel is incinerated, it does not bring about the same advantages of carbon capture that durable wood products bring. Therefore, they should be minimized unless we refer to by-products and processing residues that are not available for durable products.



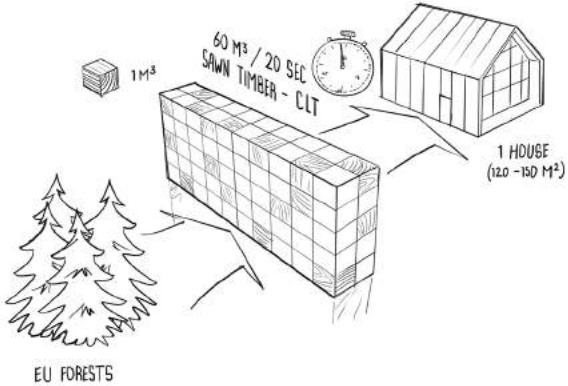
Wood based productions (01).

Additional production capacity

European forests stock 35 billion cubic meters of wood, double the amount they stocked in 1950. Indeed, European forests are growing both in area and standing stock. Where we harvest a total of about 550 Mm3 of wood per year in the EU, the forests' annual growth lies around 800 Mm^3.

This net annual growth in timber volume has been higher than roundwood removal for years, leaving an unused capacity for the relatively young European production forests. For the EU, this additional harvesting potential lies at 250 Mm^3 per year (10, 60, 61).

However, this does not mean that this additional volume is readily available, as most of it is difficult to reach. Taking into account forest ownership,



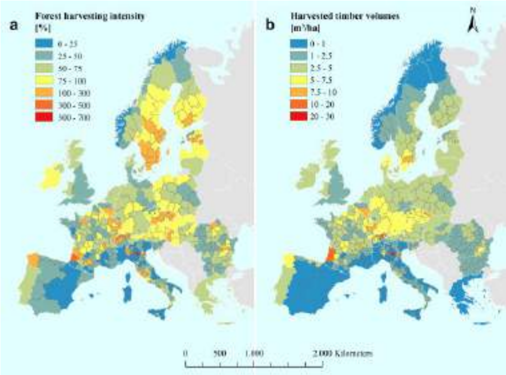
Every 20 seconds, the European forestry industry produces enough wood to produce a large timber house (about 60 m3 of timber). If designed well, a large apartment would require less than half that amount (01).

distance to infrastructure, accessibility of slopes and the distance to Natura2000 areas, the realistic additional potential is estimated between 45 and 90 Mm3 per year (62).

Assuming an additional potential of 45 Mm3 per year, a conversion factor logs to timber of 50%, and an average of 45 m3 for a large family house, this means there is enough additional capacity for 500.000 houses per year (in case of apartment buildings, more dwellings could be built) in Europe. This can partly cover the housing demand in Europe, i.e. in the UK, housing demand lies at 390.000 dwellings per year and in the Netherlands at 100.000 dwellings per years (63, 64, 65).

Realising the potential of additional capacity can happen in the short term by stimulating both the demand and supply side of the timber products industry. On the supply side, appropriate policies should be implemented that create financial incentives for private forest owners, which account for no less than 50% of European forests, stimulating the development of infrastructural capacity for harvesting and processing wood. The supply of timber can be further increased by better forest management, including CSF practices, increasing processing capacity and afforestation. For example, a reforestation potential of 77 Mha is projected in Europe, primarily outside of Natura 2000 areas.

Next, there is a world to win in increasing the efficiency of the forestry and timber products industry. This can happen on various levels. Firstly, by increasing the amount of construction timber products from logs and processing residues, for example for the production of veneer sheet or LVL. Currently, only 47% of logs in the EU are used for construction products. Secondly, by making more efficient use of timber in construction, for example, LVL construction concepts instead of solid CLT slabs for multi-storey buildings. Thirdly, by developing products that



Harvesting volumes are reaching limits in some countries, whereas other countries still have room for growth (37).

are more material-efficient, such as I-beams or CLT with OSB or wood cellulose cores. Lastly, increased recycling (cascading) and reuse of timber products could provide a high-value secondary timber flow to help meet demand (see also M7). These processing innovations should be complemented by creating additional demand for durable timber products, also from lesser-known (deciduous) species, as these will become more prominent in the face of climate change. (65, 66, 67, 68).

Mass timber production in Europe

Also, in terms of mass timber production, Europe is the leading region in terms of manufacturing capacity (a nice overview of the capacity of various CLT and glulam suppliers can be found at 69).

- CLT: 2.8 Mm^3 in 2020 (48% in Europe, 43% in North America), 4.0 Mm^3 expected in 2025.
- Glulam: approx. 3 Mm^3 in 2020 with anticipated growth, 0,48 Mm^3 in North America.

No production volumes are reported for LVL, but the production capacity seems to ramp up here. In North America, the production capacity is steadily growing from 2.1 Mm3 in 2019 to 2.4 Mm3 in 2021.

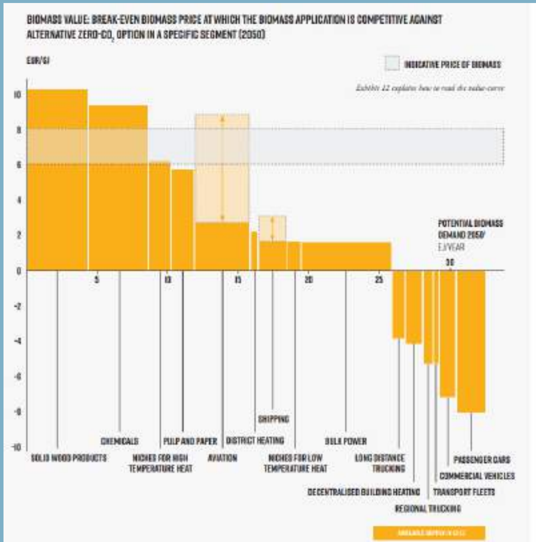
Although this seems a lot, these amounts are still small compared to the amount of sawn timber produced on the European market (about 127Mm3 sawnwood, softwood and hardwood combined), which besides as input for mass timber products, is also used for timber frame structures and other applications (70).

Can we prioritise forestry products that add the most to our society's primary needs and carbon storage?

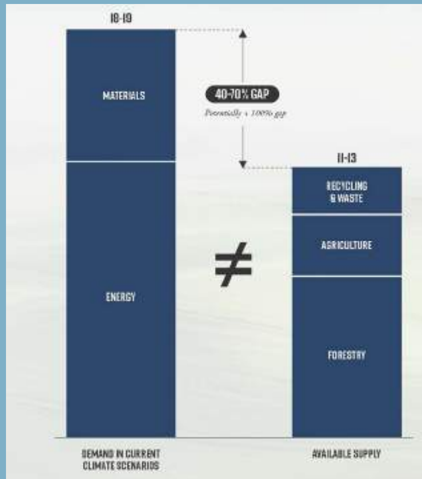
Solving a potential biomass deficit

The demand for wood products is expected to double worldwide between 2010 and 2030 and will hence put additional pressure on forest production systems worldwide (67, 71).

Although the European forestry sector is currently able to provide enough wood to meet material needs, an ever-increasing demand for biomass energy products is expected to lift demand to exceed supply by 40 to 70% in 2050. In other words, continuing to grow the demand for bioenergy products as planned, puts the sector's claim on forestry products in direct competition with that of the timber construction industry (72).



A value curve for EU biomass use in 2050 (72).



Biomass supply and demand for materials and energy in the EU (72).

This potential future deficit can be solved by sound EU policies that reduce biomass energy use and prioritize solid wood products. These wood products have the highest added value, contributing to a net-zero society, complemented by biochemistry, fibres, textiles and possibly some speciality fuels (e.g. biofuel for aviation). Prioritizing according to this logic would mean shifting 30 to 40 million hectares of land from energy crops to forestry and material crops, yielding an additional reduction of 144 Mt CO2 per year (72).

economics

there is a strong need for research and better information on the financial implications of mass timber

Myth 12: Timber is always more expensive than traditional construction

Facts in a nutshell:
When an experienced building team focuses on timber from the outset, fully utilizing the unique properties of mass timber in the design and construction process (e.g. lightness, prefabrication possibilities, etc.), a timber building can be very competitive in price. Not yet even mentioning the potential higher societal value, now and in the future.

FACT

Higher material costs overcome through different design and construction approach

When taking into account material costs alone, mass timber projects are about 5% to 10% more expensive than traditional ones in Western Europe (73).

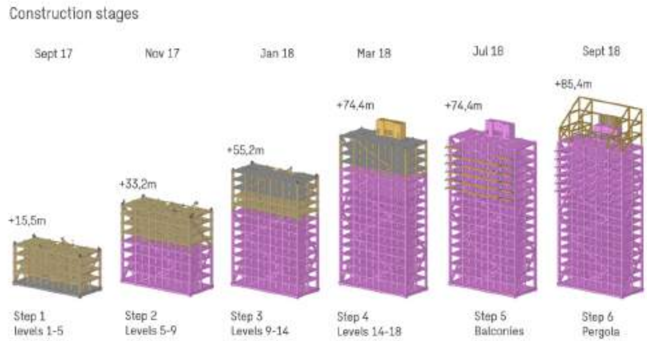
This holds especially true for very tall timber buildings of more than ten stories high, where additional timber is needed to meet structural demands. Note that most timber frame housing, on the other hand, is lower in price than traditional construction (74).

While timber is more expensive than concrete per volume unit, we need to consider more than just material costs for an honest understanding of the economics of timber construction. The additional material cost can be compensated in the following ways, based on a more holistic life-cycle costing approach: lightweight, industrialized production, future (residual) value, upscaling, risk (perception), health benefits, and true pricing.

Light weight

Timber is five times lighter than concrete per volume unit. This can yield significant benefits in the design, where we can save on materials using lighter foundations; also during the construction process, where lighter cranes and vehicles suffice for transport and manoeuvring.

The largely prefab mass timber construction method was quicker by one year compared to building with traditional, in-situ cast concrete, largely compensating for the higher material costs Mjostarne (75).



The choice for a prefab mass timber CLT load-bearing structure for the massive Dalston Works apartment building in London was largely based on practical arguments related to the construction process. Because of the small building site on top of a metro tube (a raft foundation was required) and because of its location in the busy heart of London, a very quick building process was demanded with as little nuisance as possible. Eventually, the prefab mass timber building method reduced the construction time by nine months while lowering the number of heavy truck deliveries from 700 (typical for traditional cast concrete) to only 98 deliveries.
Design: Waugh Thistleton Architects
Picture: Jason Rabbow

Industrialized production

The consistency and workability, moreover, make mass timber products especially suited for prefabrication production practices. Such industrialization could increase productivity by a factor of 5 to 10, yielding 10% to 20% cost savings (76, 77). Here, the construction site turns into an assembly site with a very short and low nuisance building process, as well as a lower risk of failure and mistakes. Speeding up the construction process furthermore facilitates quicker return on investment for project developers.

In the new office of energy company Alliander in Amsterdam, the cassette flooring elements (Lignatur) cover acoustic, aesthetic and structural requirements, avoiding the use of additional material: the shell structure is also the finishing, saving the need for decorational finishing materials.
Design: De Zwarte Hond

Upscaling

Prices are expected to decrease further, due to economies of scale as production factories continue to grow and multiply. In the Netherlands, for example, the production capacity of timber housing factories is expected to increase from about 20,000 houses to about 76,000 houses per year (78, 79).

Building cost comparison between a standard 7 story apartment building in London with a CLT and a concrete shell structure shows that while the above ground structure is more expensive in CLT, this is largely compensated for lower foundation costs (lighter building) and the quicker building process (lower main contractor items) (01).

Figure 5.14
Cost comparison

Cost comparison (in British pounds) on project level for a typical CLT and concrete 7-story building in London (excluding professional fees, external works, utilities and VAT).[159]

	Total (£)		
Element / description	CLT	Concrete	Variance
Foundation	5.248.535	6.011.035	(762.500)
Above-ground bearing structure and fit-out	57.070.618	55.882.224	1.188.394
Main contractor items (preliminaries OH&P, fixed price risk)	14.751.225	15.084.934	(333.709)
Total (£)	**77.070.378**	**76.978.193**	**92.185**

Startblock is a scale-up in the Netherlands which produces low-cost housing for starters, optimized for the smart use of vertical CLT slabs and prefabrication in the factory. A whole house fits on the back of a truck and can be installed within a couple of days at a very competitive price point (125.000 EUR turnkey for a starter's house).

...how can we quanti-fy health and well-being benefits in the economic balance of mass timber?

The 86 meter tall hybrid timber building Wellhouse in Amsterdam to be built in the Central Business District Amsterdam is driven by ESG goals of the investing developer (NSI), but also because of the expected demands from tenants in competition for (increasingly more climate conscious) new talent. Design: Dam & Partners

Future value

As shown in M9, mass timber and industrialized timber constructions are very suitable for dry, demountable construction, increasing the chances of high-value reuse at the end of life. This can represent a considerable residual value—particularly for large mass timber elements. We indeed see increased interest amongst institutional and commercial developers to invest in timber construction, as timber buildings' market liquidity and value as investor products will improve. In contrast, buildings made from traditional materials can be perceived as risking becoming a stranded asset, based on an increasing focus of investors on Environment Social Governance (ESG) critera.

Risk (perception)

Risk, or perceived risk, currently drives up the cost of timber housing. Timber construction is, for example, often understood to be less fire-safe than traditional construction methods. Even though this risk is unsubstantiated, this myth can lead to higher premiums or the need for other cost-increasing measures, such as sprinkler installations (43). Conversely, commissioners and contractors with experience in mass timber assume lower risk percentages thanks to the controlled environment of the prefabrication process.

the health benefits of mass timber

i.e. The Maggie's Cancer Support Centres based on a design philosophy that is linked to the deeply embedded human preference to be in contact with nature and includes measures such as exposure to natural elements including water and daylight, views on nature, visual adoption of plants and natural materials in the interior and several other features. Studies have found that the adoption of biophilic design principles in office environments can lead to higher productivity (+13%) and an increased sense of well-being (+8%).

Primary School de Letterboom in Brussels, Belgium.
Design: Lava Architects

The Maggie's Cancer Support Centres featuring Maggie's Yorkshire and designed following biophilic design principles. The visible application of timber plays an important role.
Design: Heatherwick Studio
Picture: Hufton + Crow

Timber in sight offers benefits for biophilic design and indoor climate

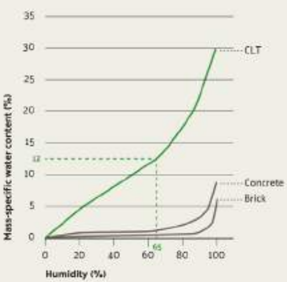
Besides aesthetic advantages, the indoor use of timber also holds significant advantages in terms of health and well-being. Timber is a hygroscopic material, which means it absorbs or releases moisture depending on indoor humidity, balancing the indoor climate in terms of both temperature and humidity to a level perceived as very comfortable by residents. Evidence also reveals that the visible application of timber indoors fits well with the 'biophilic design' philosophy, leading to lower stress levels, higher physical and mental well-being levels, and, ultimately, higher productivity. (80).

The city hall in the municipality of Venlo, the Netherlands combines the visible application of a large amount of timber and plants (including moss walls) indoors, with a large atrium connected to a solar warehouse on the top floors for a natural ventilation system following healthy building and biophilic design principles. Compared to the previous office, the absence levels of civil servants dropped by 1.5%, providing an impressive saving on annual costs (480.000 EUR annually) to compensate for the higher investment costs.
Design: Kraaijvanger Archietcts
Picture: Ronald Tilleman

Timber has excellent moisture absorption qualities which can improve the indoor climate (01).

Figure 5.07
Moisture absorption

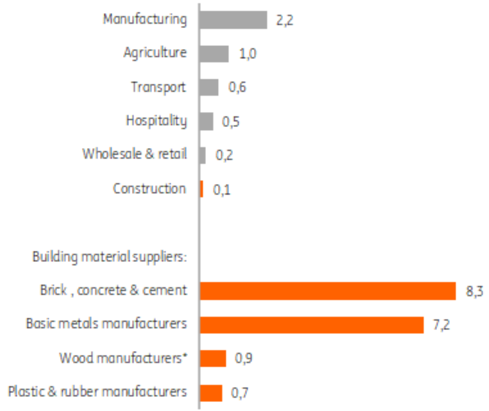
Compared to other building materials, timber (in this case CLT) has a far greater moisture absorption capacity. Adapted from Binderholz [65]



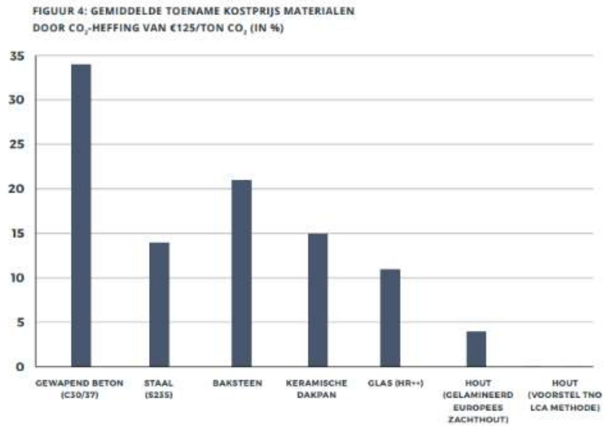
...the total balance of the business case is set to be in favor of mass timber

Balance shifting in favour of timber construction

As a result of the trends mentioned when describing the facts, (increased industrialization, economy of scale, rising energy prices, increasing confidence and experience, lower risk fees, increasing focus on ESG with investors, potential carbon taxing, life cycle costing—residual value, improved consumer perception, etc.) it seems that the total balance of the business case is set to be in the favour of timber construction. By setting the right preconditions (knowledge, research, policy, legislation, investment environment, among others), these benefits can be further accelerated.



When introducing of a carbon tax in the Netherlands (based on a carbon price of 125 EUR / ton CO_2), mass timber pricing would hardly be affected, while abiotic materials can expect a significant increase in price (81).



Rising gas prices hit producers of metails and minerals exponentially hard.
Contractors use little gas, producers of building materials use a lot of gas (82).

True pricing

The health benefits of timber show that, we also need to take non-financial benefits and avoided negative effects into account. This can happen following a true pricing method. If we put a price on CO_2 and NOx emissions, for example by means of a carbon tax, we see that timber construction is barely affected while costs for steel, masonry and concrete would increase by 15%, 20% and 30%, respectively (81). Next to carbon taxation, which is based on prevention costs, one could prize the social costs of climate change or its damage to achieve a fairer price for construction.

next steps

final words

Mass timber construction offers many benefits for Europe, from climate mitigation and circularity to health and process advantages. Because of its carbon sequestration properties, both in forests and in the built environment, mass timber provides an important solution to lower CO2 emissions right here, right now—something that has never been as urgent as in light of the conclusions of the latest IPCC report.

Upscaling the European forestry and timber industry and increasing circular building practices could make it possible to meet European housing demand largely based on timber from European forests.

However, it is not yet realistic nor mandatory that all new buildings are made of timber.

Traditional, abiotic building materials have several properties that make them technically better suited to meet the requirements of specific applications such as the use of concrete in foundations (for its durability and compression strength) and elevator shafts (for its compression strength and stability), or steel for large spans and bracing (for its tensile strength). Sometimes, the high weight of concrete is also required in hybrid CLT-concrete flooring systems to create mass and increase thermal capacity, while lowering vibrations and sound transmission in multi-storey residential buildings.

The synergy between timber and traditional abiotic materials should lead to even, more efficient material usage as well as interesting architectural designs. However, given their high environmental impact, abiotic materials need to be produced in a circular manner and designed for reuse.

As yet, the concrete industry's claims of high recycling percentages typically mask the downcycling practices. In the Netherlands, for example, 86% of concrete is 'recycled' into road bedding for highways. But downcycling hardly lowers demand for new virgin concrete and its carbon-intensive cement component. And whereas metals are indeed recycled and sometimes reused at relatively high levels, the demand for these secondary materials is far higher than supply, meaning that huge amounts of additional virgin metals, with their high carbon footprint, still need to be produced—about two thirds of the demand for steel and aluminium.

...our cloud of desires

Some final words are in order. To summarize the Steering Group debate and inputs, an open and transparent approach and diverse perspective on the next steps of the timber transition is demanded.

Therefore, we have decided to conclude with a collection of the desires expressed by our members. These desires are open for interpretation to anyone interested in becoming a part of this community.

Our suggestion is to conclude not concluding. To close this booklet, but, open possibilities for you to contribute and be part of the ecosystem that is becoming a living force towards a more real and systematic mass timber transition.

JOIN US!

"...everyone of us has a choice to either contribute to business as usual or to a regenerative built environment."

" We should focus on convincing people that timber building can be built for several generations, but also about the fact that our needs are changing and that timber buildings can be changing according to our needs - design for deconstruction/changes."

"...Supportive regulation is needed to reduce subsidies to fossil based materials at least (level the playing field), and then regulate the bio-based materials (for example through emissions cap / regulations around carbon)."

"Large scale upskilling of the workforce"

"Networking and collaboration to give consistent answers."

"...shifting the decision-makers behaviours (among the stakeholders or political leaders) in practice. There is a gap between "being convinced" and "taking action."..."

The origin and supply of wood is a main point of concern, where there is a lot of skepticism on how sustainable are forest management practices, and how can we provide high yields without compromising soil quality and biodiversity

"...we don't have decades to change our ways. It needs to happen ASAP. "

"A major risk is an unholy alliance between the conventional construction industry and fundamentalist environmental groups. One needs to convince both the public and the decision-makers that a proactive transformative approach is necessary. In order to achieve this, one has to win the sympathy battle - especially emphasizing that timber construction is social, healthy, and beautiful!"

"Science based facts are of great importance."

"...Development of production capacity for engineering wood products to match a scale up of demand."

"Education for all parts of the value chain from developers to end users."

"...mass timber is a relatively innovative material to build with. So we need best practices to convince people that it's possible."

"...Deeper connection / integration of the value chain from forest to frame (have data flow better on carbon, climate impacts along the value chain, but also so that the built environment sector better understand the impact of its decisions/choices on the productive ecosystems such as forests)."

"The future requirement to address "Too expensive"; new fi-tools like Green Bonds; from VAT to CAT... and/or including carbon sequestration (total value chain comparison)"

"Next step would also be to have practical solutions, where to find them, how to share them?"

"Clear insight for developers/ investors and asset owners on what the policies will likely be in place and how their portfolio will fit in there."

"An urban/metabolic approach to the process to understand large scale, scale up dynamics and systematization of timber mass design"

"Developers engage with timber materials as priority"

"...Architectural design education in timber."

"Sometimes adaptation of legislation and building regulations will be needed."

"Policy to frame real estate and to unlock design possibilities in timber"

end notes

1. van der Lugt, P. and Harsta, A. (2020) Tomorrow's Timber.

2. Circle Economy. (2023). Circularity Gap Report.

3. www.fao.org/faostat/en/#data/FO

4. Wallius, V., et al. (2023). Stakeholder perceptions of wood-based products in the built environment: a literature review

5. INGENII (2023). Consumentenonderzoek waardering houtbouw, Lente-akkoord Circulair Industrieel Bouwen 2023.

6. Ramage, M. H. et al. (2017). The wood from the trees: The use of timber in construction.

7. https://www.youtube.com/watch?v=TO8KRyVhyeo

8. Riberholt, H. (2007). Performance of glulam structures in Europe. Byg Rapport No. R-177

9. Brandon, D., Qvist, S., van Straalen, I., Wattez, Y., & Steenbakkers, P. (2022). Literatuurstudie-Brandveiligheid en Bouwen met Hout.

10. Nabuurs, G-J. et al. (2022). Agriculture, Forestry and Other Land Uses (AFOLU). In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, et al. (eds.)].

11. Pomponi, F. (2020). Buildings as a Global Carbon Sink? A Reality Check on Feasibility Limits

12. Fraanje, P. et al. (2021). Valuation of carbon performance of biobased construction

13. ASN Bank & Climate Cleanup. (2022). Construction stored carbon.

14. EN 16449 Wood and wood-based products - Calculation of the biogenic carbon content of wood and conversion to carbon dioxide

15. www.materialepyramiden.dk/

16. Leskinen, P. et al. (2018). Substitution effects of wood-based products in climate change mitigation.

17. Place, T. et al. (2021). Mass timber embodied carbon factors.

18. Mishra, A. et al. (2022). Land use change and carbon emissions of a transformation to timber cities

19. Riahi, K. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview.

20. www.royalsociety-org.tudelft.idm.oclc.org/topics-policy/projects/greenhouse-gas-removal/

21. NIBE & DGBC. (2021). Paris proof embodied carbon, background report.

22. Nabuurs, G-J. (2015) A new role for forests and the forest sector in the EU post-2020 climate targets.

23. Nabuurs, G-J. et al. (2017). By 2050 the mitigation effects of EU forests could nearly double through climate smart forestry.

24. Yousefpour, R. (2017). Realizing Mitigation Efficiency of European Commercial Forests by Climate Smart Forestry.

25. European Environment Agency. (2018). The circular economy and the bioeconomy, partners in sustainability.

26. www.openbuilding.co/

27. Kayaçetin, N. C. et al. (2021). Evaluation of Circular Construction Works During Design Phase: An Overview of Valuation Tools. Sustainability in Energy and Buildings 2021, 89-100.

28. www.derix.de/en/sustainability-in-timber-construction/building-sustainability-with-wood/#ruecknahmeverpflichtung

29. Mantau, U. et al. (2010). Real potential for changed in growth and use of EU forests.

30. www.circularity-gap.world/sectors

31. www.c2ccertified.org/certified-products-and-materials/loctite-hb-s-purbond-line

32. www.c2ccertified.org/certified-products-and-materials/derix-x-lam

33. https://c2ccertified.org/certified-products-and-materials/derix-x-lam

34. European Environment Agency. (2015). Forest map of Europe. www.eea.europa.eu/data-and-maps/figures/forest-map-of-europe-1

35. www.pefc.org/standards-implementation/standards-and-guides

36. www.connect.fsc.org/document-centre

37. FSC. (2023). FSC Principles and Criteria for Forest Stewardship V5-3

38. FSC. (2018) International Generic Indicators V2-0

39. PEFC. (2018). Sustainable Forest Management - Requirements.

40. Di Girolami, E. et al. (2023). Two systemic literature reviews of scientific research on the environmental impacts of forest certifications and community forest management at a global scale.

41. www.wur.nl/en/project/Climate-smart-forestry.htm

42. Hemery, G. E. et al. (2010). Growing scattered broadleaved tree species in Europe in a changing climate: a review of risks and opportunities.

43. Hlásny, T. et al. (2021). Bark Beetle outbreaks in Europe: State of knowledge and ways forward for management.

44. Patacca, M. (2022). Significant increase in natural disturbance impacts on European forests since 1950.

45. FAO. (2020). The state of the world's forests 2020.

46. UNECE. (2021). Forest products annual market review 2020-2021.

47. www.cities4forests.com/forests/faraway/

48. Simons, D.J. et al. (2022) Carbon Accounting for Building Materials An assessment of Global Warming Potential of biobased construction products.

49. Kraxner, F. et al. (2017). Mapping certified forests for sustainable management – A global tool for information improvement through participatory and collaborative mapping.

50. Teeuwen, S. et al. (2021). Europe's sourcing of verified tropical timber and its impact on forests: What's next?

51. www.fao.org/faostat/en/#data/FO

52. Probos. (2022). Resultaten VVNH monitoring 2021.

53. https://www.dovetailinc.org/upload/tmp/1650893629.pdf

54. Gustavsson, L. et al. 2017). Climate change effects of forestry and substitution of carbon-intensive materials and fossil fuels.

55. Nabuurs, G-J. et al. Dutch scientists respond to concrete and cement industry report acknowledging role of biobased materials, questioning numerous assumptions and findings.

56. Högberg, P. et al. (2021). Sustainable boreal forest management challenges and opportunities for climate change mitigation.

57. Van den Ouden, J. et al. (2020). Kan uitstel van houtoogst bijdragen aan CO2-mitigatie?

58. Nabuurs, G.J. et al. (2022). Agriculture, Forestry and Other Land Uses (AFOLU). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

59. Eurostat. (2021). 39% odf the EU is covered with forests.

60. Nabuurs, G-J. (2021). More than enough wood in the European forest.

61. Forest Europe. (2020). State of Europe's forest 2020.

62. Lerink et al. (2023). How much wood can we expect from European forests in the near future? Forestry. In prep.

63. Bramley, G. et al. (2019). Housing supply requirements across Great Britain for low-income households and homeless people, research for Crisis and the National Housing Federation.

64. Ministerie van Binnelandse Zaken en Koninkrijksrelaties. (2022). Nationale woon- en bouwagenda.

65. Lerink B.J.W., et al. (2023). How much wood can we expect from European forests in the near future? Forestry. In preparation.

66. Baston, J-F. et al. (2020). Tree restoration potential in the European Union.

67. FAO. (2022). Forest products in the global bioeconomy.

68. Ecos. (2023). Seeing forest through the trees, How sustainable timber buildings can help fight the climate crisis.

69. The Institution of Structural Engineers. (2021). Mass timber embodied carbon factors.

70. https://unece.org/sites/default/files/2021-11/2114516E_Inside_Final_web.pdf

71. UNECE. (2021). Forest sector outlook study, 2020-2040.

72. Material Economics. (2021). EU biomass use in a net-zero economy.

73. Van Sante, M. (2022). Houtbouw: duurzamer, lichter en ideaal voor industrialisatie bouwproces.

74. Centrum Hout. (2021). Rapportage woningbouw in hout.

75. Sweco

76. McKinsey Global Institute. (2017). Reinventing construction: A route to higher productivity.

77. Bertram, N. et al. (2019). Modular construction : from projects to products.

78. Fraanje, P. (2023). Groei industriële houtbouw in Nederland.

79. Holland Houtland. (2022). Gids biobased bouwen 2022.

80. Suttie, E. (2019). Wood and wellness.

81. Circle Economy. (2020). Building a future in timber.

82. Van Sante, M. (2021). Soaring gas prices will raise the cost of some building materials.

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TOMORROW'S TIMBER
Tomorrow's Timber (P. van der Lugt and A. Harsta, 192 pp, published by MaterialDistrict) gives an overview of the most recent developments with regards to mass timber construction. It discusses aspects such as sustainability, circularity, building technology, acoustics and logistics, and as such has formed an important baseline and inspiration for this publication. Some of the sketches and graphs in this publication were kindly provided by MaterialDistrict.

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