City Handbook for Carbon Neutral Buildings

CNCA
CARBON NEUTRAL CITIES ALLIANCE

ARUP

BUILT BY NATURE

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Preface

Urban growth and ever-increasing consumption patterns are putting pressure on our planet's resources like never before. This is challenging the traditional methods employed by an increasing number of climate-conscious local governments and influential stakeholders within the construction industry. These stakeholders encompass material producers, developers, designers, and architects who are actively engaged in researching and implementing diverse biobased construction materials and are looking to explore the potential of these materials to serve as a viable solution for mitigating the large carbon footprint often associated with construction projects.

To keep pace, it is estimated that two billion square metres of new building stock will be required every year between 2023 and 2028 alone. The climate impact of such development will be significant in terms of both embodied and operational emissions. To reduce impact on climate and promote healthy living places we must focus on the consequences of our material, design, and fabrication choices.

To ensure that the buildings and construction sector is on track to meet the Paris Agreement goals, we need to acknowledge the built environment as a system in which all actors in the construction material supply chain have a role and responsibility to reduce emissions across the full life cycle of built assets. Carbon performance needs to become an integral part of the assessment during every transaction all along the value chain and cities are uniquely placed to demand this and integrate carbon performance into procurement and regulations.

Space and resource constraints, climate change mitigation and resilience, and a greater focus on human well-being, among other factors, have stimulated new solutions and encouraged innovation.

For some this has meant a return to various biobased building materials. The potential of these versatile materials is immense, with benefits including reduced energy consumption, reduced CO_2 emissions, healthier spaces, and a route to sustainable forest, spatial and agricultural management — all key tenets of the UN Sustainable Development Goals (SDGs).

Appropriately diverse and well managed biobased supply chains and models of construction can help to reduce net carbon emissions by locking carbon into the building fabric.

It is encouraging to witness a significant increase in the use of wooden buildings in recent years. This shift towards timber construction reflects a growing recognition of the benefits associated with biobased materials. This trend is not limited to any specific region; it is a global phenomenon. As we strive to address the challenges posed by urbanization, climate change, and the pursuit of healthier, more sustainable living environments, the adoption of biobased building materials, such as wood, is gaining momentum. To accelerate this transformation and make a meaningful impact on our built environment, we must continue to promote and expand the use of these materials on a larger scale.

Acknowledgements

The following have shared their insights in the making of the report:

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James Nowlan, Toronto

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Disclaimer

This publication is part of the CNCA´s project “Dramatically Reducing Embodied Carbon in Europe’s Built Environment”, funded by Laudes and Built by Nature. Arup is responsible for its content.

About CNCA

The Carbon Neutral Cities Alliance (CNCA) is a collaboration of leading global cities working to achieve carbon neutrality in the next 10-20 years – the most aggressive GHG reduction targets undertaken anywhere by any city.

CNCA’s mission is to mobilise transformative climate action in cities in order to achieve prosperity, social equity, resilience and better quality of life for all on a thriving planet. CNCA is committed to a just carbon neutral future that recognises and redresses the disproportionate burdens and the disproportionate benefits of the fossil fuel economy by prioritizing climate action that advances the well-being of low-income people, Indigenous Peoples, communities of colour, immigrants and refugees and other historically marginalised communities.

About Arup

Arup is a global collective of designers, consultants and experts dedicated to sustainable development. We use technology, imagination and rigour to shape a better world.

Arup’s primary goal is to develop a truly sustainable built environment. This means that in all our work, we aim to identify a balance between the needs of a growing world population and the finite capacity and health of our planet.

Table of Contents

Glossary

Term	Explanation
A1-A3 (LCA)	The “product stage” of a component's life cycle. A1 refers to raw material extraction and processing and processing of secondary material input (e.g., recycling processes). A2 refers to transport to the manufacturer. A3 refers to manufacturing.
Binder	A binder is a substance that causes two or more materials to bond together or blend.
Biogenic carbon	Biogenic carbon is carbon that is sequestered from the atmosphere during growth of biomass and may be released back to the atmosphere later due to combustion of the biomass or decomposition. The principles for biogenic carbon accounting are defined in the international standard, ISO 21930. Standard EN 16785-1 determines the content of biobased elements through a radiocarbon and an elementary analysis.
Biomaterials	Biomaterials are materials that have non-specific biological association and includes a wide array of materials (such as natural materials e.g., timber through to bio synthetics). All biomaterials are bio-based and are generally used to describe an end-product, a finished material in the built environment.
Biotic material	Biotic material is defined by materials made from living organisms without further modification.
Bio-based material	Bio-based materials are made from substances derived from living organisms. These kinds of materials might go through a process before reaching the product state. When the term biobased material is used as it is defined by the standard EN 16575:2014, we consider the part of the product that comes from the biomass. This origin can be total or partial, the minimum rate that should contain a material to benefit from this designation is not mentioned by any standards.
Bio-fabricated material	Any biological product made by micro-organisms such as yeast, mycelium, algae, and bacteria.
CO2-eq	CO2-equivalent (CO2-eq) is a comparable way to measure the emissions from various GHG based on their GWP, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same GWP.
Embodied carbon	Embodied carbon is the total GHG emissions associated with the production of a material/product/asset. This includes emissions caused by extraction, manufacture/processing, transportation and assembly of every product and element in a material/product/asset. In some cases, it may also include the maintenance, replacement, deconstruction, disposal and end-of-life aspects of the materials and systems that make up the material/product/asset. ISO 16745, Sustainability in buildings and civil engineering works – Carbon metric of an existing building during use stage, Parts 1 and 2, will provide, in a simple way, a set of methods for the calculation, reporting, communication and verification of a collection of carbon metrics for GHG emissions arising from the measured energy use during the activity of an existing building, the measured user-related energy use, and other relevant GHG emissions and removals
End-of-life	End-of-life refers to the final stages of a products life when it’s no longer in the stages of being used.

Glossary

Term	Explanation
Endocrine-disrupting chemical (EDC)	Endocrine-disrupting chemicals (EDCs) are substances in the environment that interfere with the normal function of the human body's endocrine system. The endocrine system works through hormones and with other systems to regulate the body's healthy development and function throughout life. EDCs can be found in everyday products such as plastics, pesticides, flame retardants, personal care products, and certain industrial chemicals.
Environmental product declarations (EPD)	A third-party verified, standardised document that provides the environmental impact of a product, based on the data from a life cycle assessment (LCA). An EPD is usually valid for five years and is generated according to the relevant standards. Construction EPDs are based on the ISO 14040/14044, ISO 14025, EN 15804 or ISO 21930 standards.
Global warming potential (GWP)	GWP is a numerical value used to measure the relative contribution of GHGs to global warming. It compares the warming effect of a particular gas to that of CO_2 over a specific time period, usually 100 years. GWP values help in assessing the overall climate impact of different GHGs.
Greenhouse gases (GHG)	GHG is a common name for the gasses in the atmosphere that trap heat in the atmosphere.
Hygroscopic buffering	Hygroscopic buffering refers to a protective barrier that prevents a solid substance from absorbing moisture from the surroundings.
Life cycle assessment (LCA)	LCA refers to a method of evaluating the impact that a material, product or an asset has on the environment during its whole life cycle.
Mycelium	Mycelium is the root-like network of fine, branching threads called hyphae that make up the vegetative part of a fungus.
Sequestered CO_2	Sequestered carbon dioxide (CO_2) is the removal and long-term storage of CO_2 that originally comes from the atmosphere.
Soil permeabilization	Soil permeabilization is the process allowing penetration through the membrane in the cells. This process allows new properties to be added to the soil without the soil being broken down.
Vapour permeability	Vapour permeability refers to a material's ability to allow water to pass through it.
Volatile organic compounds (VOC)	VOCs are organic chemicals that easily evaporate into the air at room temperature. They are emitted by various sources such as industrial processes, solvents, paints, and cleaning products. VOCs can contribute to air pollution, impact human health, and play a role in the formation of ground-level ozone and smog. Controlling VOC emissions is important for improving air quality and reducing environmental and health risks.

Scope

With support from the Laudes Foundation and Built By Nature, in 2021 the Carbon Neutral Cities Alliance (CNCA) launched the "Dramatically Reducing Embodied Carbon in Europe" project which aims to foster widespread adoption of ambitious local, national and regional policies that will reduce embodied carbon and increase the uptake of bio-based materials in the built environment in Europe.

In 2022, CNCA commissioned Arup to develop a "City Handbook for Building Carbon Neutral Buildings" specifically to support cities in evaluating how to reduce whole life carbon in construction, using bio-based building materials. The handbook has been developed in close collaboration with CNCA to support policymakers and planners with technical information on the benefits of bio-based materials, challenges, misconceptions and knowledge gaps for the application of biobased construction, as well as regulation and good practices to grow the opportunity for cities to access and utilise bio-based building materials.

The handbook incorporates the findings of:

- Interviews carried out with procurement officials across CNCA member cities,
- Interviews with key stakeholders along the procurement chain (procurement leads, law makers, investors, developers, designers, insurers, consultants, contractors, material suppliers),
- Engagement workshops,
- Review of commercially viable bio-based building materials,
- Current best practice, regulatory context and state of the art in relation to 3 selected exemplary European countries.

Limitations

- It is important to highlight that this handbook does not provide an exhaustive list of biomaterials or manufacturers currently available on the market.
- Arup has not carried out a technical due diligence of the products described in the handbook.

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Context

It is estimated that one billion new homes need to be built in cities around the world between 2020 to 2025. There will be twice as many buildings on earth by 2050 than there are today. Without low-carbon construction, those buildings are going to lock in huge amounts of greenhouse gas emissions and accelerate the climate crisis. Delivering a carbon net zero built environment is one of the most critical challenges of our times.

The built environment and construction industry contributes significantly to global greenhouse gas emissions and broader environmental impacts, e.g. impacts to biodiversity, waste generation and depletion of non-renewable resources. As cities around the world increasingly recognise the role of this industry, we are seeing trends across all actors in the supply chain towards more sustainable approaches, with improvements to the way we design, use materials and operate assets. To make a meaningful contribution, the construction industry must aim not only to significantly reduce negative impact, but also strive for more planet and people positive and regenerative outcomes.

Cities are uniquely placed to demand that carbon performance become an integral part of the assessment during every transaction along the entire value chain and that it is integrated in both procurement and building regulations. In 2020 CNCA outlined 52 detailed policies to reduce embodied carbon as part of the City Policy Framework for Dramatically Reducing Embodied Carbon [1]. This current work builds upon the CNCA's previous guidance for policymakers, emphasizing the importance of addressing the full carbon footprint to meet the Paris Agreement's goal of achieving net zero embodied carbon by 2050.

Materials are rarely inherently sustainable; even materials that are purported to be low-carbon or low-impact may cause harm when used inappropriately. Environmental impact is not just defined by the type of material or where it comes from, but how it is used, how long it is used for, and what happens to it at the end of its useful life. For example, engineered timber is often considered a sustainable structural material. Despite this, if responsible forestry practices are not followed and/or the timber is used inappropriately (through inefficient design or use for a short life application), the global net carbon impact can be unfavourable, in addition to wider negative impacts from deforestation. The right material must be selected for each application and scenario; the lowest impact material for one application, will often be completely different from another.

This technical handbook showcases products available on the market, providing information about technical performance, health and safety, responsible sourcing, circularity and names of specific manufactures, to support city officials and public procurement officers in developing low carbon construction tenders. The Handbook also outlines challenges, misconceptions and knowledge gaps for the application of biobased construction materials from applied cases in Europe and North America.

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Biomaterials in construction

The term bio-based material is broad, covering all materials that are to some degree derived from living organisms such as plants, which have been processed into a functional product. Bio-based construction refers to the use of such materials in construction of the built environment.

Building structures can be considered predominantly made up of four constituent parts:

1. **The structure**
   Which can be either a frame or a series load bearing walls

2. **The insulation**
   Which gives the building its thermal and/or acoustic performance

3. **The lining**
   Which forms the internal surfaces

4. **The envelope**
   Which forms the outer skin of the building

Examples of bio-based materials in construction include: timber (used for multiple applications including the structure and external cladding), bamboo (used for lightweight construction, in geographical regions where bamboo is prevalent), hemp (as a plant-based aggregate and insulative material), straw (typically wheat straw, the stalk of which is a waste material), wood-fibre (used as sheathing and insulation board), cork (used as insulation and as an internal finish), wool (as insulation) and mycelium (as insulation and interior finishes).

Benefits of the application of bio-based construction

For many applications, the use of biomaterials can deliver several benefits as compared to traditional construction materials and approaches.. The benefits associated to bio-based materials as well as the limits of these are highlighted below.

Renewable

When sustainably and responsibly sourced, bio-based construction materials can be described as renewable. They can be harvested and regenerated within years or decades.

While bio-based materials are derived from biological sources, some might contain non-degradable compounds. In such cases, separating the biological content from non-biodegradable materials is necessary for biodegradation.

Low-embodied carbon

Construction materials made from biological components require significantly less energy in their production than more conventional materials, such as aluminium, concrete, and steel, which often require high temperatures during processing.

Furthermore, bio-based materials can actively absorb carbon dioxide (CO_2) while the constituent elements are growing. This sequestered CO_2, also referred to as biogenic carbon, is then trapped in the material when it is harvested.

In other words, by including bio-based content in our building and construction products, specifically renewable plant-based materials, we can keep previously absorbed carbon from re-entering the atmosphere. And by doing so, we significantly reduce the carbon footprint of those products since carbon footprint is measured as the greenhouse gas (GHG) emissions. The use of bio-based building material has a ripple effect as well. Lowering the carbon footprint of products means reducing the carbon footprints of the consumers who buy them. As we better understand the severity of the climate crisis, more and more consumers and companies are taking strides to reduce their environmental impact. This includes taking a deeper look into how the products and materials they consume are made.

If the material is sent to landfill or burnt for energy, the sequestered CO_2 will be released. The reuse or recycling of bio-based materials to extend their life-cycle and CO_2 storing capacity therefore presents an opportunity to lower the carbon footprint even further over time.

Finally, if bio-based materials can be sourced locally, i.e. at a regional level, their use can also reduce the carbon impact associated with transportation, further reducing the environmental impact.

Benefits of the application of bio-based construction

Low toxicity

One factor influencing building indoor air quality is contaminants introduced by materials and fittings, including volatile organic compounds (VOCs) and Endocrine Disrupting Chemicals (EDCs). The presence of VOCs and the associated health risks in residential and public buildings are well reported. VOCs are widely used in construction and building products like paints, varnishes, adhesives, solvents and flame retardants.

Bio-based materials typically will be low-emitting and create a healthier indoor environment.

Bio-based construction is predominantly breathable, which can help to regulate moisture, humidity and indoor air quality within the structure, provided that correct design and installation approaches are followed.

Job opportunity and construction safety

Increasing job numbers in biobased construction and its associated supply chains could result in labourers being exposed to fewer contaminants and hazardous conditions during construction and many jobs being moved off the construction site. Off-site jobs can be up to 80% safer with working conditions often significantly improved. [25]

Additionally, the expedited construction process facilitated by prefabrication and preassembly minimises disturbance to neighboring activities and users.

Local social value generation

Local sourcing of bio-feedstocks and manufacturing can also bring socio-economic benefits, such as creating local employment, helping to retain economic value in the region, and supporting diverse economic distribution across the supply chain. Where materials are developed from agricultural waste streams, these new products can bring value diversification to the existing industry and businesses.

Resource use

The use of bio-based construction materials encompasses significant land use for the growth of the required biomass. The natural limitation of available resources imposes cross-sectoral land use competition which could affect both reforestation efforts and food security.

Forests, including plantation forests, provide a series of both tangible and intangible services to society and to human well-being, ranging from the production of raw materials and regulation of water flows to the protection of soils and conservation of biodiversity.

The rise of bio-economy-driven wood markets presents an opportunity to redefine the equilibrium between wood demand and the preservation of vital ecosystem services.

While tree plantations inherently exhibit lower plant and animal diversity due to their defined nature and limited wildlife resources, they can still play a significant role in enhancing biodiversity when replacing human-modified ecosystems like degraded pasture, rather than native ecosystems.

There is a strong argument in favour of fast-growing bio-based materials such as wheat, corn and rice. In particular, materials that are currently by-products of agricultural practice such as straw, corn stalks, or rice husks which can be repurposed and transformed into construction materials.

Another fast-growing crop with potential in the construction sector is industrial hemp. Studies have shown that hemp can be used to regenerate brown fields, meaning to restore areas that suffered from industrialization, while avoiding land competition with existing crops. Although hemp is available in many European countries its use remains limited due to policy restrictions.

Misconceptions and knowledge gaps for the application of bio-based construction

Despite the growing use of bio-based construction materials and methods, such as the increasing use of structural timber instead of steel and concrete in Finland and Sweden, and the rising popularity of biobased insulation in countries like France and The Netherlands, many challenges remain to be overcome for these innovations to achieve wider adoption. Some of the challenges are technical, other financial or regulatory, and some are perceived, based on insufficient information or misconceptions. Some of the primary challenges, misconceptions and knowledge gaps are described below:

Availability of data

Data, whether describing technical performance, supply chain transparency, or environmental impact and attributes, is critical to enable scaled use of a new product. Due to the costly nature of testing and supply chain monitoring, availability of data often presents a key barrier for new products to enter the market. Without such data, it can be challenging for designers to have confidence in their performance, ensuring compliance with building codes and regulations. Environmental impact data is also increasingly required by designers, who seek to take data-informed approaches to reduce the impact of their designs, through review of data products like Environmental Product Declarations (EPDs) and Life Cycle Assessment (LCA).

Fire performance

Regulation relating to combustible materials has a significant impact on the use/applicability of bio-based materials in the built environment. All building materials, bio-based or otherwise, must meet a minimum fire safety requirement. While bio-based materials are organic and, therefore combustible, synthetic and/or biobased natural additives can be combined with these to significantly improve their fire performance. For example, lime, a biobased natural additive, is often used as a binder in biobased materials to improve fire performance.

Furthermore, fire safety can be engineered and there are numerous strategies for achieving this with biomaterials as with any other construction material. The nature of materials, bio-based or otherwise, must be considered when developing the fire strategy for a building. Best practice for fire safe design, regardless of the material used, is to design knowingly using evidence from research, testing and validated methods of calculation. This allows specific risks to be defined and quantified and appropriate fire safety provisions to be made as part of a holistic design strategy.

Moisture regulation

A common perception is that bio-based materials create damp environments. However, when properly utilised, these materials can facilitate the moisture regulation of indoor environments and is therefore also mentioned in the previous section on benefit.

Hygroscopicity is the capacity of a material to absorb and release water vapour from and to the air as the relative humidity of the air changes. Many bio-based materials have excellent hygroscopic performance, as well as a higher degree of vapour permeability than non-bio-based materials, enabling the development of 'breathable' build-ups and stable environments. In any construction method, the correct design and installation of vapour control layers and vapour permeable layers in wall build-ups is necessary. The relevance of this moisture regulating performance will also depend on the operation of a space – hygroscopic buffering of moisture regulation requires low air changes for a space.

Misconceptions and knowledge gaps for the application of bio-based construction

Rodents and insects

There is a popular misconception that bio-based materials provide more attractive homes to common household pests such as rodents and insects. While some bio-based materials may be more susceptible to pests compared to traditional materials like concrete or steel, proper preventive measures can effectively mitigate these risks and ensure the long-term durability and performance of bio-based construction materials. Preventative measures include:

- Proper storage: Storing materials in dry and well-ventilated areas, away from potential sources of pests, such as food or waste.
- Surface treatments: Applying protective coatings or sealants to the surface of bio-based materials can act as a barrier against pests and moisture.
- Pest control measures: Implementing pest control measures, such as regular inspections, using bait stations, traps, or insecticides, can help prevent or address infestations.
- Structural design: Incorporating design features that minimise access points for pests, such as sealing gaps or using mesh screens, can reduce the likelihood of infestations.

Durability

The durability of a material is dependent on its exposure condition. Bio-based materials are often considered to have a short lifespan. However, this misconception is often due to a lack of knowledge, poorly detailed use or outdated information. By keeping bio-based materials dry, their lifespan can be comparable to traditional construction materials. For example, some straw bale insulation manufacturers offer warranties for 25 years, which is comparable to Expol Extruded Polystyrene (XPS) insulation systems.

Bio-based materials can be treated to improve their durability, but like for treatments for fire performance, it should be noted that such treatments may have negative embodied carbon or toxicity implications. As is true of all materials used externally, lifespan will be determined by the project location, material type, treatment, detailing and maintenance.

Misconceptions and knowledge gaps for the application of bio-based construction

Availability, scalability and cost

Bio-based materials can be more expensive than traditional construction techniques. The availability, scalability, and cost of bio-based construction materials varies depending on the specific material, regional production, market demand, and government policies.

In Europe, as in many other regions, there has been an increasing focus on bio-based materials, driven by the need for low-carbon construction solutions. Many bio-based materials, such as timber, straw, and flax, are available in some European regions due to the specific region's abundant agricultural and forestry resources. Studies have shown that the land currently available for growing wood and straw is sufficient in every European region to meet the future evolution of the building stock. However, this is not the case for other materials, such as cork and hemp, which will need to be scaled as markets expand.

The scalability of bio-based construction materials is improving as the industry continues to grow. There is a rising trend in research and development efforts to enhance the performance and expand the range of bio-based materials suitable for construction applications. However, scalability is highly dependent on market demand which needs clear policy signals in order to grow steadily.

The supply and demand conflict in turn affects the cost. In general, bio-based materials can be more expensive than traditional construction techniques. Timber projects for example are generally 5% to 10% more expensive than traditional ones in Western Europe [1]. Bio-based materials usually have higher upfront costs compared to conventional materials due to production methods, limited economies of scale, or additional processing steps. However, as the industry matures and demand increases, economies of scale and technological advancements are expected to drive cost reductions over time. Furthermore, as society decouples economic growth from resource use through higher resource efficiency, material cost can be compensated based on a more holistic whole life-cycle cost taking into account the benefits of lightweight construction, prefabrication construction practices, and true pricing (considering health benefits and carbon emissions).

Lack of certification and testing

The provision of objective information on the performance of available biobased technologies through product certifications needs to be accelerated in order to facilitate materials coming to market. Harmonised and standardised national/international testing and evaluation procedures for specific biobased products and technologies should be prioritised to increase understanding among developers, architects and installers and accelerate the maturity of the industry more broadly. To a large extent the current standardised tests are not appropriate and/or effective for bio-based materials (e.g. moisture regulating effect and fire regulation of biobased materials).

Opportunities and recommendations

for cities to increase uptake of bio-based materials

Cities can address the barriers and accelerate the adoption of bio-based building materials by fostering knowledge dissemination and cross-sector collaboration, as well as creating policy support and financial incentives to promote sustainable and resilient construction practices that benefit both the environment and society.

Knowledge and collaboration

- **Knowledge enhancement:** Develop comprehensive educational programs and workshops to increase knowledge and understanding of bio-based materials among procurement officials, decision-makers, and stakeholders. This should include training sessions on the benefits, characteristics, and applications of bio-based materials, as well as sharing successful case studies and best practices.

- **Capacity building and training:** Provide ongoing capacity building and training programs for procurement officials, ensuring they have the necessary skills and knowledge to evaluate, compare, and select bio-based materials effectively. This can include training on life cycle assessments, cost-benefit analyses, and sustainable procurement practices.

- **Community based biogenic hubs:** Cities have a major role to encourage community transformation and to establish the infrastructure to ensure that carbon remains stored within the city. This could include specific community-based wood recycling projects, biobased material libraries, bio-based building material master classes etc.)

- **Incorporate bio-based materials in learning curricula:** Collaborate with educational institutions to include bio-based materials in relevant curricula, such as architecture, engineering, and construction programs. This ensures that future professionals are equipped with the knowledge and understanding of bio-based materials, fostering their adoption in the industry.

- **Share best (and worst) practices:** Establish platforms or networks to share best practices, lessons learned, and case studies related to bio-based materials. This information sharing can help disseminate knowledge, promote successful projects, and highlight challenges to avoid, ultimately advancing the understanding and implementation of bio-based materials.

- **Establish a local collaborative bio-based construction materials working group:** Create a collaborative working group that brings together government representatives, industry stakeholders, and experts to drive the development, promotion, and standardization of bio-based construction materials. This group can work towards creating supportive policies, sharing knowledge, and establishing certification or labelling schemes for bio-based materials.

- **Sourcing locally:** Cities are uniquely placed to map out potential regional biobased material sources locally (within 100km), to understand current product availability, existing supply chains into the city, potential biomaterial sources and highlight supply chains that could benefit from support. Cities might find some surprising opportunities if they do this. Examples can be found as [24] [25]

Opportunities and recommendations

for cities to increase uptake of bio-based materials

Knowledge and collaboration

- **Collaboration with industry partners:** Collaborate with industry partners, such as manufacturers and suppliers of bio-based materials, to enhance their availability, affordability, and accessibility. Encourage the development of a diverse range of bio-based materials and establish reliable supply chains to meet the increasing demand in the market. An example is the Timber Perception Lab in the Milan Innovation District which is a one million square meter showcase for an ambitious regeneration project designed to feature innovative timber buildings selected for their quality in design and construction. The Timber Perception Lab presents an opportunity to overcome the barriers related to limited knowledge and experience, as well as cultural acceptance, by involving stakeholders across the timber value chain. The Lab is a public-private partnership with Arup, Built by Nature, EIT Climate-KIC, Lendlease, Polytechnic Foundation of Milan, Store Enso, UCL and Waugh Thistleton Architects.

- **Awareness campaigns:** Launch awareness campaigns targeting both professionals in the construction industry and the general public to promote the benefits and potential of bio-based materials. Highlight the environmental advantages, carbon sequestration potential, and positive social impacts associated with the use of these materials.

Policy

- **Advocate for governmental change:** Engage in advocacy efforts to influence governmental policies and regulations that support the adoption of bio-based materials. This can involve participating in policy discussions, providing expert input, and highlighting the benefits of bio-based materials in terms of sustainability, carbon reduction, and local economic development.

- **Policy support:** Advocate for supportive policies at the local, regional, and national levels that encourage the use of bio-based materials in construction projects. This can include incentives and regulations that promote sustainable procurement practices and prioritise the integration of bio-based materials in public and private construction initiatives.

- **Change planning policy:** Work with local authorities and planning bodies to revise planning policies and regulations to explicitly encourage or incentivise the use of bio-based materials in construction projects. This can include incorporating sustainability criteria, providing streamlined approval processes, and granting exemptions or bonuses for projects using bio-based materials.

- **Multi-criteria decision-making:** Implement decision-making frameworks that consider multiple criteria beyond just cost, including environmental impact, social sustainability, and long-term benefits. This can help prioritise sustainable choices and overcome the conflict between cost and sustainability objectives.

- **Focus on the largest material flows:** Identify and prioritise the largest material flows in construction and target efforts towards replacing these conventional materials with bio-based alternatives. This strategic approach can maximise the impact of adopting bio-based materials and facilitate a more significant shift towards sustainable construction practices.

Opportunities and recommendations

for cities to increase uptake of bio-based materials

Finance

- **Fund demonstrator projects:** Allocate research like H2020, Mission Innovation and European Research funds and philanthropic funding to support small-scale demonstrator projects that showcase the successful integration of bio-based materials. These projects can serve as tangible examples of the feasibility, performance, and benefits of bio-based materials, instilling confidence and encouraging further adoption. An example could be the 15 multiple examples of biobased pavilions showcased during the World Congress of Architects in Copenhagen in July 2023 funded by philanthropic funds, private enterprises and EU research programmes. Each pavilion is the result of a collaboration between architects, engineers, material producers, science institutions, associations, and foundations, all working towards asking the right questions when it comes to building for the future, relating to one or more of the UN's 17 Sustainable Development Goal (SDGs).
- **Fund large-scale bio-based flagship projects:** Provide financial support for large-scale flagship projects that utilise bio-based materials extensively. These projects can demonstrate the capacity and viability of bio-based materials in meeting the requirements of significant construction endeavours, building confidence in the supply chain and driving market demand. An example is the 8.200 square meter InnoRenew CoE research institute in Livade which is the largest wooden building in Slovenia and a unique facility for research and innovation in the field of renewable materials and healthy living environments
- **Stimulate innovative procurement measures:** Encourage the use of innovative procurement measures, such as open innovation calls and targeted calls for small and medium-sized enterprises (SMEs), to foster collaboration and stimulate the development and supply of bio-based materials. These measures can support the growth of the bio-based industry while ensuring a diverse and competitive market. An example of such innovative procurement measure is the Urban Food from Residual Heat Open Innovation program, facilitated by EIT Climate-KIC in partnership with the Swedish Cities of Malmö, Lund, Bjuv and Oskarshamn in collaboration with E.ON, ICA Fastigheter, and Veolia, aiming to design low carbon building to utilise low temperature residual heat. The final design is currently under construction in Malmö and is a textbook example of executing Open Innovation ideas into low carbon construction building.
- **Updated product specifications:** Support industry stakeholders in developing and updating product specifications for bio-based materials, addressing any gaps or outdated requirements. Specifically, ensure that fire safety specifications are adequately incorporated to enhance confidence in the performance and compliance of bio-based materials.
- **Incentives and financial support:** Introduce financial incentives, such as grants, tax incentives, or subsidies, to offset the higher upfront costs associated with bio-based materials. This can encourage procurement officials and builders to consider sustainable options and promote the wider adoption of bio-based materials in construction projects.

Regulations

The EU has declared in a position paper on the Commission's Bioeconomy Strategy and Action Plan Review [1], published in 2017, that the bio-based products sector is a priority area with high potential for future growth, reindustrialisation, and addressing societal challenges. An assessment done by the European Commission has indicated that bio-based products and biofuels represent approximately €57 billion in annual revenue and involve 300,000 jobs. The annual revenue and job creation potential specifically for bio-based building materials is not estimated but could be up to 18-20% of the entire bio-based production sector.

In general terms the bio-based sector is seen as a catalyst for systemic change by the EU commission, national governments, and the private sector. From a regulation perspective the bio-based sector is opening new ways of producing and consuming resources while respecting our planetary boundaries. Thus, it contributes directly to achieving the economic, social, and environmental goals of the EU's Green Deal.

In this context, bio-sourced construction materials, if managed in a sustainable way during their whole life cycle, have a major role in the decarbonisation of the construction sector. The development of technological innovation, value chains and skills ecosystems however require evidence-based regulation across sectors. The following section describes the newest regulations, policy adaptations and best practices which are and will be influencing the legal framework for developing bio-based building materials going forward and commercialise the entire value chain behind bio-based building material design, production and use.

Key EU regulations

The European Union (EU) has implemented various regulations and policies that promote the use of bio-based construction materials and encourage sustainable construction practices. Listed below are some key regulations and initiatives relevant to bio-based construction materials in the EU:

The European Green Deal

In November 2019, the Parliament declared a climate emergency asking the European Commission to adapt all its proposals in line with a 1.5 °C target for limiting global warming and ensure that greenhouse gas emissions are significantly reduced.

In response, the Commission unveiled the European Green Deal, a roadmap for Europe becoming a climate-neutral continent by 2050, where:

- There are no net emissions of greenhouse gases by 2050.
- Economic growth is decoupled from resource use.
- No person and no place is left behind.

In order to achieve these goals, the deal spans across many policy areas including biodiversity, from farm to fork, sustainable agriculture, eliminating pollution, climate action and sustainable industry.

Examples of how the bioeconomy contributes to the European Green Deal:

Climate pact and climate law: Carbon sequestration in soil, blue carbon and carbon storage in forests and harvested wood products, is mentioned in the climate pact and climate law of the European Green Deal as examples of impactful bioeconomy contributions. Together with material substitution of fossil-based products (plastics, energy, textiles), they can generate significant carbon savings and make us fit for -55% by 2030.

Striving for green industry: Circular use of biomass promotes resource efficiency and stimulates the production of high added-value products from side and waste streams. Bark residues, for example, can be used for extraction of protective compounds used for non-toxic treatment of wood-based construction materials.

Regulations

Making homes energy efficient, renovate:. The use of bio-based insulation materials such as cellulose fibre and sheep's wool can effectively insulate buildings in a way that also minimises their embodied greenhouse gas emissions.

Life cycle assessment and circularity are among the key principles for building renovation towards 2030 and 2050. As such, they have been enshrined in the Renovation Wave for Europe Strategy, adopted by the European Commission in October 2020 in the framework of the European Green Deal. According to the EU executive, to achieve a climate-neutral building stock in the long-term it is essential to invest in resource efficiency and circularity and to start seeing buildings as 'carbon sinks'. This can be done by turning to low-impact and bio-based construction materials, such as sustainably sourced wood, storing CO2 and avoiding emissions associated with the production of conventional construction materials.

The European Circular Bioeconomy Fund with a volume of up to €250 million will invest in innovative circular bioeconomy projects, in the areas of agriculture, aquaculture and fisheries, the forest-based sectors, biochemicals and biomaterials.

The New European Bauhaus

The New European Bauhaus initiative, launched in January 2021, points to the extensive role that bio-based products like wood and hemp as a building material can play in the design of "beautiful, sustainable and inclusive forms of living together", thus contributing to turn the European Green Deal into a tangible and aesthetically pleasant experience for all Europeans.

EU Timber Regulation (EUTR)

The EUTR prohibits the placement of illegally harvested timber and timber products on the EU market. It aims to prevent deforestation and promote sustainable forest management practices. Timber used as a bio-based construction material must comply with the EUTR requirements.

Construction Products Regulation (CPR)

The Construction Products Regulation (CPR) which has been applied fully since July 2013 aims to achieve the proper functioning of the internal market for construction products (such as sheets for waterproofing, thermal insulation foams, chimneys and wood-based panels produced for permanent incorporation in construction works), by means of harmonised rules for their marketing in the EU. CPR provides a framework for assessing the performance of construction products, including bio-based materials, and requires the CE marking for products placed on the EU market. Currently the directive is under revision to make sustainable products the norm in the EU and boosting circular business models.

Fitfor55

The European climate law makes reaching the EU's climate goal of reducing EU emissions by at least 55% by 2030 a legal obligation. Published by the Commission on 16th of July 2021 under the 'Fitfor55' package, the new EU Forest Strategy for 2030 is set to enhance the multifunctional role of forests in achieving climate neutrality, putting biodiversity on the path to recovery and supporting a circular bioeconomy. To achieve these goals, the new Strategy calls upon the forest-based sector to optimise the use of wood in accordance with the cascading principle, which also entails prioritising the resource-efficient production of long-lived building materials to replace carbon-intensive and fossil-based ones. To help turning the construction sector "from a source of greenhouse gas emissions into a carbon sink", the Strategy sets forth the intention of the EC to develop a 2050 roadmap for reducing whole life-cycle carbon emissions in buildings and to define a methodology to quantify the climate benefits of wood construction products in the next revision of the Construction Product Regulation. The Fitfor55 fund will be part of the EU budget and be fed by external assigned revenues up to a maximum amount of €65 billion.

Regulations

Energy Performance of Buildings Directive (EPBD)
Without an effective EPBD with clear embodied carbon reduction targets, the EU is unlikely to meet its 2050 carbon neutrality goal. The Energy Performance of Buildings Directive (EPBD) is pointed out as the main policy tool for setting requirements to reduce carbon emissions over the full life cycle of buildings. The approval by the European Parliament on this proposal represents a crucial step in the Directive's revision process, which is currently going through interinstitutional negotiation.

Embodied carbon is responsible for roughly 10–20% of the total carbon footprint of buildings and is estimated to represent as much as half of the whole-life cycle emissions for new buildings constructed in line with advanced energy performance standards.

The European Parliament passed its EPBD recast in March 2023, calling for an EU-wide framework for calculating life-cycle Global Warming Potential (GWP), and for Member States to publish roadmaps that introduce limit values and targets on life-cycle GWP.

The EPBD vote ensures several positive steps forward for decarbonising buildings, of which two need to be highlighted: 1) It will establish a harmonised framework for addressing and measuring whole-life carbon, and 2) it will set targets for embodied carbon reduction in the EU. This results in that each Member State must develop national building renovation plans, including renovation targets suited to each country's building stock and needs, and illustrate how these national targets are to be met.

By calling for this, the EU is ensuring that high quality data on embodied carbon will be widely available to all relevant actors in the buildings sector. Coupled with the clear signals provided by targets, this information could help trigger a scale-up of the production and use of low-carbon construction materials. [1]

EU Circular Economy Package

Transitioning to a circular economy is one of the EU's ambitions. A circular economy calls for minimizing resource use by using as few resources as possible, keeping materials and products in the economy for as long as possible and making use of generated waste so that waste materials are fed back into the economy. These resource savings may contribute to mitigating climate change by avoiding emissions associated with the extraction and processing of new resources.

The Circular Economy Package was published by the EU Commission on November 2022 and sets out a comprehensive strategy to transition the EU to a more circular economy. It includes measures to promote resource efficiency, waste reduction, and recycling. These initiatives indirectly support the use of bio-based construction materials derived from renewable and recycled resources.

By avoiding or delaying the use of new materials in buildings, circular economy-based approaches to renovation can help to reduce embedded greenhouse gas emissions. It is estimated that 20-25% of the life cycle emissions of the current EU building stock are embedded in building materials.

Circularity is one of the most effective tools to reduce embodied emissions in buildings. They can be implemented without the need to establish benchmarks on WLC. Based on the current data of available secondary materials in the market and European experiences on Circular Economy, the EPBD should establish requirements for the Member States to set specific national targets for 2030 of at least 15% for reused and recycled contents in buildings by 2025 based upon current average levels in the construction sector.

Regulations

EU Waste Framework Directive (WFD)

Construction and demolition waste is the largest waste stream in the EU, accounting for more than a third of all waste generated in the EU. Reuse and recycling rates currently vary considerably across the EU.

The WFD establishes waste management principles and sets targets for waste prevention, recycling, and landfill diversion. It promotes the concept of a circular economy, encouraging the use of recycled or waste-derived bio-based materials in construction.

The Renovation Wave for Europe strategy, published by the Commission in October 2020, aims to help at least double the annual energy renovation rate of residential and non-residential buildings by 2030, and to foster deep energy renovations, where energy consumption is reduced by at least 60%. This could lead to the renovation of 35 million building units – with all that this implies in terms of construction products' use.

Green Public Procurement (GPP)

GPP encourages public authorities in the EU to consider environmental and sustainability criteria when procuring goods and services. It can drive the demand for bio-based construction materials by including specific requirements or preferences for these materials in public tenders.

A solid provision for green public procurement (GPP) was approved by the EU Commission in March 2023, highlighting the fact that GPP is a key tool to drive development and uptake of low-carbon construction materials. So far, green public procurement has been an underutilised tool to drive low-carbon solutions that should be strengthened in all relevant legislation.

Green public procurement is a potential tool to integrate and advance bio-based, circular, green, sustainable and even innovative purchase at regional level and in considerable volume. Hence, it can help in the profiling of a region, and in communicating and implementing bioeconomic strategies.

Horizon 2020 and Horizon Europe

These EU research and innovation funding programs support projects and initiatives focused on sustainable construction and the development of bio-based materials. They provide financial support for research, development, and demonstration of innovative bio-based construction materials and technologies.

Materials handbook

How to use this handbook

This handbook seeks to inform the reader of available bio-based products in the European market and highlights key aspects that should be considered when evaluating them for use in building and construction applications. These considerations are grouped by the following themes: technical performance; health and safety; responsible sourcing and circularity. An overview of what is captured within these sections is described in turn below.

It is also important to highlight that the appropriate use of materials (both for bio-based and traditional materials) goes beyond the material choice. It is also dependent on a suitable design, detailing, workmanship and maintenance practices.

Description

The handbook is divided into three sections, based on the key elements of a building where bio-based materials can be used:

1. the structure - which can be either a frame or a series load bearing walls;
2. the insulation - which gives the building its thermal and/or acoustic performance;
3. the lining - which forms the internal surfaces.

The fourth key element of a building, the envelope, has not been included as a section as these products are already included in other sections or have a low readiness level. Products currently available include timber cladding, reed, hemp fibre cladding and expanded cork.

Each section contains different types of products based on their biotic origin and use, which is depicted under the Description heading.

Technical Performance

For a selected example product for each material type, this section highlights the technical performance, illustrating the achievable properties of different product groups. These are not intended to show the highest or lowest performing products but rather illustrate what is achievable. Based on this they should not be used to compare different product types.

Key metrics have been defined for each product category (structure, insulation, lining). Technical properties are product dependent; contacting manufacturers for product specific information is recommended. Continuous monitoring of the development of products is advised due to ongoing fast-paced developments of these types of products.

Health and Safety

As we seek to use materials for as long as possible, we must ensure that the materials we are using are safe for all people through the supply chain (from extraction through use and end of life), as well as to the environment. In the European Union, legislation and standards such as REACH, COSHH, ECHA, POPs and local building regulations establish the chemicals that are restricted in construction material. Compliance with these is highly dependent on the materials making up the products. However, the legislations and standards still allow for the use of certain substances which still present higher health, wellbeing and environmental impacts, and these should be identified, and the use minimised where possible.

How to use this handbook

Responsible Sourcing

Responsible sourcing is 'the management of sustainable development in the provision or procurement of a product'. This involves the incorporation of key ethical, sustainability, and social responsibility/value principles into the sourcing and procurement of materials and labour within the supply chain. It is recommended to look for FSC, PEFC and EKO and other similar responsible sourcing certifications schemes.

Ethical sourcing of input materials and labour includes ensuring that the procurement of labour and materials for the product does not contribute to or sustain modern slavery, forced labour, or child labour. Another additional consideration for biomaterials is the impact of these on biodiversity, and soil health, carbon sequestration, the impact of land intensity, land use and harvest cycles are also key considerations.

Circularity

The sustainability of materials must be considered from a whole life-cycle perspective. Considering the entire life cycle of a product gives the most accurate reflection of the impact of the existence of the product on both people and the planet. The life-cycle approach according to EN 15804 and EN 16449 taken for a product by a manufacturer is key to minimising negative whole-life impacts of the product, and maximising its potential benefits, such as how and where input materials and energy are sourced, and the ability to participate in a circular economy.

The three key principles of the circular economy are: the elimination of waste and pollution; the circulation of products and materials at their highest value; and the regeneration of nature. The overall goal is to decouple economic activity from the consumption of finite resources.

The Global Warming Potential (GWP) of specific products have been reported in the handbook, in order to illustrate achievable values of different product groups. GWP values have been reported considering emissions associated with lifecycle stages A1-A3 'cradle-to-gate' as defined in EN15978. The 'cradle to gate' emissions considers the impacts associated with the production of a product or material that is ready to ship to the construction site, including raw materials extraction, transport during production, and manufacturing emissions. The transportation of materials to site, construction processes, use and operational carbon are not included. Where possible the biogenic carbon (amount of CO_2 absorbed by bio-based materials) has been reported in addition to the A1-A3 emission. Whilst it is generally accepted that bio-based materials are more sustainable than traditional materials, the assessment of biogenic benefits is manageable. The principles for biogenic carbon accounting are defined in the international standard, ISO 21930. It must be noted that sequestered carbon can be managed at end-of-life but is not mandatory. End-of-life options include reuse, recycling, biomass energy extraction through combustion or landfill. In the case of the material being sent to landfill or burned for energy, the sequestered CO_2 will be released and further GHG emissions may occur.

However, it is worth to highlight that carbon capture and storage in biobased buildings is one of the greatest CO_2 benefits: it helps us to mitigate climate effects, combined with cascading carbon can be stored for centuries and CO_2 emissions are postponed.

Manufacturers and Scale of Production

A non-exhaustive list of manufacturers have been listed under each product type. It is important to note that this is a fast-changing industry, therefore continuous monitoring of both manufacturers and available products is recommended.

The scale of production and manufacturing of bio-based materials for construction varies depending on the specific material and geographic region. While there is an increasing interest and demand for bio-based construction materials, their overall market share is still relatively small compared to conventional construction materials. A high-level overview of the scale of production in the context of bio-based materials has been provided for each product type based on the European market.

Structure

Timber

Structure and Envelope

Description

Structural timber refers to timber that is strength-graded for construction use. The classification system gives reasonable predictions of the structural performance of the individual piece of timber, ensuring that it can withstand the highest anticipated load. In general, across Europe, the grading is regulated by Building Standards, in accordance with EN 14081. Structural timber can be either sawn directly from logs, or it can be processed into Engineered Timber.

Engineered Timber is another form of structural timber. A broad term, it can refer to timber processed to make use of waste, or to timber processed to improve the performance of the construction product. Commonly used engineered timbers are: Engineered Joists, Cross Laminated Timber (CLT), Glue Laminate Timber (Glulam), Structurally Insulated Panels (SIPS) and the innovative new Dowel Laminated Timber (DLT). It is important to highlight that timber-based products are also widely used as cladding material as well as lining.

Technical Performance

EN 1995 contains the mechanical resistance, serviceability, durability and fire resistance of timber structures.

The carbon assessment of timber is highly sensitive to sourcing, as well as the energy use during production. Refer to the IStructE's guide for "Mass timber embodied carbon factors" [1]. Considerations of the processing and transportation of structural timber products is necessary in order to calculate an accurate GWP.

Health and Safety

Timber is intrinsically a healthy and safe material, however it may be subjected to processes where additives are added.

Engineered timber products such as CLT and Glulam, for example, contain adhesives such as Polyurethane, two-part thermosetting adhesives or single pack adhesives. Adhesives such as PRF, MUF or MF contain added formaldehyde which is a known carcinogen which is also toxic and causes skin and eye damage. Production methods have greatly reduced formaldehyde emissions, and these can be reduced further by selecting no added formaldehyde products, however this can affect the performance (as formaldehyde-based adhesives are typically the most durable, moisture and heat resistant).

Similarly, additional sealants, intumescent paint or varnish or chemical treatments may be added in order to improve fire and/or moisture resistance of timber elements. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing

The wood used in engineered timber products comes from trees grown in forests worldwide. Re-growing these trees and maintaining ecological systems is essential to mitigate the impacts of climate change. Understanding how our forests can be maintained and restored to become sustainable sources of wood requires intricate knowledge on the wider carbon cycles and the importance of biodiversity.

On a global scale, forests are key in managing and maintaining the earth's carbon balance as they act as one of the world's largest carbon sinks by storing carbon in soil long-term. If managed correctly, harvesting improves the carbon balance of forests in the long run.

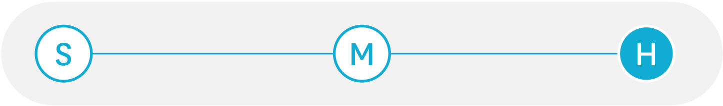
In Europe, almost all timber is grown sustainably; however, there are two global certification schemes (FSC and PEFC) which ensure supplies are from sustainably managed forests.

Being conscious about where timber is harvested from plays a significant role in creating carbon stores and lowering greenhouse gas emissions. The ability to protect and restore these forests lies within the biodiversity of these ecosystems.

Village Walk Mall © Arup

Circularity

At the end of its life timber products can be reused, processed into other products such as panel boards or animal bedding or used as biomass fuel (which returns the sequestered carbon back to the atmosphere). However, surface treatments (paints and varnishes) and other chemical treatments (for preservation or fire performance) may impact the ability for timber products to be recycled.



Scale of Production

Bamboo

Structure and Envelope

Description

More than 1,600 bamboo species have been identified worldwide, but only a few possess the characteristics that make them compatible for construction. Moso, Asper and Guadua are the most common. Bamboo as a structural element can be used directly from bamboo culms or processed into Structural Engineered Bamboo (SEB). Natural bamboo is vulnerable to insects, fungi and ultraviolet radiation; hence it usually requires additional chemical treatments to improve durability.

SEB products improve the performance of the building product. Laminated bamboo is produced from flat bamboo strips, which are laid horizontally or vertically and adhesively fixed together, producing base material for different applications. The density and strength of laminated bamboo can be compared to that of laminated timber products; however, they are likely to consume more energy due to the higher amount of processing, waste and adhesives required.

Technical Performance

Like trees, different bamboo species have different structural and mechanical properties. For example, some have large, straight culms, while others are smaller and more flexible. In addition, there are other conditions in bamboo growth that can affect the mechanical properties of bamboo within a species, such as climate, altitude and soil. Tropical bamboos tend to be taller and larger than temperate bamboos and have thicker walls, which usually translates into better structural and mechanical properties. ISO 22156 contains the requirements for mechanical resistance, serviceability and durability of bamboo structures.

The embodied carbon of bamboo is highly dependent on whether energy is required for drying the bamboo or heating up the treatment liquid.

Furthermore, given the locations bamboo grows embodied carbon associated with transportation may dominate the total global warming potential. Considerations of the processing and transportation of bamboo are necessary in order to calculate an accurate GWP.

Health and Safety

Bamboo is inherently a healthy and safe material, but to improve its properties it can be subjected to processes in which chemical additives are added.

Chemical treatments containing boron or copper-based chemicals may be added to improve the fire and/or moisture resistance of bamboo elements. Furthermore, through the incorporation of varnishes or during the manufacture of bamboo laminate products, formaldehydes or other harmful compounds may be added to the product. Compliance with COSHH, REACH, ECHA and local building regulations must be checked for each product.

Responsible Sourcing

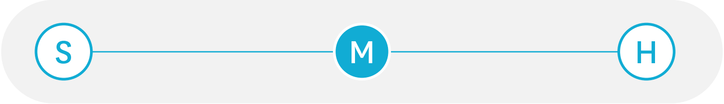
Bamboo is a rapidly self-generating crop: it grows fast, and when well managed it can be harvested without the need to replant. Bamboo grows in a “belt” running through tropical, subtropical and temperate climates around the globe, and up to 3,500m altitude. Depending on the species, bamboo can be ready for harvesting in less than 10 years. It has a higher yield per hectare and greater resilience than traditional timber resources.
When suitably managed, bamboo plantations may aid in restabilising eroded landscapes, enhancing soil health and preventing erosion. However, special care must be taken with bamboo plantations and their relationship with ecosystems, as some species can become invasive if not strictly controlled. Similarly to timber, it is important to maintain ecological systems around these crops to mitigate the impacts of climate change. Products with FSC certification or similar should be sought to ensure supplies are from sustainably managed plantations.

Circularity

Bamboo cannot realistically be recycled, but it can be reused, for example, for building something else. SEB elements can be reused, transformed into other products such as fibreboard, particleboard, flooring, furniture or used as biomass fuel. However, surface treatments and other chemical treatments will limit the ability of bamboo products to be recycled.

© Laminated Bamboo by ReNüTeq

At the end of its useful life, depending on the preservatives used, it can be burnt as a biofuel or safely buried and composted. This is the case for boron treated bamboo however, bamboo treated with copper-based chemicals is more difficult to safely dispose of, should not be burnt, and generally should be buried. Any residual solution from the boron treatment can be safely diluted down and used as a fertiliser. However, overuse or simply dumping into rivers can have detrimental impacts such as eutrophication of rivers.



Scale of Production

Hemp Brick

Structure and Envelope

Description
Hemp blocks are the most accessible form of hempcrete, as well as being an alternative to conventional masonry solutions, such as clay or concrete. They are made from a mixture of hemp shives with a binder and mineral aggregates such as hydraulic lime, which provide mechanical strength, density and thermal inertia. Used as traditional masonry, there are many brick options; solid, hollow, with straight joints, amongst others. They are light and easy to install, both in new construction and retrofit.

Technical Performance
The hemp blocks can be used to form the building envelope, external insulation, interior insulation, floor insulation and interior masonry. Depending on the thickness, they are self-supporting up to 10 metres high. Depending on the product they may need to be protected from the weather. Technical performance data for hemp blocks by Hemp Block Company is provided below to illustrate the achievable properties of hemp in structural use.

THICKNESS: 30 mm
BULK DENSITY: 330 kg/m³
COMPRESSIVE STRENGTH: 0,40 N/mm2

REACTION TO FIRE: B-s1, d0 (EN 13501-1)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY λ: 0,07 W/mK
THERMAL RESISTANCE RD: 4,54 m2K/W

GWP: fossil 240 / biogenic -264 kgCO2-eq/m3 1
BIOGENIC CARBON: 66 kg C / m3

1. EPD functional unit GWP calculations hempcrete blocks, pallets and packaging.

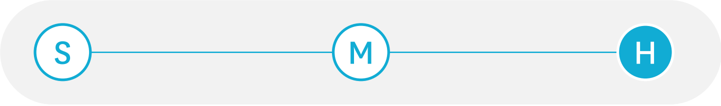
Health and Safety
Hemp shives are non-toxic themselves, however they are often mixed or applied with other materials such as adhesives and flame retardants. The treatments improve properties such as durability and fire resistance but can commonly contribute to decreased air quality. Through design, off-gassing periods and alternative materials such as VOC-free adhesives, the health and safety of materials can be mitigated, however these are product specific solutions. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing
Industrial hemp is a very fast-growing plant which improve soil structure and nutrient levels due to its particularly long taproots. Due to its rapid growth, it only requires a very simple type of crop management and does not require pesticides. Its root system promotes soil permeabilization, i.e., water retention, and replaces carbon and nitrogen, and the plant can act as a barrier to fires. Moreover, according to recent studies, industrial hemp absorbs more CO2 per hectare than any forest or cash crop and is therefore the ideal carbon sink.

Circularity
The recyclability of hemp blocks is highly dependent on the type of binder used in the product. Tuorla Agricultural School tested blocks made from hemp head and slaked lime as a binder. Blocks were crushed into the soil and found to be degradable. In addition, the residual material was found to improve the soil structure and hemp cultivation could be resumed from this point.

© Hemp bricks by Hemp Block Company. Photos by Wiliam Stanwix

Manufacturers
- ISOHEMP, Belgium
- Schönthaler Bausteinwerk, Germany
- Cannabric, Spain
- Edilcanapa, Italy
- Biosys, France
- CÂNHAMOR, Portugal
- Gohemp, India
- Afrimat, South Africa
- Hemp Block Company, UK



Scale of Production

Insulation

Hemp Fibre Batts

Thermal Insulation

Description

Rigid and flexible insulation batts can be manufactured from hemp fibre. Some batts are mixed with supplementary materials, such as recycled polyester or clay.

In general, hemp fibre batts are light and provide thermal insulation for internal and external walls as well as floor and roof. They usually preserve a high level of breathability and are resistant against rot and mold as they are moisture absorbent.

Technical Performance

Technical performance data for Hemspan Bio Wall is provided below to illustrate the achievable properties of hemp fibre batts.

THICKNESS: 30mm -160mm
BULK DENSITY: 85-115 Kg/m³

FIRE RESISTANCE: NOT AVAILABLE
REACTION TO FIRE: E (EN 13501-1)

THERMAL CONDUCTIVITY λ: 0.039 W/mK
THERMAL RESISTANCE RD: NOT AVAILABLE

GWP: fossil 21,80 / biogenic -44 kgCO2-eq/m3 1
BIOGENIC CARBON: YES

1. EPD functional unit GWP calculations includes Hemp Fibre Batts and the use of packaging materials.

Health and Safety

Hemp fibres are non-toxic themselves, however they are often mixed or applied with other materials such as adhesives and flame retardants. The treatments improve properties such as durability and fire resistance but can commonly contribute to decreased air quality. Through design, off-gassing periods and alternative materials such as VOC-free adhesives, the health and safety of materials can be mitigated, however these are product specific solutions. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing

Industrial hemp is a very fast-growing plant which improve soil structure and nutrient levels due to its particularly long taproots. Due to its rapid growth, it only requires a very simple type of crop management and does not require pesticides. Its root system promotes soil permeabilization, i.e., water retention, and replaces carbon and nitrogen, and the plant can act as a barrier to fires. Moreover, according to recent studies, industrial hemp absorbs more CO_2 per hectare than any forest or cash crop and is therefore the ideal carbon sink.

Circularity

Circularity of the product depends on the binders and additives included in the manufacturing process. In general batts can be recycled at the end-of-life or re-processed in non-woven textile mills.

© Bio Wall by Hemspan

Manufacturers

- Cannabric, Spain
- Edilcanapa, Italy
- IndiNature, UK
- Hempitecture, USA
- Hemspan, UK

S M H

Scale of Production

Hempcrete

Thermal and Acoustic Insulation

Description

Hempcrete is a composite material that is non-structural and is created by mixing hemp shiv with a binder and mineral aggregates. It is versatile and can be used in different forms for walls, floors, and roofs. Hempcrete can be cast into formwork around a timber frame or precast in block form. After being air-dried, it can be laid with lime mortar.

Technical Performance

This material provides a thermal and acoustic insulation that allows for vapor permeability. Unlike other lighter insulation materials, hempcrete has a higher thermal mass.

Technical performance data for IsoHemp hemp block is provided below to illustrate the achievable properties of hempcrete.

THICKNESS: 70 - 360 mm
BULK DENSITY: 340Kg/m³

REACTION TO FIRE: B,s1 - d0 (EN 13501-1)
FIRE RESISTANCE: 60min (for 120mm thickness), 120min (for 200MM thickness)*

THERMAL CONDUCTIVITY λ: 0.071 W/mK
THERMAL RESISTANCE RD: 1.06-5.37 m²K/W

SOUND ABSORPTION COEFFICIENT α: 0.85
AIRBORNE NOISE TRANSMISSION: NOT AVAILABLE

GWP: 0.22-0.57 kgCO2-eq/kg
BIOGENIC CARBON: YES

*Masonry wall with redder on one side

Health and Safety

Hemp shives are non-toxic themselves, however they are often mixed or applied with other materials such as adhesives and flame retardants. The treatments improve properties such as durability and fire resistance but can commonly contribute to decreased air quality. Through design, off-gassing periods and alternative materials such as VOC-free adhesives, the health and safety of materials can be mitigated, however these are product specific solutions. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing

Industrial hemp is a very fast-growing plant which improve soil structure and nutrient levels due to its particularly long taproots. Due to its rapid growth, it only requires a very simple type of crop management and does not require pesticides. Its root system promotes soil permeabilization, i.e., water retention, and replaces carbon and nitrogen, and the plant can act as a barrier to fires. Moreover, according to recent studies, industrial hemp absorbs more CO2 per hectare than any forest or cash crop and is therefore the ideal carbon sink.

Circularity

Depending on the nature of binder used, hempcrete can be biodegradable. Tuorla Agricultural School tested blocks made from hemp head and slaked lime as a binder. Blocks were crushed into the soil and found to be degradable. In addition, the residual material was found to improve the soil structure and hemp cultivation could be resumed from these points.

© Hempcrete block by IsoHemp

Manufacturers

- IsoHemp, Belgium
- Tradical Hempcrete, France
- HempFlax, Netherlands
- Hempitecture, USA

S M H

Scale of Production

Straw Panels and Boards

Thermal and Acoustic Insulation

Description

Straw is a versatile insulating material that can be used in various construction components. When compressed, straw bales can be used as external wall insulation as they have high insulation properties and low embodied energy. They are typically paired with a timber structural frame and lime rendering on both the interior and exterior. Combining straw with earth and clay can enhance its insulation capabilities while also improving binding strength and stability. Additionally, prefabricated compressed straw Structural Insulated Panels (SIPs) are an efficient use of straw in construction.

Technical Performance

Technical performance data for EcoCocon Straw Wall System (which includes timber-straw panel, clay plaster and wood fibre board) is provided below to illustrate the achievable properties of straw board panels.

THICKNESS: 400mm timber-straw panel + 30mm clay plaster + 60mm wood fibre board
BULK DENSITY: 110Kg/m³ (average straw density)

REACTION TO FIRE: B-s1, d0 (EN 13501-1)
FIRE RESISTANCE: 120min (EN 13501-2)

THERMAL CONDUCTIVITY λ : 0,0645 W/mK
THERMAL RESISTANCE RD: 8,1 m²K/W

SOUND ABSORPTION COEFFICIENT α: NOT AVAILABLE
AIRBORNE NOISE TRANSMISSION: NOT AVAILABLE

GWP: INC .BIOGENIC CARBON -88.7 kgCO2-eq/kg/m2
BIOGENIC CARBON: YES

Health and Safety

Straw itself is a non-toxic material, and usually there is no need for any toxic binders to be mixed into the products, as the straw can easily hold its form when compressed, especially in timber framed elements.

Straw is a hygroscopic material, meaning that it can absorb moist from the surroundings until equilibrium is reached. If the absorption limit of straw is exceeded, the water molecules are available for microorganism which can lead to mold and rot, ultimately compromising the integrity of the product. Therefore, straw is safest to use in less humid surroundings.

Responsible Sourcing

Straw is a by-product of wheat production, is readily available in most geographies and can be sourced locally. Choosing locally sourced straw can help reduce transportation emissions and support the local economy, and selecting straw from regenerative agricultural practices, such as those using no-till farming, can increase soil health and carbon sequestration.

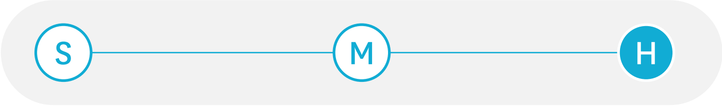
Circularity

Straw can be recycled or repurposed as animal bedding or compost or incinerated as biomass fuel. It must be noted that sequestered carbon needs to be managed at end-of-life. In the case of the material being sent to landfill or burned for energy, the sequestered CO2 will be released and further GHG emissions may occur.

EcoCocon® Straw Wall System

Manufacturers

- EcoCocon, Slovakia (and other European countries)
- Croft, USA
- Okambuva, Spain
- Modcell, UK
- Modulina, Lithuania
- Eco-Bud, Ukraine



Scale of Production

Rice Panels and Boards

Thermal and Acoustic Insulation

Description

Rice panels and boards are semi-rigid or rigid building materials made from rice husk and other natural fibres, compressed and bonded.

They are usually used as insulation material (both thermal and acoustic) for walls , floors and roofs.

The high silica content found in rice husks exhibits pesticidal properties, effectively acting as a natural pesticide against certain pests and insects.

Technical Performance

Technical performance data for the RH50 insulating panel by Rice House is provided below to illustrate the achievable properties of rice panels.

THICKNESS: 45-200 mm
BULK DENSITY: 50 Kg/m³

REACTION TO FIRE: E (EN 13501-1)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY λ: 0,039 W/mK
THERMAL RESISTANCE RD: N/A

SOUND ABSORPTION COEFFICIENT α: 0.5 – 0.9 depending on thickness
AIRBORNE NOISE TRANSMISSION: NOT AVAILABLE

GWP (kgCO2-eq/kg): NOT AVAILABLE
BIOGENIC CARBON: YES

Health and Safety

Rice husk are inherently non-toxic; however, binders may be added to products in the manufacturing process that may be classified as dangerous to health and the environment. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

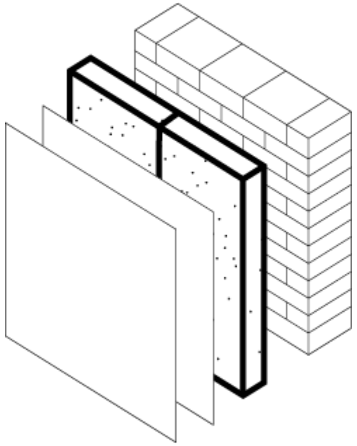
Responsible Sourcing

Rice husk represents the agricultural by-product resulting from the process of dehulling of raw rice or paddy rice. Rice is one of the only biotic materials presents on all five continents, making local sourcing possible. More than half of the world's population relies on rice as a staple food, but rice production generates significant amounts of husk annually. Presently, only around 20% of the rice husk is utilised for practical purposes. Following harvest, the straw is often either burned where it stands, incorporated into the soil, or used as mulch for the next crop.

Although rice husk is an agricultural bi-product, rice production can have a significant impact on the environment, therefore electing rice from regenerative agricultural practices is an important consideration in order to reduce the impact on land intensity and soil health.

Circularity

At their end of life, rice panels and boards can be composted depending on the nature of binders and additives used during the manufacturing process. Boards and panels can also be used as biomass fuel, generating energy or heat, however in this case the sequestered CO2 will be released and further GHG emissions may occur. Studies have demonstrated that the silicate residues generated from the conversion of rice husk to ash possess the potential to be incorporated into concrete as a partial replacement for cement, improving the concrete's compressive strength.



© RH50 Insulating panel by Rice House

Manufacturers

- Rice House, Italy
- ECOBoards, Netherlands
- Ecopanel systems, UK

S M H

Scale of Production

Hemp Panels and Boards

Thermal Insulation

Description

Hemp panels and boards are rigid natural thermal insulation solutions consisting primarily of hemp straw and binders. They are used as thermal insulation for walls, roof and floor construction. Given the nature of the product it also has good acoustic properties.

In general, these types of products are vapour-permeable and moisture-absorbent. Therefore, when installed and maintained appropriately they are resistant against rot and mold.

Technical Performance

Technical performance data for the THERMO HANF insulating panel from Hemp Flax, which also contains jute fibres from upcycled cocoa and coffee bags, is provided below to illustrate the achievable properties of this material as thermal insulation.

THICKNESS: 40 - 160mm
BULK DENSITY: 37 Kg/m³

REACTION TO FIRE: B2, E (EN 13501-1)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY λ: 0.040W/m.K
THERMAL RESISTANCE RD : NOT AVAILABLE

GWP: fossil 32,1 / biogenic -53,50 kgCO2-eq/m3
BIOGENIC CARBON: 13,18 kgC/m3

Health and Safety

Hemp fibres are non-toxic themselves, however they are often mixed or applied with other materials such as adhesives and flame retardants. The treatments improve properties such as durability and fire resistance but can commonly contribute to decreased air quality. Through design, off-gassing periods and alternative materials such as VOC-free adhesives, the health and safety of materials can be mitigated, however these are product specific solutions. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing

Industrial hemp is a very fast-growing plant which improve soil structure and nutrient levels due to its particularly long taproots. Due to its rapid growth, it only requires a very simple type of crop management and does not require pesticides. Its root system promotes soil permeabilization, i.e., water retention, and replaces carbon and nitrogen, and the plant can act as a barrier to fires. Moreover, according to recent studies, industrial hemp absorbs more CO2 per hectare than any forest or cash crop and is therefore the ideal carbon sink.

Circularity

The circularity of hemp panels and boards depend on the nature of binders and chemical treatments used. However, in general, the products can be recycled or composted.

© HEMP WOOL INSULATION BATT by ECI

Manufacturers

- HempFlax, Germany
- Hempitecture, USA
- Cannabric, Spain
- Artimestieri, Italy
- Edilcanapa, Italy
- ECI, Turkey
- Ekolution, Sweden
- KOBE, Czech Republic

S — M — H

Scale of Production

Wood Fibre Insulation

Thermal Insulation

Description

Wood fibre insulation, derived from discarded coniferous and deciduous wood. Products can be either rigid or flexible. The insulation is produced using residual wood and non-sawable thinnings obtained during the manufacturing of construction-grade timber. Wood fibre insulation can be used to insulate walls, floors and roofs. In general, wood fibre insulation is moisture-resistant and not prone to pests, fungi, and decay. Additionally, it can be treated to repel water, making it suitable to be placed below rainscreen cladding.

Technical Performance

Technical performance data for the Flex 036 insulation by STEICO is provided below to illustrate the achievable properties of wood fibre insulation.

THICKNESS: 40mm ≤ thickness ≤ 200mm
BULK DENSITY: 60 kg/m³

REACTION TO FIRE: E (EN 13501-1)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY λ: 0,036 W/mK
THERMAL RESISTANCE RD: 1.1 - 5.55 m²K/W (depending on thickness)

GWP: -84 kg CO_2-eq/m³
BIOGENIC CARBON: NOT AVAILABLE

Health and Safety

Wood fibre panels can be made both with or without the use of additional binders, depending on the processing technique used. Wood fibre insulation products, may contain binding agents or fire retardants that emit formaldehyde and VOCs. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing

Wood fibre insulation is typically made from waste wood obtained from forestry and lumber operations. The wood used in wood fibre insulation is primarily derived from non-sawable thinnings, sawmill residues, and forest residues, such as branches and treetops, that are typically left behind after the harvesting of timber.
There are two global certification schemes (FSC and PEFC) which ensure supplies are from sustainably managed forests. Even though wood fibre insulation is made from waste products of the timber industry, being conscious about where timber is harvested from plays a significant role in creating carbon stores and lowering greenhouse gas emissions from production.

Circularity

At the end-of-life wood fibre insulation with no binder product can be recycled into the fibre stream for other fibre products. Products containing binders cannot easily be recycled, therefore they are typically used as biomass fuel, generating energy or heat; however, in this case the sequestered CO_2 will be released and further GHG emissions may occur.

© Flex 036 by STEICO

Manufacturers

- STEICO, Germany and UK
- GUTEX, Germany
- Building Products of Canada/SmartCore, Canada
- BetonWood, Italy
- TimberHP, USA

S — M — H

Scale of Production

Sheep Wool Insulation

Thermal and Acoustic Insulation

Description

Sheep wool is a natural and renewable fibre with a long tradition of being used as an insulation material as it is a breathable and hygroscopic material. Within the built environment, sheep wool insulation can be used as thermal or acoustic insulation for roofs, walls and floors. Products in general contain combination of sheep wool, recycled synthetic fibres such as PET and binders. It is usually manufactured as batts, rolls, and as loose wool products.

Technical Performance

Technical performance data for CosyWool roll insulation by Thermafleece is provided below to illustrate the achievable properties of sheep wool insulation.

THICKNESS: 50mm, 75mm, 100mm, 140mm, 150mm
BULK DENSITY: 18 kg/m³

REACTION TO FIRE: E (EN 13501-1) + EN 11925-2: Pass
FIRE RESISTANCE: N/A

THERMAL CONDUCTIVITY λ: 0.039 W/mK
THERMAL RESISTANCE RD: $1,25 \leq R \leq 3,5$

SOUND ABSORPTION COEFFICIENT α: 1.05 @ 100mm
AIRBORNE NOISE TRANSMISSION: Not Available

GWP: 0.19531 kgCO_2-eq/m3 (for 100 mm thickness)
BIOGENIC CARBON: -3.3516 kgCO_2-eq/m3

Health and Safety

Sheep wool insulation is a natural material that can be made both with and without fibres and chemical binders, depending on the manufacturer. Binding chemicals may emit formaldehyde and VOCs. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products. Sheep wool has the ability to absorb moisture and release it again without compromising its insulating properties. This helps in maintaining optimal indoor humidity levels.

Responsible Sourcing

Sheep wool is typically sourced by shearing the sheep. Shearing is the process of removing the wool fleece from the sheep's body using electric clippers or scissors. The process is typically done in the spring or early summer when the weather is warm, and the sheep's fleece has grown long enough to be removed without harming the animal. Shearing helps to keep the sheep cool and comfortable during the warmer months.
Certification programs such as the Responsible Wool Standard provide guidelines for animal welfare in sheep farming and wool production.

Circularity

When sheep wool insulation is made without synthetic fibres and chemical binders it is biodegradable. When disposed of in appropriate conditions, such as composting facilities, the wool fibres will break down over time, returning to the environment without causing harm or pollution. When the product includes synthetic fibres and chemical binders the product is typically used as biomass fuel, generating energy or heat, however in this case the sequestered CO_2 will be released and further GHG emissions may occur. [2] [3]

© CosyWool by Thermafleece

Manufacturers

- Thermafleece, UK
- Sheep Wool Insulation, Ireland
- Havelock Wool, USA
- Isolena/Lehner Wool, Austria

S M H

Scale of Production

Expanded Cork

Insulation and Envelope

Description

Thermal insulation panels made from cork granules subjected to high temperatures. Under these conditions a honeycomb structure is formed with good thermal and acoustic properties. Expanded cork products are in general lightweight, resistant to water and high temperatures. Some manufacturers have developed products that are also suitable for exterior cladding applications.

Technical Performance

Technical performance data for Amorim´s Expanded insulation corkboard solution is presented below as a reference of the achievable properties of expanded cork insulation.

THICKNESS: 30 mm
BULK DENSITY: 110 kg/m3

REACTION TO FIRE: E (EN 13170)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY λ: 0,039 W/mK
THERMAL RESISTANCE RD: 0,75 m2K/W

SOUND ABSORPTION COEFFICIENT α: : NOT AVAILABLE
AIRBORNE SOUND TRANSMISSION: Rw = 50-55 dB

GWP: fossil 82,8 / biogenic -2.120 kgCO2-eq/m3 1
BIOGENIC CARBON: 4.554 kgC/m3

1. EPD functional unit GWP calculations Expanded insulation cork board, as well as packaging materials and other ancillary materials

Health and Safety

To produce expanded cork products, cork granules are exposed to superheated steam. This heating process expands the cork granules and activates a natural binder, which is known as suberin. Expanded cork products are binded naturally with its own resin, and mainly consists of cork plus water. Thus, it is a 100% natural and additive-free material, which is free from VOCs.

Responsible Sourcing

Cork production depends solely on the extraction of material from the cork oak. The cork oak is an endemic species that grows in a narrow region of the western Mediterranean, especially in the Iberian Peninsula. The importance of this agroforestry system lies in the fact that a natural and renewable raw material - cork - is extracted in a sustainable way without endangering the tree, while preserving biodiversity. Cork extraction, also known as cork debarking is done by mechanical means, and it is a process where the bark is obtained from the tree without cutting it down. Thus, its carbon footprint is almost zero. However, its transportation is done by fuel engine vehicles. According to a stydy about cork debarking from 2013 [4], during the extraction and manufacture in Catalonia, for each ton of cork extracted, 200 kg of CO2 eq were emitted. If the emissions from the extraction and the carbon contained in the products are discounted from the total fixation exerted by the tree, the resulting balance is that for each ton of cork, 18 kg of CO2 are sequestered.

Circularity

For the manufacture of expanded cork panels, the by-product from the cork stopper industry (cork granules) is often used. Similarly, during production, any offcuts are fed back into the production cycle. Expanded cork has a durability of 50 to 60 years without loss of characteristics, and because of its composition it is recyclable.

© EXPANDED INSULATION CORKBOARD by Amorim Cork Insulation

Manufacturers

- Amorim Cork Insulation, Portugal
- Diasen, Italy
- Thermacork, Spain
- Barnacork, Spain
- BetonWood, Spain
- ThermalCork, USA
- Boudjelida, Algiers
- Batiliege, France

S — M — H

Scale of Production

Mycelium Insulation Boards

Acoustic Insulation

Description
Insulating product resulting from the growth process of fungi on agricultural or forestry residues. The mycelium functions as a natural, self-assembling binder to generate a rigid structural insulation, ultimately producing a completely natural composite material. Final material is fire and moisture resistant with high acoustic and thermal insulation capacity.

Technical Performance
Due to its numerous advantages, in recent years there has been an increasing amount of research into this material with the aim of finding a solution for its use in construction. However, there are not so many examples in the current European production, as it is not yet a commonly used material and it is still under research. Mogu Acoustic is the first commercially available product of its kind, which is entirely made of fungal mycelium and upcycled textile residues. Technical performance for Mogu Plain acoustic board is provided below.

THICKNESS: 40 mm
BULK DENSITY: 100 kg/m3

REACTION TO FIRE: B,s2 - d0 (EN 13501-1)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY λ: 0,050 W/mK
THERMAL RESISTANCE RD: NOT AVAILABLE

SOUND ABSORPTION COEFFICIENT α: 0,40
AIRBORNE SOUND TRANSMISSION: NOT AVAILABLE

GWP: NOT AVAILABLE BIOGENIC CARBON: NOT AVAILABLE

Health and Safety
Insulation made from mycelium is a natural material without toxic adhesives or other synthetic resin-based compounds that can cause harmful toxic fumes and the rapid spread of flames in the event of a fire. In order to prevent any health risk for operators and future users relating to spores from the fungi, manufacturers have developed technologies securing that no spores are produced throughout the production process as well as during its lifespan. To enhance fire performance, fire retardants are used in some products. Such products commonly contribute to decreased air quality performance. However, Mogu for example uses a water-based intumescent paint which has low VOC emission and formaldehyde content.

Responsible Sourcing
Mycelium products have a great advantage over synthetic products in single-use applications in terms of carbon footprint and sustainability. The growth phase of mycelial materials is a relatively fast process that can be achieved in 5-14 days, if using an efficient fermentation setup, depending on the fungal species and fermentation conditions. Mycelium panels combined with another base element offer a variety of raw materials that can be produced through fermentation processes in which low-value agricultural by-products can be used as a nutrient vehicle to promote mycelial growth. Wood chips often come from waste from forestry and logging operations. It will be essential to check the origin of this wood and the management of the forests in order to promote responsible forestry.

Circularity
Although there are various types of substrates on which to grow mycelium, most manufacturers look for organic and/or synthetic waste to manufacture their products. This makes mycelium panels a material in line with the principle of circularity. By-products that would otherwise go to landfill are used as a valuable input to the manufacturing process. Under appropriate industrial conditions these products are in general biodegradable.

© Mycelium insulation by BIOHM

Manufacturers
- Mycelium, Egypt
- Biohm, UK
- GROWN bio, Germany
- Ecovative, USA
- Permafungi, Belgium
- Mogu, Italy

S M H

Scale of Production

Seagrass Insulation

Thermal and Acoustic Insulation

Description
Seagrass has been investigated mainly because it has been considered as a possible insulation material for buildings. The insulation material is obtained and processed from the seagrass species such as, Posidonia oceanica, which is often found on beaches in the form of balls, known as Neptune's Balls and Zostera, which is widespread throughout seashores of much of the Northern Hemisphere (especially in the Mediterranean) as well as Australia, New Zealand, Southeast Asia and southern Africa.

Technical Performance
Once the seagrass has been collected from the beaches, it is dried, sanded and chopped, resulting in a quick-drying, mould-resistant material with good thermal and acoustic insulation properties, which can be used as an insulating material without the need for chemical additives. Its inherent nature also makes it uninteresting for pests. Technical performance from Søuld's fire resistant acoustic mats is provided below to illustrate the achievable properties of this insulation.

THICKNESS: 35 mm
BULK DENSITY: 133 kg/m3

REACTION TO FIRE: C,s1 - d1 (EN 13501-1)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY λ: NOT AVAILABLE
THERMAL RESISTANCE RD: NOT AVAILABLE

SOUND ABSORPTION COEFFICIENT α: 0,90
AIRBORNE SOUND TRANSMISSION: NOT AVAILABLE

GWP: fossil 76,87 / biogenic -125,42 kgCO2-eq/m3
BIOGENIC CARBON: 81,6 kgC/m3

Health and Safety
Seagrass is environmentally friendly and completely free of toxic substances, which makes it suitable for allergy sensitive people. Moreover, in terms of resource use, there is no need to plant or fertilise it, as it comes from a natural waste product. Despite some products may content flame retardants and adhesives, most of the insulation available on the market is made entirely from natural, plant-based materials and therefore poses no risk to human health.

Responsible Sourcing
Seagrass harvesting techniques include hand cutting or picking, trawling/sledging/dredging, mechanical 'hedge' cutting and collecting washed up seagrass from coastlines. It is important to highlight that, once the seabed has been damaged for example by anchors or nets, it can take many years for the seagrass beds to recover. Some seagrass beds are now protected, and some countries have regulations on the harvesting of seagrass. Most products currently available use washed up seagrass from coastlines. Although this is the preferred method, their collection should be limited to keep the balance of the coastal ecosystem. Extraction should always be controlled by regulatory agencies.

Circularity
Currently, most of seagrass wracks (the remains of dead leaves accumulated on seashores) are considered waste and are landfilled, which is not an ecological waste management practice. It is an abundant material and during the last years the interest of using it as a raw material for the manufacture of insulation is growing. Once its useful life is over, as long as no synthetic products were used in its manufacture, its disposal is not a problem, and it can be disposed of directly into the soil as organic soil loosener.

© Seaweed acoustic mats from SøUld

Manufacturers
- NeptuTherm, Germany
- Sould, Denmark
- Møn Tang, Denmark
- Fraunhofer ICT

S — M — H

Scale of Production

1. EPD functional unit GWP calculations includes eelgrass mat and wood pallets and plastic wrapping for packaging.

Lining

Hemp Boards

Wall Lining

Description
Hemp boards, also known as hempcrete boards or hemp composites, are building materials made from a mixture of hemp fibres and a mineral-based binder for example lime. They are primarily used in construction for wall systems, including external walls, internal partitions and insulation panels. They can be easily cut and shaped, allowing for flexible and efficient construction.

Technical Performance
Hemp boards are lightweight yet strong and have good thermal and acoustic insulation properties. Technical performance data for Bio Board from Hemspan is provided below to illustrate the achievable properties of hemp boards.

THICKNESS: 19mm
BULK DENSITY: ca. 650 kg/m3

REACTION TO FIRE: B-s1 d0 Class
FIRE RESISTANCE: Not available

THERMAL CONDUCTIVITY Λ: 0.115 W/mK
THERMAL RESISTANCE RD:

SOUND INSULATION: Not available
AIRBORNE NOISE TRANSMISSION: Not available

GWP ($kgCO_2$-eq/kg): Not available
BIOGENIC CARBON: Not available

Health and Safety
A benefit of hemp boards is their breathability. They allow moisture to pass through the material, preventing the buildup of condensation and promoting healthy indoor air quality.

As hemp board is produced with a mineral-based binder (lime or similar), it may emit formaldehyde and VOCs. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing
Industrial hemp is a very fast-growing plant which improve soil structure and nutrient levels due to its particularly long taproots. Due to its rapid growth, it only requires a very simple type of crop management and does not require pesticides. Its root system promotes soil permeabilization, i.e., water retention, and replaces carbon and nitrogen, and the plant can act as a barrier to fires. Moreover, according to recent studies, industrial hemp absorbs more CO_2 per hectare than any forest or cash crop and is therefore the ideal carbon sink.

Additionally, the carbon sequestration properties of the mineral binder make these boards carbon-negative, meaning they absorb more carbon dioxide during their lifecycle than is emitted during production.

Circularity
Hemp lime boards and other hempcrete products can easily be demolished at end-of-life, and could be biodegradable, depending on the amount of cement in the mineral binder. If end-of-life does not include re-use or recycling, it is typically used as biomass fuel, generating energy or heat, however in this case the sequestered CO_2 will be released and further GHG emissions may occur.

© Bio Board by HEMSPAN

Manufacturers
- Adaptavate, UK
- Hemspan, UK

S — M — H

Scale of Production

Compressed Straw Boards (CSB)

Wall Lining

Description

CSB is a building material for lining the interior surfaces of walls and ceilings. It is produced by subjecting straw to a pressure and high temperature process, creating a compressed straw core without binding agents, which is covered with a recycled paper or cardboard sheet on both sides which is adhesively fixed.

Technical Performance

During the manufacturing process, high pressure and temperature facilitate the release of a natural resin from the straw, which acts as a natural binder between the fibres. The resulting panels are resistant to combustion and have non-dispersible fire resistance values. A disadvantage of this material is its weight, which is often heavier than traditional solutions. Technical performance for FBT PR Wall Systems Insulation by FBT Insulation is provided below to illustrate the achievable properties of CSB.

THICKNESS: 50mm
BULK DENSITY: NOT AVAILABLE

REACTION TO FIRE: NOT AVAILABLE
FIRE RESISTANCE: Class 1[1]

THERMAL CONDUCTIVITY λ: 0,081 W/mK
THERMAL RESISTANCE RD: 0,62 m^2K/W

GWP (kgCO_2-eq/kg): NOT AVAILABLE
BIOGENIC CARBON: NOT AVAILABLE

1. In accordance with AS 1530 parts 3, 4.

Health and Safety

CSB panels are building products that only contain straw (biomass) + paper or cardboard, both of which are non-emissive materials that do not pose a health risk, and contribute to a healthy indoor environment. According to the literature, most manufacturers use water-based adhesives to bond these materials, which also do not constitute a health risk.

Responsible Sourcing

The production of CSB boards involves the processing of agricultural waste and therefore does not involve the additional planting of plant species for use as a natural raw material.
Straw is a material that comes from detaching cereal grains from the plant, thus it is a waste product of agriculture. The impact on the manufacture of straw is closely related to the agricultural system used in the cultivation of the cereal used as raw material.

Circularity

The manufacturing process converts an agricultural by-product and wastepaper into a building material that at the end of its useful life is recyclable and biodegradable. At the end of its lifetime, it can be easily dismantled for reuse and its components are biodegradable, and if no chemical adhesives are used, it can be incorporated back into the soil.

© Compressed Straw Boards by Durra Panel

Manufacturers

- Durra Panel, Australia
- Ekopanely, Czech Republic
- Strawtec, Rwanda
- CooBio Circular Materials, UK
- Straw Resource Limited, Global
- aKacia, France
- FBT Insulation, France

S — M — H

Scale of Production

Wood Wool Boards

Wall Lining

Description

Wood wool boards are made of an interlacing of wood fibres, water and Portland cement. The wood wool is combined with Portland cement and water to give the product the strength and structure needed to hold up in any environment. Once the three components are assembled, they are pressed into large blocks of wood fibre. Wood wool boards are primarily used as wall linings. However, due to the air that is fixed between fibres, the panels have good thermal and acoustic properties too.

Technical Performance

The table below includes technical performance for CEWOOD construction panels to illustrate the achievable properties for this product category. As this is a Portland cement-based product, wood wool boards generally have good water and frost resistance, as well as high fire resistance and resistance towards mould.

THICKNESS: 25mm
BULK DENSITY: 460kg/m3

REACTION TO FIRE: B,s1 - d01 (EN 13501-1)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY Λ: 0,066 W/mK
THERMAL RESISTANCE RD: 0,35 m2K/W

GWP (kgCO2-eq/kg): fossil 244 / biogenic -300 kgCO2-eq/m3 [1]
BIOGENIC CARBON: 81,6 kgC/m3

1. EPD functional unit GWP calculations includes Wood Wool Boards and the use of packaging materials.

Health and Safety

The main component of these construction materials is wood and mineral compounds, mainly Portland cement which do not contain VOCs, heavy metals, formaldehyde or other harmful substances or allergens. In addition, in case it burns, it does not emit toxic fumes. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing

The wood used to manufacture wood wool panels comes from waste from other wood industries, whose raw material, trees, grow in forests around the world. Therefore, the responsible sourcing of wood fibres will depend on the management and maintenance of forests. It is important to ensure that products have sustainable forest management certifications, such as FSC and PEFC, as supporting the sustainable management of forests will ensure the responsible sourcing of wood fibres.

Besides wood fibres, Portland cement is present in a significant proportion in wood wool boards. Unfortunately, Portland cement has a high environmental cost, both in terms of CO2 emissions and raw material use. Therefore, it should be noted the importance of studying the incorporation of sustainable cements or even investigating more sustainable alternatives to cement that serve as a binder.

Circularity

At the end of their useful life, wood wool products can be recycled, reused, or used as biomass fuel (returning sequestered carbon to the atmosphere). However, surface treatments, such as paints or other wall finishes, may affect its recyclability. Manufacturers are achieving aesthetically pleasing walls that do not need additional finishing, making them easier to recycle and using less materials.

© Wood Wool Board by Cewood

Manufacturers

- Savolit, UK
- Celenit, Italy
- Cewood, Latvia
- Knauf, Global
- Baux, Sweden
- Heraklith, Austria

S — M — H

Scale of Production

OSB - Wood

Wall Lining

Description

OSB, Oriented Strand Board, is a board made from agglomerated wood shavings and binders which are later subjected to pressure and temperature processes that give them their density and resistance.

Technical Performance

The internal composition of OSB results in benefits similar to that of plywood boards, however with a reduced thickness, which has an impact on reducing material costs. The biggest drawback of this type of board is that when faced with adverse humidity conditions and without the corresponding treatment, they deform to a greater extent than plywood.
Technical performance for OSB2 by EGGER is provided below to illustrate the achievable properties of OSB.

THICKNESS: 25mm
BULK DENSITY: 460kg/m3

REACTION TO FIRE: B,s1 - d01 (EN 13501-1)
FIRE RESISTANCE: NOT AVAILABLE

THERMAL CONDUCTIVITY Λ: 0,066 W/mK
THERMAL RESISTANCE RD: 0,35 m2K/W

GWP (kgCO2-eq/kg): fossil 244 / biogenic -300 kgCO2-eq/m3 1
BIOGENIC CARBON: 81,6 kgC/m3

Health and Safety

From a health perspective, wood strands themselves are not toxic. However, unless healthy alternatives are intentionally considered, most oriented strand board will contain binding chemicals that may emit formaldehyde and VOCs. Compliance with COSHH, REACH, ECHA, as well as local building regulations should be checked for individual products.

Responsible Sourcing

The trees used in wood-based OSB come from forests worldwide. Re-growing these trees and maintaining ecological systems is essential to mitigate the impacts of climate change. Understanding how our forests can be maintained and restored to become sustainable sources of wood requires intricate knowledge on the wider carbon cycles and the importance of biodiversity.

In Europe, almost all timber is grown sustainably; however, there are two global certification schemes (FSC and PEFC) which ensure supplies are from sustainably managed forests. Being conscious about where timber is harvested from plays a significant role in creating carbon stores and lowering greenhouse gas emissions. The ability to protect and restore these forests lies within the biodiversity of these ecosystems.

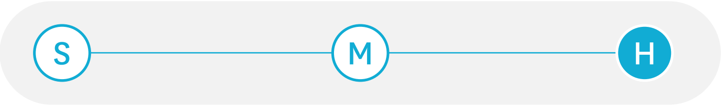
Circularity

Wood-based OSB cannot be easily reused due to its low durability. Therefore, it is typically used as biomass fuel, generating energy or heat, however in this case the sequestered CO2 will be released and further GHG emissions may occur.

© OSB 2 by EGGER

Manufacturers

- EGGER
- Weyerhaeuser
- SMARTPLY
- Kronospan
- West Fraser



Scale of Production

Bio-based construction material cases

Bio-based construction material cases

Several EU member states have their own national or regional regulations and initiatives that promote the use of bio-based construction materials. These may include tax incentives, subsidies, labelling schemes, or specific procurement policies.

Case: Certificates and mandate 50% timber or other natural materials use in France

Bio-based materials do not have a track record as long as traditional fossil-based products, and bio-based product developers are required to prove that these materials are functionally equivalent to traditional materials.

Certifying bodies that evaluate these materials use reference standards or (standard) test methods that are developed to evaluate the quality of fossil-based products. Certification of bio-based materials in the building industry is important as the provision of objective information on the performance (and guarantee of performance) of available bio-based technologies by product certifications can boost customers' acceptance and accelerate deployment.

Harmonised and standardised national/international testing and evaluation procedures for specific bio-based products and technologies increase understanding of functionalities and performance of bio-based building materials among developers, architects and installers and accelerates the maturity of the industry more broadly. The current standardised tests are not always sufficient to be applied to bio-based materials (e.g. moisture regulating effect of bio-based materials).

In France, the regulatory framework for construction materials is traditionally based on the Spinetta law from 1978, which declares that it is up to insurance companies to approve the choice of materials for construction. The insurance companies refer to a set of standards which lay down rules for design and implementation and technical recommendations applicable to products. New and innovative products are not covered under the traditional set of rules and standards, and therefore constitute an unknown risk for insurers. To get approved, new products must go through a different process. The two options are 'ATec' or 'ATex'. ATec is a technical approval procedure where new products are tested and declared fit for purpose by independent experts. It can take up to two years to receive this declaration, which is valid for 3 - 5 years. Alternatively, the ATex approval can be attained within three months, but its application is restricted to a small number of buildings, or a limited time period.

Especially for SMEs the process is daunting. A welcome next step would be the integration of more bio-based construction materials into the rules and standards governing 'traditional' (conventional) materials, so that these bio-based construction materials are no longer required to gain ATec/ATex approval. This is a necessary step to growing the market for these products in France. [5].

The French government implemented a new sustainability law in 2022 requiring all new public buildings to include at least 50 percent timber or other natural materials in their construction.

The law, known as RE2020 (or Environmental Regulation 2020), aims to improve the environmental performance of buildings throughout their entire lifecycle, from procurement of raw materials to construction, use of the facility and even the building's 'end-of-life.'

In this way, RE2020 is going way beyond its predecessor (RT2012) and is forcing the construction industry to reduce its carbon footprint. The law is making France a forerunner in decarbonising buildings. The sector accounts for 44% of France's energy consumption and nearly 25% of the country's climate-damaging CO_2 emissions.

The law, which took effect on Jan 1st, 2022, becomes increasingly stringent in 2025, 2028 and 2031 to ensure emissions go down. [21]

Bio-based construction material cases

Case: Introduction of carbon regulations in Denmark
In March 2021, the Danish government introduced targets in the building regulations for whole life carbon which come into effect in 2023. This whole life approach embraces both operational and embodied carbon. Buildings below 1,000 m2 will initially only be required to calculate the life cycle assessment (LCA), while buildings over 1,000 m2 will be required to meet whole life carbon limits (CO_2e). This applies for all building types. The initial limit value is 12 kg CO_2e/m2/year, supported by a specific voluntary CO_2-class with a limit value of 8 kg CO_2/m2/year. The limit values are to be tightened every second year until 2029. The regulation of smaller buildings is expected to commence in 2025 according to Ministry of the Interior and Housing.

The agreement is expected to reduce the country's CO_2 emissions by 1.3 $MtCO_2$ by 2025 and 4.3 $MtCO_2$ by 2030 contributing to achieve Denmark's target to lower its greenhouse gas emissions (GHG) in 2030 by 70% from 1990 levels. The government will use the proceed of the carbon tax to lower the electricity tax from 2028 and create a DKK1bn (€130m) green fund to accelerate green transition and phase out fossil fuels between 2024 and 2040. The agreement will be revisited in 2023, 2026 and 2028.

Similar regulations are being put in place in Finland and Sweden. The regulations is part of a broader strategy to reduce the environmental impact of the construction sector, and can be said to indirectly support an increase the use of bio-based building materials in a number of ways:

1. Focus on embodied carbon: The whole life approach encompasses both operational and embodied carbon. While operational carbon refers to emissions produced during the building's lifecycle (e.g., energy consumption), embodied carbon refers to the emissions associated with the production, transportation, and disposal of building materials. Bio-based materials often have lower embodied carbon compared to traditional construction materials like concrete and steel, as they sequester carbon during their growth and have lower energy-intensive production processes.
2. LCA: When evaluating different building materials, LCAs consider the full lifecycle emissions, including raw material extraction, manufacturing, transportation, construction, use, and end-of-life stages. Bio-based materials, such as wood, bamboo, and hempcrete, generally have favourable LCA profiles due to their renewable and lower-energy production processes.
3. Tightening of the limit values: The initial set limit values provide an incentive for builders to adopt materials and construction methods that emit lower levels of carbon. Bio-based materials, which often have lower embodied carbon, can help buildings meet these stringent standards. Furthermore, the regulations plan to tighten the limit values every second year until 2029, which will drive further adoption of low-carbon materials like bio-based alternatives.
4. Innovation and market demand: As the regulations push for reduced carbon emissions, there will be an increased demand for innovative solutions that can help meet these requirements. This presents an opportunity for manufacturers and suppliers of bio-based building materials to expand their offerings and invest in research and development to enhance the performance and availability of these materials.

Bio-based construction material cases

Case: Bio-based certification in the Netherlands

In the Netherlands, a certification body for the construction and real estate sector, SKG-IKOB, issues the KOMO quality certificate. The KOMO quality certificate stands out because the demands it places on products, processes and services are determined by all parties involved (manufacturers, suppliers, customers, consumers and governments). Those parties record the requirements in writing. Based on this, a so-called assessment guideline (BRL) is established. It states exactly what must be met for the KOMO quality certificate and how it must be tested and checked. Since recently, a KOMO quality certificate has been issued based on an innovative assessment guideline (IBRL). Here, as the name implies, specific attention in the process is given to the fact that it concerns an innovative (e.g. biobased) product. On average, writing an IBRL takes one year, and the certification process takes six months. The validity of the certificate is a maximum of 3 years. SKG-IKOB is affiliated to the European Organization for Technical Approvements (EOTA).

Case: Green Deal Timber Construction

The Netherlands faces the challenge of building two million new homes and insulating a further 7 million existing homes by 2050. During the Metropolitan Region of Amsterdam (MRA) Sustainability Summit 2021, 32 municipalities signed the Green Deal Timber Construction.

In the covenant Green Deal Timber Construction the starting point is to make a scale jump for all new construction in MRA from 2025 onwards by building at least 20% with timber construction/biobased construction. This will lead to an annual reduction of approximately 220,000 tons of CO_2 (equivalent to the average emissions of 22,000 households) and a significant reduction in nitrogen emissions. [22]

Using mass timber over abiotic building materials in the built environment contributes to achieving Amsterdam's ambition to become climate-neutral and circular by 2050.

Case: National Approach to Biobased Building

The National Approach to Biobased Construction in the Netherlands aim of develop a market for bio-based construction. With the National Approach, the ministries are making 25 million euros available until 2025 (phase 1) to set up a market. The remaining 175 million euros is a reserve to expand the market in the following years (2025-2030, phase 2). The approach has been drawn up in collaboration with other government parties, market parties and knowledge institutions.

The ambition is to realise at least 30 percent of new-build homes with at least 30 percent bio-based materials by 2030. The same percentage applies as a target for insulation measures for sustainability and for the materials used for non-residential construction. A substantial part of the materials for infrastructural structures and objects, such as asphalt, street furniture and bicycle bridges, must also be biobased. To achieve this, there must be at least 25 production chains of farmers, industrial processors and builders by 2030. The aim is for the cultivation of fibre crops for building materials to grow from approximately 2,000 to 50,000 hectares and the processing capacity to at least 400,000 tonnes of fibre per year. [23]

Bio-based construction material cases

Case: Munich subsidy programme for timber housing constructions

Because of its unique qualities in multi-story urban construction and its environmentally friendly, sustainable nature, timber construction has gained increasing significance. Consequently, Munich City Council's Committee for Urban Planning and Building Regulation made in January 2022 the decision to enhance their support for modern timber construction projects via a subsidy programme for timber construction/timber hybrid construction as well as promote the construction of new, contemporary timber construction projects. It is estimated that it can potentially support the development of up to 1,000 apartments each year. The subsidy program came into effect in March 2022.

Running for a period of six years, the program aims at supporting timber construction in housing schemes in a larger urban development context as well as for individual projects in the city area. The decisive factor of the size of subsidy is the mass of renewable raw materials installed in the building per square meter of living space. The amount of funding is set at 1.00 euros per kilogram of renewable raw materials. The timber used must come from sustainable timber management. The subsidy program also focuses on an integrated planning approach and a planning team experienced in timber construction. The subsidy programme is designed for both individual projects and for larger housing estates and neighbourhoods. The aim of the city administration is to ensure that around 50 percent of the buildings on municipal land are constructed using timber. [6]

Case: Wood Building Programme in Finland

In Finland, the Wood Building Programme (2016–2023) stands as a collaborative governmental initiative led by the Ministry of the Environment. Its core objective is to enhance the incorporation of wood within urban development, public buildings, and substantial structures like bridges and halls. The programme also aims to diversify and expand different applications for wood while creating as much value added as possible. The Wood Building Programme works to encourage using wood by improving industry skills, updating laws and rules related to wood construction, and giving practical info about wood construction. The ultimate aim of the programme is to make using wood a normal part of construction in Finland during the 2020s. [7]

Bio-based construction material cases

Case: Supporting timber construction in Tampere through subsidy grants

The Housing Finance and Development Centre of Finland (ARA) has created a start-up subsidy, which supports building with timber-framed residential apartment buildings. The start-up subsidy is granted for the construction of ordinary rental apartments, and its size is dependent on the location of the construction project (variations between different municipalities). In Tampere, the basic subsidy grant amounts to 3,000 EUR per apartment. However, if the apartment building is constructed with a wooden frame, the subsidy per apartment increases with more than 150% up to 8,000 EUR. This extra subsidy creates a clear financial incentive for contractors to seriously consider building with timber instead of other more carbon-heavy construction materials. [8]

Case: Increasing use of bio-based materials through building codes and procurement guidelines in Washington DC

Washington DC's sustainability plan, "Sustainable DC 2.0" [9], supports sustainability in the broadest sense. Part of the plan is dedicated to sustainable construction and underlines how Washington DC is looking to lower its carbon emissions through multiple actions, one being the continuous adoption of the latest green construction codes (target BE4.4).
The International Green Construction Code (IgCC) is an international standard for the most innovative practices in green building, including better indoor environments, lower impact on natural resources, better neighbourhood connections, and increased walkability. The IgCC is typically updated every three years. As the IgCC is updated, the District Government will quickly integrate the most recent version of the IgCC in the city's construction codes. By consistently integrating the most recent IgCC, the District will remain at the forefront of green building best practices.
Besides the construction codes, Washington DC supports the use of bio-based materials through their procurement guidelines stating that "Agencies and contracting officers shall use environmentally preferable product and service (EPPS) specifications to the maximum extent possible and feasible". [10]

Case: Bigwood Interreg project overcomes resistance against the use of timber in high-volume construction

Bigwood is an Interreg-funded project which has set up a cross-regional network between Italy and Austria to increase wood usage for high-volume projects. The creation of awareness and reduction of prejudices and barriers for high-volume wooden constructions are main challenges. The project has built up an environment for testing, validation and education/training, and a main goal is the realisation of 3 different "demonstrators": two small-and medium-sized building mockups (1:5, 1:20) and a 1:1 mockup in Bozen at the NOI Techpark which are being used for education in the local involved schools. Agreed quality standards need to be defined, and important planning issues regarding building with wood communicated. The Bigwood project is focusing on the huge need for gaining the trust of construction companies, local governments and the general public as well as to spread the information concerning the possibility of timber multi-storey construction. [11]

Bio-based construction material cases

Case: InnoRenew CoE research institute – Slovenia's largest wooden building

InnoRenew CoE is the Centre of Excellence for Research and Innovation in Renewable Materials and Sustainable Construction. Its new building covers 8,200 square meters in Livade, Izola (Slovenia), and is created as a hybrid combination of timber, concrete and steel. The upper three floors of the main building are entirely wooden, making it the largest wooden building in Slovenia to date. The building houses offices, meeting rooms and research laboratories, and the building was built according to verified principles of contemporary sustainable building construction.

The EU-funded InnoRenew CoE project was launched with the aim to develop and operate a new research institute focused on conducting cutting-edge scientific research regarding renewable materials utilisation and creating the next generation of experts and technologies. The InnoRenew CoE brings interdisciplinary, international and inclusiveness-oriented scientific excellence to the field of green architecture and is drawing inspiration from nature to build the human habitat of the future.

Many natural materials have been incorporated into the building's design, and many of the materials used are of local origin, like Istrian stone for the façade and exterior design and wood for furniture, interior design and lighting. These natural construction materials reduce the building's environmental footprint, since they did not have to be brought from other parts of the world and cause unnecessary transport pollution.

The interior of the building has been equipped according to the principles of restorative environmental and ergonomic design (REED), which emphasises the use of natural materials to create ergonomic, accessible, adaptable and sustainable buildings. This is the first example of a REED building in Slovenia. To enhance the understanding of the materials, making them more tangible, the products have been designed to be touched, such as railings, doors, electric switches and furniture. The materials were selected according to results from the institute's research into the type of wood most likely to positively affect human well-being. [12]

Bio-based construction material cases

Case: Timber innovation in social housing in Barcelona

In Barcelona the municipality has taken a bold step in utilising timber as a primary construction material for social housing. With a project in Cornellà de Llobregat where 85 social housing units are built around a timber structure, Barcelona showcases how innovative use of timber alongside thoughtful architectural design can lead to a building which embodies contemporary, environmentally conscious construction methods, emphasizing both efficiency and adaptability. Additionally, it places a strong emphasis on fostering a sense of community among its residents.

The project distinguishes itself through several key features, including a layout characterised by interconnected rooms, the integration of timber as a primary material, enhancements in construction quality, significant reductions in construction timelines, and a notable decrease in CO_2 emissions. Remarkably, the building manages to shrink its environmental footprint by an impressive 55% compared to a conventional counterpart.

The use of timber plays a pivotal role in enhancing the sustainability of the project. Given its status as a social housing initiative, the amount of wood required per square meter has been meticulously fine-tuned to achieve an economical threshold, ultimately reaching an efficient 0.24 m^3 per m^2 of constructed space.

As one of the main aspects of this project is the deliberate choice of sustainable construction materials, local sourcing of the timber has been of great importance to the municipality. Approximately 8,300 m^2 of KM0 wood sourced from the Basque Country were used for the construction of this 10,000 m^2 building. This commitment to local, sustainable materials aligns perfectly with contemporary environmental concerns and highlights Barcelona's dedication to responsible urban development.

Barcelona's innovative approach to social housing construction in Cornellà de Llobregat sets a high standard for future projects. By combining efficient space utilization, sustainability, and community engagement, this project exemplifies best practices in timber construction. Moreover, it demonstrates that socially responsible architecture can go hand in hand with environmental sustainability.

In conclusion, Barcelona's use of timber in the construction of social housing in Cornellà de Llobregat serves as an example to follow of sustainable urban development and innovative design. The project showcases the city's commitment to creating vibrant, inclusive communities while respecting the environment, setting a precedent for future developments in the field of timber construction. Inspired by the project, a similar social housing project is already under construction in the district of La Verneda (also in Barcelona). This project has a budget of 4,99 million euros, is expected to be completed during Q1 2024, and can also be viewed as part of the wider strategy within the city to increase building with timber. [13][14][15][16][17][18]

Bio-based construction material cases

Case: Social housing in Rovereto (Italy) utilising recovered wood from storm Vaia

In October 2018, a devastating natural disaster struck the Alpine regions of Italy, as the storm Vaia caused extensive destruction to tens of thousands of hectares of alpine forests. As a result of the storm, millions of conifers, comprising certified wood, lay felled, representing an estimated loss of over 9 million cubic meters and 42,500 hectares of woodland. However, in the face of adversity, a remarkable initiative emerged from the debris – the recovery of storm-felled wood. In Bolzano, nearly 80% of the wood was salvaged, with Trento and Veneto achieving a commendable 60% recovery rate each and Friuli-Venezia Giulia recovering about half of the fallen wood.

The city of Rovereto seized this opportunity to demonstrate resilience and sustainability by utilising some of the retrieved wood in the creation of a new social housing project. Here, a total of 2,300 cubic meters of wood from the storm-felled conifers formed the prefabricated cross-laminated load-bearing structures.

The housing project comprises two wooden buildings, one rising to five floors and another to an impressive nine, making it one of Italy's tallest wooden structures. Both buildings have achieved an energy class A+ rating. The two buildings contain 68 apartments designed to accommodate some of society's most vulnerable individuals, including the elderly, single-parent families, and students. The apartments vary in size, offering living spaces ranging from 55 to over 100 square meters, ensuring that the housing units cater to diverse needs. [19][20]

The use of the recovered wood not only adds to the level of sustainability of the project but also symbolises resilience in the face of adversity, as it serves as a reminder that even from the remnants of a devastating storm, hope and renewal can emerge.

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