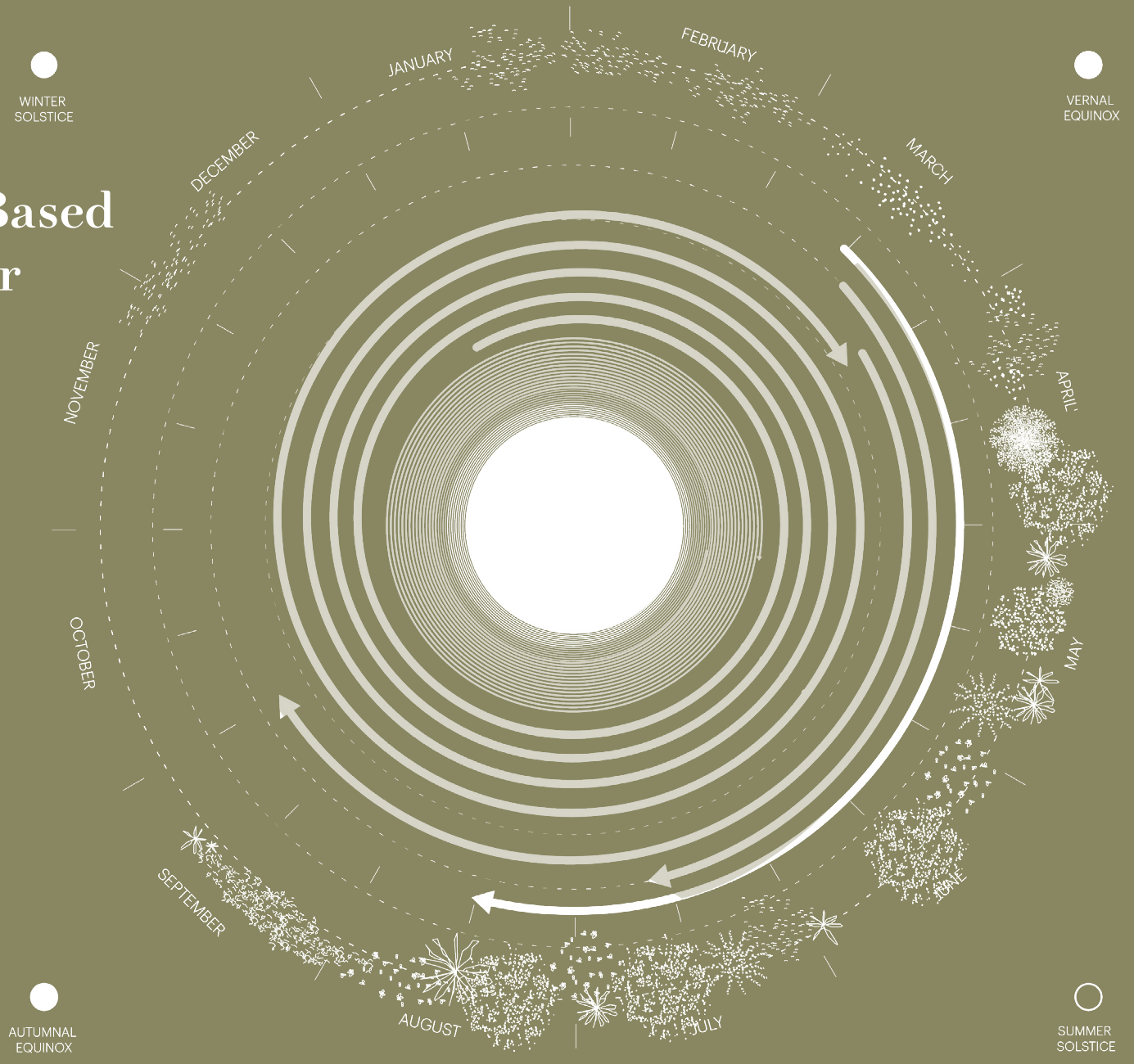


# Bio- & Mineral-Based Materials Primer

April, 2026 – v1.0

- BAMBOO
- BIOCHAR
- CORK
- EARTH
- FLAX
- HEMP
- STRAW
- WOOD



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## Bio-Based Materials Collective

The Bio-Based Materials Collective (BBMC) was founded by MASS and New Frameworks in 2023, with the mission to increase the use of regional, regenerative, bio-based building materials in North America. The BBMC is a collective network of members hailing from diverse roles across the built environment landscape, including foresters, farmers, manufacturers, architects, builders, developers, academics, students, engineers, educators, artists, journalists, policy-makers, and more. We are united in scaling regional bio-based materials across North America through bold, collaborative action and creative, cross-disciplinary solutions.



[www.biobasedcollective.org](http://www.biobasedcollective.org)

## Model of Architecture Serving Society

Model of Architecture Serving Society (MASS) is a mission-driven design collective founded in 2008 to leverage architecture as a tool for justice, health, and social transformation. With offices in the U.S. and Africa, MASS partners with communities to create buildings, landscapes, and systems that improve human dignity and environmental well-being. Their interdisciplinary approach integrates research, policy, and design to address challenges ranging from public health and education to climate resilience and memorialization. Guided by the belief that architecture is never neutral, MASS advances an inclusive, regenerative practice that centers people, place, and long-term impact.

**MASS.**

[www.modelofarchitecture.org](http://www.modelofarchitecture.org)

## Perkins&Will

Perkins&Will is a global, interdisciplinary architecture and design firm founded in 1935 on the belief that design has the power to transform lives. Today, we operate across 11 countries, bringing deep local insight to a global practice. As a collective of designers and change makers working across cultures and disciplines, we take a contextual, human-centered approach to every project. Sustainability has long been a guiding principle; today, our approach has evolved from harm-reduction toward regenerative, solution-oriented design. Grounded in ecological placekeeping, our firm integrates research and practice to create resilient, future-focused environments.

**Perkins&Will**

[www.perkinswill.com](http://www.perkinswill.com)

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# Introduction

The Bio- & Mineral-Based Materials Primer is intended as a practical and reflective guide for architects and designers, inclusive of those working on larger-scale buildings in North America. It supports informed decision-making by situating materials within ecological, cultural, and performance-based contexts, and by acknowledging both their strengths and limitations.

The format of the material chapters reflects that materials are part of a series of ongoing processes. Plants and minerals grow and form, knowledge and traditions are shared, materials are crafted, products are installed, buildings are cared for and one day dismantled. Designers should see themselves as part of these processes.

*As relates to bio- and mineral-based materials, this primer will help architects and designers to:*

- Understand material and product options available and how they can be applied within building systems.
- Evaluate the potential positive and negative impacts of using these materials.
- Recognize the mechanisms that enable or constrain the use of these materials.
- Appreciate the continued ecological and cultural influences of these materials.
- Introduce more of these materials into buildings in a way that aligns with holistic social and environmental goals.
- Connect to resources, networks and professionals that can support further learning and implementation.
- Meet the moment as the North American building ecosystem shifts to include more bio- and mineral-based materials in projects of all scales.

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# Chapter Framework

This Primer is composed of eight chapters, examining materials that are currently gaining traction in architectural practice. The selected materials reflect a range of plant-based, earth-based, and biogenic carbon-enhancing systems that are increasingly relevant to low-carbon, healthy, and regenerative building design.

## The materials covered in this Primer are:

- Bamboo
- Biochar
- Cork
- Earth
- Flax
- Hemp
- Straw
- Wood

While each material has distinct properties, histories, and performance characteristics, all chapters follow a consistent structure to support comparison, application, and informed specification.

Each material chapter is organized as a practical reference that balances ecological context, technical performance, and design decision-making. The chapters are concise and modular, allowing readers to engage with individual sections as needed.

## Each chapter includes the following sections:

### Source

An overview of the material provenance including species and scientific classifications

### Ecology & Growing

Growth habits, land use, biodiversity, soil health, water impacts, and broader ecosystem relationships

### Culture & History

Indigenous, vernacular, and industrial histories that shape contemporary use and perception

### Harvesting & Processing

Harvesting and processes that prepare raw materials to become products

### Making

Fabrication methods and techniques for transforming a material into various product types

### Featured Applications

Common and emerging uses across structural, enclosure, insulation, and interior systems

### Care & Maintenance

Considerations for long-term performance, repair, and stewardship

### End of / Next Life

Disassembly, reuse, recycling, composting, or safe reintegration into biological or technical cycles

### Governing Regulations

Relevant standards, certifications, approvals, and regulatory constraints influencing adoption

### Technical Design Data

Key performance metrics (e.g., thermal, acoustic, moisture, fire, density) to support early design decisions

### Strengths & Opportunities

Evaluated through the lens of the AIA Materials Pledge/Common Materials Framework impact areas

### Challenges & Considerations

Material limitations, tradeoffs, risks, and conditions that require careful detailing or project-specific evaluation

### Products

Known products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework

### Case Studies

Built examples illustrating real-world applications, detailing strategies, and implementation pathways

### Further Reading

Resources, research, organizations, and tools to support deeper exploration

### Networks & Groups

Organizations and other groups that are engaging with this material type

*Together, these chapters are intended to help designers to move beyond material substitution, toward more informed, place-responsive, and systems-based approaches to specifying bio- and mineral-based materials.*

# Framework for Evaluating Strengths & Opportunities

## Start with “Less”

Given the current pressure on our biosphere, even advocates of bio- and mineral-based materials often advocate for a design process that begins with using less material.

*Before reaching for any new material as a solution, teams are encouraged to prioritize the following hierarchy:*

1. **Don't build** - Propose non-material approaches to solving the problem
2. **Use less** - Design more highly utilized buildings and systems within buildings
3. **Reuse** - Adapt existing buildings and salvaged materials

When carefully sourced, made, detailed, and installed, bio- and mineral-based materials have the potential to demonstrate positive impacts across the five core impact areas of the [AIA Materials Pledge](#) and associated [Common Materials Framework](#), as detailed in the center of this page.

## AIA Materials Pledge Areas of Impact

- ◆ **Circular Economy:** *Prioritizes materials and systems that enable reuse, repair, recycling, and safe return to biological or technical cycles.*

This includes designing for durability, adaptability, and disassembly, as well as prioritizing renewable or recycled inputs. By maintaining materials in continuous cycles of use and value, these strategies reduce waste, conserve resources, and support more resilient material systems.

- ◆ **Climate Health:** *Focuses on reducing greenhouse gas emissions across the material life cycle, including embodied carbon, while supporting carbon reduction and storage strategies.*

This includes minimizing emissions from extraction, manufacturing, and transportation, while recognizing the role of biogenic carbon storage. It also encourages consideration of full life cycle impacts, not just operational energy, and prioritization of low-carbon, durable, and regionally sourced materials that support long-term emissions reduction and climate resilience.

- ◆ **Ecosystem Health:** *Considers impacts on land, water, biodiversity, and ecological systems, prioritizing materials that avoid degradation and support regenerative practices.*

.... This includes avoiding materials that are linked to deforestation, habitat loss, pollution, or over-extraction, even when they appear low carbon. It also supports ecologically managed or waste-derived material streams that contribute to soil health, biodiversity, and broader ecosystem function.

- ◆ **Human Health:** *Focuses on selecting materials that support occupant and worker health across the material life cycle.*

This includes prioritizing materials that reduce exposure to harmful chemicals, minimize emissions such as VOCs, and support healthy indoor air quality. Materials that are non-toxic, breathable, and compatible with moisture-safe assemblies can help prevent condensation, mold risk, and pollutant accumulation, supporting healthier environments for occupants, workers, and surrounding communities.

- ◆ **Social Health + Equity:** *Addresses labor practices, community impacts, and supply chain transparency to support equitable and just material sourcing and production.*

This includes consideration of worker safety, fair labor practices, and the distribution of environmental and economic benefits and burdens. It also emphasizes transparency and support for local economies connected to material sourcing and production.

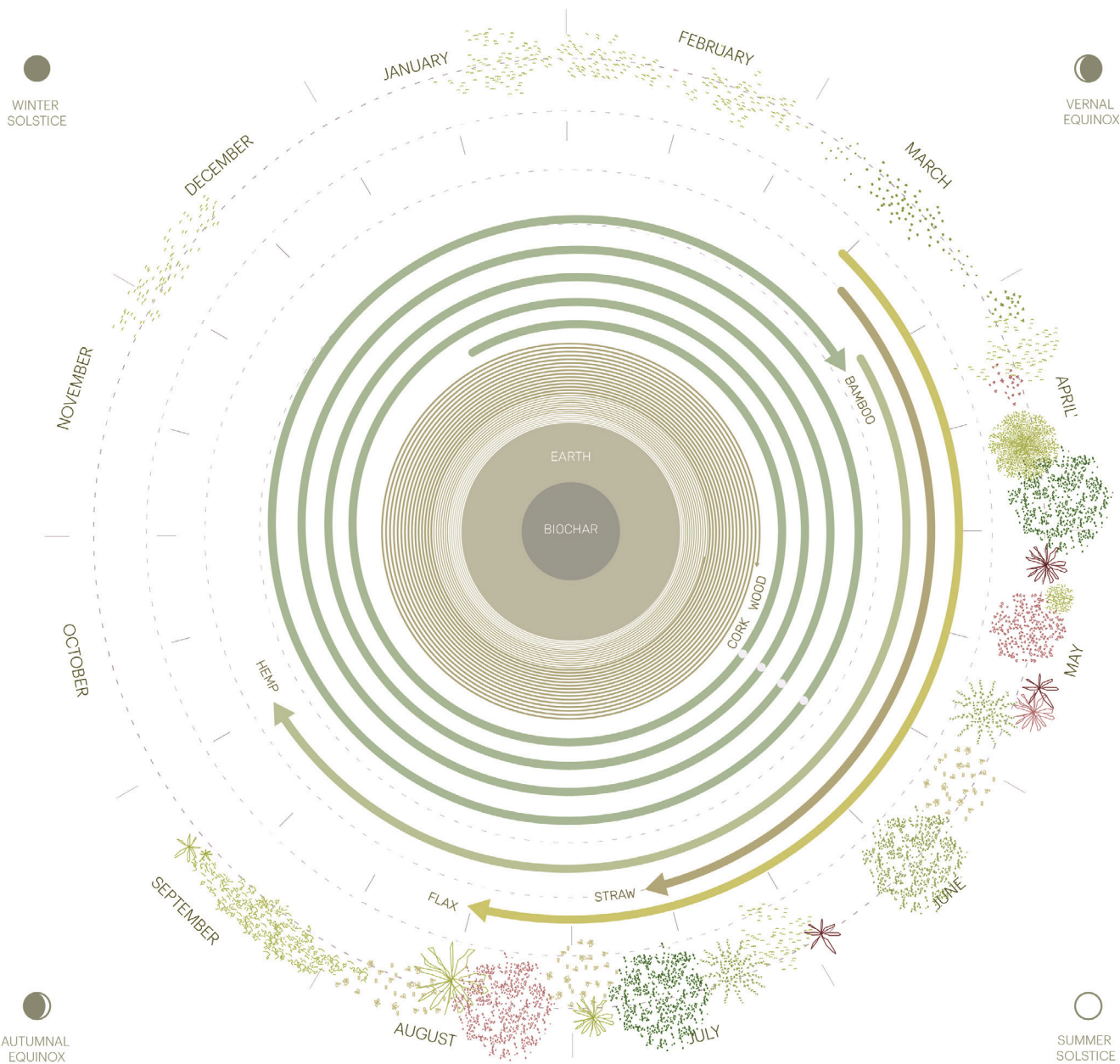
*Bio-based materials aren't inherently good.*

The benefits of bio- and mineral-based materials depend on sourcing, processing, and life cycle impacts. While some can store biogenic carbon, “business-as-usual” practices can degrade soil health, rely on synthetic inputs, and reduce biodiversity. Long-distance supply chains can erode climate benefits and shift environmental burdens away from end users.

Furthermore, “bio-based” does not guarantee safety; some bioplastics contain harmful additives and introduce microplastic risks. Poorly designed policies can incentivize ecological harm, including deforestation for biomass or biofuels. Without ecological land management, careful material selection, and responsible sourcing, bio-based materials can replicate extractive industry impacts.

We strongly advocate for bioregional sourcing and supply chains where feasible. These approaches increase transparency by connecting material use to local ecological impacts and land management practices, and can reduce exploitative or high-pollution extraction. They also support resilience by reducing reliance on global supply chains and strengthening local economic and social networks.

[Bio-Based Materials: Discussion and Definitions](#)



**Image:** The development and harvest cycles of materials vary by type, species, and other factors. Some materials can be harvested after one season of growth, while others develop over 100 or more years.

# Sourcing Best Practices

**Ecological agriculture and forestry practices** emphasize stewardship over extraction by prioritizing systems that are adaptive, diverse, and capable of sustaining human and ecological communities over time. While land certifications such as ROC (Regenerative Organic Certified) and FSC (Forest Stewardship Council) can support specifications, even these may carry unintended consequences, like sourcing farther from a construction site while missing opportunities to establish relationships with local suppliers. Understanding good land (and aquaculture, though not covered here) practices can help designers engage more directly with land stewards rather than relying fully on certifications for sourcing decisions. Best practices are nuanced and vary from site to site.

**Ecological agricultural practices** center on ecosystem function. Intercropping and agroforestry integrate multiple plant species, sometimes alongside trees, to enhance resilience, diversify yields, and improve nutrient cycling. Eliminating synthetic chemicals helps protect soil microbiology, water quality, and pollinators. Crop rotation and cover cropping maintain soil fertility, prevent pest and disease buildup, and reduce erosion. Minimizing or eliminating tillage preserves soil structure, enhances carbon storage, and supports a thriving soil ecology.

**Ecological forestry practices** share several defining characteristics. Longer rotation periods may allow forests to mature and regenerate ecological complexity. Selective harvesting, the removal of individual trees or small groups rather than large clear cuts, helps maintain canopy cover and habitat continuity. Protecting soil structure is critical to sustaining forest productivity and preventing erosion, while safeguarding waterways supports clean water and aquatic ecosystems. Equally important is preserving habitat, including standing dead trees, understory vegetation, and wildlife corridors, all of which contribute to biodiversity.

# Top 10 Questions to Ask

Consider these ten questions while evaluating bio- and mineral-based materials throughout the design process:

- 1. Where is the material sourced, and who made it?** How transparent is the material supply chain? What is the risk of forced labor? Can it be sourced regionally or through low-impact, consolidated logistics?
- 2. How is the material produced and managed at the source?** Does extraction or cultivation protect and enhance biodiversity, soil health, water, and labor practices? Are certified, regenerative, or climate-smart management systems in place?

- 3. Is the material and system appropriate for the application?** Which variant, density, or system best matches the project's structural, thermal, acoustic, durability, and aesthetic requirements? Or can these requirements be adjusted to meet the strengths of the material?
- 4. How does the material support embodied carbon and climate goals?** Does it store biogenic carbon, reduce GWP relative to comparable materials, or contribute meaningfully to whole-building carbon targets? Is there an EPD or equivalent data?
- 5. What additives, binders, treatments, or coatings are used?** Are they plant-based, low-VOC, non-toxic, and compatible with indoor air quality, durability, and recyclability? Do they compromise compostability or circular use?

- 6. How does the material perform with moisture and fire?** Is it suited to the local climate? Can assemblies be shielded, dry safely, remain vapor-open where appropriate, and meet fire code through material choice or detailing?
- 7. Is performance data verified and code-aligned?** Is there third-party testing for thermal, acoustic, structural, fire, and hygrothermal performance that aligns with codes, standards, and project needs? Is an alternative means and methods approach to building code required? Does the insurance company have any additional requirements?
- 8. What prior experience exists with this material?** Has this material or product been used in this region before? What is the experience of consultants, contractors and cost estimators? Can a material expert be brought onto the team?

- 9. What is the end-of-life and circularity strategy?** Can the material be disassembled, reused, recycled, composted, or safely returned to biological or technical cycles without contamination?
- 10. What is the unique value proposition of the product that may help the project team to overcome any challenges?** Does it enhance occupant comfort, biophilic quality, spatial character, or connection to place while supporting low-energy performance?

# Industry Resources

The resources presented here relate to a variety of bio-based and regenerative materials. Additional material-specific Networks & Groups are identified at the end of each material chapter.

## **Architecture 2030**

A non-profit organization transforming the built environment into a central solution for the ongoing global climate emergency.

## **AIA Materials Pledge**

A collective commitment by architects to prioritize building products that advance human health, climate and ecosystem health, social equity, and a circular economy throughout the materials life cycle.

## **Building Materials and the Climate: Constructing a New Future**

A global report outlining strategies to decarbonize the building sector by prioritizing bio-based materials, circularity, and innovative technologies to achieve a net-zero future.

## **Build Well**

A curated database providing research-backed guidance and product selection tools to help professionals create low-carbon, healthy buildings.

## **Common Materials Framework**

A shared language for sustainable building products, mapping information from the most widely used certifications across five core impact areas.

## **Lot21: Design for Decarbonization**

A content and resource hub that curates and translates climate, materials, and design knowledge for the design community. It provides directories of materials, tools, projects, policies, and “solutions” content.

## **Developing a Database of Bio-based Materials for Building Envelope Applications**

A database of hygrothermal transport properties for low embodied carbon building materials that can be added to energy and durability simulation tools, produced by Oak Ridge National Laboratory.

## **Carbon-Storing Materials: Summary Report, CLF**

This summary report evaluates diverse carbon-storing materials, providing a foundational framework for utilizing building elements to sequester atmospheric carbon dioxide.

## **Building with Biomass: A New American Harvest, RMI**

RMI explores scaling agricultural biomass in construction, detailing how “New American Harvest” materials can rapidly decarbonize the built environment nationwide.

## **Bio-Based & Natural Materials: Context, Applications and State of the Industry, Perkins&Will**

Perkins&Will examines the state of bio-based industries, offering technical context and practical applications for natural materials in contemporary architecture.

## **BBMC Resources**

Depository of resources from the BBMC including proceedings from the BBMC summits highlighting the challenges and solutions to scaling up bio-based materials and the monthly Grow & Tell webinars.

## *Networks & Groups*

### **Carbon Leadership Forum**

A non-profit research and advocacy organization advancing embodied carbon in construction through collective action.

### **Northwest Eco Building Guild (NWEBG)**

An education network empowering transformation in the built environment for long-term ecological health.

### **Ontario Natural Building Coalition (ONBC)**

An advocacy group promoting healthy, high-performance natural building strategies.

### **Natural Building Alliance**

A non-profit advancing bio-based construction by educating and developing resources for professionals and homeowners.

### **Canadian Alliance for Natural Building Engineering (CANBE)**

An organization dedicated to advancing natural materials in construction through research, consulting, and education.

### **Toronto Biobuild Collective**

A collaborative committed to transforming urban building practices by integrating bio-based materials into mainstream construction.

### **Root Down Building Collective**

A non-profit advancing climate-smart, equitable housing through research and development, workshops, and advocacy.

# Where to Find Products

## **2050 Materials**

A dataset of climate data for materials, products and processes.

## **ACAN Natural Materials Detail Library**

A collection of natural construction details and collated list of natural materials manufacturers, suppliers and installers.

## **Bio-based Materials Library**

a library of all bio-based materials used in the projects of Company New Heroes and Bio-based Creations.

## **Builders for Climate Action (BfCA) Bio-Based & Circular Materials Database**

a living resource highlighting bio-based and circular building products that store carbon, support human and ecosystem health and challenge the extractive norms of construction.

## **Circular Material Library**

a library of a diverse range of materials suitable for use in the circular economy that are categorized into two main groups: BioCycle and TechCycle.

## **Future Materials**

a discovery engine showcasing design-led, low carbon, bio and circular products: the building materials of the future.

## **Future Materials Bank**

an archive of materials that supports and promotes the transition towards ecologically conscious art and design practices.

## **Ecomedes**

a robust online platform that simplifies sustainable procurement by helping buyers find, compare and verify high-performing building products.

## **Materials Assemble Materials Library**

a library of the finishes and techniques (including bio-based) from working craftsmen, artisans and makers.

## **Material Bank**

a platform for searching, comparing and sampling materials from hundreds of manufacturers, streamlining product discovery and enabling fast, sustainable sourcing decisions.

## **Materials District**

an innovative material database as well as a match-making platform connecting material manufacturers and distributors with creative professionals, such as architects, product and industrial designers.

## **Material Order**

a leading resource for design materials collections at academic and cultural institutions.

## **Parson's Healthy Materials Lab (HML) Healthy & Regenerative Materials Collection**

a featured material collection, focused on materials that originate from ecological sources.

## **Revalu**

a collaborative platform for smart material decisions; helping teams choose the right building materials with confidence and ease.

## **Sustainable Minds Transparency Catalog**

an online catalog of high-performance building products and associated transparency documentation for simplified sustainable specification and procurement.

## **Tocco Matterbase**

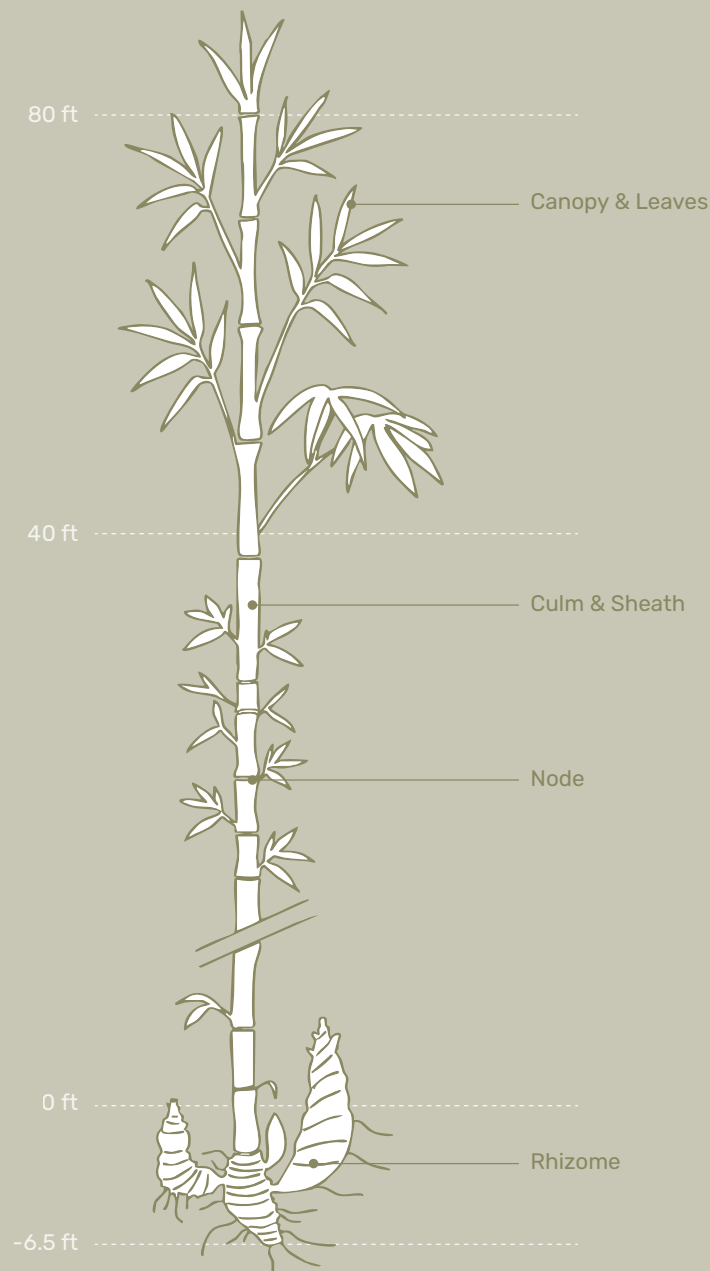
an intelligence platform for discovering and sourcing next-generation material solutions.

## **USDA BioPreferred Catalog**

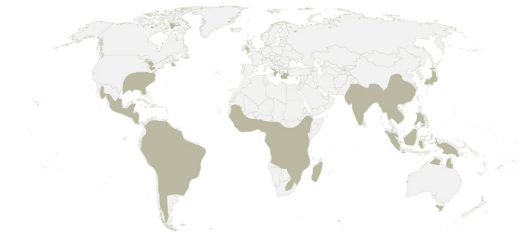
a catalog of certified bio-based products that meet the minimum bio-based content as measured according to ASTM D6866 (see "Construction" tab).

## **UTSOA Materials Lab**

a student research-driven online database of existing, new and upcoming materials.



## BAMBOO



Source Map

Peak growth rate ~30–120 cm/day  
(12–47 in/day); mature height  
~15–30 m (49–90 ft)<sup>1</sup>

Full height in ~60–90 days;  
harvestable in ~3–6 yrs with selective  
harvest every 1–2 yrs thereafter<sup>2</sup>

Biomass yield ~30–80 t/ha/harvest;  
~15–40 t/ha/yr<sup>3</sup>

Biogenic carbon storage  
~1.5–1.7 tCO<sub>2</sub> per dry t of bamboo<sup>4</sup>

Forest ecosystem sequestration rate  
~10–48 tCO<sub>2</sub>/ha/yr (net flux)<sup>5</sup>

### Source

Many of bamboo's 1,400+ species are used in building applications, including for structural purposes. The three most well known species for their extraordinary size are Moso Bamboo (*Phyllostachys edulis*) which is native to China and Taiwan, Guadua Bamboo (*Guadua angustifolia*) which is native to Colombia, Ecuador, Venezuela and Peru, and Giant Bamboo (*Dendrocalamus asper*) which is native to southeast Asia. River Cane (*Arundinaria*)

### Best used for:

Lightweight structural systems; interior finishes like flooring and ceilings, cladding

### Key considerations:

Moisture sensitivity and detailing; preservative treatments, synthetic adhesives, sourcing practices

is the genus of the only bamboo species native to North America that is traditionally used for weaving. Bamboo forests can receive Forest Stewardship Council (FSC) certification.

**Ecology & Growing**

Bamboo is well known for fast growth, storing carbon, building soil health and restoring ecosystems quickly. During establishment, irrigation may be required (particularly when grown from seedlings) to support early root development, but once established, water requirements reduce significantly. Bamboo grows from a clumping or running rhizome, meaning it doesn't need replanting, and that soil health is built up over harvests. Running varieties commonly grow in temperate regions and are known for their rapid horizontal expansion. Clumping varieties, which occur primarily in tropical regions, grow in predictable, compact groves.

Under the right growing conditions and management Moso typically reaches up to ~23m (92 ft) height, with culm diameters commonly in the 4-8 inch range, Guadua can grow to up to ~ 30m (98 ft) with culm diameters often 5-6 inches, *Dendrocalamus asper* typically grows to up to ~ 25m (82 ft), with culm diameters commonly in the 4-8 inch range. River Cane typically grows to less than 1 inch diameter and 6-15 feet tall.<sup>10</sup>

The major ecological concern comes from monoculture planting that removes native habitat and potentially contributes to the introduction and spread of invasive bamboo species.

**Culture & History**

Bamboo has been used in Asia for millennia as an accessible construction material. In Balinese culture it serves not only as a

building material or as a tool for religious ceremonies, but also as a living language to express humanity's relationship with nature and spirituality. It seems to "speak" through sound, manifesting itself in visual symbols, and being felt in social spaces.<sup>7</sup> In South and Central America, before colonization,<sup>8</sup> Guadua bamboo was prevalent in construction due to its strength and ability to support cohesion and promote biodiversity in forests.<sup>9</sup>

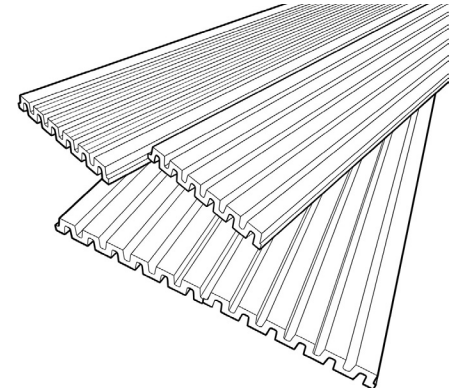
**Harvesting & Processing**

Bamboo, as a crop, benefits from active management where mature culms are selectively harvested each year, which supports healthy growth and encourages continual renewal. Bamboo is often harvested by hand to ensure the preservation of the stump for future harvests. The plant is cut right above a node to prevent water collection in the culm and rotting. Bamboo is then sorted to determine its use as a structural member, split, reed, or fiber. The stalk is cut longitudinally into sections. Depending on application, internal diaphragms may be retained or removed.

Bamboo is often harvested between the third quarter and new moon when the starch content is lowest. Further starch is typically reduced through leaching, smoking, heat treatment to crystallize the sugars, boron, or modern chemical preservatives.<sup>6</sup> Air drying for a target moisture content of below 15-20% can take up to 6-12 weeks. Drying rooms can be used to reduce the time frame and increase consistency.

**Making**

Bamboo poles can be harvested and used with minimal processing in their natural form. They can also be split and used without further processing in laths, mats and woven panels. Engineered bamboo can be made by combining strips, chips or sawdust with an adhesive under heat and pressure. This creates products that mirror many engineered wood products such as Laminated Veneer Lumber (LVL), Cross Laminated Timber (CLT), Oriented Strand Board (OSB) and particle board.



**Featured Applications**

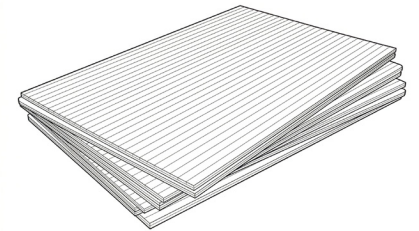
Structure & Envelope:

- Bundled or unbundled culms (for framing)
- Corrugated OSB style structural panel
- Hybrid load bearing panels / wattle and daub / bahareque
- Laminated bamboo panels
- Straw-woven bamboo (for cladding)
- Thermally modified engineered bamboo cladding



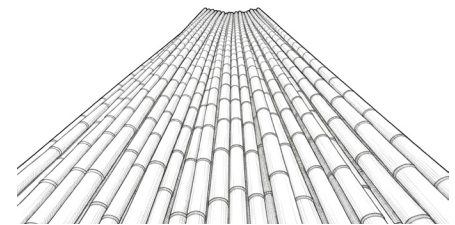
Interior Finishes & Applications:

- Bamboo fiber textiles
- Bamboo flooring
- Bamboo plywood
- Bamboo strand board (BSB)
- Bamboo strip composites panels
- Decorative woven panels
- Reed ceiling board
- Woven bamboo mat board (BMB)



Miscellaneous:

- Bamboo scaffolding



**Care & Maintenance**

Due to the nature of bamboo, products perform best at an interior relative humidity of 40-60%. Since bamboo is hygroscopic, uncontrolled moisture is the primary cause of failure, therefore vapor open assemblies are recommended in conjunction with breathable sealers. Bamboo is also susceptible to termites. Exterior applications require careful detailing, raised clearances, and drip edges to manage moisture exposure.

**End of/Next Life**

Solid culms have the highest reuse and biodegradation potential, while the end-of-life outcome for engineered bamboo products heavily depends on the adhesive type and quantity. The likelihood of a bamboo product being reused/repurposed may depend on accessibility and fastenings (reversible connections preferred).

**Governing Regulations**

The IBC does not explicitly mention bamboo as a structural material, but bamboo can be used if compliant with performance standards such as fire performance, and load resistance. American National Standards Institute (ANSI) and International Organization for Standardization (ISO) reference bamboo in ISO 22156 and ISO 22157 in structural and physical/mechanical properties of bamboo and were developed by the International Network of Bamboo and Rattan (INBAR). The Manual for the design of bamboo structures to ISO 22156:2021 is a particularly useful and freely available document.

There are no direct references to bamboo in American Society for Testing and Materials (ASTM) standards, which often creates a barrier for code compliance. International Code Council Evaluation Service (ICC-ES) reports certify specific engineered bamboo products, not bamboo as a general material.

**Technical Design Data**

Properties vary significantly by species, culm position, and final product type.

**Structural:** Laminated panels can have a compressive strength of 40-70 N/mm<sup>2</sup> (5,800-10,000 psi).<sup>11</sup> Culms can have a

tensile strength of c. ~160 N/mm<sup>2</sup> (23,000 psi).<sup>12</sup> Connection detailing often governs performance more than material strength.

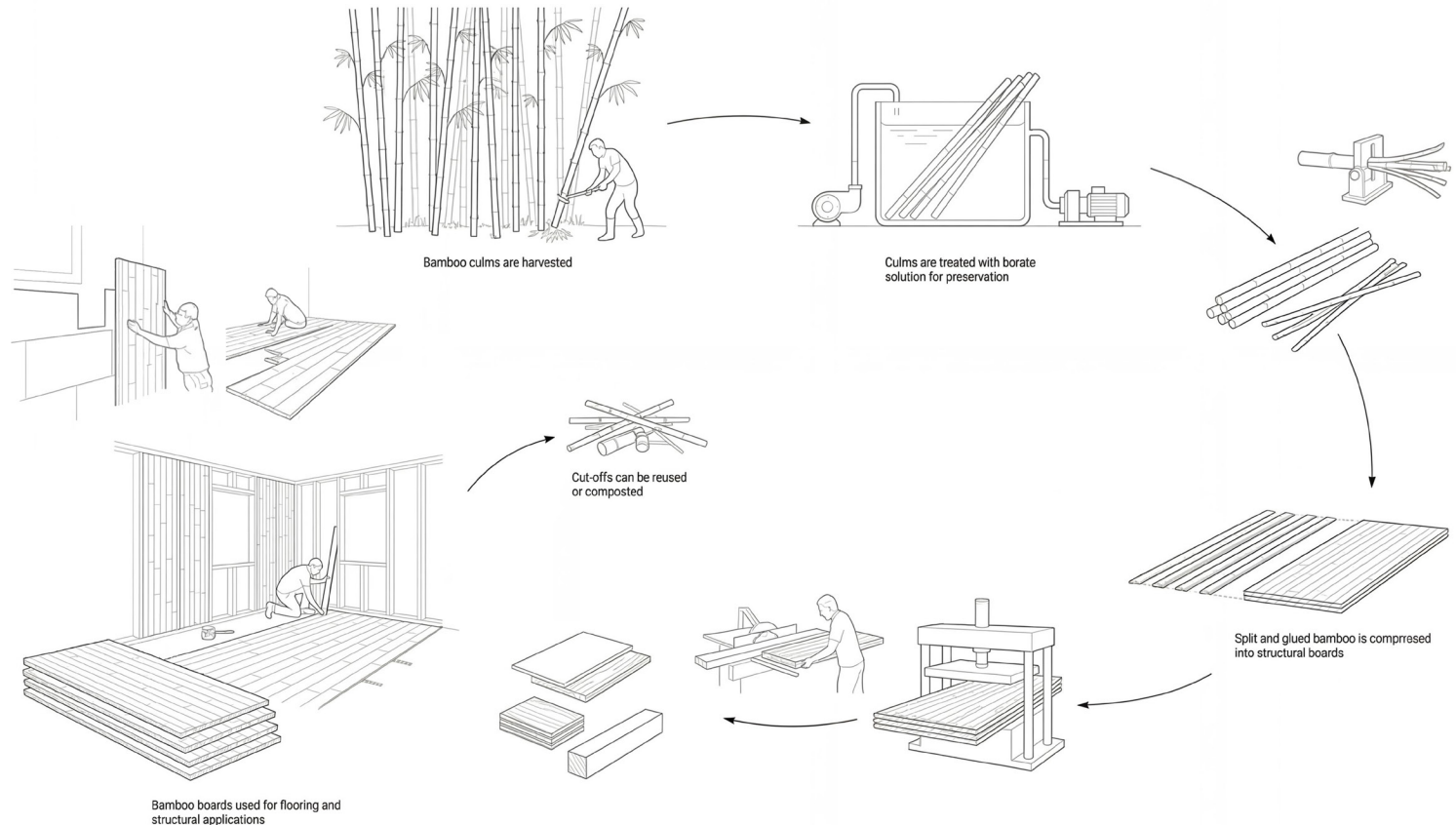
**Thermal:** Not typically used for insulation but in the range of RSI-0.16 to 0.21/25mm (R-0.9 to 1.2/in).<sup>13</sup>

**Density:** Natural culms typically range from 650-800 kg/m<sup>3</sup> (40-50 lbs/ft<sup>3</sup>)<sup>14</sup> and laminated panels have a range of 700-850 kg/m<sup>3</sup> (44-53 lbs/ft<sup>3</sup>). Strand-woven bamboo is typically around 1,200 kg/m<sup>3</sup> (75 lbs/ft<sup>3</sup>).<sup>15</sup>

**Fire:** Bamboo assemblies can achieve 1-2 hour fire ratings of Class A when flame retardant products are used.<sup>16</sup> High density products and types of adhesive determine the rate of ignition.

**Moisture & Vapor:** Whole materials require sealant as bamboo can be susceptible to water damage. If cured with resin or adhesive, it typically does not require additional sealant.

**Acoustic:** Perforated boards may offer levels of acoustic absorption, but solid bamboo products do not.



**Material Process Example**

## Strengths & Opportunities

### Human health

- Can be non-toxic and contain low volatile organic compounds (VOC), and contribute to healthy interior air quality.
- Naturally hygroscopic nature can support natural interior humidity regulation.

### Ecosystem Health

- Rhizomes help stabilize soil and improve watershed health.
- Bamboo forests can promote the development of strong native plant communities and biodiversity.

### Climate Health

- Bamboo sequesters carbon quickly and is a great carbon storage resource. Bamboo forests have a mean carbon sequestration rate of 6–13 tC/ha/yr (22–48 tCO<sub>2</sub>/ha/yr).<sup>17</sup> Products can have a net-negative Global Warming Potential (GWP), for example MOSO High Density -1101 kgCO<sub>2</sub>e/m<sup>3</sup>.<sup>18</sup>

### Social Health & Equity

- Rapid growth allows for a regional material economy.
- Labor requirements in processing provides accessibility in areas with limited technology.
- The high tensile capabilities of bamboo allow it to withstand the ramifications of earthquakes and allow for greater housing stability for earthquake prone areas.

## Circular Economy

- Bamboo is renewable, biodegradable and ideal for modular construction; the members can be reused in multiple ways.
- The versatility of bamboo allows for all parts of the plant to be used, limiting waste produced in processing.

## Challenges & Considerations

- **Bamboo used for constructions grows primarily in South America and Asia.**
- Dimensional variability of natural culms requires skilled fabrication, and strong relationships between growers, designers and builders.
- Large diameter bamboo for structural poles have a restricted range. Smaller diameter bamboo, not suitable for structural poles, is more typical.
- Engineered bamboo is often combined with synthetic materials which may negatively impact human, ecological and climate health as well as recyclability.
- **The high sugar content of bamboo makes it susceptible to insect attack unless treated properly.**
- Large humidity fluctuations can cause dimensional changes which can lead to cracking, warping, or joint failure if not properly treated or detailed.
- Limited familiarity among code officials and insurers can slow approvals.

## Products

*Known bio-based products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework.*

### Structure

- DassoXTR bamboo beams by [Dasso](#)
- DuoShear/ MonoShear framing systems by [Bamcore](#) (recently stopped manufacturing)
- [Rizome](#) engineered bamboo LVL, LSL, cross-ply panels, and veneers
- Structural Engineered Bamboo by [ReNuTeq](#)

### Enclosure

- DassoXTR siding and decking by [Dasso](#)
- [Lambo](#) structural, exterior, and interior bamboo applications
- Roofing/ Siding/ Structural Wall Panels by [Ocean](#)
- Siding and decking by [MOSO](#)

### Interior Finishes

- [Ambient](#) BP Bamboo Flooring
- [CALI bamboo](#) engineered flooring
- [ChopValue](#) wall paneling and furniture
- Engineered Bamboo Flooring by [Cali Bamboo](#)
- Flooring, panels, veneer and countertops by [Teragren](#)
- Flooring, veneer, interior panels, acoustic panels, and fire resistance panels by [Dasso](#)
- [Interwood Forest Products Inc.](#) bamboo veneers
- [Plyboo](#) interior wall and ceiling panels, plywood, veneer and flooring
- [Richlite](#) Stratum bamboo core panels and countertops



## Arc for the Green School

**Location:** Bali, Indonesia

**Climate Zone (ASHRAE):** Zone 1A/B

**Year:** 2021

**Architect:** Studio Ibuku

**Builder:** Bamboo Pure

**Bamboo Craftsman:** Jorg Stamm

**Structural Engineer:** Atelier One

The Arc is a 760m<sup>2</sup> wellness space and gymnasium that advances bamboo engineering. Completed in eight months, the 14-meter-high structure spans 19 meters, demonstrating how geometry and material intelligence can dramatically reduce structural mass while maximizing volume.

A series of intersecting parabolic bamboo arches act in compression, rising like ribs to form the primary structure. These arches are stabilized by anticlastic bamboo gridshells, double-curved lattices that gain stiffness through opposing curvatures.

The bamboo used to construct The Arc was

**Materials:** Bundled bamboo structure, double split bamboo.

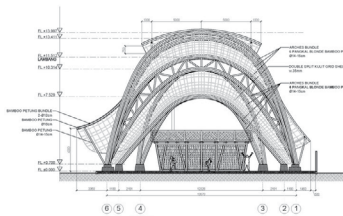
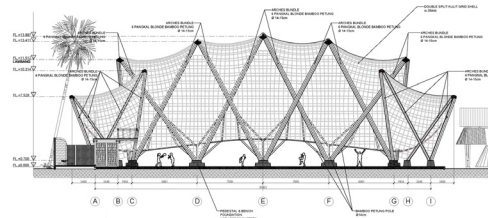
**Sources:** [Studio Ibuku](#), [Archello](#)

sourced mostly from Bali, with a small portion from Java, and protected from insects with a boron chemical solution. A vinyl finishing layer with a water base was applied to the bamboo and will require reapplication every 2 years. At the base, rebar is inserted into each of the bamboo arches, and then concrete is poured into the hollow bamboo, only enough to anchor the bamboo to the rebar.

The project demanded rigorous research, prototyping, and the development of tailor-made connection details. Craftspeople worked within a precise three-dimensional coordinate system to ensure the curvature of each gridshell met engineering tolerances. The design was effectively communicated to the artisans using physical models.



1



2

1. The Arc's bamboo roofing and structure. Image by Tommaso Riva.
2. Long elevation & Short Section. Image by Ibuku.
3. Mock up to communicate design and demonstrate structural capacity. Image by Ibuku.



3



# Bambu Atmosfera

**Location:** Ubatuba, São Paulo, Brazil

**Climate Zone (ASHRAE):** 1A

**Year:** 2023

**Architect:** Perkins&Will

**Developer:** Atmosfera Incorporadora

**Structural Engineer:** MRG

**Materials:** Bamboo culm façade screens; interior finishes and landscape elements; wood cladding (balustrades and soffits), interior finishes and planters.

**Source:** [Perkins&Will](#)

Bambu Atmosfera is a multifamily residential development that features whole bamboo culm sections as a defining architectural material.

A dynamic, layered façade of sliding bamboo brise-soleil panels responds to the hot and humid coastal climate of Ubatuba. Behind the panels, apartments open onto balconies that wrap continuously along the building's edge. The panels span the full height of each story and are composed of 6–7 cm diameter bamboo culms. Fasteners pass through each culm, connecting to lightweight frames on a track system that allows the panels to slide horizontally along the exterior.

This façade system functions as an adjustable environmental filter. When opened, the panels create apertures that increase daylight and natural ventilation. When placed side-by-side, they provide shade, privacy, and protection from the elements while maintaining airflow between culms. The building's U-shaped plan, organized around a central courtyard planted with native Atlantic Forest species, further supports airflow and daylight within the residential units.

Beyond the façade, bamboo culm sections appear in lobby areas, elevator interiors, circulation spaces, and landscape screens. Wood ceilings, soffits, flooring, balconies, and balcony planters complement the bamboo screens, balancing bamboo's lightness with the warmth and durability of timber finishes.

Culms used in exterior applications must be treated; they are typically preserved through borax-based mineral treatments that neutralize natural starches that attract pests. Combined with design-for-durability strategies, such as elevating culms from ground contact and applying protective sealers, these treatments can extend service life from a few years to several decades.

While bamboo in Brazil has historically been harvested for paper, pulp, biomass, or temporary structures, Bambu Atmosfera exemplifies a shift toward longer-lived architectural applications. Its use of moderate-diameter culm sections provides an adaptable precedent for parts of North America where bamboo can be cultivated.



1. Exterior view. Image by Nelson Kon Photography.
2. Screen detail. Image by Nelson Kon Photography.
3. Bamboo & wood finishes in the lobby. Image by Nelson Kon Photography.



## Brown House

**Location:** Washington, DC, USA

**Climate Zone (ASHRAE):** 4A

**Year:** 2016

**Architect:** BLDUS

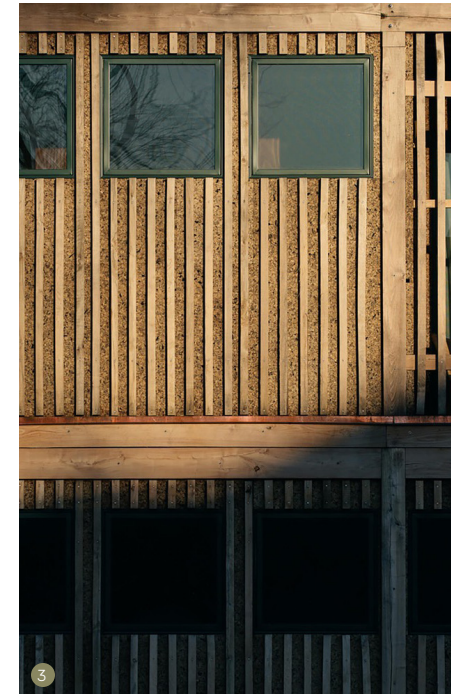
**Structural Engineer:** JZ Engineering

**Materials:** Cork cladding (Amorim, Jelinek), bamboo interior finishes, bamboo structural panels (Bamcore), wood cladding (black locust), cellulose and hemp insulation (Hempitecture), spray-cork finish, PolyWhey stain.

**Sources:** [Dezeen](#); [ArchDaily](#)

Brown House is a two-story, 1,600 sq ft alley house in Washington, DC's Capitol Hill that explores sustainable urban infill through a carefully curated palette of natural, healthy materials. Designed by BLDUS, the home balances privacy, light, and material expressiveness within a narrow urban lot. The exterior combines black locust wood slats, cork cladding, and bamboo structural walls, creating a textured, tactile façade that reads as both contemporary and timeless against the surrounding brick and concrete. Inside, the architects continue their commitment to material honesty with spray cork ceilings, bamboo panels stained with a bio-based finish, and hemp and cellulose insulation filling the wall cavities. These choices foreground longevity, indoor environmental quality, and a visceral connection to natural materials.

Beyond its materiality, Brown House is designed for healthy, efficient living and urban resilience. Its plan includes a ground-floor suite accessible without stairs and a central switchback stair optimized for daylight via skylights and clerestory glazing, enhancing both comfort and accessibility. Outdoors, a rooftop garden terrace irrigated by harvested rainwater supports food growing and passive cooling, while balconies and terraces expand living space and foster human-environment interaction. The project exemplifies BLDUS's "farm-to-shelter" ethos, marrying ecological performance with a refined residential aesthetic that challenges conventional alley infill typologies and prioritizes sustainability, well-being, and dense urban living.



1. Brown House. Image by Ty Cole.
2. Bamboo clad interiors with some bamboo structural panels left exposed. Image by Ty Cole.
3. Cork and black locust cladding. Image by Ty Cole.



## Madrid Barajas Airport Terminal 4

**Location:** Madrid, Spain

**Climate Zone (ASHRAE):** 3B

**Year:** 2006

**Architects:** Rogers Stirk Harbour and Partners and Estudio Lamela

**Structural Engineer:** Anthony Hunt Associates/TPS with OTEP/HCA

**Materials:** Linear Moso bamboo strip composites (Dasso Group).

**Sources:** [Estudio Lamela](#), [ArchDaily](#); [Dezeen](#)

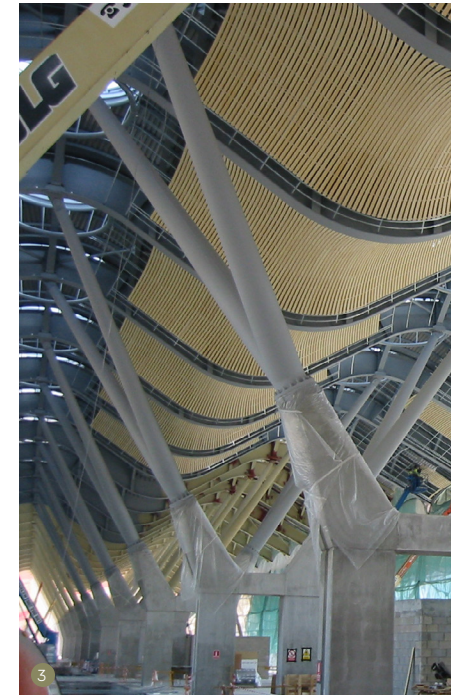
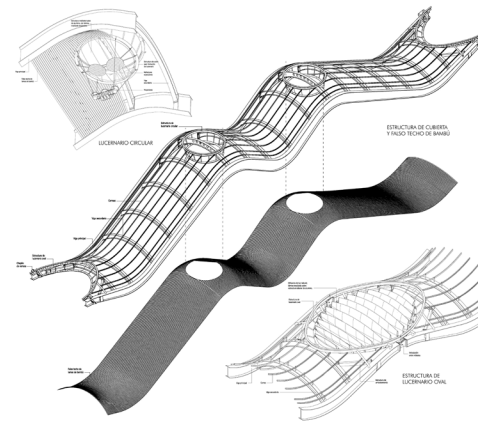
Terminal 4 at Adolfo Suárez Madrid-Barajas Airport is one of Europe's most celebrated transport infrastructures. Completed in 2006, the project's defining feature is its undulating bamboo-lined roof, conceived as the primary spatial and environmental element of the new terminal and satellite complex.

A total of approximately 212,000 m<sup>2</sup> of bamboo ceiling was required. The material selected was *Phyllostachys pubescens*, sourced from large plantations in eastern China, ensuring reliable supply at the scale demanded by the project. Bamboo accounted for just 2.83% of the total cost of the facility, demonstrating its economic viability within a major public infrastructure project.

The bamboo slats, each 2m long and 100mm wide, were developed to address the roof's double-curved geometry. Their flexibility allows a bending radius of up to 4m and torsion of up to 45 degrees, enabling precise adaptation to the waved canopy. The repetitive structural module

facilitated standardized installation, with slats mounted perpendicular to the main roof beams for efficiency and clarity of construction.

Manufacturing involved splitting culms into strips, drying, color sorting, and laminating them with special resins before treatment for specific environments. Internally, the bamboo achieved M1 Fire Classification (UNE 23727:1990) through lamination and impregnation processes. Externally, additional waterproof protection ensured durability against humidity and temperature variation. Beyond performance, bamboo was chosen for its spatial quality: its natural texture and warm tone create a calm, friendly atmosphere within the vast terminal, reinforcing wayfinding and human comfort. The material's ecological credentials, flexibility, ease of installation, and durability together make Terminal 4 a landmark case study in large-scale bamboo application.



1. Bamboo ceiling. Photo by Estudio Lamela
2. Axon showing bamboo ceiling to steel structure. Image by Estudio Lamela
3. In construction. Photo by Estudio Lamela

## Further Reading

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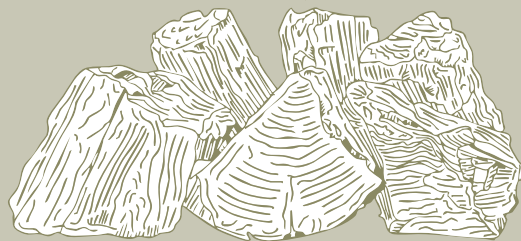
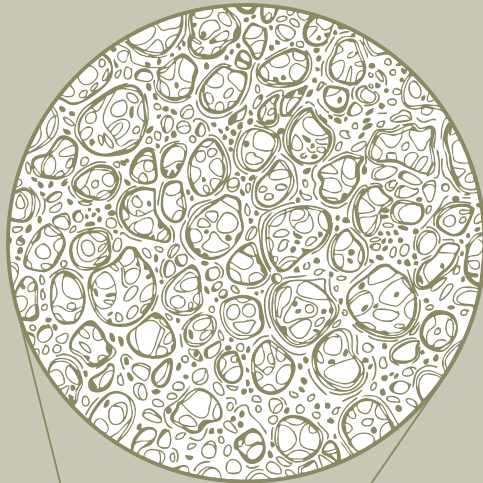
## Networks & Groups

[International Network for Bamboo and Rattan \(INBAR\)](#). An intergovernmental organization promoting sustainable development using bamboo.

### [World Bamboo Organization \(WBO\)](#):

A U.S.-based non-profit that facilitates global exchange and hosts the World Bamboo Congress.

Microscopic honeycomb structure of biochar



Biochar  
(carbon-rich material produced through pyrolysis)

## BIOCHAR

Surface area of 100–1,000 m<sup>2</sup>/g<sup>19</sup>

Pyrolysis temperature ~350–700 °C<sup>20</sup>

Biomass-to-biochar yield ~20–35%;  
~0.2–0.35 t biochar per dry t of biomass<sup>21</sup>

Biogenic carbon storage ~2.5–3 t of CO<sub>2</sub> per t of biochar; net CO<sub>2</sub> storage ~1.4 tCO<sub>2</sub> per t of biochar<sup>22</sup>

Half-life of ~100–1,000+ yrs (stable carbon storage)<sup>23</sup>

### Source

Biochar can be created from any biomass feedstock and often what is available locally. In North America this is typically waste from forestry and agriculture, such as wood chips, poultry manure, and rice husks, and municipal waste, such as waste water sludge or food waste. Biochar derived from primary ecosystems or monoculture plantations can undermine climate and biodiversity benefits. Brazil is the largest producer of steel derived from biochar, which replaces coal as a reactant

### Best Used For:

Products that incorporate it to improve properties or for climate and ecological benefits; concrete mixes; insulation and interior finishes; paints and pigments; landscapes

### Key Design Consideration:

Feedstock origin and pyrolysis method; not directly referenced in building codes; limited emerging products

in the blast furnace. The biomass for the biochar is often sourced from non-native Eucalyptus plantations in the Amazon rainforest. These plantations lead to primary rainforest deforestation, resulting in significant biodiversity loss, a lowered groundwater table, and altered soil acidity.<sup>24</sup>

## Culture & History

Biochar occurs naturally in soils as a result of historical vegetation fires, contributing to long-term carbon storage and soil fertility in ecosystems such as North American prairies. Humans have been producing charcoal, a chemically similar material to biochar, for millennia.<sup>25</sup> Both are carbon-rich materials produced via pyrolysis, the thermal decomposition of organic material in low-oxygen conditions. The key distinction lies in the intent of use and quality control: biochar is produced specifically for applications such as soil enhancement, construction, carbon storage and is typically subject to standards for contaminants, stability, and performance.

Biochar has been used as a soil enhancement for at least 800 years, notably by Indigenous communities in the Amazon basin. By adding charred organic material to otherwise nutrient-poor soils, they created highly fertile, carbon-rich soils known as Terra Preta,<sup>26</sup> or “dark earth.” Since the mid-1990’s biochar has been primarily used as a soil enhancer by increasing carbon content, improving water retention and supporting nutrient availability. In 2007, the International Biochar Initiative (IBI) was formally established following its first international conference in Australia, marking a significant step in research and awareness. Since then, both the body of research and the range of applications for biochar have expanded globally.<sup>27</sup>

## Making

The production process and feedstock greatly influence biochar properties, and therefore viable and preferred applications. Biochar is produced through a process called pyrolysis, which involves heating organic materials in a low-oxygen environment. This controlled heating, typically between 350–700°C (660–1300F), prevents the biomass from fully burning and instead breaks it down into three products: biochar (a solid carbon-rich material), a liquid known as bio-oil, and a mixture of combustible gases referred to as syngas. The gases and oils can be captured and used as renewable energy sources, while the biochar is cooled and collected for use. Biochar can also be made through gasification, however this is normally a secondary co-product of energy production.

Pyrolysis units come in different forms and different levels of sophistication. They can range from an oil drum in the back garden to a specialized unit the size of a shipping container. Different units can accept different feedstock, heat to different temperatures, have different levels of efficiency, and potentially recover syngas to self-power the pyrolysis process, improving overall energy efficiency and climate benefit.

## Featured Applications

### Structural & Envelope

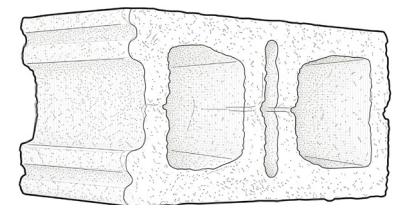
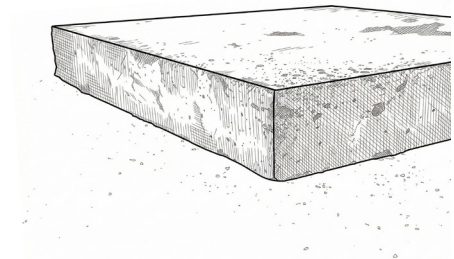
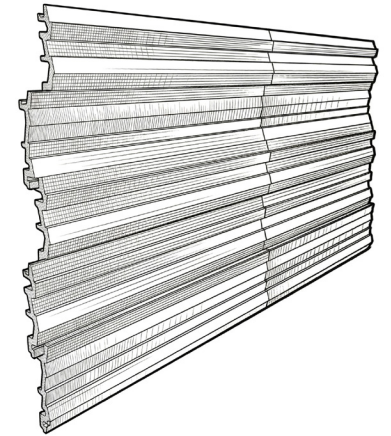
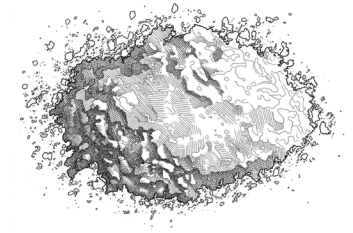
- Concrete: cement or sand replacement
- Exterior facade panel
- Low density, high porosity insulation

### Interior Finishes & Applications:

- Low density, high porosity insulation
- Paints and coatings
- Tile glazing pigment

### Miscellaneous

- Soil fertilizing additive
- Asphalt - modifier or filler in bitumen



**Care & Maintenance**

Biochar has an extremely stable atomic structure, composed of aromatic carbon rings which allows it to resist decay and oxidation. Maintenance requirements depend on the specific product or system in which the biochar is incorporated.

**End of/Next Life**

The process of making biochar through pyrolysis is shown, in some circumstances, to destroy forever chemicals like per- and polyfluoroalkyl substances (PFAS)<sup>31</sup> allowing even contaminated feedstocks to be safely returned to the soil. During use, biochar can also act as a sorbent, effectively capturing contaminants. When necessary, these contaminants may be removed through thermal, chemical, or microbial regeneration processes, depending on the application and level of exposure.

In soil, well-produced biochar is highly persistent, with some analyses estimating half-lives ranging from approximately 100 to over 1,000 years.<sup>32</sup>

**Governing Regulations**

Pyrolysis can release pollutants into the atmosphere and can therefore can be governed by the Clean Air Act in the U.S. Pyrolysis units can fall under different categories of the regulation. Biochar is predominantly used as a soil enhancement in agriculture and forestry, and its application may be guided by frameworks such as the USDA Soil Carbon Amendment (Ac.) (336). Product quality, feedstock sourcing, and production impacts are often

verified through certification schemes such as the World Biochar Certificate, which set criteria for contaminants, sustainability, and emissions control.

**Technical Design Data**

Biochar properties vary widely depending on feedstock, temperature, and processing. All performance data should be confirmed with product-specific testing.

**Thermal:** Biochar-clay/plaster composites: RSI-0.14 to 0.42/25mm (R-0.8 to 2.4/in) at densities ~222-610 kg/m<sup>3</sup> (13-38 lbs/ft<sup>3</sup>) (dry), good insulating range.<sup>28</sup>

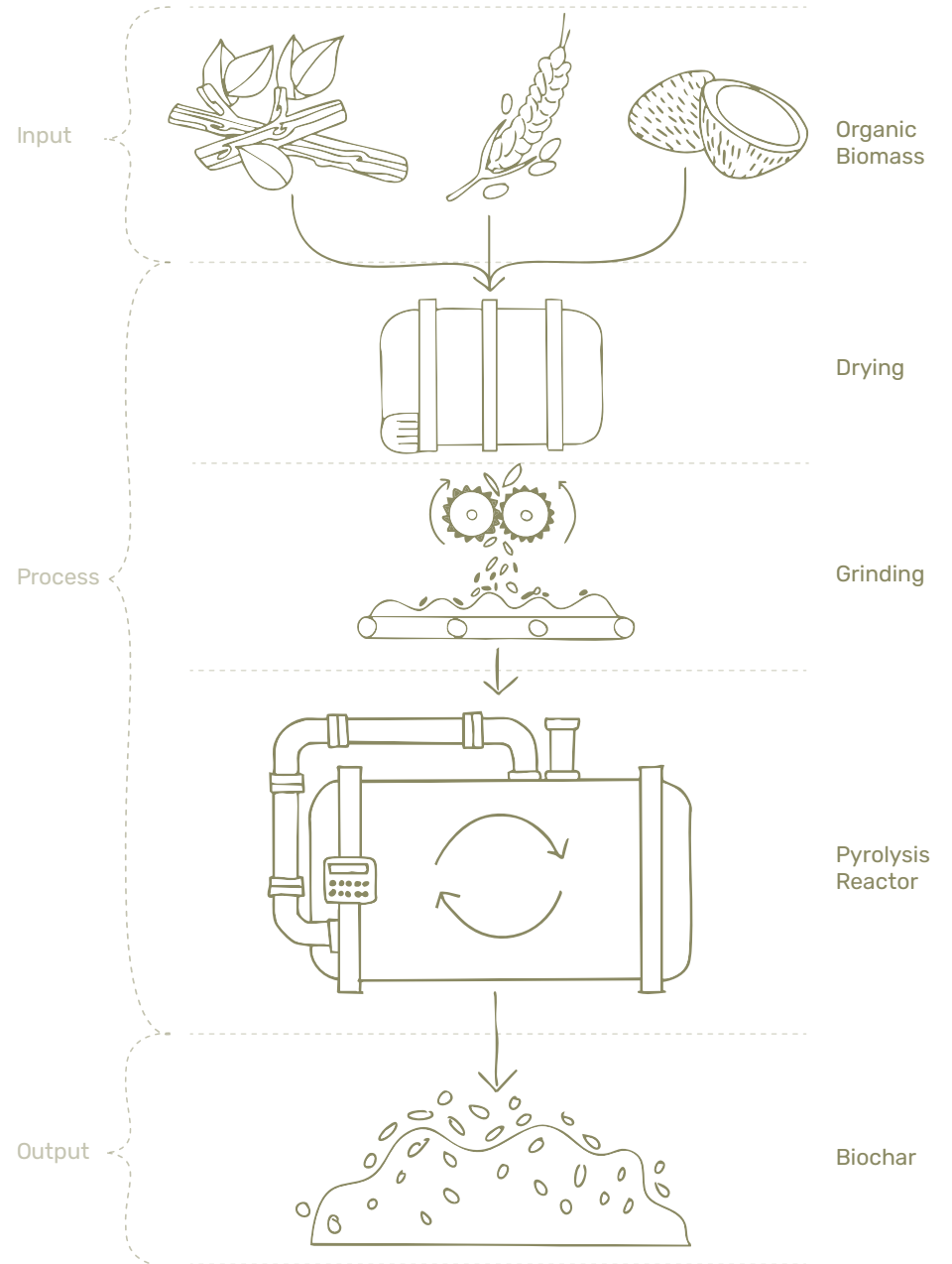
**Acoustic:** Biochar can enhance sound absorption but specific performance varies with matrix and dosage. Concrete with 10-15% biochar showed a noise reduction coefficient (NRC) ~0.45, comparable to moderate acoustic panel materials.<sup>29</sup>

**Density:** ~300-800 kg/m<sup>3</sup> (19-50 lbs/ft<sup>3</sup>) depending on feedstock and processing.

**Structural:** Biochar is not typically used as an additive to improve structural properties.

**Fire:** Often thermally stable and non-flammable, depending on the temperature the biochar was produced at. Can improve results in composites, but does not guarantee the product is non-combustible. Biochar dust can be combustible.

**Moisture & Vapor:** Biochar can have a surface area of 100-1,000 m<sup>2</sup>/g<sup>30</sup>, enabling moisture storage and release, aiding humidity regulation in plaster and wall systems.



**Material Process**

Biochar processing steps

## Strengths & Opportunities

### Human health

- Biochar has high surface area and chemical reactivity, allowing it to potentially absorb pollutants and purify the air
- The high porosity of biochar wall finishes can allow for natural humidity regulation
- Early studies suggest it may be able to reduce asthma and atopic dermatitis by diminishing the population of molds and ticks<sup>33</sup>
- High fire resistance of biochar provided added protection to materials
- It has the potential to remove forever chemicals stored in biomass from the environment.

### Ecosystem Health

- Biochar can help divert contaminated biosolids from leaching metals, pharmaceuticals and forever chemicals into the land and food system
- Biochar can support soil remediation of contaminated sites due to its high surface area and porosity

### Climate Health

- Biochar-crete has a median removal of 1.4 kgCO<sub>2</sub>e/kg of biochar, with a range of 0.9-4.8.<sup>34</sup> Net climate benefit depends on system boundaries, replacement rate, feedstock, processing technique and durability.<sup>35</sup>
- Biochar provides a long-term carbon storage solution, compared to other bio-based products that will decompose.
- Diverts wood and biosolids from the landfill that would otherwise release methane

### Social Health & Equity

- Biochar does not rely on global, potentially unethical, supply chains. It can be made anywhere, subject to local supply.

### Circular Economy

- Innately a circular material that utilizes organic waste resources, preventing the release of greenhouse gases during decomposition
- Biochar can be made from a wide range of biomass sources

## Challenges & Considerations

- There is limited data available on the performance qualities of biochar composite products. Longer term performance analysis of biochar enhanced materials is still needed due to the relative novelty of these applications and the lack of extended in-service case studies.
- Poor quality pyrolysis can lead to the escape of syngas, which includes methane, a potent greenhouse gas. It can also release particulate matter that is detrimental to human health.
- Biochar properties vary widely depending on biomass source and pyrolysis conditions, affecting strength, porosity, and chemical behavior. Some consistency can be provided using voluntary industry standards.
- Biochar is governed by voluntary industry standards such as European Biochar Certificate (EBC) and International Biochar initiative (IBI) and certifications and have yet to be incorporated into national or international building codes. An ASTM C09.28 Subcommittee formed in 2025

to develop a new concrete standard and testing methods for the use of biochar in concrete.

- Handling requires Personal protective equipment (PPE) and other safety protocols during production due to the dust and fine particulates.
- Designers should verify feedstock origin and land-use impacts, opting for agricultural byproducts that do not contribute to ecological degradation.
- Building products including biochar are not readily available.
- Designers should anticipate additional testing, mockups, and approvals when specifying biochar-containing materials.
- Biochar's low density and high water absorbency can affect the flexibility of materials if not taken into account
- Biochar-based products and materials come with a black pigmentation, which can affect design aesthetics

## Products

*Known bio-based products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework.*

### Structure

- [Eco Locked](#) biochar concrete additive
- [Our Carbon](#) concrete additive
- [Solid Carbon](#) low carbon concrete
- [Zero Twelve](#) low carbon concrete

### Enclosure

- [Made of Air](#) facade panel

### Insulation

- [Carbon Cell](#) high performance expandable foam
- [Echo systems](#)

### Interior Finishes

- [C interest](#) low carbon Gypsum Wall board
- [Cast Carbon](#) biochar interior tile
- [Living Ink](#) algae based pigment
- [Nature Coating](#) Black pigment additive
- [Our Carbon](#) black pigment



# Basic Services Unit

**Location:** Exhibited in Venice  
**Climate Zone (ASHRAE):** N/A  
**Year:** 2025  
**Architect:** ELEMENTAL  
**Manufacturer:** Holcim

**Materials:** Biochar concrete  
**Source:** [Holcim](#)

In Venice, during the 2025 Architecture Biennale, Holcim and Alejandro Aravena’s firm ELEMENTAL presented Basic Services Unit, a new incremental housing design that incorporates biochar technology that transforms buildings into carbon sinks. The structure’s precast concrete panels are made from a biochar concrete mix with recycled aggregates, which leads to a net-zero (A1–A3 cradle to gate) concrete formulation. This work is a continuation of Aravena’s 20-year development of incremental housing, whereby owners start with a safe architect-designed framework and build from there as and when they can afford to.

Biochar is diverting organic matter from decomposing and releasing greenhouse gas emissions. Each kilogram of biochar prevents the release of up to 3 kgCO<sub>2</sub>, and also contributes to a circular economy by providing a value to organic waste.

Beyond Venice, Holcim are producing trials of biochar based buildings in France, Spain, the UK and Greece.



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1. Basic Services Unit at 2025 Venice Architecture Biennale. Image by Celestia Studio.
2. Render of street built from Basic Services Units. Image by ELEMENTAL.
3. Render of neighborhood built from Basic Services Units. Image by ELEMENTAL.



# Ithaka Institute

**Location:** Arbaz, Switzerland

**Climate Zone (ASHRAE):** 6A

**Year:** 2013

**Builder:** Ithaka Institute

**Materials:** Biochar plaster

**Source:** [Ithaka Institute](#)

At the headquarters of the Ithaka Institute in Valais, an office and adjacent historic wine cellar demonstrate how biochar-clay plaster can transform indoor climate and comfort. The project uses biochar's two defining properties, low thermal conductivity and the ability to absorb up to five times its weight in water, to create high-performance interior envelopes.

In the renovated cellar, a 10 cm layer of spray-applied biochar-clay plaster was installed using compressed air technology. The thick application acts as both insulation and a powerful moisture buffer, a critical requirement for wine storage.

Upstairs, the institute's office walls feature biochar-clay plaster, some up to 7cm thick with embedded wall-heating pipes. The plaster, composed of roughly 50% biochar, 30% sand, and 20% lean clay by volume,

serves as thermal mass, storing and gently releasing radiant heat. The plaster creates a comfortable indoor climate while maintaining breathable wall assemblies that adsorb odors and indoor toxins.

The material is workable using standard plastering techniques and can be finished in a deep anthracite tone with a fine charcoal topcoat or painted with clay paints for lighter interiors. Compared to lime or cement plasters, it is also more pleasant for installers to handle.

Together, the office and cellar illustrate biochar plaster's potential as a carbon-storing, health-promoting alternative to conventional insulation and interior finishes.



1. Biochar plaster in office. Image by Ithaka Institute.
2. Spray applied biochar plaster. Image by Ithaka Institute.
3. Basement wine cellar. Image by Ithaka Institute.



# Low Carbon Campus

**Location:** Oakland, CA, USA

**Climate Zone (ASHRAE):** 3C

**Year:** 2025

**Architect:** Skidmore, Owings & Merrill (SOM)

**Manufacturer:** Bioforcetech Corporation

**Materials:** Biochar enhanced concrete (OurCarbon by Bioforcetech)

**Sources:** Valorize Systems, [Bioforcetech](#)

The Low Carbon Campus project in Oakland, CA, demonstrates how material innovation can meaningfully reduce embodied carbon in structural systems. In collaboration between SOM, Central Concrete, Bioforcetech, and Valorize Systems, the project replaces a portion of conventional concrete aggregate with OurCarbon, a biochar derived from wastewater biosolids.

The biochar is produced through a process that diverts biosolids from landfill, dries them using heat-generating microbes, and converts them into stable biochar via pyrolysis. Rather than decomposing and emitting methane, the carbon in the waste stream is locked into a durable form. When incorporated into concrete, each kg stores more than one kg of CO<sub>2</sub>, transforming a traditionally emissions-intensive material into a vehicle for net carbon storage.

Material integration required rigorous testing and mix design optimization. Central Concrete developed and batched the biochar-enhanced mix to meet American Concrete Institute (ACI) standards for strength, durability, and workability, while third-party testing validated performance. Conditioning the biochar to saturated surface dry (SSD) was critical to maintaining slump and ensuring consistent batching. In some applications, additional binders were introduced to achieve structural requirements for footings and site work.

The final Environmental Product Declarations (EPDs) show a 16.6% reduction in global warming potential (GWP) for footings and a 14% reduction for sitework, with a combined 2.38 metric tonnes of CO<sub>2</sub> removed and avoided. The project establishes biochar-enhanced concrete as a viable pathway for decarbonizing one of construction’s most ubiquitous materials.

3

Application	Baseline EPD (kgCO <sub>2</sub> e/cy)	OurCarbon® enhanced concrete (kgCO <sub>2</sub> e/cy)	GWP Reduction
Footing	209	174.3	16.6%
Sitework	248	213.3	14.0%



1. Trowel finish. Image by Bioforcetech.
2. Ready-mix concrete delivery. Image by Bioforcetech
3. GWP reductions. Table from Valorize Systems.
4. OurCarbon biochar. Image by Bioforcetech.

## Further Reading

- Bio-Based Materials Collective. (n.d.). Resources, Episode 6: Biochar. <https://biobasedcollective.org/resources/>
- Biochar Today. (n.d.). Biochar Today: The latest industry news and scientific research from the field of biochar. <https://biochartoday.com/>
- Draper, K., Tomlinson, T., & Zwart, K. (2018). Biochar-based building materials [Presentation]. Biochar-US. [https://biochar-us.org/sites/default/files/presentations/4.2.5%20Biochar%20Building%20Materials\\_Draper.pdf](https://biochar-us.org/sites/default/files/presentations/4.2.5%20Biochar%20Building%20Materials_Draper.pdf)
- Osman, A. I., Farghali, M., Dong, Y., Kong, J., Yousry, M., Rashwan, A. K., Chen, Z., Al-Fatesh, A., & Rooney, D. W. (2023). Reducing the carbon footprint of buildings using biochar-based bricks and insulating materials: A review. *Environmental Chemistry Letters*, 22(71–104). <https://link.springer.com/article/10.1007/s10311-023-01662-7>
- Schmidt, H.-P., & Shackley, S. (2016). The 55 uses of biochar. *Biochar Journal*. <https://www.biochar-journal.org/en/ct/2>
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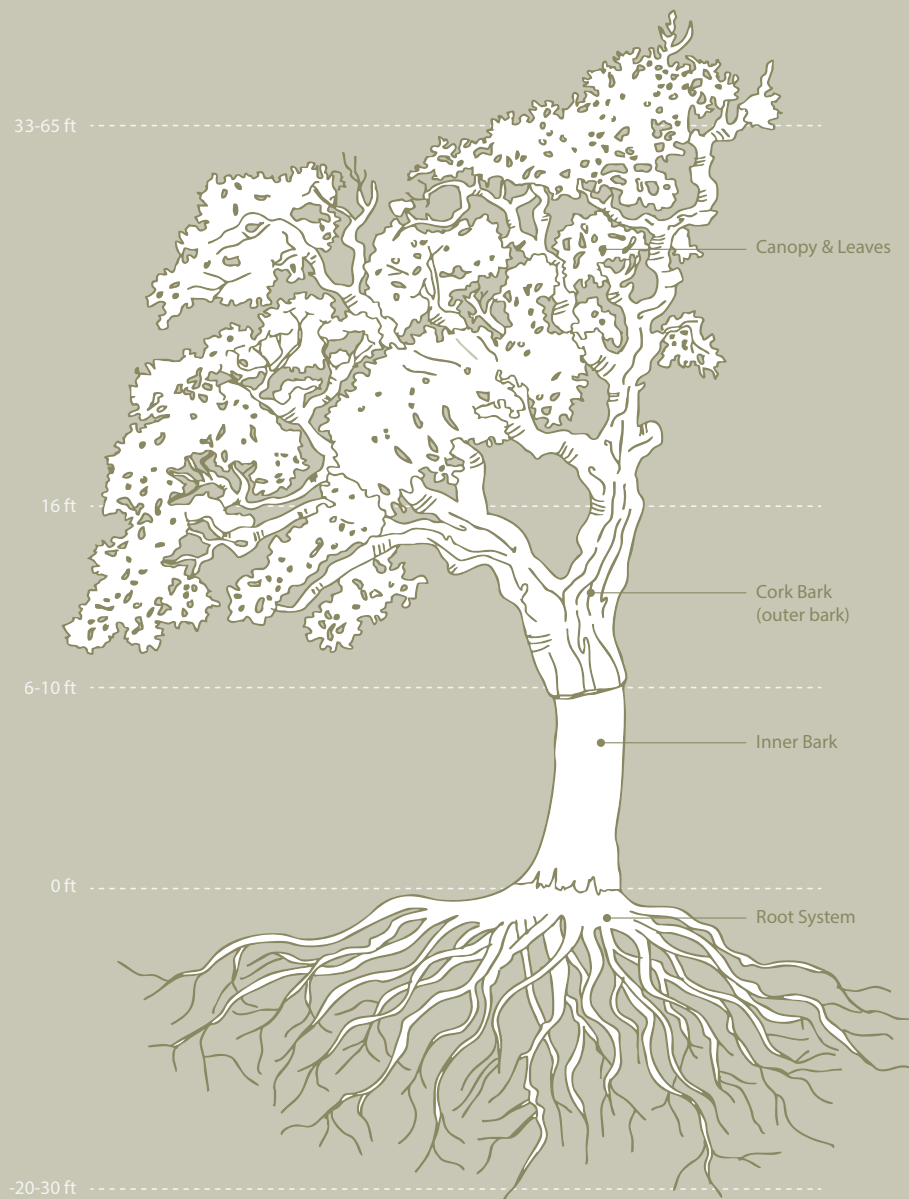
## Networks & Groups

**European Biochar Industry Consortium (EBI)**: Focuses on policy and industry standards for biochar within the EU.

**Ithaka Institute**: The Institute specializes in biochar production, characterization, certification, and application.

**International Biochar Initiative (IBI)**: The primary global hub for biochar research, standards, and commercial networking.

**U.S. Biochar Initiative (USBI)**: A North American network promoting the production and use of biochar for soil health and carbon sequestration.



## CORK

Phellem (outer bark) growth rate  
 -1–3 mm/yr (0.04–0.12 in/yr);  
 mature height -15–20 m  
 (49–66 ft)<sup>36</sup>

Phellem harvest cycle every ~9 yrs ;  
 tree lifespan of 150–250 yrs<sup>37</sup>

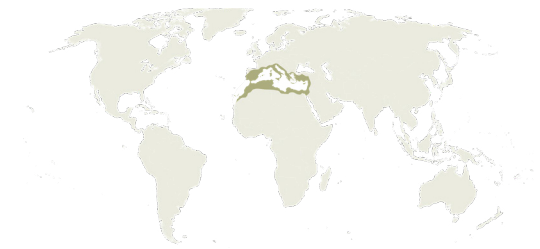
Biomass yield -2.25–4.5 t/ha/  
 harvest; -0.25–0.5 t/ha/yr<sup>38</sup>

Biogenic carbon storage:  
 -1.7–1.85 tCO<sub>2</sub> per dry t of cork<sup>39</sup>

Forest ecosystem sequestration rate  
 -14.7–48 tCO<sub>2</sub>/ha/yr (net flux);  
 cork forests sequester 70–75 tCO<sub>2</sub>  
 per t of harvested cork<sup>40</sup>

### Source

Cork comes from the outer bark of the cork oak (*Quercus suber*), a Mediterranean tree whose thick, protective bark can be sustainably stripped and regrown throughout its long lifespan. Most cork is sourced from Portugal and Spain, with lower-grade granulate also produced from the Asian cork oak (*Quercus variabilis*).



Source Map:

### Best Used For:

Rainscreen façades and continuous exterior insulation; interior finishes such as flooring, acoustic paneling and wallcovering.

### Key Design Considerations:

International sourcing and responsible suberculture; product type and quality; binders and sealants (added chemicals); fire performance and assembly compliance; detailing and moisture strategy

**Ecology & Growing**

Cork oak can live over 150 years<sup>43</sup>, absorbing carbon while regenerating bark for multiple generations. Native to the western Mediterranean, cork oak landscapes, known as montados or dehesas, are not conventional forests, but long-managed agro-silvo-pastoral systems. Trees are intentionally spaced to allow grazing, seasonal cultivation, and understory biodiversity beneath an open canopy. These landscapes represent integrated land-use systems where forestry, agriculture, and animal husbandry coexist.

Often described as among the richest ecosystems in Europe, montados/dehesas can support over 135 plant species per square meter and provide habitat for thousands of fauna, including endangered species such as the Iberian lynx. Cork oaks thrive in dry, nutrient-poor, well-drained soils, where deep root systems and symbiotic mycorrhizal fungi enhance nutrient cycling, soil stability, and long-term forest resilience. These systems require minimal irrigation, fertilizers, or pesticides and help prevent erosion and desertification across approximately 2.1 million hectares globally.<sup>44</sup>

However, cork oak landscapes are increasingly under pressure from a synergistic combination of climate stress, biological pressures, ecological degradation, and, in some regions, overexploitation or poor management. The long-term viability of cork depends not only on harvesting cycles but on the continued

stewardship of these cultural landscapes. Specifying cork, therefore, draws from and influences a living land-use system shaped by ecological and social continuity.

**Culture & History**

Cork has been used for millennia, with early records in ancient Egypt and Rome. By the 16th century, Portuguese builders routinely used cork for roofs, linings, and façades. The rise of bottled wine in the 17th–19th centuries expanded global cork commerce, and the patenting of cork agglomerate in 1891 enabled modern insulation and façade applications.

Many contemporary cork products emerged from efforts to utilize by-products of cork stopper production, which remains the industry’s largest market. The high waste-to-product ratio of punched cork stoppers drove innovations in grinding and recombining cork residues, leading to agglomerated cork used in linoleum, insulation, composites, and architectural materials.

Cork production is rooted in the cultural landscapes of Portugal and Spain. Harvesting is a highly skilled seasonal craft requiring years of training to remove bark without harming the tree. The montado/dehesa system reflects intergenerational land stewardship, where forestry, grazing, and rural livelihoods are intertwined. Today, cork production remains geographically concentrated and shaped by a consolidated industry, and long-term supply depends not only on ecological

resilience but also on sustaining rural labor, cultural knowledge, and responsible forest management.

**Harvesting & Processing**

Cork is harvested by hand from mature cork oaks using specialized axes to remove large bark sheets without harming the tree. Bark grows 1–3 mm per year, with the first “virgin” harvest occurring after 25+ years<sup>42</sup> and then subsequent cycles every 9 or more years, which yield higher-quality bark. After stripping, cork planks are air-dried to stabilize moisture and cell structure, then in some cases boiled or steamed to remove tannins and increase flexibility. It is later cut, graded (sorted into quality tiers) if amadia cork, and either processed into solid sheets or milled into granulate for agglomerated products.

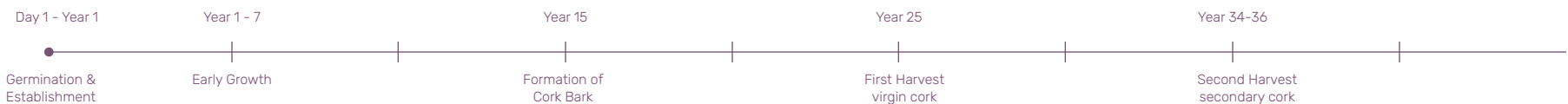


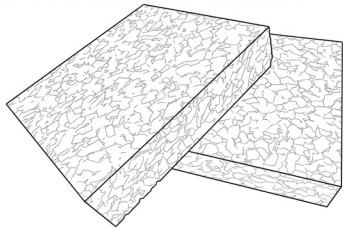
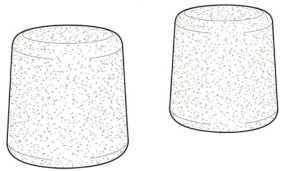
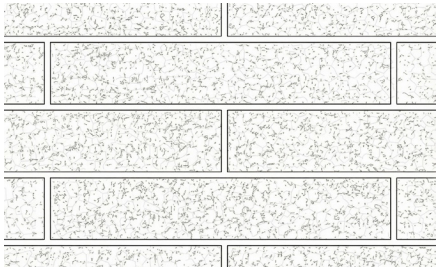
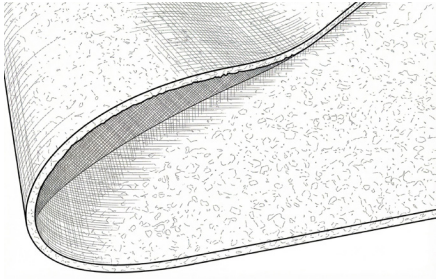
Cork harvesting process

**Making**

Cork can be used whole or ground, with product pathways closely tied to bark quality. Early harvest “virgin” cork, which is irregular and resin-rich, is often milled into granulate for expanded cork insulation and agglomerated composites. Higher-quality amadia cork from later harvest cycles can be cut into solid sheets for bottle stoppers and premium cork products such as flooring or wall finishes. Granulated cork is bound with natural resins or synthetic adhesives (UF, MUF, phenolic, or polyurethane) to form tiles, boards, composites, and molded products. Expanded cork agglomerate is produced without additives by heating cork granules with superheated steam in an autoclave, causing them to expand and self-bind through natural suberin. The expansion process significantly reduces density, increasing the material’s thermal performance while creating lightweight insulation boards that can be used in both concealed and exposed façade applications.

Cork is also blended into linoleum (with linseed oil, resins, pigments, and wood flour), combined with gypsum in lightweight boards, and incorporated into polymer composites for injection molding, extrusion, and sandwich panels to enhance toughness, acoustics, and impact resistance. Cork manufacturing is typically considered near zero-waste: offcuts and grinding residues are reused in agglomerated products, and fine cork dust is often burned as biomass energy within cork processing facilities.





## Featured Applications

Cork's versatility allows it to function across structural assemblies, insulation systems, and finished surfaces. Its unique combination of low density, elasticity, thermal stability, and acoustic damping enables use in both high-performance building components and refined design applications, from façade systems and flooring to furniture, composites, and CNC-milled architectural elements.

### Structure:

- Acoustic/vibration-damping structural layers
- Cork-core structural sandwich panels
- Load-bearing interlocking cork blocks

### Envelope:

- Expanded cork façade panels and rainscreens
- Exterior cladding and shutter systems
- Thermal envelope assemblies (high-density cork boards)
- Cork composite mortar, screed and stucco

### Insulation:

- Expanded cork insulation boards (wall, roof, floor)
- Thermal and acoustic cavity fillers (cork granulate)
- Subfloor underlayment (sound and vibration control)

### Interior Finishes & Applications:

- Acoustic wall and ceiling panels
- Wall coverings and decorative panels (including CNC-milled cork)
- Cork-gypsum composite boards
- Interior partition systems (cork composites)
- Linoleum (cork dust blended with linseed oil and resins)
- Flooring tiles and planks
- Furniture and fixtures
- Molded furnishings

## Care & Maintenance

Cork is naturally durable, water-resistant, and decay-resistant, requiring minimal maintenance. When exposed outdoors, cork gradually lightens in color due to UV exposure, shifting from warm browns to pale gray or whitish tones. This surface-level change affects only the lignin in the outer cellular layer and does not compromise structural or thermal performance<sup>45</sup>, similar to weathering in wood. In humid climates, moss or lichen may occasionally appear on shaded surfaces, similar to tree bark, but this does not degrade the quality of the material. Appearance can be refreshed by simply sanding the surface. Care primarily involves maintaining breathable assemblies and protecting finishes where cork is used as flooring or interior surfaces. Cork composites may be sealed with natural or synthetic coatings depending on the application

## End of/Next Life

Cork supports a relatively circular material cycle because the bark can be harvested repeatedly without cutting down the tree, allowing the same tree to produce cork over many decades. Manufacturing is nearly zero-waste, with residues reused or burned for process energy. At end of life, cork products can be recycled, reground, or cleanly combusted, though composting may be limited by synthetic sealants and adhesives. Loose-laid or mechanically fixed expanded cork boards (ICB) can be relatively easy to recover for reuse or recycling, while agglomerated cork

products that incorporate synthetic binders (such as polyurethane) are more difficult to reclaim due to their composite nature. Dry-fit systems such as cork blocks can also support disassembly and material reuse.

## Governing Regulations

Cork production is guided by regulated subculture practices across Mediterranean regions to ensure sustainable harvesting cycles.

If considering cork for interior applications, products are typically reviewed under the International Building Code (IBC) as interior finishes and must demonstrate compliance with ASTM E84 (UL 723) for flame spread and smoke development, with additional tests such as ASTM E648 or ASTM E662 for flooring where applicable.

If considering cork for exterior applications, materials are evaluated as part of an exterior wall assembly under IBC Chapter 14. Combustible cork products typically require incorporation into an NFPA 285-compliant assembly, supported by ASTM E84 baseline data and durability testing such as ASTM E96 (vapor permeability) and ASTM C272 (water absorption). Approval commonly depends on assembly design, encapsulation strategies, or acceptance through alternate means and methods (IBC Section 104.11) in coordination with the Authority Having Jurisdiction.

In Europe, fire performance is evaluated under EN 13501-1, with many expanded cork boards achieving Euroclass E.

Year 45-50

~ 200 Year Lifespan

Third Harvest  
amadía/ high-quality cork

15 - 17 total harvest

**Technical Design Data**

Cork's performance stems from its lightweight cellular structure, elasticity, and natural fire- and moisture-resistant chemistry. It is composed largely of suberin (a waxy biopolymer that provides elasticity and water resistance), along with lignin (which gives structural strength), and smaller amounts of cellulose and other compounds. Together these components produce cork's characteristic combination of compressibility, durability, thermal resistance, and acoustic dampening. Properties vary by product type (natural cork, agglomerated boards, or expanded cork) but remain consistent in offering stable thermal, acoustic, and hygric behavior across building applications.

**Thermal:** Thermal resistance typically ranges from RSI-0.56 to 0.63/25mm (R-3.2 to 3.6/in)<sup>46</sup> for natural and expanded cork boards (with a density of 140-170 kg/m<sup>3</sup> (9-11 lbs/ft<sup>3</sup>)), with low thermal diffusivity (~10<sup>-7</sup> m<sup>2</sup>/s).<sup>47</sup> High-density expanded cork provides robust thermal stability for both interior and exterior assemblies.

**Density:** Density ranges from 110-120 kg/m<sup>3</sup> (~7 lbs/ft<sup>3</sup>)<sup>48</sup> for expanded cork insulation boards, 200-300 kg/m<sup>3</sup> (12-19 lbs/ft<sup>3</sup>)<sup>49</sup> for medium density expanded cork facade panels, and up to 500-750 kg/m<sup>3</sup> (30-47 lbs/ft<sup>3</sup>) for densified cladding and flooring products.

**Fire:** Cork remains stable below 200°C (390F),<sup>50</sup> with major decomposition beginning near 300°C (570F).<sup>51</sup> Many expanded cork boards char predictably and resist flaming due to low oxygen permeability within sealed cells.

**Moisture & Vapor:** Vapor diffusion factor  $\mu$  = 5-30,<sup>52</sup> indicating vapor-open behavior compatible with breathable assemblies. Water diffusion coefficients are low (10<sup>-11</sup>-10<sup>-10</sup> m<sup>2</sup>/s), and cork maintains dimensional stability under humidity cycling.

**Acoustic:** Cork provides strong mid-frequency absorption, with noise reduction coefficients of 0.33-0.8 (500-1500 Hz) for expanded cork. Its elastic cell structure also delivers effective impact and vibration damping.

**Strengths & Opportunities**

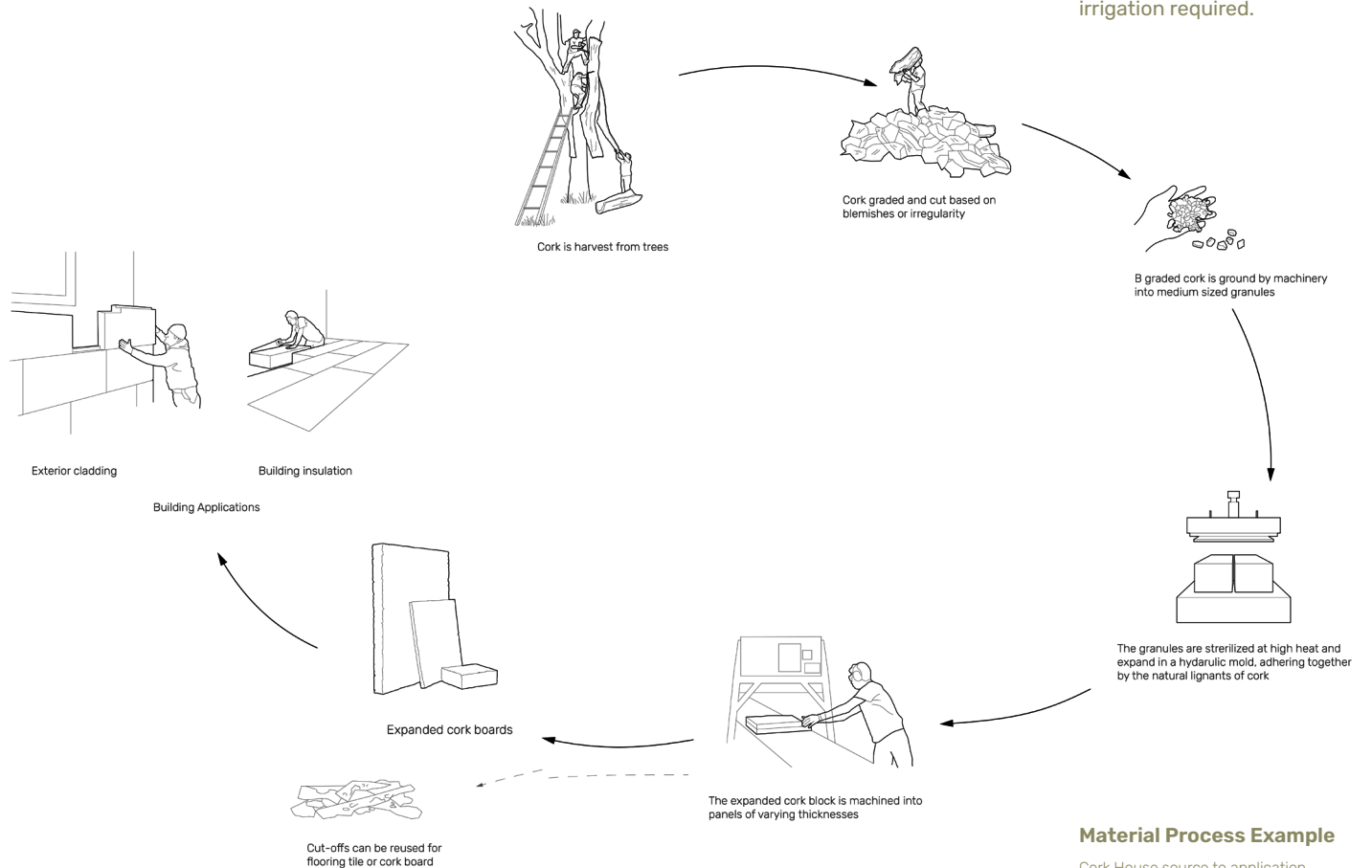
Human health

- Naturally non-toxic, with no chemical additives required for expanded cork production (steam-expanded, binder-free). Low-VOC interior applications (flooring, panels) when paired with safe finishes.
- Cork's acoustic absorption and vibration damping contribute to healthier indoor environments by reducing noise and reverberation.

- Vapor-open behavior supports breathable wall assemblies that help maintain healthy moisture levels.

Ecosystem Health

- Harvested from living trees without felling, supporting long-lived forest ecosystems.
- Cork oak landscapes (montados/dehesas) are recognized biodiversity hotspots, supporting mixed forestry, grazing, and wildlife habitat.
- Cork oak systems prevent erosion and combat desertification, particularly in dry Mediterranean climates.
- Minimal pesticides, fertilizers, or irrigation required.



**Material Process Example**

Cork House source to application

### Climate Health

- Cork stores atmospheric carbon for the lifespan of the material.
- Expanded cork insulation can achieve net-negative GWP at the product stage due to carbon storage and energy-efficient processing.
- Cork processing is nearly energy self-sufficient, using residues and cork dust as fuel for steam generation.
- Long-lived cork trees (150–250+ years) act as persistent carbon sinks across generations of harvest cycles.
- The lightness of cork allows for reduction in the structural requirements of the façades and decreases the risks in case of façade fracturing and falling.

### Social Health & Equity

- Cork harvesting is a skilled, culturally embedded profession in Mediterranean regions, requiring years of training to strip bark without damaging the tree. In Portugal and Spain, cork strippers are among the highest-paid seasonal agricultural workers, reflecting the precision and value of the craft.
- Suberculture supports regionally specific rural livelihoods and reinforces socio-ecological relationships within cork landscapes, where forestry, grazing, and land stewardship are intertwined.
- Long-term monitoring of cork buildings (e.g., Portugal Pavilion) contributes to transparency, technical learning, and broader industry confidence.

### Circular Economy

- Cork is renewable, with bark regenerating every 9–12 years throughout a tree's long lifespan.

- All residues from manufacturing become fuel, granulate, or composite feedstock.
- Cork products can be recycled, reground, or cleanly combusted at end-of-life.
- Systems like dry-fit cork blocks (e.g., CorkHouse) demonstrate disassemblable, reusable, mono-material assemblies.
- Binder-free expanded cork enables mono-material products that are easier to reuse and recycle.

### Challenges & Considerations

- Cork oaks take 25+ years to reach first harvest, and bark regenerates slowly (9–12 years), limiting rapid scaling and making supply inherently regional.
- Cork oak forests are concentrated in the western Mediterranean. While this limits global production and requires transport to distant markets, this regional concentration is integral to cork's ecological and cultural integrity. Transport impacts should be weighed alongside carbon storage, durability, and land-stewardship benefits.
- Cork harvesting relies on skilled manual labor. Declining rural populations in parts of the Mediterranean may affect long-term labor availability, making fair compensation and continued cultural transmission essential to supply resilience.
- Cork bark quality varies by harvest cycle. Early harvest "virgin cork" has different characteristics than secondary or amadia cork.

- Many expanded cork products will require a project-specific fire strategy and detailing depending on code context.
- Exterior cork lightens due to UV exposure, and in some conditions, lichen/moss growth is possible without careful density selection or detailing.
- Some cork composites use synthetic adhesives (UF, MUF, phenolic, PU), and cork finishes may use synthetic sealants, which may affect emissions, recyclability, and health criteria.

### Products

*Known bio-based products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework.*

#### Enclosure & Insulation

- [Amorim Cork Solutions\\*](#) medium density facade and standard insulation grade expanded cork panels
- Cork Render Spray by [Corkco](#)
- [Jelinek Cork Group](#) semi-Rigid Expanded Insulation Cork Board and Cork Spray
- [MCC Inc](#) insulating Corkboard
- [ThermaCork](#) expanded cork insulation boards – façade and decorative grades

#### Interior Finishes

- [Amcork](#) flooring, wall tiles, and rolls/sheets
- [Amorim Cork Solutions\\*](#) acoustic insulation solutions, vibration isolation solutions, and flooring underlayment
- [APC Cork](#) floating floors and cork tiles
- [Astek](#) cork wallcoverings
- [CapriCork](#) cork flooring and wall tiles
- [Corklife by Amorim](#) flooring

- [Duro Design](#) cork flooring and wall panels
- [Globus Cork](#) floor tiles
- [Go4Cork by Amorim](#) flooring underlayment, cork-rubber mats and padding, thermal and acoustic insulation boards, multipurpose tiles, multi-purpose cork-composite rolls, and memoboards
- [Innovations](#) cork wallcovering
- [Jelinek Cork Group](#) cork flooring, wall/ceiling coverings, rolls/sheets, and acoustic treatment
- [Koroseal](#) cork wallcovering
- [Nordgrona](#) cork collection applied by Scandinavian Spaces
- [ThermaCork](#) expanded cork insulation boards
- [Spinneybeck](#) acoustic cork wall tiles
- [Suberra](#) ultra High-Density Cork (countertops, wall paneling, millwork, furniture, and acoustic finishes) supplied by Amorim
- [UNICO](#) cork flooring
- [WeCork](#) flooring
- [Wolf Gordon](#) cork wallcovering and corkboard
- [Zandur](#) cork rubber flooring, solid cork flooring, and cork wall planks

#### Miscellaneous

- [Amorim Expandacork\\*](#) for expansion joints
- [Amorim Sports\\*](#) cork-based solutions for sports applications (infills, shock pads, etc.)
- [Corkeen by Amorim\\*](#) cork playground surfaces
- [Zandur](#) natural cork products

\*Amorim Cork Solutions represents several brands. Check out U.S. supplier of Amorim, [Cross Cabin Supply](#).



# A Square in Summer

**Location:** Lisboa, Portugal

**Climate Zone (ASHRAE):** 3C

**Year:** 2017

**Designer/Architect:** José Neves

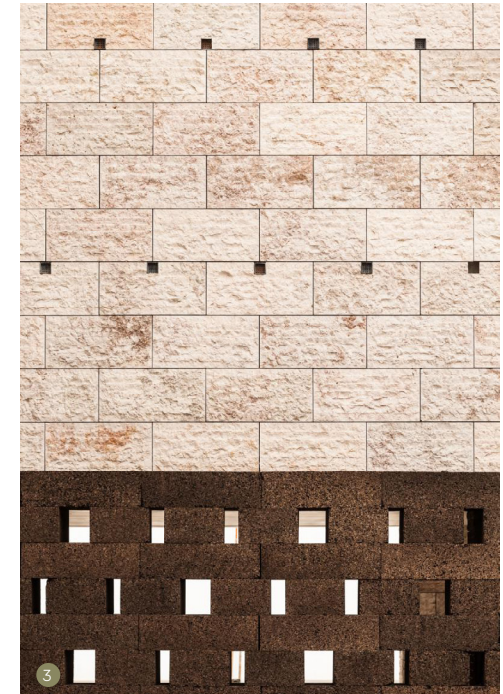
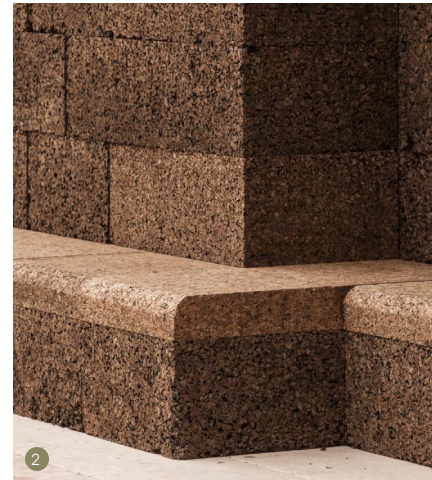
A Square in Summer is a site-specific installation that transforms the public space of the Belém Cultural Center Square in Lisbon. Originally conceived to support an open-air cinema program, the project reimagines the square, not as an object, but as an activated place of movement and pause. The design responds directly to the existing architectural rhythm of the Manuel Salgado and Vittorio Gregotti-designed center by referencing its grid, limestone cladding, and monumental scale. A long cork wall, 2.8 meters high, runs along the south edge of the square in the shade throughout most of the day, establishing a new spatial sequence that invites people to gather, rest, and engage with the surroundings.

**Materials:** Cork block

**Sources:** [Divisare](#); [Archello](#)

Constructed from modulated blocks of black cork composite, the wall not only provides functional seating and shelter but also modulates light, materiality, and human scale within the open space. Its alternate thicknesses create a rhythm that echoes the architectural metrics of the Cultural Center, and the placement at the western end forms a corner suitable for evening film viewings protected from wind. The warm, textured cork whose brown tones shift with light and age softens the contrast with the limestone while encouraging tactile engagement from passersby. By integrating material, form, and urban movement, A Square in Summer both redefines and humanizes a civic space in one of Lisbon's most visited cultural precincts.

*\*This 2017 installation was part of an annual temporary architecture program at the CCB; other editions include the 2018 version by Promontorio.*



1. View from Square. Image by Francisco Nogueira.
2. Cork bench closeup. Image by Francisco Nogueira.
3. Cork wall closeup. Image by Francisco Nogueira.



# Cork House

**Location:** Eton, UK

**Climate Zone (ASHRAE):** 4C

**Year:** 2019

**Architect:** Matthew Barnett Howland with Dido Milne (CSK Architects) and Oliver Wilton (UCL)

**Structural Engineer:** Arup

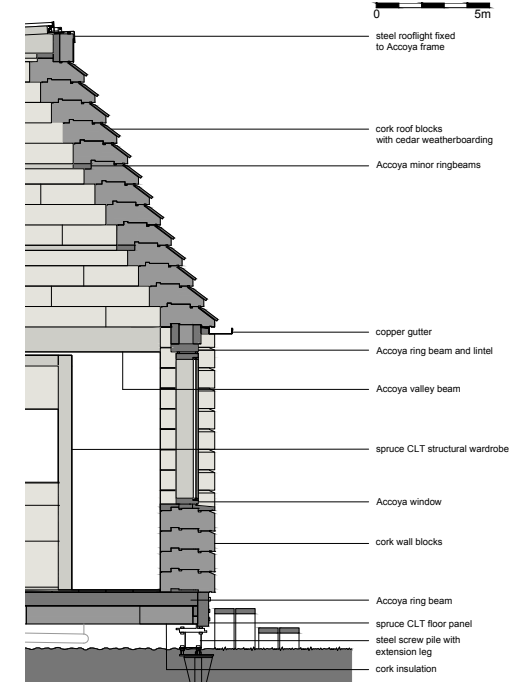
Cork House is an experimental mono-material building system constructed almost entirely from solid expanded cork blocks, developed as a prototype for radically simplified, low-carbon architecture. The house uses CNC-milled modules, stacked and interlocked like a dry-jointed masonry system, that require no mortar, adhesives, membranes, or mechanical fasteners. The same block performs as structure, enclosure, insulation, airtightness, and acoustic control, replacing the multi-layered complexity of conventional walls.

The blocks are binder-free expanded cork, produced by heating granules until they expand and self-bind through natural suberin. The result is a lightweight, breathable, antimicrobial, and thermally insulating material with an exceptionally low environmental footprint. Because the system relies on a single bio-based material, the building is designed for full disassembly and reuse, embodying circular construction principles.

**Materials:** Expanded cork block

**Sources:** [ArchDaily](#), [Matthew Barnett Howland](#), [Dezeen](#), [Materials Assemble](#)

Inside, stacked cork masses create a tactile, stone-like interior with deep reveals and sculptural light wells. The minimal architecture allows the material's density, thermal mass, and acoustic character to define the atmosphere. A carbon assessment estimated a negative GWP of  $-780 \text{ kgCO}_2\text{e}$  at practical completion, with whole-life emissions far below typical UK homes. Resting on a reversible steel platform, Cork House demonstrates how ecological origin, fabrication logic, and architectural expression can be fully aligned.



1. Exterior View, Photo by David Grandorge
2. Construction Process, Photo by Matthew Barnett Howland
3. Section Drawing, Graphic by Matthew Barnett Howland



## Cork Houses in Catalonia

**Location:** Palafrugell, Girona, Spain

**Climate Zone (ASHRAE):** 3B

**Year:** 2016

**Architect:** López Rivera Arquitectos

**Materials:** Cork panels, Cork insulation, Lime mortar, Timber (pine), Ceramic tiles

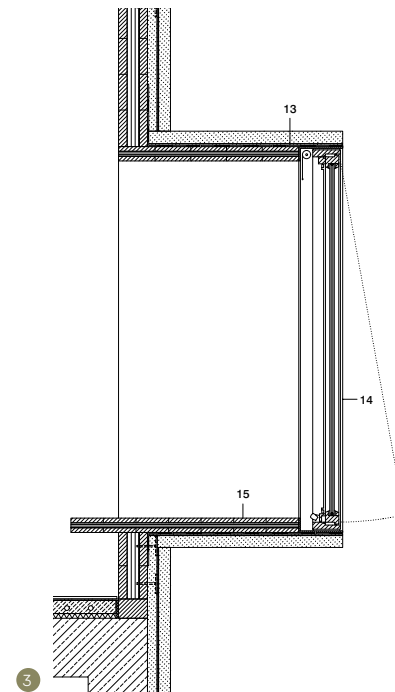
**Sources:** [Natural Building Materials SML](#), [Designboom](#), [HIC Arquitectura](#), [López Rivera Arquitectos](#)

Set within the dense cork oak and pine forests of the Catalanian coast, the Two Cork Houses by López Rivera Arquitectos use cork both as external insulation and primary façade cladding, creating a unified, materially expressive envelope. The project comprises two tall, slender holiday homes for a multigenerational family, each carefully shaped to the steep hillside; one volume partially embedded into the slope, the other elevated on concrete columns with a split-level interior and expansive terraces overlooking the coastline.

The façade system uses a homogeneous cork shell applied in two layers: a 40mm cork board mechanically screwed to a timber structure, and a 50 mm layer adhered with breathable lime mortar. This monolithic wrapping continues across walls, porches, window niches, and even shutters, giving the buildings a textured, earthy presence that blends into the

surrounding forest. The approach recalls the region's long relationship with cork production; although most industrial cork processing has shifted to Portugal and southern Spain, the nearby Palafrugell museum and former cork factory preserve the area's historic cork-working heritage.

Inside, the architects pursued the same commitment to natural materials. Exposed pine (structural members, walls, slabs, stairs, furniture, and projecting bay windows) creates warm, cohesive interiors. Operable wooden windows slide upward or tilt outward for passive ventilation, while locally made gray ceramic tiles provide durable flooring. Together, the cork-clad exterior and pine-lined interior form a low-impact, climate-responsive architecture that reflects both the ecological context and cultural history of Catalonia's cork oak landscape.



1. Exterior Facade, Image by José Hevia
2. Seating nook, Image by José Hevia
3. Wall Section, Drawing by López Rivera Arquitectos



## Cross Cabin

**Location:** Austin, TX, USA

**Climate Zone (ASHRAE):** 2A

**Year:** 2023

**Designer/Architect:** Cross Cabin Build & Supply : Greg Esparza

**Materials:** Cross-laminated timber (CLT) panels (Douglas-fir); expanded cork insulation panels (Amorim MD Facades); hemp and wood fiber insulation; thermally treated larch flooring; laminated recycled paper (Richlite)

**Sources:** [Cross Cabin Build & Supply](#); [AIA Austin](#); [The Architect's Newspaper](#)

Cross Cabin in Austin, Texas is a pilot project by Cross Cabin Build & Supply that centers materials, climate, and human health in residential design. The 1,000sf structure was conceived as a plant-based prototype, replacing conventional carbon-intensive products with renewable, minimally processed alternatives. The result is a zero-carbon home built entirely from plant-derived components that looks, smells, and feels distinct from typical construction.

Cork anchors the material strategy, serving as both primary exterior cladding and continuous insulation. Expanded cork panels, such as Amorim's MD Façade, are expressed directly on the envelope, providing a waterproof, thermally resistive, and non-toxic barrier that weathers from warm browns to silvery grays. Cork's cellular structure offers strong insulation, fire resistance, and moisture stability while supporting a healthy indoor environment free of synthetic additives.

The structural system pairs cross-laminated timber (CLT) with solid-sawn lumber and thermally treated larch, while cork continues into the interior alongside recycled paper-based materials like Richlite. By avoiding drywall, paint, foam, and fiberglass, the cabin creates a biogenic, sensory-rich environment. The project achieves a cradle-to-gate embodied carbon of 72 kgCO<sub>2</sub>e/m<sup>2</sup>, a 64% reduction from baseline, while storing 216 kgCO<sub>2</sub>/m<sup>2</sup> of biogenic carbon.



1. Cork-clad exterior. Photo by Casey Woods.
2. Exterior wall assembly. Photo by Greg Esparza.
3. Cork and wood interiors. Photo by Casey Woods.

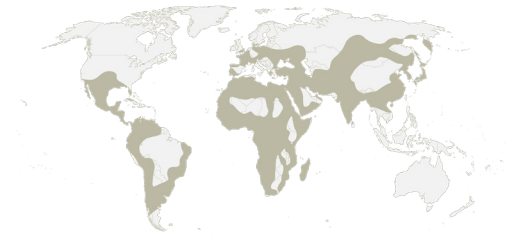
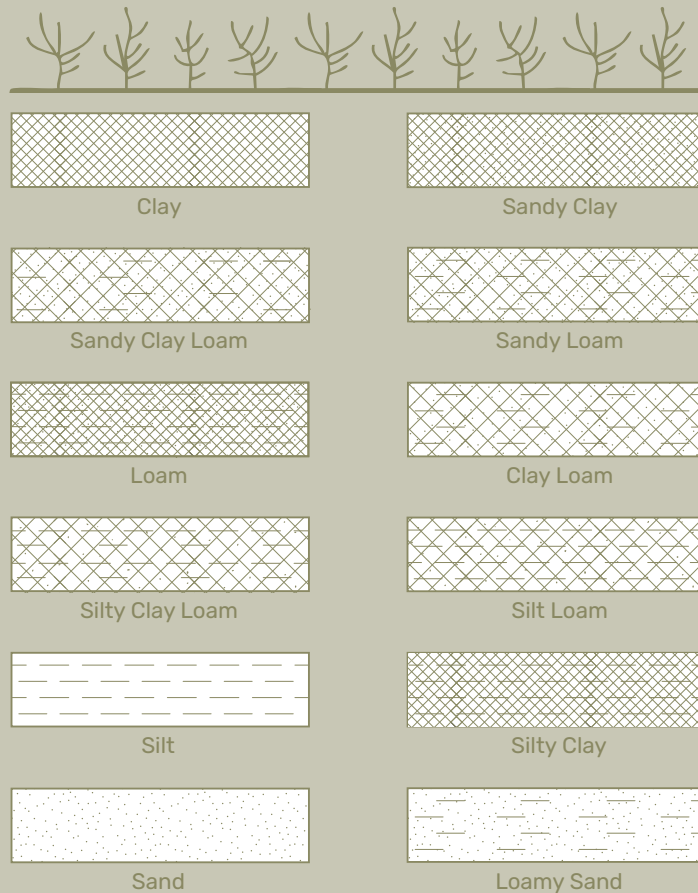
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## Networks & Groups

### **APCOR (Portuguese Cork Association):**

The global leader in cork representation (since Portugal produces ~50% of the world's cork).

Source Map: Areas with Tradition of Earthen Construction<sup>58</sup>

## EARTH

Unreinforced rammed earth walls up to ~11–15 m in (36–49 ft) in height<sup>53</sup>

Unstabilized earth compressive strength ~1.7 N/mm<sup>2</sup> (250 psi)<sup>54</sup>

Globally ~8–10% of homes are made from earth<sup>55</sup>

Adobe embodied carbon ~94 kgCO<sub>2</sub>e/m<sup>3</sup><sup>56</sup>

Adobe buildings of Taos Pueblo have been lived in continuously for over ~1000 yrs<sup>57</sup>

### Source

Earth shares many of the natural, non-toxic, and low-carbon properties of bio-based materials and is frequently used alongside them. Engineering science classifies these particles based on their diameter: clay particles are smaller than 0.002 mm; silt ranges from 0.002 to 0.06 mm; and sand falls between 0.06 and 2 mm. Particles with a diameter larger than 2 mm are categorized as gravels and stones. In construction contexts, “earth” typically refers to unfired mineral-based

### Best used for:

Load-bearing walls (where permitted); high-mass enclosures, interior finishes.

### Key considerations:

Detailing for moisture protection governs durability more than material strength; ; architectural simplicity particularly in seismic areas

materials where clay acts as the primary binder. Clay particles have an electrostatic charge, which creates an attractive force between particles. There are different clay minerals that can have different crystalline structures and therefore characteristics. Earth is naturally a combination of different sized particles, the ratio of which can be adjusted by mixing different sources of earth together.

**Geology**

Earth, considered a non-renewable but abundant resource globally, is primarily composed of eroded rock from the earth’s crust, a process that occurs over geological timescales. The final composition and characteristics of the resulting earth are highly dependent on specific local environmental conditions. Due to earth’s importance in agriculture and construction, most communities understand the earth in their region through maps, descriptions, or passed down knowledge.

Soil and earth are fundamentally different but often used interchangeably. Soil is the dynamic, living ecological system that forms the biologically active upper layer of the ground, supporting plant growth, nutrient cycling, water filtration, and biodiversity, while earth, in the context of construction, is a naturally occurring mineral-based mixture engineered for performance rather than ecological function, with organic matter intentionally minimized to ensure stability and durability.



Gravel %	Sand %	Silt %	Clay %	Source
	30-75	10-30	10-40	ARUP, 2013. Low tech soil and block testing
35	30	-	35	Dbaieh, M., 2009. Building with Rammed Earth - A practical experience with Martin Rauch
-	-	-	40	Berge, B., 2009. The Ecology of Building Materials
	55-70	15-25	10-20	Ministry of living, construction and sanitation Peru, 2017. Design and construction with reinforced earth.
	35-70	10-30		Walker, P., 2001. The Australian Earth Building Handbook
-	-	-	5-29	Houben, H. & Guillaud, H., 1994. Earth Construction: a Comprehensive Guide
	70-80		10-15	Brown, P. W. & Clifton, J. R., 1978. Adobe I: The Properties of Adobe.
	-	-	25-45	Boudreau, E. H., 1971. Making the Adobe Brick
15-20	45-55	10-20	10-20	Sri Lanka Standards Institution, 2006. CSEB draft part 3 production and use of CSEB
15	50	15	20	Centre of Resilience Development, 2012. Standard Norms and Specification for CSEB block.
0-10	50-80	10-40	5-18	Bureau of Indian Standards, 2013. Stabilized Soil Blocks used in general.

**Culture & History**

Clay is nearly universal in the human creation story across the world. In Greek mythology, Prometheus fashioned humans from clay. In the Hebrew creation narrative, God forms Adam from the dust of the ground. Many pueblo communities in the Southwest U.S. have origin stories connected to earth and pottery. In Chinese mythology, Nüwa shapes humans from yellow earth. In Yoruba (West Africa) cosmology, the god Obàtálá molds humans from clay. In Latin, Homo (Human) and Humus (Soil) share the same root.

In North America, Indigenous peoples built with earth long before European colonization, using adobe and rammed earth in the Southwest, and earth lodges on the Great Plains. Spanish colonists expanded adobe traditions, leading to distinctive regional architectures in the American Southwest and California. There is still a strong cultural affinity with earth construction in the Southwest and tribal communities. Taos Pueblo, NM, made from adobe, has been inhabited since ~1000-1450 AD.<sup>60</sup> It is estimated that globally, 8-10% of present-day homes are made from earth.<sup>61</sup> When working with Indigenous communities it may be important to discuss earth construction from a cultural and spiritual perspective.

1. Outer bounds of literature recommended soil particle distribution for earth construction shown in Table 1
2. Table 1 Literature recommended particle size distribution for earth construction

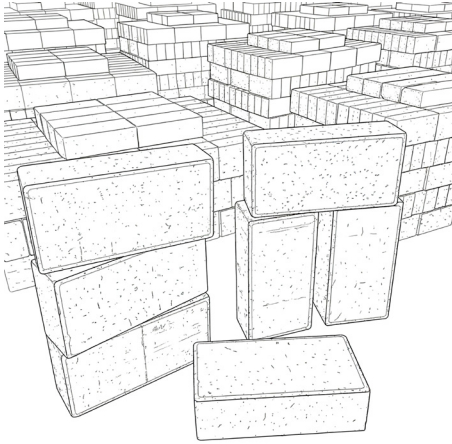
**Excavating**

Earth for construction may be sourced from on or off-site excavation, aggregate byproducts, or waste streams from mining and infrastructure projects. Soil dug from depths of less than 450 mm (16 in) usually contains plant matter and humus (the product of rotting plants), which consists mainly of colloidal particles and is acidic (pH-value less than 6). Topsoil containing humus should be excluded from earth mixes.

**Making**

To break down clods of earth the soil can be ground or soaked and allowed to dry. Depending on the size and type of the final product, large particles are sieved out of the earth.

Sometimes clay, sand or gravel is added to improve adhesion and particle distribution. This guide focuses on unfired earth construction, where stabilizers may be added to improve strength, durability, or moisture resistance. Stabilizers range from widely used mineral binders (lime, cement), petrochemical ones such as bitumen, and experimental or regionally specific bio-based additives (e.g., plant extracts, urine).<sup>59</sup> As increasing amounts of cement are introduced, clay-based binding mechanisms become less dominant and cement hydration products begin to govern performance. The soil-cement mixture behaves more like a low-strength concrete, exhibiting higher compressive strength and durability, but reduced working time and vapor permeability. In high clay content soils, adding cement can actually decrease strength until it becomes the dominant binder. Lime acts differently from cement by modifying clay particle



interactions, which increases strength and durability, but largely maintains the vapor permeability of earth. In certain Indigenous communities in the U.S. it may be inappropriate to use stabilizers that do not allow the earthen material to naturally return to the ground. Designers should verify performance data and code acceptance when specifying non-standard stabilizers. Fibers, most commonly plant fibers such as straw, can be added to control shrinking in unfired clays.

Water is added to the mix to activate the binding strength and achieve workability. For compacted products like compressed earth blocks and rammed earth, the optimum moisture content (OMC) is the water level at which a soil can be compacted to achieve its maximum dry density.

### Featured Applications

#### Structure & Envelope:

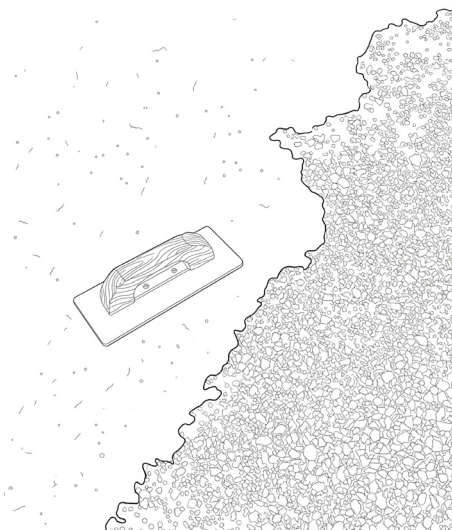
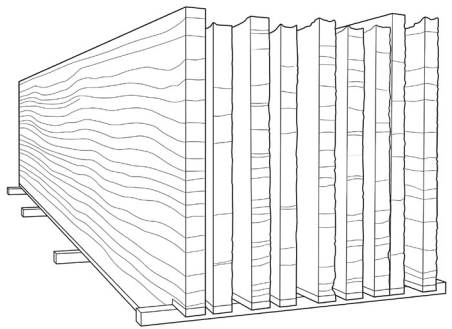
- 3D printed earth
- Adobe
- Rammed Earth
- Cob
- Compressed Earth Block (CEB)
- Compressed earth tiles
- Exterior clay plasters (in certain climates)

#### Insulation:

- Light straw clay (detailed in the Straw section)

#### Interior Finishes & Applications:

- Earth plaster
- Clay paint
- Clayboard
- Earthen flooring



### Care & Maintenance

Earth construction is particularly susceptible to water, abrasion and impact. Earth can be stabilized enough so that it can be extremely durable, often acting like a weak cementitious material. Earth buildings succeed or fail primarily through detailing or regular maintenance rather than material strength. It is common to design earth buildings with a “good hat, boots, and coat”.

- Hat: roof with adequate overhangs to avoid inclined rain
- Boots: raised off the ground on more durable concrete or fired brick materials to protect against standing water and splash back.
- Coat: a repairable plaster layer or rainscreen to protect against rain.

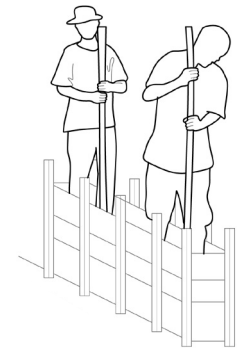
Building maintenance should continue to follow good earth construction practices. It is common to see earth buildings repaired poorly leading to major, often hidden, issues, particularly with regards to moisture and water.

### End of/Next Life

Well cared for and protected earthen buildings can last centuries. Earth with non-toxic stabilizers and fibers can be returned to the earth to erode. Mineral stabilizers like lime and cement can change soil chemistry and cement may contain additives and industrial by-products like fly ash, can often be crushed and reused as fill or aggregate. Organic fibers are biodegradable, but synthetic fibers are not.

### Governing Regulations

IBC Chapter 21 covers masonry with reference to the suite of The Masonry Society (TMS) standards. IBC Section 2109 covers empirical design of adobe masonry referring to TMS 402 Appendix A. IRC Appendices cover Cob Construction (Monolithic Adobe) and Light Straw-Clay Construction. ASTM E2392 is a concise guide, not a regulation, for the design of earthen walls. 14.7.4 NMAC is a New Mexico state code for adobe, rammed earth, and CEB construction for one- and two-family dwellings in which earthen building materials form the bearing wall system. Some cities, like Boulder, CO, have specific ordinances for adobe. Internationally, NZS 4297, 4298 and 4299 from New Zealand are highly respected and have been made available for free.



Rammed earth wall form making

## Technical Design Data

**Thermal:** Earth applications are typically not used for insulation, but have high thermal mass making them excellent for storing and releasing heat in locations with large diurnal temperature swings. Light Straw Clay is used as an insulation and is covered in the Straw section.

**Acoustic:** Thick, dense earth assemblies provide high airborne sound attenuation due to mass. Sound Transmission Class (STC) values range from 45–60+ for adobe, rammed earth, fired brick, and CEB assemblies.

**Density:** Adobe and cob density range 1200–1800kg/m<sup>3</sup> (75–110 lbs/ft<sup>3</sup>). CEB and rammed earth density range 1650–2150kg/m<sup>3</sup> (100–135 lbs/ft<sup>3</sup>).

**Structural:** For reference, fired brick has a compressive strength of 10–20 N/mm<sup>2</sup> (1500–3000 psi). Adobe has a compressive strength of 1.7 N/mm<sup>2</sup> (250 psi).<sup>62</sup> Cob has a compressive strength of 0.4–0.6 N/mm<sup>2</sup> (60–85 psi).<sup>63</sup> Rammed earth and CEB strength is highly dependent on stabilization and can range from 1.7 N/mm<sup>2</sup> (250 psi)(unstabilised) to 20 N/mm<sup>2</sup> (3000 psi)(highly stabilized).

**Fire:** Earth is non-combustible.

**Moisture & Vapor:** Earth materials are vapor permeable and hygroscopic. Adobe, cob, rammed earth, and compressed earth block vapor permeance range of 300–1,700 ng/(Pa.s.m<sup>2</sup>) (5–30 US perms), depending on density and finish. Non-fired earth materials require protection from bulk water exposure through capillary breaks and roof overhangs.

## Strengths & Opportunities

### Human health

- Hygrothermal mass supports passive thermal comfort and humidity buffering
- Non-toxic when unstabilized or stabilized with non-toxic materials

### Ecosystem Health

- Appropriate earth for construction is abundant, so sources with low ecological impact are often available.
- Can provide a high value use for waste from mining or infrastructure projects.
- Excavation pits can be reclaimed after use, therefore reducing impact.

### Climate Health

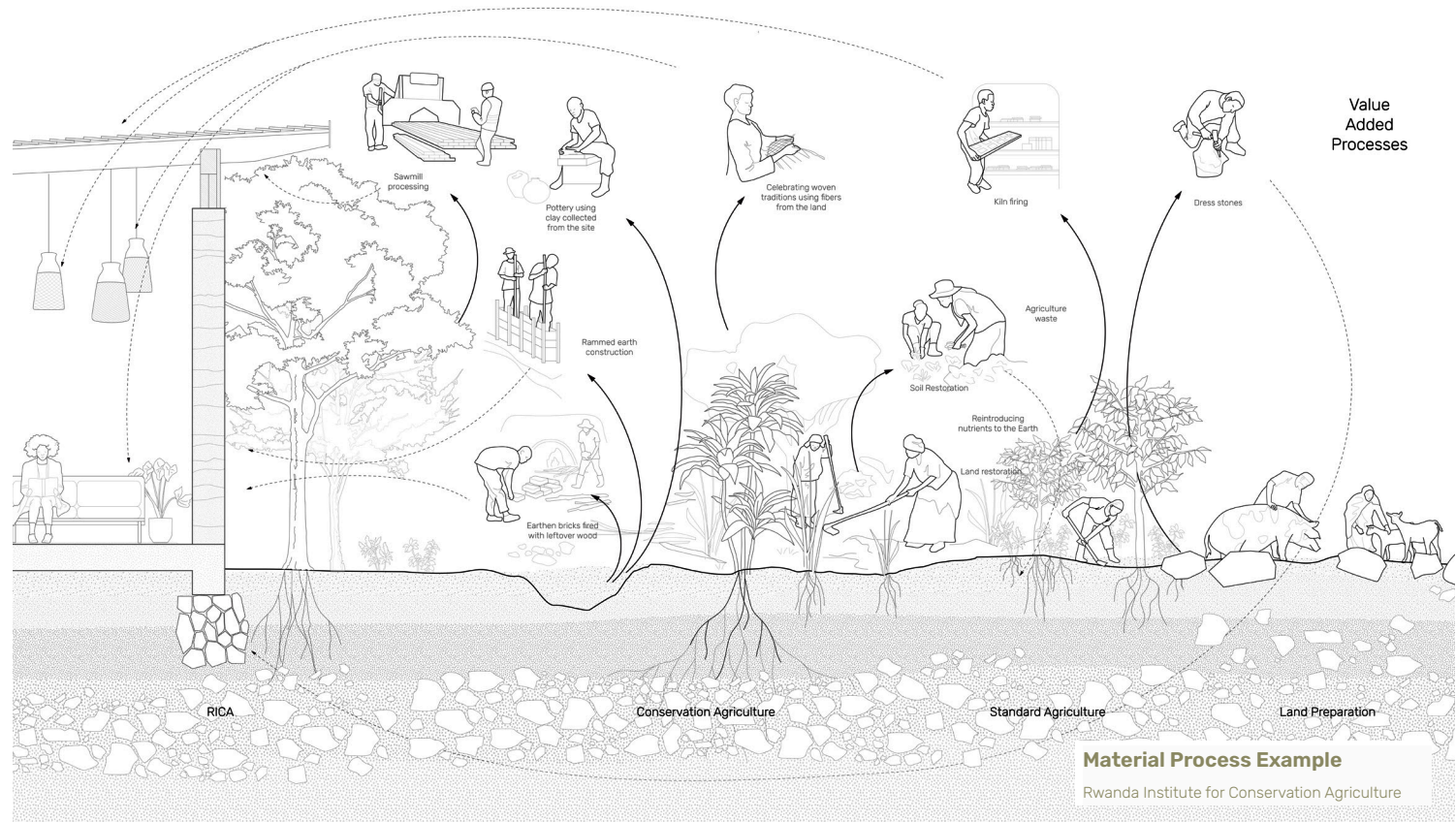
- Extremely low embodied carbon when unstabilized or lightly stabilized. Unfired brick is 5x less carbon intensive than fired brick (94 kgCO<sub>2</sub>e/m<sup>3</sup> vs. 529 kgCO<sub>2</sub>e/m<sup>3</sup>).<sup>64</sup>
- **Cement stabilization significantly increases GWP; ~10% cement yields impacts comparable to concrete blocks.**

### Social Health & Equity

- Can enable local, low-capital construction using regional materials and labor.
- A culture of care for earth buildings can be a source of community building.

### Circular Economy

- Fully reversible and reusable when free of toxic additives and stabilizers.
- Can be crushed for aggregate or fill when common mineral stabilizers are used.
- Long service life achievable through maintenance and protective detailing.



## Challenges & Considerations

- Load-bearing earth construction has architectural design constraints e.g. height, wall thickness, window locations, etc., that need to be understood at concept stage.
- Work with experienced engineers and builders during design, as well as construction.
- Requires experienced builder, as site excavated earth may not always be appropriate for use due to the composition and variability. Field tests can be easily performed to determine if earth is appropriate for construction.<sup>65</sup>
- During construction, lay down and staging areas for materials can be significant, especially if site fabricated.
- Due to moisture sensitivity, earthen elements should be sheltered from rain until roofing is completed, while also allowing adequate air flow.
- Chemical stabilizers can improve strength and durability but also increase risks to planetary and human health.

## Products

*Known bio-based products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework.*

### Structure

- Adobe blocks by [New Mexico Earth Adobes](#)
- Compressed earth blocks by [Colorado Earth](#)
- [Dwell Earth](#) compressed earth block (CEB) systems (Dwell primarily provides CEB equipment and training)
- Puddled and pressed adobe bricks by [Arizona Adobe blocks](#)
- [SIREWALL](#)
- [Watershed Materials](#) / Watershed Block

### Enclosure

- Panels by [Rammed Earth Works](#)

### Interior Finishes

- Clay dry plasterboard and plasters by [ClayTec](#)
- Clay paint by [Auro clay paint](#)
- Clay plasters by [American Clay Loma Plasters](#)
- Clay plasters by [Clayworks Clay Plasters](#)
- Clay plasters by [Gold Hill Clay Plaster](#)
- Clay plasters and paints by [Conluto](#)
- Clay plasters and paints by [Tierrafino](#)
- Drywall alternative by [Lemix](#)
- [Rammed Earth Works](#)
- Wall tiles by [Criaterra Wall Tiles](#)



# Hortus

**Location:** Allschwil, Switzerland

**Climate Zone (ASHRAE):** 5A

**Year:** 2025

**Architect:** Herzog & de Meuron

**Structural engineer:** ZPF Ingenieure AG

Completed in 2025, Hortus (House of Research, Technology, Utopia, and Sustainability) is a 14,100 m<sup>2</sup> timber office building with 600 workplaces developed for Switzerland Innovation Park near Basel. Material strategy drove the design from the outset. The project minimizes high-embodied-carbon materials while prioritizing renewable and locally sourced materials such as mass timber, rammed earth, and wood fiber insulation. The building's compact form and reduced glazing area further limit carbon-intensive components.

The primary structure is a multi-story timber frame fabricated from wood sourced from nearby Swiss forests and prefabricated by timber contractor Blumer-Lehmann. Structural components are assembled using mechanical joinery rather than adhesives, allowing the structure to be dismantled and reused at the end of its life.

The project's most significant material innovation is its hybrid timber-earth floor system. Each floor module consists of a prefabricated timber frame infilled with unstabilized rammed earth shaped into shallow vaults between beams. The dense earth layer provides fire resistance, acoustic performance, and thermal mass,

**Rammed-earth specialist:** Lehm Ton Erde

**Materials:** mass timber structure, hybrid timber-rammed earth floor, wood fiber insulation.

**Source:** [Herzog & de Meuron](#)

improving interior comfort by absorbing heat during summer conditions. Earth excavated during site construction was reused directly in the slabs, which were manufactured in a temporary on-site field factory before installation. The timber-earth slabs generate approximately ten times less CO<sub>2</sub> than conventional reinforced concrete slabs with equivalent structural capacity. The system had to meet strict fire safety requirements and pass project specific testing.

The building integrates a ~5,000 m<sup>2</sup> photovoltaic system across the roof and parapets, generating a surplus of renewable electricity. As a result, the building is projected to offset the embodied energy of its construction within approximately 31 years, after which it will be energy positive. The estimated embodied carbon is 5 kgCO<sub>2</sub>e/m<sup>2</sup>/yr, 44% lower than the SIA 2040 benchmark.

Together, these strategies position Hortus as a leading example of material-driven decarbonization in office construction, demonstrating how structural innovation, local sourcing, and circular design can dramatically reduce embodied carbon in large commercial buildings.



1. Interior view. Image by Maris Mezulis.
2. Pre-fab module construction install. Image by Herzog & De Meuron
3. Section. Render by Herzog & de Meuron.



# Owe'neh Bupingeh Rehabilitation & Preservation

**Location:** Ohkay Owingeh, NM, USA

**Climate Zone (ASHRAE):** 5B

**Year:** 2023

**Architect:** Model of Architecture Serving Society (MASS), Atkin Olshin Schade (AOS) Architects

**Materials:** Adobe, Earth Plaster

**Source:** [MASS](#)

The Owe'neh Bupingeh Preservation Project at Ohkay Owingeh, a Tewa-speaking Pueblo established over 700 years ago in Northern New Mexico, addresses the critical deterioration of its historic village core. When planning began in 2005, many ancestral dwellings were in such poor condition they were uninhabitable, creating a life-safety hazard that threatened the community's cultural existence. In collaboration with the Ohkay Owingeh Housing Authority, the project team guided the community through a self-determined preservation approach based on specific tribal values. This initiative balances the functional renovation of nearly 60 adobe homes with the preservation of the village plazas, allowing contemporary life and cultural traditions to comfortably coexist.

The technical intervention focused on reversing the tremendous damage caused by impermeable cement plaster installed in the 1970s. By removing the cement and reintroducing traditional mud plaster and earthen materials, the project restored the breathability of the structures while reducing transportation costs, extensive processing, and the use of VOC-laden

materials. Modern amenities, such as the burial of overhead electrical lines and complete infrastructure replacement, were integrated discreetly to maintain the area's traditional form. Five construction phases have been completed to date, resulting in the rehabilitation of 45 historic homes.

Central to the project's success was a workforce development program that trained over 20 Tribal members in traditional adobe and mud plaster restoration techniques. This labor-intensive process returned ancestral technology to the community, empowering residents to become regional and even international experts in adobe restoration. This collaborative model, which began with a modest \$7,500 grant and leveraged over \$13 million in funding, has been hailed as a national standard for preserving traditional communities. Ultimately, the project reinforces the community's social and cultural connection to their built environment and the land.



1. View from the plaza. Image by Minesh Bacrania
2. Mixing earth plaster. Image by Minesh Bacrania
3. Applying earth plaster. Image by Atkin Olshin Schade Architects



# Rwanda Institute for Conservation Agriculture

**Location:** Bugesera, Rwanda  
**Climate Zone (ASHRAE):** 2A  
**Year:** 2023  
**Architect/Builder:** MASS  
**Structural Engineer:** MASS, Arup

**Materials:** Rammed Earth, Compressed Earth Blocks, Fired brick, Clay roof and facade tiles, Stone Foundations, Wood trusses and structure  
**Sources:** [MASS](#), [Best Practices Handbook](#)

The Rwanda Institute for Conservation Agriculture (RICA) is a 69 building climate-positive campus in Bugesera, Rwanda built with local materials and craftsmanship. Over 96% of building materials by weight were sourced within Rwanda, including earth, stone, timber, clay, and plant fibers. Structural foundations are constructed from locally quarried stone masonry, laid by hand using traditional techniques that significantly reduced concrete use while reinforcing durable, place-based knowledge.

Walls across the site were made with site-produced compressed earth blocks and rammed earth, using soils selected through indigenous expertise and validated through rigorous engineering testing for strength, durability, and seismic performance. Approximately 2.5 million earth blocks were produced on site in one of the largest-scale, institutional applications of these material forms to date.

Labor was treated as a design resource rather than a cost to be minimized. Thirty-five percent of the construction budget was spent on labor, and 90% of the workforce was hired locally. Skills in natural building extended beyond the project itself: as a direct outcome of RICA, trained earth

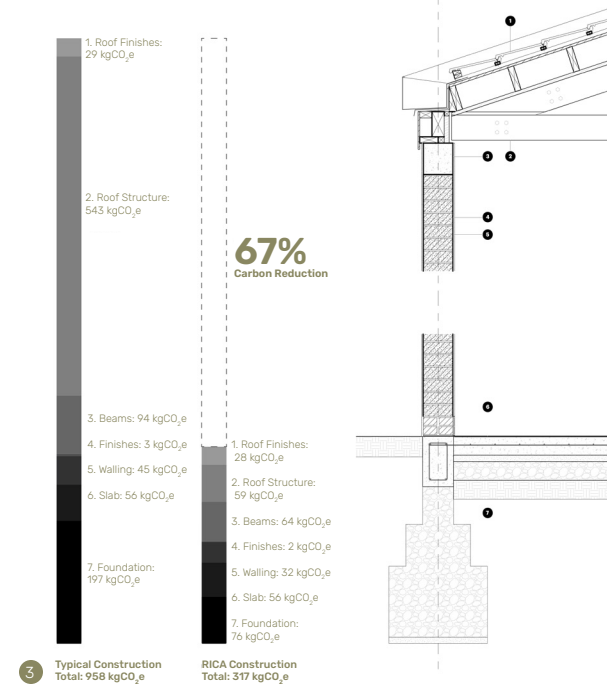
masons formed Rwanda’s first rammed earth construction cooperatives, which went on to build projects nationwide, including hotels and public buildings, establishing a newly growing construction typology previously absent in the country. Earth is typically considered a poor person’s material, but projects like RICA have changed the perception.

Material systems were further expanded through the use of clay tiles fired with agricultural waste, FSC-certified timber roof structures, and furniture and shading elements woven from papyrus, bamboo, banana, palm, and sisal. By coupling architectural production with skills training, cooperative formation, and regulatory advancement in earth construction, RICA demonstrates how natural materials, when paired with labor-intensive, knowledge-rich processes, can generate enduring social, economic, and environmental value well beyond the site itself.

The buildings demonstrate a 65% reduction in upfront embodied carbon, and the whole project, including infrastructure and landscape is expected to be Climate Positive, sequestering and storing more CO<sub>2</sub> than is emitted, by 2040.



1. RICA, Photo by Iwan Baan.
2. Brick wall construction, Photo by MASS
3. Building Section, image by MASS.





# The Theodore Roosevelt Presidential Library

**Location:** Medora, ND, USA

**Climate Zone (ASHRAE):** 6A

**Year:** 2026

**Architect:** Snøhetta and JLG Architects

**Builder:** JE Dunn

**Materials:** Mass timber (CLT and Glulam);

Rammed Earth

**Sources:** [ENR](#), [TRPL](#), [Snøhetta](#)

The Theodore Roosevelt Presidential Library in Medora, North Dakota, is a 95,000sf cultural landmark under construction that exemplifies material innovation aligned with conservation values. The library combines steel framing and mass timber as its primary structural systems. A robust steel framework provides the main load-bearing skeleton, while Douglas Fir engineered wood, 87,000 ft<sup>3</sup> of glulam, cross-laminated timber (CLT) and column wraps, forms the expressive curved roof and exposed interior structure that supports a living, planted roof assembly. Steel columns and girders are frequently clad in glulam to maintain aesthetic continuity and connect the two systems.

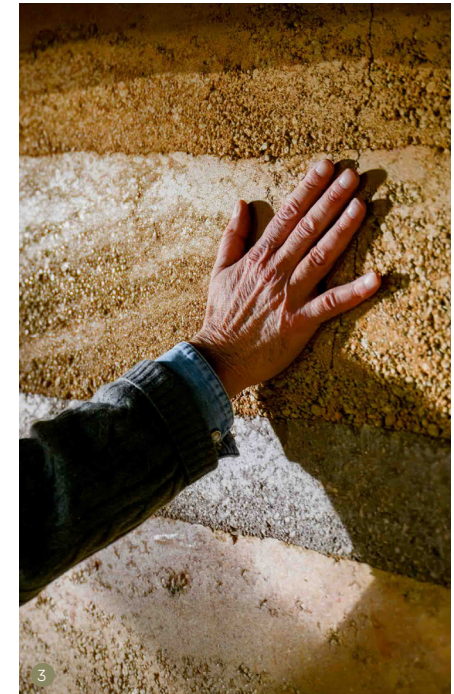
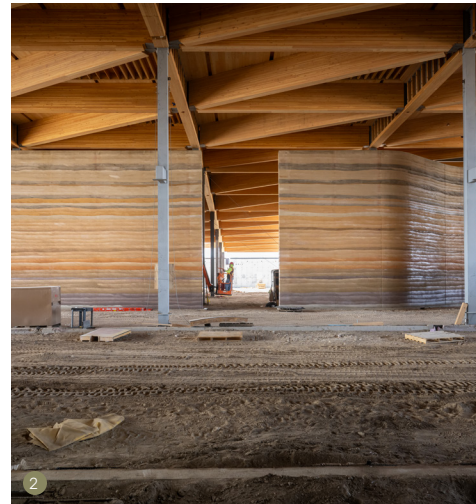
The use of mass timber represents the largest deployment of engineered wood in North Dakota to date. The project also uses a significant amount of reclaimed timber for flooring, finishes, signage and furniture.

Complementing timber, the library incorporates approximately 11,850 ft<sup>3</sup> (221.5 ft x 26.75 ft average height x 2 ft wide) rammed earth walls, locally derived soil compressed into layered finishes that echo the Badlands' stratigraphy. Soil was sourced from Dickinson, ND, less than 50 miles away, and combined with

approximately 8-9% portland cement as a stabilizer. The walls achieved a compressive strength of 1,530 psi at 56 days. While not part of the superstructure, the walls are largely self supported by virtue of their shape, with a few lateral tiebacks to columns but no connection to the roof. The 2 ft thick rammed earth walls are rammed in-situ with steel reinforcement. The sub-contractor was Earth Wall Builders, who train and manage local concrete sub-contractors to execute the work. The local team that did the work was Winn Construction.

The living roof, with 16 in of soil is planted with native grasses and prairie species, blurs the boundary between architecture and landscape while enhancing thermal performance, stormwater management, and biodiversity.

The project also explores low-carbon concrete mixes with a performance based spec that reduced the GWP by 49%. The library is targeting Living Building Challenge certification, LEED Platinum and SITES, aiming for net-zero energy, water, waste, and emissions, making it among the most ambitious green cultural institutions in the U.S.



1. Rammed earth walls and mass timber roof. Render by Plomp, courtesy of Snøhetta
2. In Construction. Photo by Chad Ziemendorf, courtesy of the Theodore Roosevelt Presidential Library
3. Rammed earth wall, Photo by Chad Ziemendorf, courtesy of the Theodore Roosevelt Presidential Library

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## Networks & Groups

[Adobe In Action](#): Empowering owner-builders through online classes and hands-on workshops, this organization focuses on traditional adobe production and sustainable home construction techniques.

[Earth USA](#): The premier biennial international conference held in New Mexico, focusing on the latest advancements in architecture and construction using earth.

[The Adobe Alliance](#): Founded by Simone Swan, this group preserves vaulted earthen architecture, teaching communities to build affordable, beautiful, and thermally efficient homes.

[The Earthbuilders' Guild](#): A professional trade association dedicated to preserving and promoting earthen construction through advocacy, workforce education, and updated building code standards.

[The Earthen Construction Initiative](#): This nonprofit fosters sustainable building practices by providing technical resources, community outreach, and professional training for modern earthen masonry projects.



## FLAX

Peak growth rate ~3–5 cm/day (1.2–2 in/day); mature height ~0.3–1.2 m (1–4ft)<sup>66</sup>

Harvest ready after ~90–120 days; 1–2 crops/yr<sup>67</sup>

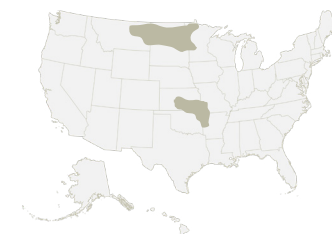
Biomass yield ~1.2–4.5 t/ha/harvest, ~1.2–9 t/ha/yr<sup>68</sup>

Biogenic Carbon storage ~1.4–1.8 tCO<sub>2</sub> per dry t of flax straw<sup>69</sup>

Harvested above-ground biomass sequestration rate ~3.7–12 tCO<sub>2</sub>/ha/yr<sup>70</sup>

### Source

Flax (*Linum usitatissimum*) is a bast-fiber and oilseed crop native to the eastern Mediterranean through India. Today, in North America, it is primarily sourced from Canada (Manitoba, Saskatchewan, Alberta) and the northern United States (North Dakota, Montana, Minnesota). Significant production also occurs across Europe, with additional cultivation in parts of Africa and Asia.



Source Map

### Best Used For:

Vapor-open insulation; textiles; flooring and acoustic panels; oils and paints

### Key Design Consideration:

Detailing and moisture management; variability tied to harvesting and fiber processing quality; additives and binders when used in composites; fire performance; lack dedicated building code recognition

**Ecology & Growing**

Flax is an annual plant historically valued for its strong fibers. It typically grows 3–4 feet tall and performs best in deep, organic-rich loam soils. Flax is well-suited to cool climates and is sensitive to heat stress. It is planted in early spring as soon as soils are workable, has a relatively short growing season of approximately 90–110 days, and is harvested in mid- to late summer, depending on latitude and whether it is grown for fiber or seed.

Ecologically, flax is a low-input crop that typically requires no irrigation, fertilizers, herbicides, or pesticides, reducing impacts to soils and waterways. Its flowers support pollinators, and when integrated into mixed or rotational cropping systems, flax can diversify cereal-dominated agricultural landscapes, improve soil productivity over successive years, and enhance biodiversity. Flax cultivation produces minimal waste, as all parts of the plant can be utilized, and it sequesters an estimated 3.7 tCO<sub>2</sub> per hectare annually, strengthening its ecological value relative to more input-intensive monocultures.

**Culture & History**

Flax has one of the longest known material histories, with evidence of fiber use dating back 30,000 years in present-day Georgia and widespread cultivation across the Fertile Crescent by 9,000 years ago. Flax linen held cultural and symbolic importance in ancient Egypt, Greece, Rome, and medieval Europe, associated with purity, durability, and everyday utility. Colonists introduced flax to

North America in the 1600's, where it became a common household fiber crop for clothing, sailcloth, and rope until cotton displaced it in the 19th century. Today, flax remains significant as an oilseed crop, with renewed interest in its fibers for sustainable textiles and bio-based building materials.

**Harvesting & Processing**

Flax for fiber is harvested by pulling plants up with roots attached to preserve fiber length; stems are laid in windrows to field-rett, where moisture and microbes in the soil break down pectins binding fibers to the woody core. Once dried, straw is baled and processed through breaking, scutching, and heckling to separate long fibers, short tow, and shives. For seed production, cut, typically with a combine, and dry plants before threshing. Retting lasts 2–8 weeks, depending on the climate. Shives and straw, formerly burned, are now often sorted and used for panels, insulation, and composites.

**Making**

Flax is transformed into multiple products by separating and refining its components. Long bast fibers are spun and woven into linen textiles or blended with materials like bio-epoxies to form lightweight building composites. Short fibers and shives are combined with lime or cement to create vapor-open hempcrete like materials, or with binders for insulation, panel boards, and acoustic materials. Flaxseed is pressed to produce linseed oil, a drying oil used in paints, varnishes, putties, and linoleum

(made with oxidized linseed oil, cork dust, wood flour, pigments, and jute backing). This whole-plant utilization supports diverse, low-waste product streams.

**Featured Applications**

Flax and its co-products lend themselves to a remarkably wide spectrum of building uses, from structural composites to refined interior finishes. Because the plant yields multiple functional materials (long fibers, short fibers, shives, and oil) designers can specify flax across systems that require strength, acoustic or thermal performance, durability, and natural aesthetics. These applications span structural envelopes, interior systems, and finishes, supporting both performance-driven and ecological design goals.

Structure & Envelope:

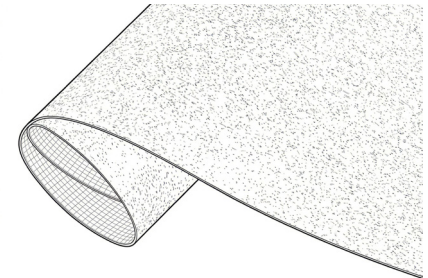
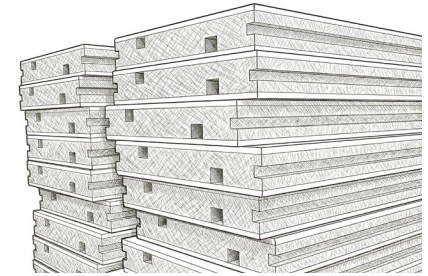
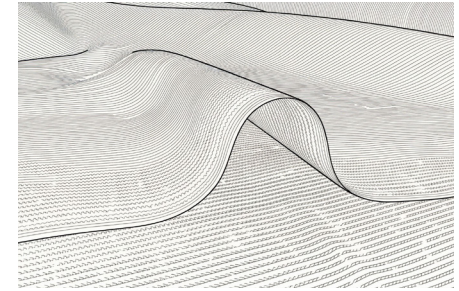
- Flax-fiber composites (lightweight structural components)
- Flax-reinforced concrete
- Flax-shive bio-concretes / lime-shive mixes
- Flax-based panels
- Flax reinforcement for wood panels

Insulation:

- Flax-based insulation batts

Interior Finishes & Applications:

- Linseed oil finishes (protective coatings, sealers)
- Linseed-oil paints and natural putties/mastics
- Linoleum flooring and wall surfacing
- Linen textiles
- Acoustic panels
- Interior partition boards
- Linen fabrics
- Door cores



**Care & Maintenance**

Flax-based materials perform best when kept dry from bulk water but allowed to breathe, as their thermal and hygric properties depend on vapor openness. Flax insulation shows slight conductivity increase with humidity, and flax-shive concrete need drying pathways. Linseed oil finishes require periodic reapplication as they cure oxidatively over time.

**End of/Next Life**

Flax supports multiple circular pathways: all plant components can be reused, with fibers, shives, and straw entering products such as insulation, panels, and composites. Many flax-based materials are biodegradable or suitable for bio-energy recovery, while composite elements can be downcycled or mechanically recycled. Local cultivation further reduces transport impacts and supports regional bio-economies.

**Governing Regulations**

Flax does not yet have material-specific code provisions in major building regulations, so products are typically evaluated through existing performance-based pathways. Flax insulation has been tested under European reaction-to-fire classifications and achieves Class E, indicating the need for protective layers in regulated assemblies. Research on flax composites and flax-shive concretes demonstrates compliance with conventional testing frameworks for thermal conductivity, hygric behavior, mechanical performance, and durability,

but approvals remain product-specific rather than universal. Broader bio-based code developments, such as the International Code Council (ICC) appendices for straw bale and earthen materials, signal increasing openness, yet flax products generally require project-by-project certification, documentation, or evaluation reports to demonstrate equivalence with conventional materials.

**Technical Design Data**

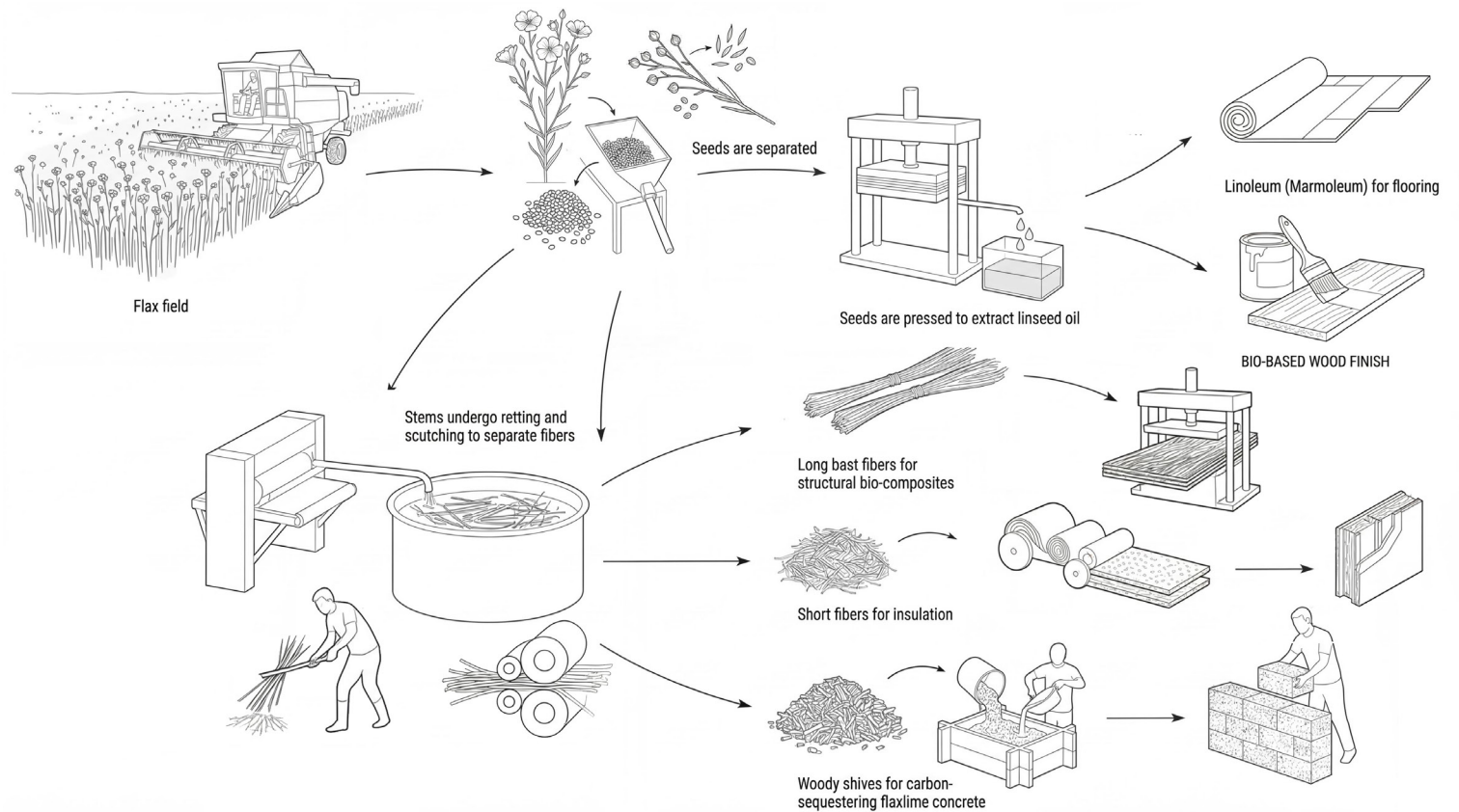
Flax’s performance varies by fiber type, moisture conditions, and its integration with binders such as bio-epoxies, lime, or mineral wool. Bast fibers provide high tensile capacity, while shives contribute to thermal and hygric regulation in composite systems.

**Thermal:** Thermal resistance ranges from RSI-0.55 to 0.66/25mm (R-3.1 to 3.7/in) for flax-shive insulation<sup>71</sup> and ~RSI-0.13/25mm (R-0.7/in) for flax-shive concretes, offering a lower conductivity than conventional

concrete and strong moisture-buffering (MBV = 2.3 g/(m²·%RH); sorption ≈ 120 kg/m³).<sup>72</sup> These properties enable vapor-open, hygrothermally stable wall assemblies.

**Structural:** Flax fibers exhibit tensile strengths of 343–2000 MPa (50–290 ksi) and modulus of elasticity of 27–103 GPa (3,900–15,000 ksi), supporting their use in structural composites.<sup>73</sup> Low density (1.4–1.5 g/cm³) (~90 lbs/ft³) gives high specific strength relative to many natural fibers.

**Density:** Flax–mineral wool insulation:



**Material Process Example**

~23 kg/m<sup>3</sup> (~1.4 lbs/ft<sup>3</sup>). Flax-shive concretes: lightweight, with densities lower than mineral concretes.

**Fire:** Flax-based insulation tested as Class E, indicating combustibility and the need for protective layers in assemblies.

**Moisture & Vapor:** Vapor-open behavior ( $\mu = 10$ ) enables assemblies to dry; thermal conductivity shows only modest sensitivity to humidity. Strong moisture-buffering in flax-shive mixes regulates interior humidity.

**Acoustic:** Flax insulation and composite panels achieve strong sound absorption, with performance relatively stable across humidity variations.

Flax materials offer a lightweight, vapor-open, high-tensile, and potentially carbon-storing option for insulation, composites, and bio-concretes. Their hygric stability and high mechanical performance make them suitable for applications ranging from interior systems to advanced composite structures.

## Strengths & Opportunities

### Human health

- Flax-based materials are low-emitting, vapor-open, and breathable, helping regulate humidity and reduce mold risk.
- Linseed oil finishes provide a natural alternative to petrochemical coatings, lowering exposure to solvents and additives.
- Linen textiles offer non-toxic, hypoallergenic interior surfaces suitable for sensitive occupants.

### Ecosystem Health

- Rotational and polyculture systems improve soil health and biodiversity.
- Flax is naturally pest-resistant, reducing dependency on toxic pesticides.
- Full-plant utilization minimizes agricultural waste and ecological footprint.
- Flax can be easily integrated into mixed cropping, which enhances resilience compared to resource-intensive monocultures.

### Climate Health

- Flax cultivation sequesters ~3.7 t CO<sub>2</sub>/ha annually.<sup>74</sup> The flax fiber sequesters 1.5 to 2 kg CO<sub>2</sub>/kg.<sup>75</sup>
- Fibers and shives enable low-carbon composites, insulation, and moisture-buffering concretes.
- Local cultivation is possible, which reduces transport emissions and strengthens regional supply chains.
- Replacing carbon-intensive materials with flax-based products supports decarbonization goals.

### Social Health & Equity

- Flax supports agricultural livelihoods in fiber- and oilseed-producing regions.
- Growing bio-based markets create rural economic and manufacturing opportunities.
- As a heritage crop in North America and globally, flax enables culturally grounded and regenerative design narratives.

### Circular Economy

- Flax is low-waste: fibers, shives, seeds, and straw feed diverse product streams.

- Many flax-based materials are biodegradable or compostable, supporting biological cycling.
- Shives and straw can replace higher-impact materials in concretes, boards, and geotextiles.
- Flax composites can be recycled or downcycled, reducing landfill waste.
- Local cultivation supports short-loop, reusable material systems.

## Challenges & Considerations

- Flax fibers and shive-based materials are highly hygroscopic; thermal conductivity rises with humidity, and flax-shive concretes require assemblies that avoid bulk water while allowing vapor diffusion.
- Flax insulation achieves only Fire Class E, indicating combustibility and the need for protective layers, fire-tested assemblies, or encapsulation in regulated applications.
- Mechanical properties depend heavily on retting quality, harvesting timing, fiber length, and processing methods, leading to greater variability compared to industrial mineral or synthetic fibers.
- Natural fibers absorb moisture, potentially affecting long-term stability, interface performance, and durability in polymer composites unless adequately protected or treated.
- Flax products lack dedicated building code recognition, requiring performance-based approvals or project-specific documentation, which can slow adoption.

- While low-input, flax is still influenced by climate, soil conditions, and regional infrastructure, and fiber-grade production is geographically concentrated, which may limit consistent global supply.

## Products

*Known bio-based products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework.*

### Enclosure & Insulation

- [Isolina](#) flax thermal and acoustical insulation, batt and semi-rigid
- [IsoNat](#) / Nature! Isolation flax insulation batts
- [Isovlax](#) building insulation

### Interior Finishes

- [Duracyl](#) natural floors
- [Ekoa](#) wall/ceiling coverings by Lingrove
- [Faay](#) flax wall partitions
- Flax Natural Surfaces by [Organoid](#)
- [Forbo](#) Marmoleum/Linoleum flooring/wall/furniture finishes
- [Innovations](#) linen wallcoverings
- [Kravet](#) linen fabrics
- [Linex](#) linen Flaxboard
- [Pindler](#) linen fabrics
- [Schumacher](#) linen fabrics and [wallpapers](#)
- [Tarkett](#) linoleum flooring
- [Wolf Gordon](#) linen wallcoverings



# Caddo National Child Care Center

**Location:** Hinton, Oklahoma, USA  
**Climate Zone (ASHRAE):** 3A  
**Year:** 2025  
**Architect:** MASS  
**Builder:** Arrowood Kakinah Enterprise

**Materials:** Linoleum flooring (Forbo Marmoleum), cedar shake façade, wood frame and glulam structure, cement wood fiber ceiling panels (Armstrong Tectum), laminated paper countertops (PaperStone)  
**Source:** [MASS](#)

The Caddo Nation Child Care Center is a culturally grounded early childhood facility designed to support the Caddo Nation’s youngest members while reinforcing community identity, resilience, and care. Conceived through close collaboration with the Caddo Nation, the project responds to the region’s climate and social context by prioritizing durability, comfort, and a strong connection to place. The building is organized around clear, legible spaces that support safety, supervision, and age-appropriate learning, while also creating a welcoming environment for families and caregivers.

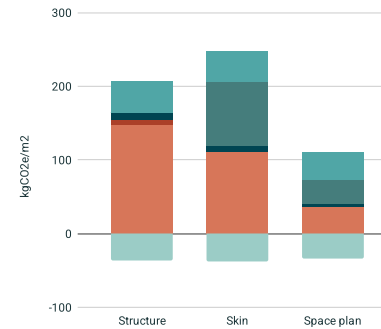
Material choices and environmental strategies are central to the project’s intent. The design emphasizes healthy interiors, natural light, and robust envelope systems suited to Oklahoma’s climate, balancing energy performance with long-term maintainability. Beyond its functional role, the Child Care Center acts as a civic anchor, embedding cultural values into everyday spaces of learning and care. The

project demonstrates how architecture can support Indigenous self-determination by aligning design quality, environmental responsibility, and cultural continuity in a facility that serves both present needs and future generations.

The healthy materials were a priority for this space because children’s developing bodies are typically more impacted by toxins, and they tend to have their hands and faces in closer contact with these materials, increasing their exposure. Forbo Marmoleum floor was used throughout, with the modular tile option preferred for its ease of replacement, and ability to form patterns.



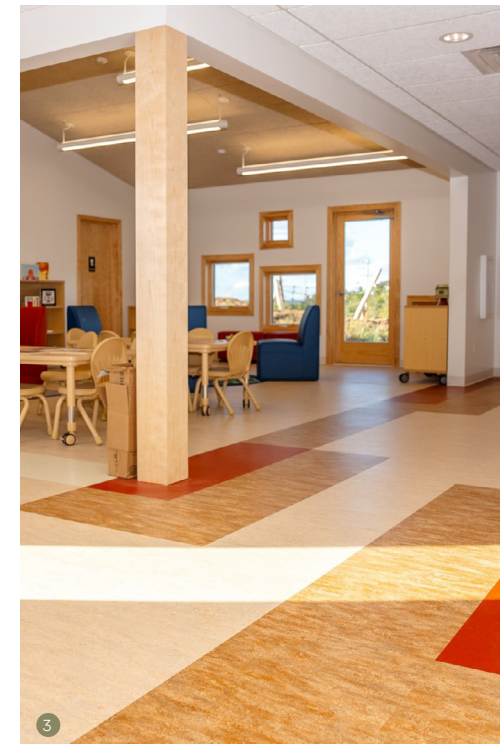
1



2

- Biogenic Storage (A1-3)
- End of Life (C)
- In Use (B)
- Construction (A5)
- Transportation (A4)
- Material Production (A4)

1. Exterior view. Photo by MASS.
2. Embodied carbon LCA. Image by MASS.
3. Interior view. Photo by Mass.



3



# Cité Scolaire Internationale de Jacques Chirac

**Location:** Marseille, France

**Climate Zone (ASHRAE):** 4A

**Year:** 2024

**Architect:** Rudy Ricciotti (Lead) and Roland Carta (Carta Associés)

**Manufacturers:** Bcomp and Temca  
**Builder:** Bouygues Bâtiment Sud-Est

**Materials:** AmpliTex™ technical fabric, a structural fiber-reinforced polymer (FRP) of flax-fiber embedded in a fire-rated resin matrix, reinforced with glass fiber, and wood wool insulation

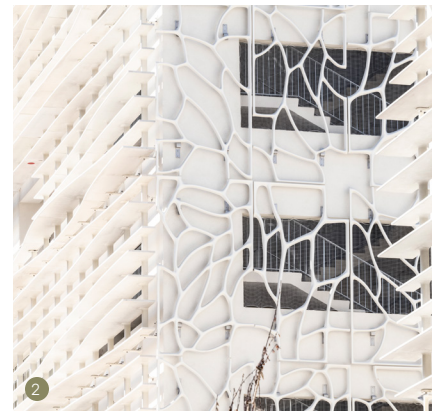
**Sources:** ArchiExpo, [FFB](#), [Abitare](#), [Carta Associés](#), [JEC Composites](#), [Rudy Ricotti Architecture](#)

This scholastic complex represents the largest architectural application to date of flax-fiber composite materials for exterior cladding, covering a surface area of approximately 5,000 m<sup>2</sup>. Developed in response to France's push for material sobriety and low-carbon public construction, the project replaces conventional heavy materials like concrete or glass-fiber reinforced panels with ampliTex™, a flax-fiber technical fabric developed by Swiss cleantech company Bcomp. The façade system emerged through close collaboration between the architects, composite specialists, and the builder.

The cladding consists of 880 openwork façade panels manufactured by French composite specialist Temca using a Resin Transfer Molding (RTM) process. This industrial process ensures high structural precision and a significant reduction in weight; each panel weighs only 18–37 kg, drastically lowering the load on the building's primary structure compared to traditional concrete solutions while enabling efficient installation and structural integration.

The panels are finished with a white gel coat engineered to withstand ultraviolet exposure, Mediterranean salt air, and intense sunlight. Their intricate geometry, featuring five different molded shapes, is specifically tuned to provide optimal solar shading, reducing solar gain and interior energy demands while maintaining a unique architectural identity inspired by traditional Mediterranean trellises. The architects coordinated the technical integration of the system within the broader building envelope, ensuring durability, constructability, and compliance at scale.

Critically, this innovative use of flax-fiber composites was validated through an Experimental Technical Assessment (ATEX) issued by the French Scientific and Technical Centre for Building (CSTB). This certification was essential for the approval of a bio-based composite for large-scale exterior use on a major public building. Together, the project team established a new benchmark for natural-fiber composites in architecture, demonstrating how agricultural materials can transition from aerospace and automotive niches into mainstream, large-scale civic design and construction.



1. View towards the courtyard. Image by Lisa Ricotti
2. View of the ampliTex™ screen. Image by Lisa Ricotti.
3. View from behind the ampliTex™ screen. Image by Lisa Ricotti.



## Hybrid Flax Pavilion

**Location:** Wangen Allgäu, Germany

**Climate Zone (ASHRAE):** 4C

**Year:** 2024

**Design Team & Partners:**

Cluster of Excellence IntCDC (Integrative Computational Design and Construction for Architecture), University of Stuttgart; ICD Institute for Computational Design and Construction; ITKE Institute for Building Structures and Structural Design;

Landesgartenschau Wangen im Allgäu 2024; Stadt Wangen im Allgäu; HA-CO Carbon GmbH; STERK abbundzentrum GmbH

**Materials:** Prefabricated Flax fiber components and CLT panels

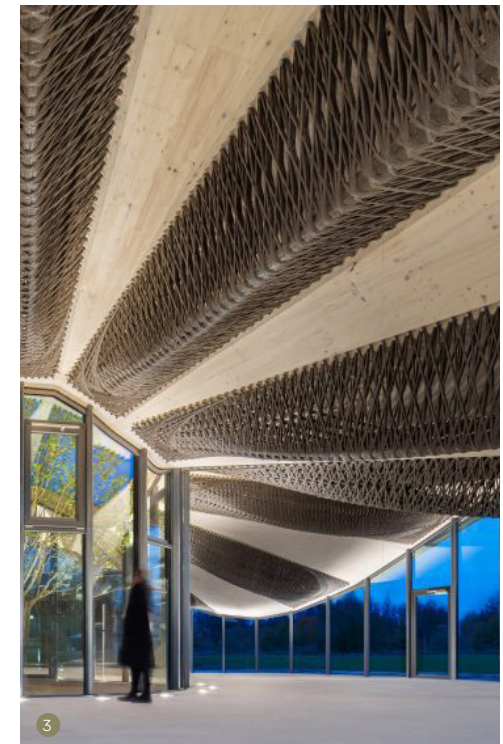
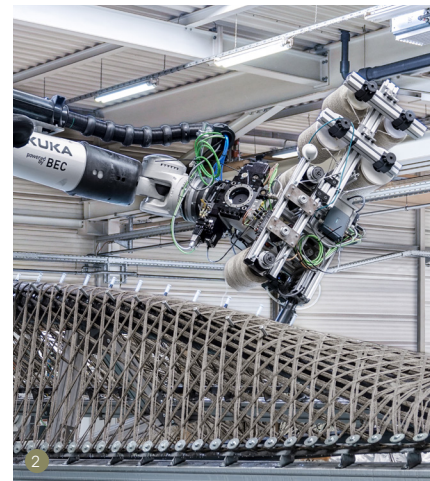
**Sources:** [Dezeen](#); [IntCDC](#), [University of Stuttgart](#)

The Hybrid Flax Pavilion is an experimental bio-based structure developed by the Cluster of Excellence "Integrative Computational Design and Construction for Architecture" (IntCDC) at the University of Stuttgart. The project explores how renewable flax fibers can be combined with cross-laminated timber (CLT) to create a lightweight, high-performance hybrid system that reduces material use and embodied carbon compared to conventional steel- or synthetic fiber-reinforced solutions. Building on the IntCDC's long-standing research into robotic fabrication and fibrous structural systems, the pavilion demonstrates a novel construction method in which robotically wound flax fiber bodies reinforce thin timber plates, uniting the tensile capacity of natural fibers with the compressive strength of wood.

This material synergy enables impressive structural efficiency while avoiding glass- or carbon-fiber composites and their associated environmental burdens.

Through a coreless filament winding process, fibers are placed precisely where structural forces demand them, eliminating molds and reducing waste. The resulting hybrid components are thin, materially optimized, and expressive, achieving a column-free exhibition space through the calibrated interaction of timber and flax. The project illustrates how fast-growing, regionally available bio-based materials can meet demanding architectural performance criteria when paired with advanced digital design and fabrication.

Beyond its technological innovation, the pavilion represents a meaningful step toward scalable, circular construction practices. The system is conceived to allow sorted separation and future material reuse, aligning research-driven fabrication with principles of circular design. As both a permanent public building and a research demonstrator, the Pavilion shows how renewable fibers, computational design, and industrial production can converge to expand the structural and aesthetic possibilities of bio-based architecture.



1. Hybrid Flax Pavilion, view across the Argenwiese. Image by ICD/ITKE/IntCDC University of Stuttgart.
2. Robotic tool effector: Filament winding head with inline impregnation. Image by ICD/ITKE/IntCDC University of Stuttgart.
3. Hybrid Flax Pavilion, interior in empty state. Image by ICD/ITKE/IntCDC University of Stuttgart.

## Further Reading

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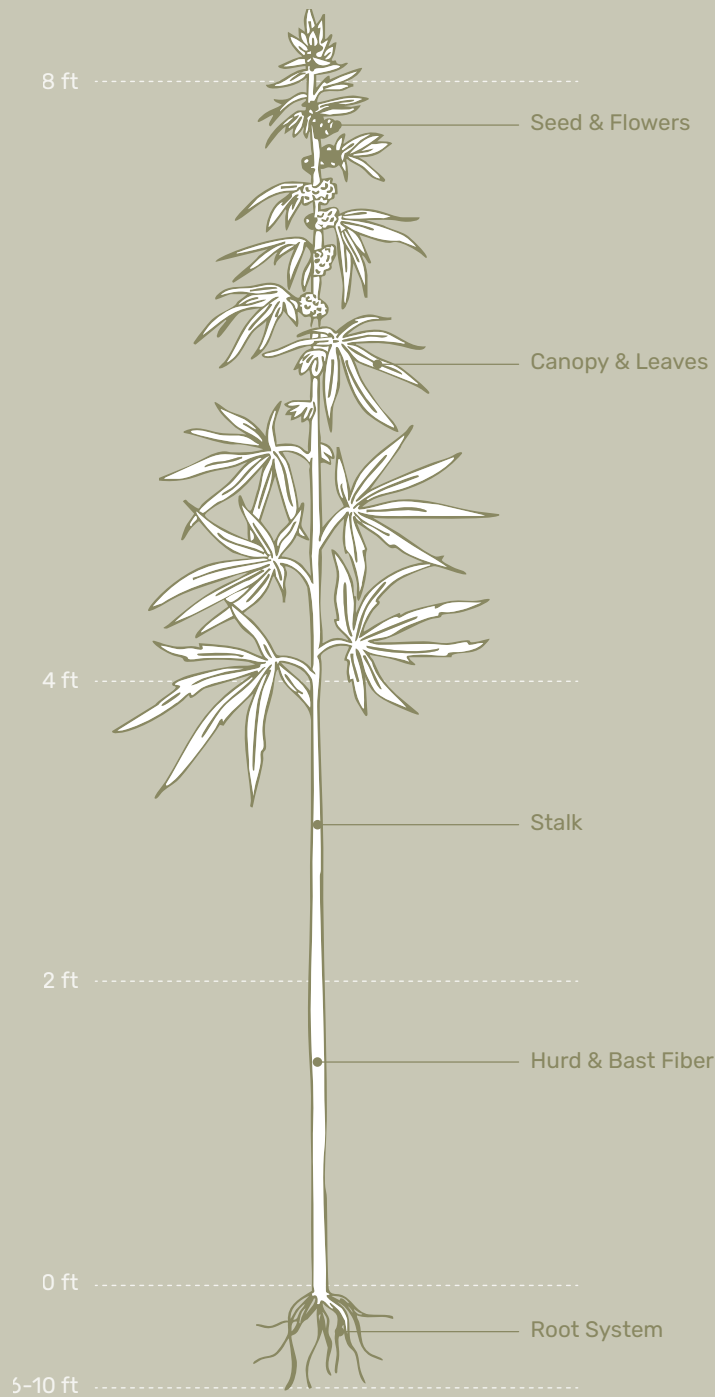
## Networks & Groups

[Alliance for European Flax-Linen & Hemp \(formerly CELC\)](#): The definitive global reference for the industry. They represent their 10,000+ member companies across 16 countries.

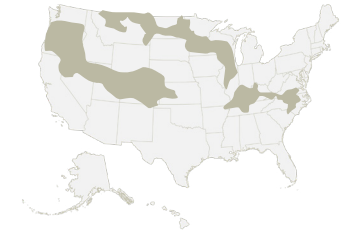
[AmeriFlax](#): Based in North Dakota, this group focuses on the commercial and industrial side of flax, particularly seed, oil, and fiber research for the food and livestock industries.

[North American Linen Association \(NALA\)](#): A trade association for anyone trying to bring flax fiber production and processing back to the U.S. and Canada.

[Saskatchewan Flax Development Commission \(SaskFlax\)](#): Representing the largest flax-growing region in Canada, this commission is a major funder of R&D for new flax varieties and industrial fiber applications.



## HEMP



Source Map

Peak growth rate ~4–6 cm/day (1.6–2.4 in/day); mature height 3–5 m (9.8–16.4 ft)<sup>77</sup>

Harvest ready after ~90–120 days; typically 1 crop/yr; 2 crops/yr in warmer regions<sup>78</sup>

Biomass yield ~ 5–10 t/ha/harvest, ~5–20 t/ha/yr.<sup>79</sup>

Biogenic Carbon storage ~1.4–1.7 tCO<sub>2</sub> per dry t of hemp hurd/shive<sup>80</sup>

Harvested above-ground biomass sequestration rate ~8–26 tCO<sub>2</sub>/ha/yr.<sup>81</sup>

### Source

Hemp is a cultivar of *Cannabis sativa* L. cultivated for fiber, hurd (shive), and seed/oil. While part of the Cannabis genus, industrial hemp is legally distinct from marijuana and must contain no more than 0.3% THC by dry weight<sup>76</sup>.

### Best Used For:

Vapor-open wall infill; insulation; non-structural enclosures.

### Key Design Consideration:

Wall thickness; drying time; and vapor-open detailing.

## Ecology & Growing

Originating from central Asia and brought to North America in the early 17th century, hemp thrives in well-draining, fertile loam soil with a neutral pH and grows at elevations up to ~2,100 m (~6,890 ft). Industrial hemp for long fibers can reach up to 5 m (16 ft) tall, whereas dual-purpose crops (hemp grown for fiber and grain) are generally smaller; ~2-4 m (6-12 ft).<sup>82</sup> Hemp typically requires fewer fertilizers than many conventional crops and is considered water-efficient and drought-tolerant, though irrigation may still be necessary in dry climates. It has few natural pests. Hemp grows rapidly and, when densely seeded, can suppress weed growth, often reducing the need for herbicides. While frequently cultivated in monocultures, it can function effectively within crop rotation systems, where it may help suppress weeds and contribute organic matter to soils. Hemp is also capable of phytoremediating contaminated soils by absorbing heavy metals, though material grown on such sites is typically unsuitable for building applications. Between growth cycles, hemp is commonly grown in rotation of corn and wheat. **Rapid biomass accumulation enables sequestration of approximately 8-15 tCO<sub>2</sub>/ha<sup>83</sup>** within a single growing season, depending on cultivar and conditions. Industrial hemp cultivated for building products is typically grown for either fiber, hurd, or a balance of both, depending on cultivar selection and harvest timing.

## Culture & History

Hemp has been cultivated since 8,000 BC<sup>84</sup>, with over 200 historically documented products cultivated for use such as textiles, medicine, and food. In the United States (U.S.), prior to its prohibition under the 1937 Marijuana Tax Act and 1970 Controlled Substances Act, which led to Cannabis being identified as a Schedule I narcotic and effectively stopped its cultivation, hemp was widely used in paper, rope and textile production.<sup>85</sup> Since the 2018 Farm Bill legalized industrial hemp, the industry has grown rapidly, though it remains hindered by regulatory inconsistencies and stigma due to its confusion with marijuana.

## Harvesting & Processing

Hemp can be harvested within 11-12 weeks of seeding.<sup>86</sup> After harvest, the plant is separated into flower and seed (grain), bast fiber, hurd (shive), and stalk. These components are prepared through cleaning, drying, and subsequent processing to enable stable storage and downstream use. While a growing number of U.S. companies now process industrial hemp, specialized equipment for efficient separation at scale remains regionally limited, particularly compared to more established European systems. Under favorable conditions, the average dry-stem yield is 2.2 tonnes/ha (5 ton/acre), though yields generally vary from 4.5-28 tonnes/ha (2-12.5 ton/acre)<sup>87</sup>

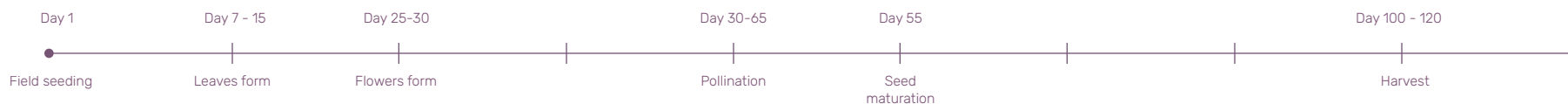
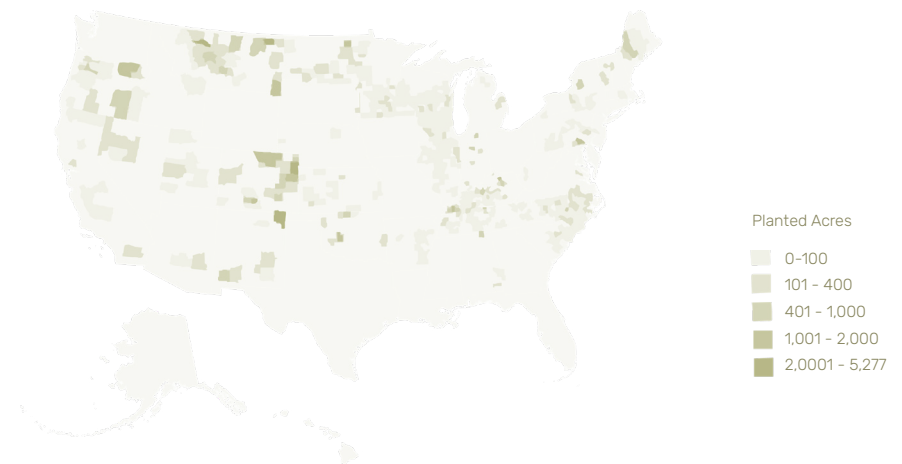
Hemp stalks undergo retting, a controlled process that loosens the bonds between the bast fibers and the woody hurd. Retting may occur in the field after seed harvest or as a post-harvest step and varies widely in duration, fiber quality, and environmental impact. Methods include dew, water, warm, mechanical, chemical, and emerging sonic retting, with timelines ranging from a few days to several weeks. Slower biological methods typically yield higher-quality fibers with lower embodied impacts.

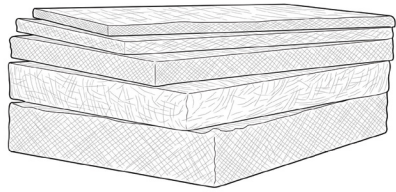
For textile applications, bast fibers require an additional degumming step to remove residual pectins and lignins. This process is distinct from cannabinoid extraction, which involves hemp flower processing and is unrelated to fiber or building-material production.

## Making

For building applications, hemp is most commonly used as insulation (hemp wool), bio-aggregate infill (hemp-lime), or compressed panel products. Each part of the plant can be made into different products. The bast fibers can be woven into textiles, rope, shredded and combined with lime to make plaster. The hurd can be milled and mixed lime to create boards and blocks. The stalks can be compressed into panels and boards of varying thickness and strengths. Other methods include using parts to create dyes, combining with other resins to create bioplastic, inoculating with mycelium or processing as biofuel, to name a few.

Industrial hemp production by county 2019, USDA. Note that 2019 was a boom year for planting hemp, particularly for Cannabidiol (CBD), and the USDA did not differentiate planted area by use (e.g. CBD, fiber, hurd) until 2025

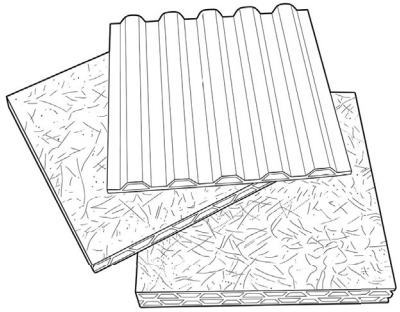




## Featured Applications

### Envelope & Insulation

- Hemp Batt
- Hemp Board
- Hempcrete
  - Cast
  - Spray-applied
  - Blocks
  - Panels

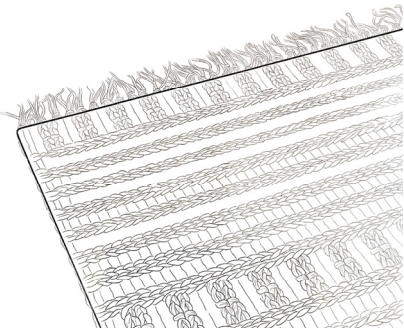
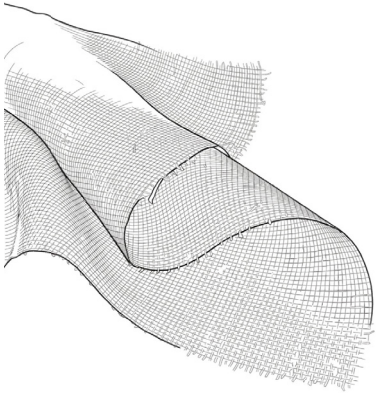


### Interior Finishes & Applications:

- Acoustic panels
- Carpet (yarn)
- Compressed hemp panels
- Drywall
- Floor Screed
- Hemp lime Plaster
- Hemp floor boards
- Mixed fiberboard panels
- Woven textiles

### Miscellaneous

- Fiber Insulation
- Hemp fiber rope
- Hemp rebar
- Hemp-based bioplastic



## Care & Maintenance

Hemp-lime assemblies are typically protected by lime or clay plaster finishes or rainscreen cladding systems. They should be detailed using established building-science principles to maintain continuous control layers for bulk water, moisture, air, and thermal performance. **These systems are not intended to resist prolonged exposure to bulk water and must be detailed to shed moisture and dry effectively after incidental wetting.** Due to its hygrothermal properties, hemp-lime should not be used below grade and must be separated from foundations with a capillary break or vapor barrier.

Moisture management is critical during storage, handling, and construction. Hemp hurd must be kept dry prior to mixing and placement; mold resistance in hemp-lime assemblies results from the alkaline lime binder and mineralization process, not the hemp material alone. Once cured, hemp-lime assemblies remain vapor-permeable, allowing moisture vapor to dissipate. Compatible finishes, such as lime or clay plasters and other vapor-open coatings, support this drying behavior, with long-term maintenance typically limited to periodic skim coats, lime washes, or repainting with vapor-permeable finishes.

## End of/Next Life

End-of-life pathways for hemp-based materials depend largely on binder chemistry. Assemblies using lime and clay binders may be mechanically separated and downcycled as aggregate or soil amendment, while blended or cementitious binders can limit compostability and reuse options. Disassembly and material recovery should therefore be considered at the specification stage.

## Governing Regulations

The use of hemp, in particular hempcrete, in architecture is gaining momentum in the U.S., though it remains constrained by code unfamiliarity and limited institutional precedents. The U.S. Hemp Building Association (USHBA) plays a key role in advancing the material's adoption by providing architects with technical specifications, material guidance, and policy updates. **In 2022, USHBA collaborated to include Appendix BL in the 2024 International Residential Code (IRC), permitting prescriptive (non-engineered) use of hempcrete insulation in one- and two-story buildings in low seismic zones.** With the IRC serving as the residential code foundation in 49 states, this milestone significantly lowers permitting barriers and expands design opportunities for integrating regenerative materials into residential construction. Commercial applications typically rely on performance-based design approaches, including fire testing, alternative materials approvals, and early engagement with code officials.

Day 114 - 162

Day 121- 169

Stalk clean and separated

Once dried can be stored 6-12 months in dry shaded environment

**Technical Design Data**

**Thermal:** Hemp wool insulation thermal resistance range of RSI-0.62 to 0.70/25mm (R - 3.5 to 4.0/in),<sup>88,89</sup> similar to fiberglass. Hemp-lime thermal resistance range of RSI-0.26 to 0.39/25mm (R - 1.5 to 2.2/in ).<sup>90,91</sup>

**Acoustic:** Hemp-lime wall assemblies can achieve Sound Transmission Class (STC) ratings around 40–45<sup>92</sup>, depending on thickness and finish.

**Density:**  
 Hemp batts: ~32kg/m<sup>3</sup>(2 lbs/ft<sup>3</sup>)<sup>93</sup>  
 Hemp insulation board: ~96kg/m<sup>3</sup>(6 lbs/ft<sup>3</sup>)  
 Hemp-lime: ~190-400 kg/m<sup>3</sup> (12-25 lbs/ft<sup>3</sup>)  
 Roofs: ~200-250 kg/m<sup>3</sup> (12-16 lbs/ft<sup>3</sup>)  
 Walls: ~250-350 kg/m<sup>3</sup> (16-22 lbs/ft<sup>3</sup>)  
 Floors: ~320-400 kg/m<sup>3</sup> (20-25 lbs/ft<sup>3</sup>)

**Structural:** Hemp-lime is typically non-structural, but load-bearing blocks are under development with expected results of 17 N/mm<sup>2</sup> (2,500 psi).<sup>94</sup>

**Fire:** Three 1-hour fire-rated hemp-lime wall assemblies will be included in the IRC 2027.<sup>95</sup>

**Moisture & Vapor:** Hemp-lime is highly vapor open, with over 575 ng/(Pa.s.m<sup>2</sup>) (10 US perms) at 300mm (12in) thick.<sup>96</sup>

**Strengths & Opportunities**

**Human health**

- Vapor-open and hygroscopic, supporting passive humidity regulation and reducing condensation and mold risk when properly detailed.
- Low-toxicity during installation and use, with minimal off-gassing

compared to petrochemical insulation systems.

- Lime is very alkaline and inhibits mold growth in hemp-lime.
  - Hemp fiber insulation is non-irritating to handle relative to fiberglass and spray foam.
- Ecosystem Health**
- Reduces reliance on extractive mineral and petrochemical-based insulation materials.
  - Can support rotational agriculture systems that improve soil structure, suppress weeds, and reduce chemical inputs when responsibly managed.
  - Rapid growth cycle allows hemp to function as a short-rotation crop,

reducing pressure on long-rotation forest resources.

- When grown appropriately, contributes to improved soil organic matter and reduced erosion.

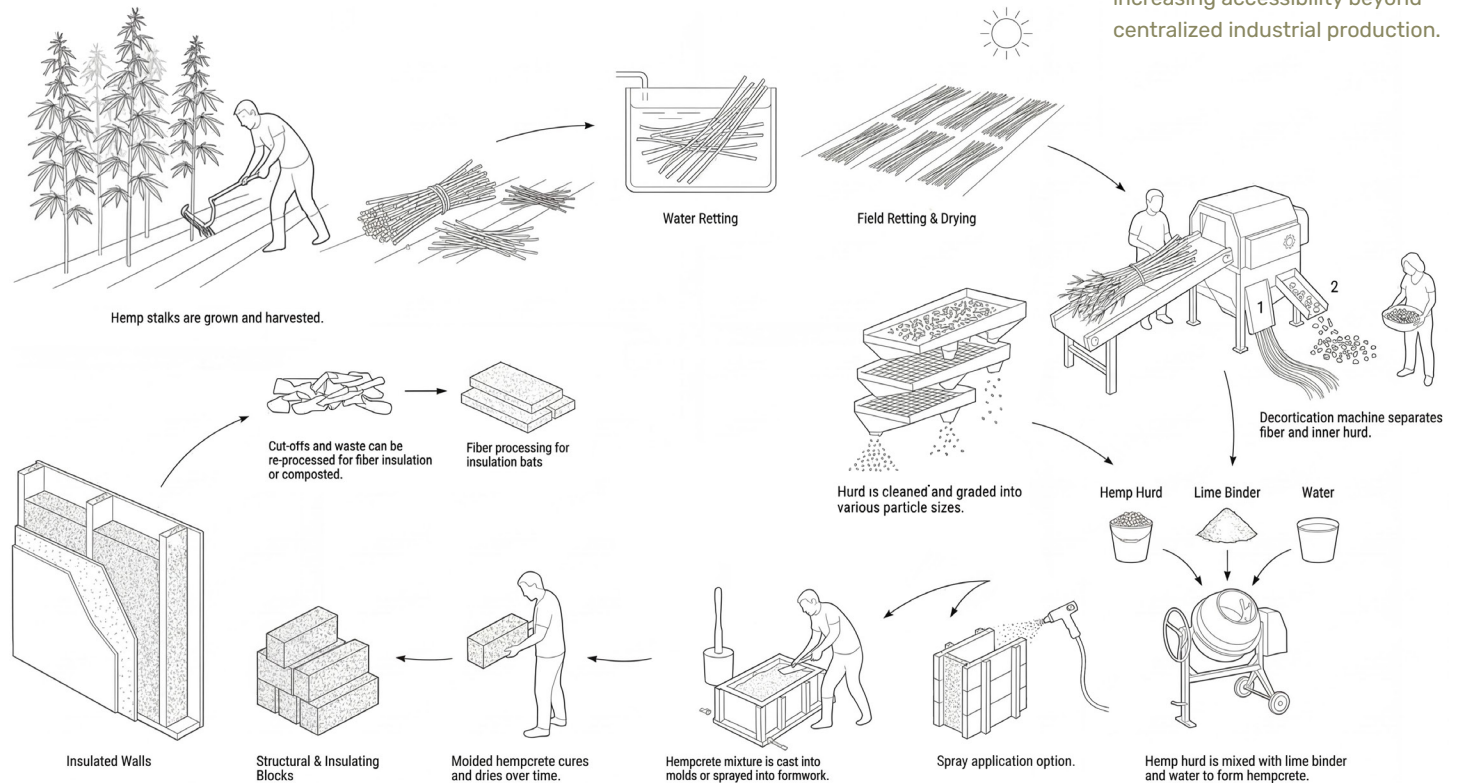
**Climate Health**

- Rapid biomass growth enables fast biogenic carbon sequestration within a single growing season.
- Can result in net biogenic carbon storage within building assemblies (e.g. Hempcrete blocks: Biogenic carbon storage 220 kgCO<sub>2</sub>/m<sup>3</sup>)<sup>97</sup>
- Carbon benefits occur early in the material life cycle, supporting near-term climate mitigation.

- Performance improves when paired with low-carbon binders, regional sourcing, and appropriate density selection.

**Social Health & Equity**

- Supports local and regional supply chains, particularly where hemp cultivation, processing, and construction are co-located.
- Enables community-based “grow-to-build” models, linking agriculture, manufacturing, and housing.
- Can support workforce development and training in emerging bio-based construction techniques.
- Compatible with small-scale and cooperative manufacturing models, increasing accessibility beyond centralized industrial production.



**Material Process Example**

### Circular Economy

- Compatible with disassemblable infill and enclosure systems when used within framed structures.
- Lime-based hemp assemblies can be mechanically broken down and downcycled as aggregate at end of life, depending on binder chemistry.
- Bio-aggregate origin supports non-toxic degradation pathways, avoiding persistent pollutants.
- Encourages design approaches that prioritize material reversibility and recovery over permanent composite assemblies.

### Challenges & Considerations

- Hemp-lime systems are non-load-bearing and require an independent structural frame. Misinterpretation of hempcrete as structural can lead to inappropriate use or code compliance challenges.
- Hemp-lime provides lower nominal R-values per inch than petrochemical foams or mineral wool, often requiring increased wall thickness to meet thermal targets. Performance benefits rely on hygrothermal behavior and thermal lag rather than insulation value alone.
- Assemblies must be protected from prolonged wetting; drying and curing times can extend schedules if not planned early.
- Hemp-lime mixing and placement can be associated with worker health risks due to the highly alkaline nature of most binders.
- Performance varies significantly based on binder selection (e.g., natural hydraulic lime vs blended binders),

affecting strength, curing time, carbon impact, and end-of-life outcomes.

Lack of standardized formulations can create variability between suppliers and regions.

- Limited tested assemblies (especially for commercial projects) may necessitate performance-based approvals and early authorities having jurisdiction (AHJ) engagement.
- Limited decortication and processing infrastructure remains a key barrier to scaling hemp construction, particularly in North America. Availability, product formats, and quality can vary significantly by region.
- Specialized knowledge is required for proper mixing, placement, curing, and detailing of hemp-lime systems. Limited availability of trained contractors can increase costs or risk improper installation.
- Hempcrete, if left unfinished, may be susceptible to abrasion and impact damage in high-traffic areas.
- Proper detailing and finish layers may be required to maintain building air tightness.
- Compostability and material recovery depend on binder chemistry and assembly design. Cementitious or synthetic additives can limit recyclability and circular outcomes.
- Hemp-based materials may be perceived as experimental despite growing evidence and precedents. Stakeholders whose perceptions must be considered include clients, code officials, architects, builders, insurers, lenders, and appraisers.
- Acquisition of seed is more difficult for hemp than traditional crops and risk of cross-contamination with marijuana crops compromising harvest and investment.

### Products

Known bio-based products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework.

#### Structure

- Just BioFiber's structural wall-system by [Renewabuild](#)
- Mineralized hemp hurd bioaggregate for concrete by [Down to Earth Materials](#)
- Prefabricated Hempbuild panels by [America Lime Technology](#)
- Prefabricated Hempcrete panels by [Homeland Hempcrete](#)

#### Enclosure

- [FC-Cladding](#) panels
- [Margent Farm](#) Hemp Corrugated Siding

#### Insulation

- Eready Spray Applied Hempcrete by [Americhanvre](#)
- Hempcrete blocks by [Hemp and Block LLC](#)
- Hempcrete blocks by [Iso Hemp](#), sold by [Hempitecture](#)
- Hempcrete blocks by [Senini Tecnocanapa](#), sold through [Hemp Building Company](#)
- Hempcrete mix by [Bison Biocomposites](#)
- Hemp mix ingredients and hemp plasters by [Hempire](#)
- HempWool, FiberFill, PlantPanel and Hempcrete mix by [Hempitecture](#)
- HESmix by [Hemp Eco Systems](#)
- HL Mix, Hemp blocks and hempcrete mix by [IsoHemp](#)
- Load-bearing HempBLOCK System by [Hemp Block USA](#)

- Profib Mat Batt Insulation by [Nature fibers](#)
- Z Panel Hempcrete blocks by [Sativa Building Systems](#)

#### Interior Finishes

- Acoustic Hemp tiles by [Natural Building Systems](#)
- Flooring, paneling, lumber, desks by [HempWood](#)
- Hemp board by [Boardwurks](#)
- Hemp Wallpaper by [California Wallpaper](#)
- FiberPad carpet backing by [Hempitecture](#)
- [Maya Romanoff](#) Naturals Hemp Wallcovering
- Panels for walls, ceilings, and acoustics by [BAST Fiber Technologies](#)
- [Unika Vaev](#) Ecoustic Bio Tile
- [Windochine](#) wall covering and window treatments
- [WolfGordon](#) 100% Hemp Wallcovering

#### Miscellaneous

- BioStuds by [BioTwin](#)
- Hemp fabrics by [EnvrioTextiles](#)
- Lime binders and HempLime products by [US Heritage Group](#)



# Cape Cod Hemp House

**Location:** Harwich Port, MA, USA

**Climate Zone** (ASHRAE): 5A

**Year:** 2023

**Architect:** Estes Twombly + Titrington Architects

**Builder:** C.H. Newton Builders, Inc

The Cape Cod Hemp House reimagines the traditional Cape Cod shingle house using a building envelope centered on hemp-lime (hempcrete).

Hemp-lime serves as the primary insulation and enclosure material, replacing multiple conventional layers typically found in wood-frame construction with a plastic-free alternative. In this project, 12-inch-thick hemp-lime walls (R-25) and 16-inch-thick hemp-lime roof (R-42) assemblies substitute for plywood sheathing, plastic house wrap, and petrochemical foam insulation. The result is a vapor-open, monolithic envelope that regulates humidity and temperature while remaining naturally resistant to fire, mold, and pests.

A key innovation of the project is the use of a high-production spray-applied hemp-lime installation system imported from Europe. Instead of labor-intensive hand placement, the mixture is sprayed directly between and around structural framing, forming a continuous insulating layer with reduced thermal bridging. This method significantly accelerates construction time while improving performance and material efficiency.

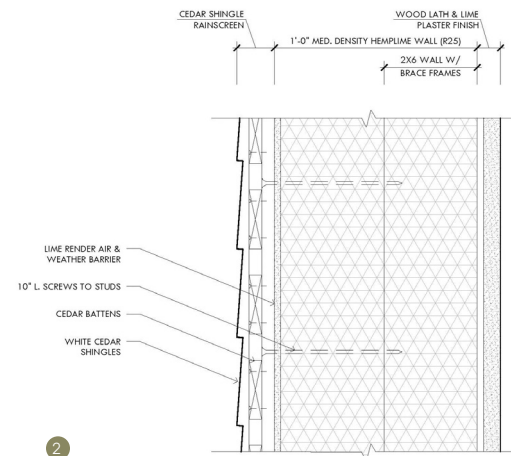
**Materials:** Spay-applied hempcrete (AKTA Technology); Hemplaster and lime plaster (DuChanvre), Hemp batt insulation

**Source:** [Cape Cod Hemp House](#)

Material selection across the project reinforces the low-carbon strategy. Hemp-lime alone is estimated to store more than 21 tonnes CO<sub>2</sub>, and the building's embodied carbon to roughly half that of a comparable conventional home. Additional substitutions, including recycled foamed-glass aggregate beneath the slab, reduced-cement concrete mixes, and mineral-based finishes, further limit petroleum-derived materials and emissions. Interior wall assemblies utilize hemp batt acoustic insulation.

Interior lime plaster, over 1-inch hemplaster substrate, complete the breathable wall system, eliminating many paints and synthetic coatings while contributing to indoor air quality and durability. Combined with an all-electric system and rooftop solar, the house is designed to operate at net-zero energy.

By pairing a traditional wood frame with a carbon-storing bio-composite envelope, the Cape Cod Hemp House offers a compelling prototype for climate-responsive residential construction, one that integrates performance, health, and material circularity within a familiar architectural language.



1. Exterior view. Photo by Michael Lee.
2. Exterior wall assembly. Image by Estes Twombly + Titrington Architects.
3. Spray-applied hempcrete. Photo by C.H. Newton Builders, Inc



## OPENLY Valley Widnau

**Location:** Widnau, Switzerland

**Climate Zone (ASHRAE):** 5A

**Year:** 2024

**Architect:** Valley Architects

**Developer & Planner:** OPENLY AG

**Timber + Hempcrete construction:** Schlob AG

OPENLY Valley Widnau is a 19-unit residential building in Widnau, Switzerland that repositions material choice as the primary driver of climate performance. Completed in 2024, the project demonstrates how multi-family housing can shift from carbon reduction toward measurable carbon storage through biogenic construction systems.

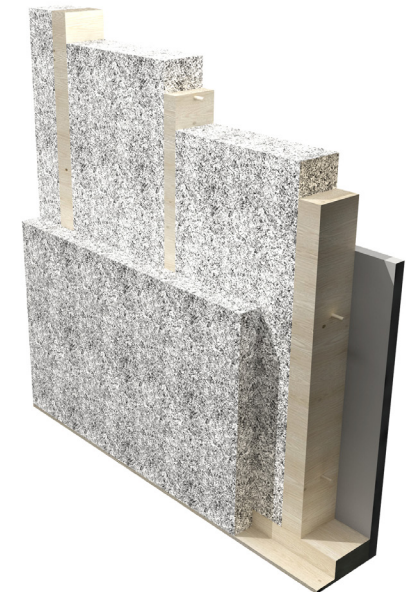
The load-bearing structure is composed of a prefabricated timber frame paired with 382 mm hollow box timber ceilings. These ceilings are filled with approximately 400 tonnes of clay, significantly increasing thermal mass while maintaining a fully diffusion-open assembly. The exterior wall system combines 32 cm timber framing with hemp-lime (hempcrete) infill and an additional 12 cm layer of hemp brick insulation, producing a total wall thickness of roughly 44 cm. Across the building, approximately 1,500 m<sup>2</sup> of hempcrete panels and 2,600 m<sup>2</sup> of hemp bricks are installed. With a thermal conductivity of approximately 0.06–0.07 W/m·K, hemp-lime provides high insulation performance and stores more CO<sub>2</sub> than is emitted during its manufacture.

**Materials:** Wood frame, hempcrete (Cancret), lime plaster, clay interior paint, hemp bricks, biochar concrete (CarStorCan), clay boards (ClayTec).

**Source:** [OPENLY](#)

Concrete is minimized and used only where structurally unavoidable, including the basement and stair cores. In these areas, approximately 300 m<sup>3</sup> of biochar-enhanced concrete by CarstorCon reduces embodied emissions while embedding stable carbon within the matrix. Reinforcement steel is 100% recycled and roughly one-third of the structural steel girders were salvaged from reuse streams, further lowering material impact.

Operationally, the building is a net energy producer, generating approximately 141% of its annual energy demand. Over a 60-year life cycle, embodied and operational emissions are calculated at roughly 6–8 kgCO<sub>2</sub>e/m<sup>2</sup>/yr (inclusive of A-C LCA modules), about 50% lower than comparable Swiss multifamily buildings, with total avoided emissions estimated at approximately 900 tonnes CO<sub>2</sub>e. The project stores 554 tonnes of CO<sub>2</sub> (119t made of hempcrete, 374t construction timber, 9t cork, 52t from biochar in concrete). The developer, OPENLY, monetized the building's biogenic carbon storage by issuing and selling verified carbon credits tied to the biogenic carbon stored in the building, which was quantified, third-party reviewed, and converted into tradable carbon certificates.



1. Exterior view. Image by Jens Ellensohn.
2. Interior view. Image by Jens Ellensohn.
3. Hemp and wood stud wall. Image by Cancret.



## Further Reading

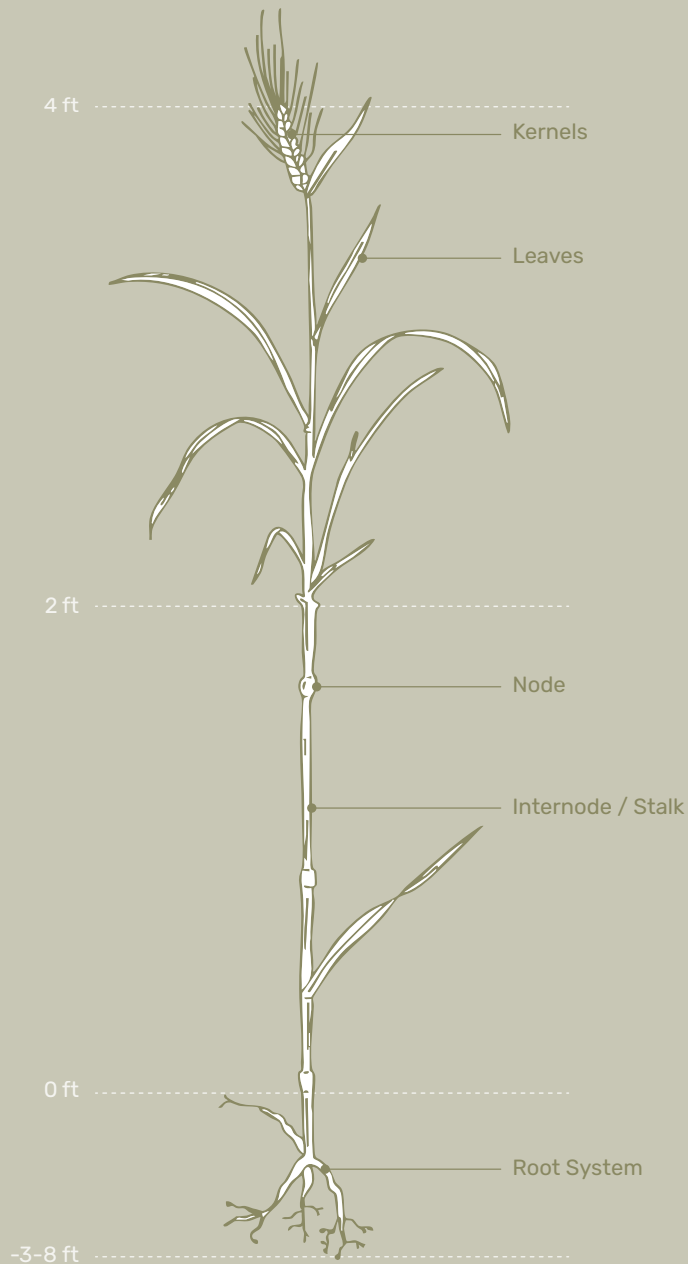
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- Stanwix, William, and Alex Sparrow. 2014. The Hempcrete Book: Designing and Building with Hemp-Lime. Cambridge: Green Books.

## Networks & Groups

**Hemp Build Network:** A professional resource and directory for contractors and architects.

**International Hemp Building Association (IHBA):** Focuses specifically on the use of hemp in construction (hempcrete, fibers, etc.) globally.

**US Hemp Building Association (USHBA):** The primary hub for advocating hempcrete and hemp-based insulation in the U.S.



## STRAW

Peak growth rate ~2–4 cm/day (0.8–1.6 in/day); mature height ~60–150 cm (2–5 ft)<sup>98</sup>

Harvest-ready after ~90–120 days; ~1–3 crops/yr depending on base crop & climate<sup>99</sup>

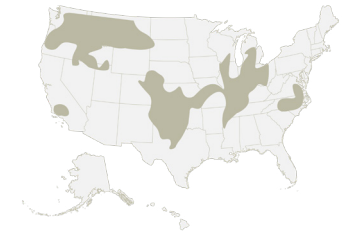
Recoverable straw biomass yield ~1.5–5 t/ha/harvest; ~1.5–15 t/ha/yr<sup>100</sup>

Biogenic Carbon storage ~1.3–1.6 tCO<sub>2</sub> per dry t of straw byproduct<sup>101</sup>

Recovered byproduct sequestration rate ~2–24 tCO<sub>2</sub>/ha /yr<sup>102</sup>

### Source

Straw is the hollow stalk left after harvesting cereal grains such as wheat, rice, barley, and oats. The stalk is composed of nodes and internodes, with the internodes comprising hollow connecting tubes. This is distinct from hay, which



Source Map

### Best Used For:

Wall and roof insulation; prefabricated assemblies; lightweight composite boards and reinforcement; ; roofing and cladding.

### Key Design Consideration:

Feedstock sourcing; regional supply; prefabrication opportunities; Moisture protection; Wall thickness and stalk direction; Fire testing and code pathway; Skilled labor availability.

includes nutrient-rich leaves and seeds. Straw is composed of 35–60% carbon by dry weight.<sup>103</sup> There is approximately 41 million tons of straw available in the U.S. each year.<sup>104</sup>

**Ecology & Growing**

Straw is an agricultural residue produced during cereal grain harvest, typically yielding roughly three tons per hectare. Globally, much of this material is tilled back into soil or burned; using straw in construction extends its carbon storage beyond the field<sup>105</sup> and avoids re-releasing that biogenic carbon immediately. Because straw is a byproduct of food production, its ecological footprint is largely determined by the farming practices used to grow the primary crop rather than the straw itself.

Conventional grain systems are often monocultures reliant on synthetic fertilizers and, in some regions, pesticides, raising concerns about soil nutrient depletion, biodiversity loss, and chemical residues. In contrast, regenerative or polyculture grain systems can reduce chemical dependence while enhancing soil carbon, ecosystem resilience, and biodiversity. Straw-producing grain systems function as active CO<sub>2</sub> bioabsorption systems through annual cultivation. When utilized holistically, straw can continually cycle atmospheric carbon into biomass, soil, and building materials.<sup>106</sup>

In North America, several native or historically adapted grains offer additional ecological benefits. Wild rice, still commercially cultivated in the Great Lakes region, supports wetland restoration, requires no fertilizers, and remains a culturally significant staple for the Anishinaabe Nation. Indian rice grass,

historically and presently used by Navajo, Hopi, and Ute Nations, is drought-tolerant, stabilizes soils, and contributes to land restoration in arid regions. Diversifying cereal production and sourcing straw from farms practicing reduced tillage, crop rotation, or regenerative management strengthens the role of straw as part of a circular, low-impact material system that supports soil health, biodiversity, and long-term carbon sequestration.

**Culture & History**

Straw has been used in building for millennia, including in the U.S., as thatch, adobe reinforcement, and wall insulation, but modern straw-bale construction emerged in the late 1800s in Nebraska, when settlers stacked newly machine-baled straw to form self-supporting walls in treeless regions. Several of these early structures still stand today. The technique was revived in the late 20th century, aligning with sustainability and natural-building movements. By the 1990s, straw-bale methods spread globally, gaining inclusion in the 2015 International Residential Code (IRC) and inspiring new prefabricated systems. Today, straw's cultural significance lies in its return as a community-oriented material. Straw bridges vernacular traditions with modern performance standards and demonstrates that agricultural byproducts can be transformed into assets that redefine low-carbon, place-based construction.

**Harvesting & Processing**

Harvested after grain threshing, which yields roughly three tons per hectare, straw is then mechanically baled (collected and compressed), kept dry, and stored. Before fabrication or installation, straw is rechecked and may be sun-dried to lower nitrogen and improve stability. Throughout, moisture control and protection from rain are essential, using ventilated storage, raised platforms, and covered transport to preserve quality and ensure the material's insulation, fire performance, and structural integrity in building applications.

While found in every U.S. State, most straw is produced in the Great Plains and Pacific Northwest, where cereal grain farming is concentrated. Major straw-producing states include:

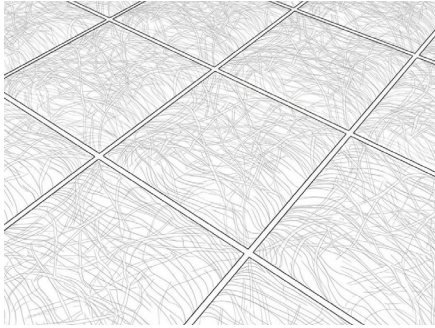
- North Dakota, South Dakota, Kansas, Nebraska, and Montana are large wheat- and barley-growing regions that generate high straw volumes.
- Washington, Oregon, and Idaho, especially the Willamette Valley (Oregon) and Palouse region (Washington/Idaho), are known for dense straw harvests from winter wheat and grass seed production.
- California's Central Valley produces substantial rice and wheat straw.

In Canada, straw production is similarly tied to grain belts, with the majority coming from the Prairie Provinces: Alberta, Saskatchewan, and Manitoba, where wheat, oats, and barley dominate. Smaller volumes are also harvested in Ontario and British Columbia's interior.

**Making**

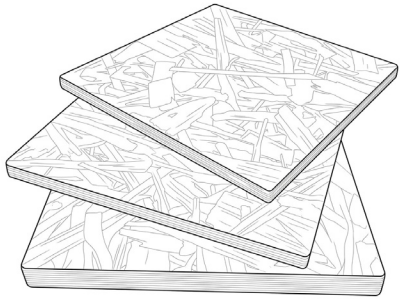
Straw is transformed into building materials through several fabrication methods that exploit its tubular, air-trapping structure and high carbon content. The most common are straw bales, which are stacked or framed as insulation and, in some cases, structure, and prefabricated wall panels, where tightly packed straw is enclosed within timber frames and finished with lime or clay plasters for vapor-permeable protection. Prefabrication allows controlled density, improved moisture management, and faster installation, transforming a low-cost agricultural residue into a high-performance, carbon-storing wall system compatible with contemporary large scale building practices





## Featured Applications

There are currently three main straw-bale wall-building applications: load-bearing walls, non-load-bearing in situ walls, and prefabricated panel construction. In addition to these systems, straw is also used as a fiber reinforcement and insulation component in cob and other earthen construction, where it is mixed with clay-rich soil and sand. Other straw-based products include compressed straw blocks, kraft-paper-bound acoustic panels, and straw-based OSB, in which split straw stalks are resin-bonded to perform similarly to wood-based panels. Straw-clay and lime-hemp-straw composites further extend straw's application into spray-applied or hand-packed infill systems.



### Structure & Envelope:

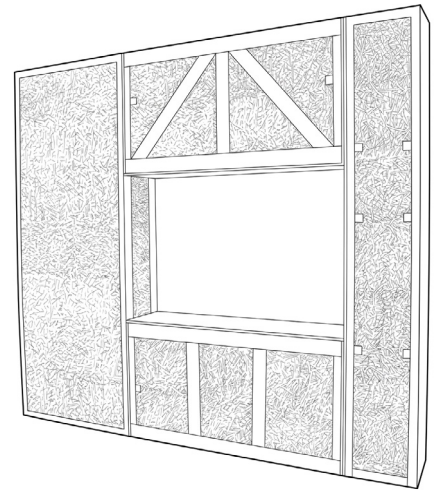
- Load-bearing straw-bale walls
- Infill systems (insulation within or adjacent to timber or steel frames)
- Prefabricated straw panels
- Compressed straw blocks
- Compressed straw boards (CAF Boards)
- Straw OSB
- Thatch (in-situ and cassettes<sup>109</sup>)

### Insulation:

- Loose-fill or blown straw insulation
- Light straw clay

### Interior Finishes & Applications:

- Straw-clay or hemp-lime composites
- Acoustic panels
- Interior wall and ceiling boards
- Lime or clay plaster over straw
- Decorative straw panels or veneers



## Care & Maintenance

Straw, like all cellulosic material, must remain dry and well ventilated during storage, transport, and installation, with moisture kept below 18–20% (dry basis) to prevent mold and decay.<sup>107</sup> Once enclosed, lime or clay plasters provide breathable, protective finishes, while wide eaves, capillary breaks, and sloped grading manage water runoff. Routine maintenance focuses on preserving these protective layers, inspecting plaster for cracks, recoating lime or clay finishes every 10–20 years, and ensuring gutters, overhangs, and drainage function properly to keep walls dry. Prefabricated panels minimize exposure during assembly, allowing straw structures to maintain fire safety, durability, and low-maintenance performance for more than a century.

## End of/Next Life

At the end of a building's life, straw materials can be reused, composted, or returned to the soil, completing a safe biogenic cycle. When paired with natural binders like lime or clay, straw decomposes without releasing toxins and can even enrich soil carbon. Alternatively, panels may be dismantled and repurposed, maintaining stored CO<sub>2</sub> in new construction. Because straw sequesters 1.6 kgCO<sub>2</sub>e/kg,<sup>108</sup> extending its lifespan through reuse or biochar conversion enhances its role as a circular material that continues storing carbon beyond the building's lifetime.

## Governing Regulations

Straw construction is increasingly recognized within formal building standards, supporting its transition from alternative to mainstream practice. In the United States, International Residential Code (IRC) codifies straw-bale construction under Appendix B.J and Light Straw Clay under B.I, providing prescriptive guidance for wall systems, fire safety, and plastering. Several U.S. states, Arizona, California, Colorado, Nebraska, New Mexico, Nevada, Oregon, and Texas, have adopted or piloted local straw-bale codes. Prefabricated straw panels are typically assessed through performance-based approvals, demonstrating compliance via structural, thermal, and fire testing. Together, these frameworks legitimize straw as a certifiable, insurable, and financeable construction material aligned with modern building standards.

**Technical Design Data**

Straw's performance depends on its density, moisture content, and integration with companion materials like timber, lime, and clay.

**Thermal:** Conductivity of wheat straw alone is around 0.046 W/m·K.<sup>110</sup> Wheat straw bale ranges from 0.066–0.084 W/m·K (depending on stalk orientation)<sup>111</sup>, with thermal resistance measuring RSI-0.25 to 0.35/25mm (R1.4 to 2.0/in).<sup>112</sup> Prefabricated straw panels can achieve R35-R45.<sup>113</sup> Light Straw Clay has a thermal resistance range of RSI-0.15 to 0.32/25mm (R0.8 to 1.8/in) (IRC B1103.2.3).

**Density:** Typical installed density is 85–145 kg/m<sup>3</sup> (5–9 lbs/ft<sup>3</sup>);<sup>114</sup> compressed products like Durra panels reach ~360 kg/m<sup>3</sup> (22 lbs/ft<sup>3</sup>). Light Straw Clay density range of 160–800kg/m<sup>3</sup> (10–50 lbs/ft<sup>3</sup>).

**Fire:** Tightly packed and plastered straw walls have been shown to withstand over 2 hours of fire exposure (ASTM E-119)<sup>115</sup> due to silica content and low oxygen permeability.

**Moisture & Vapor:**  $\mu \approx 2$ ,<sup>116</sup> highly vapor-open; lime or clay plasters regulate humidity and protect against mold.

**Acoustic:** Plastered straw walls at around 355mm (14in) are shown to achieve  $R_w \approx 43-44$  dB, providing strong sound insulation.<sup>117</sup>

**Strengths & Opportunities**

**Human health**

- Naturally low-VOC and non-toxic, particularly when paired with lime or clay plasters.
- Vapor-open assemblies regulate humidity and reduce mold risk when properly detailed.
- Can reduce reliance on petrochemical-based insulation systems and associated additives.
- Supports calmer, acoustically dampened interiors, beneficial for wellness, residential, and learning environments.

**Ecosystem Health**

- Utilizes an existing agricultural byproduct, reducing pressure on virgin resource extraction.
- Can be sourced from regenerative or low-input farming systems, supporting soil health and biodiversity.
- Diverts straw from open-field burning or decomposition, reducing particulate pollution and methane emissions.
- Encourages closer alignment between agricultural systems and the built environment.

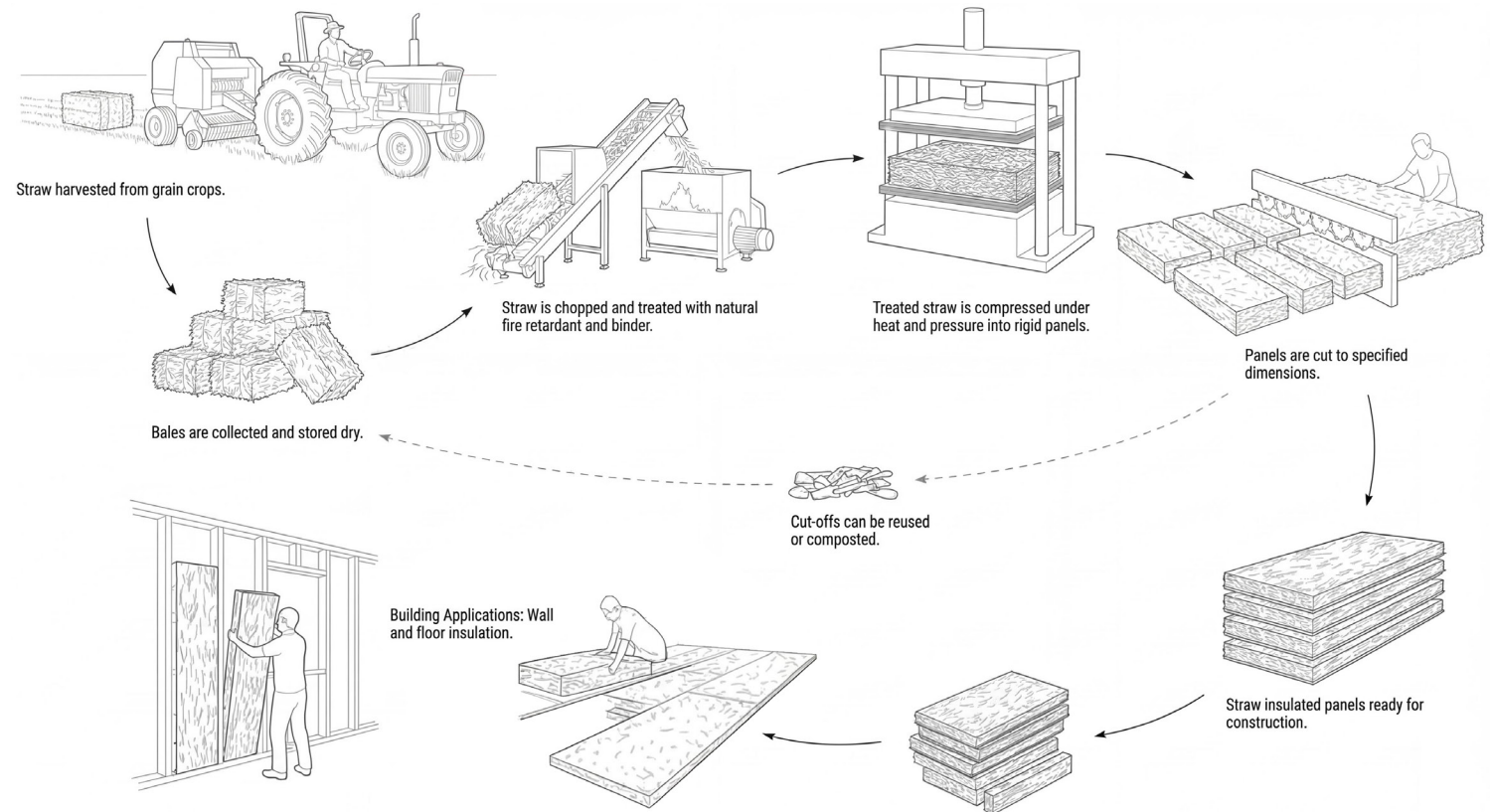
**Climate Health**

- Stores significant amounts of biogenic carbon.

- Annual crop cycle enables rapid carbon drawdown compared to forest-based materials.
- Enables high-performance envelopes that reduce operational energy demand.
- Prefabricated straw panels reduce construction waste and site emissions.

**Social Health & Equity**

- Straw is widely available and regionally distributed, supporting local supply chains and rural economies.
- Long history of use in affordable, self-built, and community-led housing.
- Panelization and certification are



**Material Process Example**

expanding access beyond niche or experimental projects.

- Provides opportunities for skills development and local manufacturing in emerging bio-based construction sectors.

#### Circular Economy

- Fully biodegradable when paired with natural binders; compatible with composting or soil return at end of life.
- Assemblies can be designed for disassembly, reuse, or repurposing.
- Long service life (100+ years demonstrated) maximizes carbon storage duration.

#### Challenges & Considerations

- Moisture sensitivity requires careful storage, detailing, sequencing, and long-term maintenance of protective finishes.
- Straw sourcing may involve monoculture grain systems with pesticide use; residue concerns should be evaluated.
- For strawbale cases, wall thickness can impact floor area efficiency, egress clearances, and accessibility requirements.
- **Straw performs best thermally when the stalks are oriented so that heat travels across them rather than along their length.**
- Fire performance depends on density and detailing.
- Limited availability of prefabricated panel suppliers in some regions can affect cost and lead times.

- Code acceptance for non-standard systems may require performance-based approvals and early engagement with authorities.
- Integration with MEP systems, openings, and curved geometries requires thoughtful coordination.
- Some straw-based panels rely on plywood or resin-bonded components, reducing full bio-based purity.
- Builder familiarity varies; training or specialist trades may be required.
- Long-term performance depends on ongoing inspection and re-plastering rather than the straw core itself.

#### Products

Known bio-based products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework.

##### Structure

- [Stak Block](#) structural and insulating block

##### Enclosure

- [Agriboard Building System](#) CAF (Compressed Agricultural Fiberboard)
- [Croft](#) wall/roof/floor panels
- [Durra Panel](#) compressed wheat straw panels designed to be included in commercial wall systems
- [Ecococon](#) pre-fabricated straw bale wall/roof panels
- [New Frameworks](#) pre-fabricated Straw-Structural Insulated Panels (S-SIPs)
- [Rare Forms](#) “Seed Panels,” prefabricated straw-insulated wall, floor, and roof panels

- [Savick](#) wall/roof/floor panels
- [Verdant Panel](#) pre-fabricated straw-insulated walls

##### Insulation

- [StakBloc](#) compressed insulating block
- [Strawboss Chopped Straw](#) loose-fill

##### Interior Finishes

- [Durra Panel](#) compressed wheat straw wall, ceiling, and acoustic panels; can be used as a finish surface
- [F. Schumacher & Company](#) Sonata Arrowroot Wallpaper
- [Great Plains](#) MDF

See the New Frameworks / Seed Collaborative (Manufacturer-led Network) [www.newframeworks.com/seed-collaborative](http://www.newframeworks.com/seed-collaborative)

Note: Be sure to check with local farmers for available straw stock (bale or loose).



# Sierra Valley Preserve

**Location:** Beckwourth, CA, USA  
**Climate Zone (ASHRAE):** 5B  
**Year:** 2026  
**Architects:** Arkin Tilt Architects

**Materials:** Straw bale (hybrid Straw-Cel method), cellulose insulation, timber structure and cladding, lime plaster  
**Sources:** Feather River Land Trust, Arkin Tilt Architects

The Sierra Valley Preserve & Nature Center is an example of bio-based construction designed to support ecological education, community gathering, and long-term land stewardship. Situated within one of California’s largest alpine valleys and wetland systems, the project was conceived to tread lightly on the land while demonstrating climate-responsive, low-carbon building strategies. The nature center serves as a hub for environmental learning, birdwatching, and engagement with Indigenous and regional history, and its architecture intentionally reinforces this mission through material choice and construction logic.

At the core of the building’s material strategy is a “straw-cell” wall system, combining straw bales with cellulose insulation, paired with a simple FSC or reused timber structural system and finished with vapor-permeable plasters. The straw bales provide high thermal performance, acoustic buffering, and significant biogenic carbon storage, while also drawing from regional agricultural byproducts. Exposed wood elements and natural finishes reinforce the building’s

educational role by making construction legible to visitors. The result is a highly insulated, low-energy envelope well suited to the Sierra Valley’s cold winters and warm summers, achieved without reliance on petrochemical insulation. The project demonstrates how straw-based construction can support durability, comfort, and ecological storytelling, offering a replicable model for rural and conservation-oriented buildings seeking alignment between mission, material, and place.

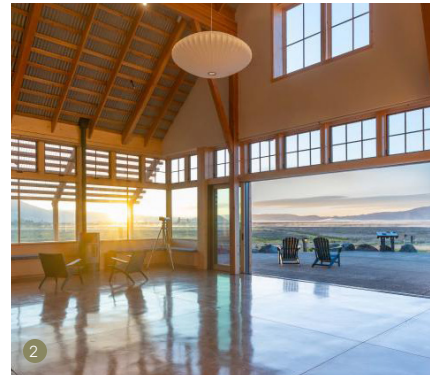
As calculated using the BEAM tool, the net material carbon intensity for the project is 66 kgCO<sub>2</sub>e/m<sup>2</sup>, which includes 50 kgCO<sub>2</sub>e/m<sup>2</sup> of biogenic carbon storage in the roof and walls.

MATERIAL CARBON EMISSIONS BY SECTION		
Footings & Slabs	18,284 kg CO <sub>2</sub> e	
Foundation Walls	1,305 kg CO <sub>2</sub> e	
Structural Elements	4,729 kg CO <sub>2</sub> e	
Exterior Walls	-8,307 kg CO <sub>2</sub> e	
Party Walls	0 kg CO <sub>2</sub> e	
Exterior Wall Cladding	1,654 kg CO <sub>2</sub> e	
Windows	3,257 kg CO <sub>2</sub> e	
Interior Walls	2,002 kg CO <sub>2</sub> e	
Floors	319 kg CO <sub>2</sub> e	
Ceilings	873 kg CO <sub>2</sub> e	
Roof	-5,631 kg CO <sub>2</sub> e	
Garage	0 kg CO <sub>2</sub> e	
<b>NET TOTAL</b>	<b>18,485 kg CO<sub>2</sub>e</b>	<b>-10,000 MCE (kg CO<sub>2</sub>e)</b>

4



1



2



3

1. Nature Center Entry. Image by Edward Caldwell.
2. Event space with “truth window” (display of strawbale wall). Image by Edward Caldwell.
3. Community bale raising. Image by Edward Caldwell.
4. Material Carbon Emmission Table, Graphic by Arkin Tilt Architects



# Sundby School

**Location:** Nykøbing Falster, Denmark

**Climate Zone (ASHRAE):** 5A

**Year:** 2026

**Architects:** Henning Larsen

**Partner Architects:** SKALA Architecture and ETN Architects

**Materials:** Thatched façade (reed), timber structure, wood cladding

**Source:** [Henning Larsen](#)

Sundby School in Denmark demonstrates how bio-based materials can be integrated into a contemporary, high-performance educational building at scale while reinforcing local identity and community pride. The project prioritizes children's well-being and long-term adaptability.

The standout "innovation" highlighted by this project is the outward-facing curved façade clad in an approximately 10-inch-thick layer of thatch, a millennia-old system of tightly bundled and layered reed, applied as part of an otherwise conventional envelope assembly.

"By introducing thatch at Sundby School, we connect to a strong local building tradition while embracing bio-based materials that store carbon and create a healthy learning environment."

- Jakob Strømmand-Andersen, Global Director of Innovation and Sustainability, Henning Larsen

The thatched façade protects from prevailing winds while enhancing the performance of the wall assembly beneath. Installed by local thatcher, Michael Jacobsen (Nyt Straa). With proper detailing and maintenance, the façade is expected to have a service life of 80-100 years and can be locally repaired or rethatched as needed.

A key challenge in implementing thatch at this scale was fire safety. Addressing this required an extensive, year-long testing process, including full-scale mockups subjected to fire testing to study flame spread, temperatures, and compartmentation behavior. These tests demonstrated that, when combined with appropriate provisions for compartmentation, egress, and firefighting access, the façade system meets applicable safety requirements. Importantly, this level of testing was highly project-specific and should not be assumed to directly transfer to other projects without similar evaluation.



1. Rendering by Sora
2. Thatch cladding in construction. Image by Rasmus Hjortshøj.
3. Thatch cladding in construction. Image by Rasmus Hjortshøj.



# Wadden Sea Centre

**Location:** Ribe, Denmark

**Climate Zone (ASHRAE):** 5C

**Year:** 2017

**Architects:** Dorte Mandrup

**Builder:** Bo Michaelsen

**Roofer:** Kim Andersen

The Wadden Sea Centre transforms a 1990's visitor facility into a cohesive, place-based gateway to Denmark's UNESCO-listed Wadden Sea National Park. Retaining only the administration wing, the renovation reshapes the remainder of the complex into a low-rise ensemble inspired by the west coast's historic U-shaped farmsteads, traditionally designed to shelter inner courtyards from shifting winds and coastal weather.

Material expression plays a defining role in differentiating old from new while rooting the project deeply in its landscape. Existing roofs and facades are reclad in slender robinia strips, whereas the new buildings are fully thatched, from plinth to ridge, with around 25,000 bundles of reeds from nearby Limfjorden and Ringkøbing Fjord. This monolithic thatch surface creates a soft yet robust skin that echoes the textures of local agricultural buildings and the surrounding marshlands. On the extensive use of thatched surfaces, especially the large overhangs, experts from both Denmark and Holland were involved in developing the different solutions of the design.

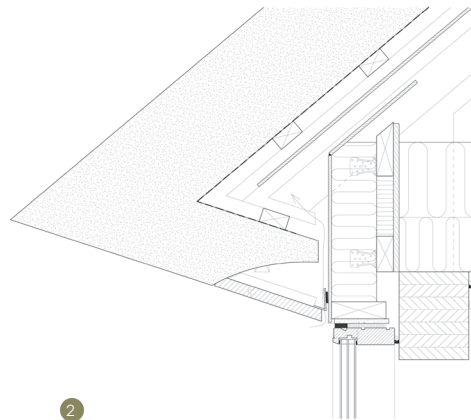
**Materials:** Thatch (reed), black locust wood cladding.

**Sources:** Dorte Mandrup, Natural Building Materials SML

Special focus was also given to the fire-concerns of using thatched surfaces to such an extent. All surfaces were therefore fire protected with a special build-up behind the straw, as well as the surfaces around main access-ways and fire-escape routes, which have been treated with a fire-retardant on the actual surface of the thatch.

Thermal resistance on reeds is approx. 0.5 K/W (it is not considered in the building, because there is an aired cavity behind the reeds). In addition to that thatch, black locust wood was used as a cladding material.

The original structural steel frame was retained, using it to maintain flexibility in configuring interior spaces while introducing prefabricated timber roof panels between the frame bays for the new extension. The standalone education building is the only fully timber structure. Together, the architectural and landscape strategies create a unified, ecologically attuned complex that both shelters visitors and sensitively interprets the unique cultural and environmental character of Denmark's west coast.



1. Exterior view. Image by Adam Mørk.
2. Roof to wall detail. Image by Dorte Mandrup.
3. Thatch close up view. Image by Adam Mørk.

## Further Reading

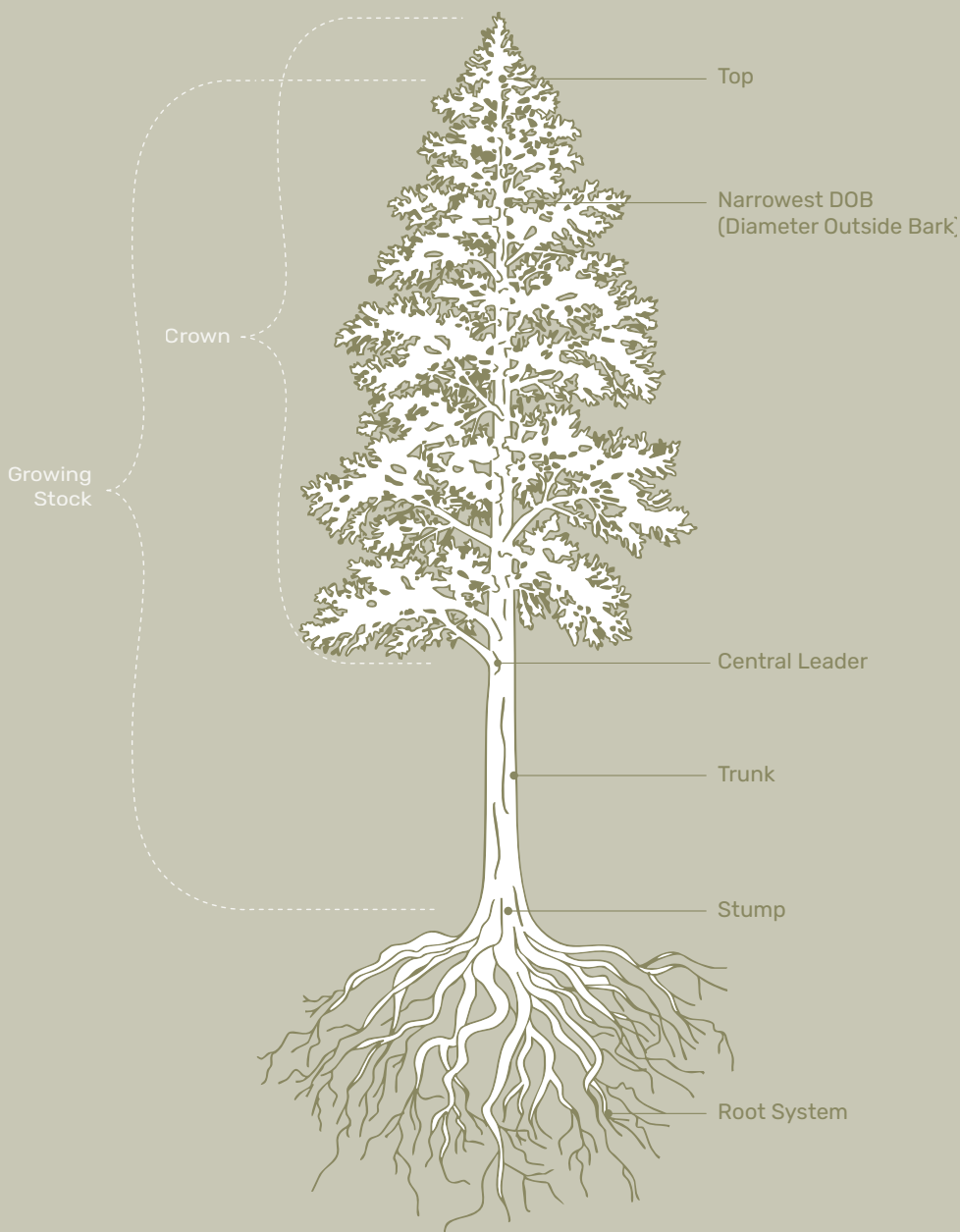
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## Networks & Groups

[California Straw Building Association \(CASBA\)](#): An influential North American group for straw bale construction standards and education.

[European Straw Building Association \(ESBA\)](#): An umbrella organization connecting various national straw building networks across Europe.

[Straw bale Building UK \(SBUK\)](#): A key resource for research and best practices in the United Kingdom.



## WOOD

Peak growth rate  $\sim 0.1\text{--}0.6$  cm/day (0.04–0.24 in/day); mature height  $\sim 5\text{--}100+$  m (16–328+ ft)<sup>118</sup>

Harvestable in  $\sim 25\text{--}120+$  yrs<sup>119</sup>

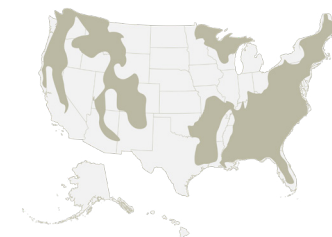
Biomass yield 50–250 t/ha/harvest, 2–8 t/ha/yr<sup>120</sup>

Biogenic carbon storage  $\sim 1.65\text{--}1.95$  tCO<sub>2</sub> per dry t of wood<sup>121</sup>

Forest ecosystem sequestration rate  $\sim 4.9\text{--}15$  tCO<sub>2</sub>/ha/yr (net flux)<sup>122</sup>

### Source

Wood is derived from the trunks and branches of trees. It is composed primarily of cellulose fibers bound by lignin. Forests function as complex ecosystems that regulate air, water, and soil health while supporting biodiversity and carbon storage. When responsibly sourced, timber can contribute to renewable material cycles while supporting biodiversity, rural livelihoods, and long-term carbon storage.



Source Map

### Best Used For:

Structural systems; building enclosure and sheathing; insulation and acoustic panels; interior finishes, millwork, and furnishings; applications where long service life and carbon storage can be achieved.

### Key Design Consideration:

Forest stewardship and sourcing practices; moisture, fire, and durability detailing; adhesive chemistry; balancing carbon storage benefits with harvesting practices, manufacturing inputs, and expected service life.

However, wood is neither inherently regenerative nor inherently climate-positive. Its environmental performance depends on forest stewardship practices, product formulation, manufacturing energy, service life, and end-of-life outcomes.

## Ecology & Growing

An estimated 70,000 tree species exist globally.<sup>123</sup> Of these, wood from ~1,600 tree species is traded on the international timber market,<sup>124</sup> 150 to 200 species account for a majority of commercial wood use,<sup>125</sup> and ~120 are approved for structural use within North America.<sup>126</sup>

The North American timber supply is primarily derived from two distinct groups: structural softwoods (e.g., Douglas-fir, Sitka spruce, and Southern yellow pine) which are widely distributed across the west and southeast, and specialty hardwoods (e.g., white oak, sugar maple, and walnut) found predominantly in the temperate forests of the East and Midwest. Forests cover roughly one-third of the U.S., and 38% of Canada's land area. In the U.S., about 58% of forest land is privately owned, providing nearly 90% of its timber harvest, while over 90% of Canada's forests are publicly managed under long-term stewardship agreements.

On average, dry wood mass consists of ~48.5% carbon.<sup>127</sup> At this percentage, a common mass timber species like Douglas Fir stores 855 kg CO<sub>2</sub>/m<sup>3</sup>. Carbon storage by volume of wood varies by species and specimen, from ~550–1550 kg CO<sub>2</sub>e/m<sup>3</sup>, with lighter woods like balsa or cedar storing less CO<sub>2</sub> and dense wood like live oak storing more.<sup>128</sup>

Carbon storage can be accounted for in a variety of ways, and its value must be weighed against speed of growth, suitability per application, and an array of sourcing and ecological factors.

For example, fast-growing softwoods can reach maturity in 25–30 years, while hardwoods can mature over 60–120+ years. Additionally, forests support air purification, water filtration, and soil stabilization while providing habitat for countless species. While industrial monocultures reduce biodiversity and often require fertilizers and pesticides, ecological forestry practices prioritize mixed-species, longer rotations, and land management to support soil health, reduce reliance on fertilizers and pesticides, improve water retention, and enhance resilience to fire, pests, and drought.

## Culture & History

Wood has been a foundational building material across cultures for millennia, shaping both architecture and identity. In North America, Indigenous peoples stewarded forests through burning and harvest, using wood for structures, canoes, textiles, tools, art, music, and medicine, reflecting deep ecological knowledge and stewardship.

European settlers expanded timber use, driving the growth of the lumber industry, first through vernacular forms such as log cabins and solid timber framing, then through industrial wood product production emphasizing consistent dimensions and performance, such as

dimensional lumber and balloon framing. By the 19th century, vast forests fueled westward expansion and urbanization, accompanied by deforestation.

Today, wood remains culturally embedded in North American construction and craft, re-emerging through evolutions in technology like mass timber, prefabrication, and modular design. Simultaneously, movements emphasizing transparency and better understanding of material origins and impacts are driving a desire to connect wood procurement decisions with support of forests' ecological health.

## Harvesting & Processing

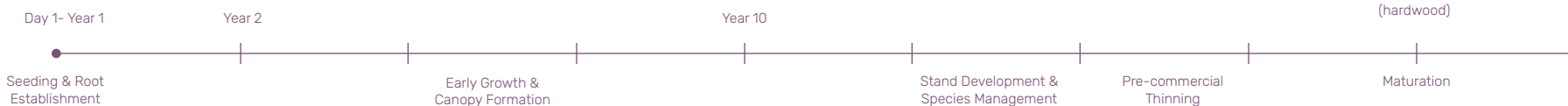
Timber is harvested through selective or mechanized logging. Sustainable harvest practices favor cuts that minimize soil disturbance, protect waterways, and promote biodiversity. Fiber that is not harvested may be left in the forest when culling occurs or when tops and slash are left behind. While this material eventually emits carbon back into the atmosphere, in some cases it benefits the forest by reducing runoff and compaction.

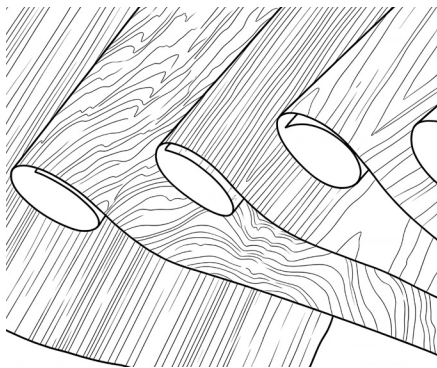
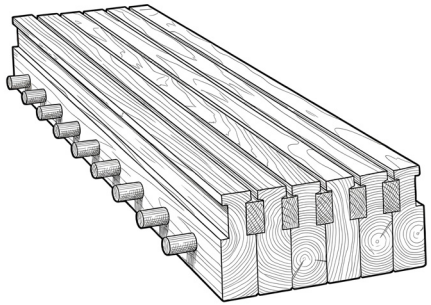
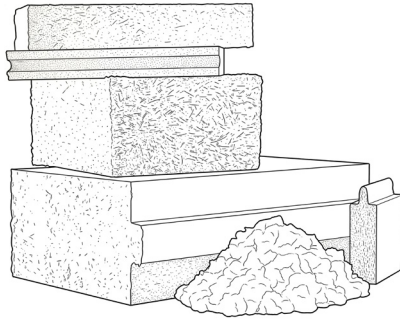
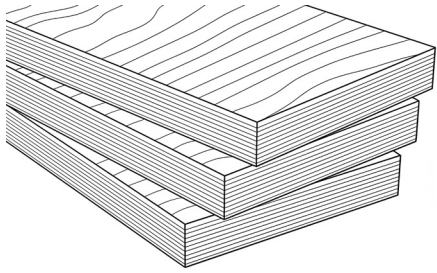
Designers can support sustainable forestry practices by specifying certified forest sources or working with suppliers to engage in informed sourcing. Additionally, teams can support effective use of wood through fiber-optimized design, use of salvaged wood and biodiverse species, and inclusion of products that utilize wood residues and byproducts (such as wood fiber insulation).

Once felled, trees undergo primary processing based on their morphology: straight-grained softwoods are often mechanically delimbed at the stump, whereas mature hardwoods may require manual delimiting. While the main trunk (bole) provides primary sawlogs, larger limbs are increasingly recovered for short-log production or specialized applications.

At the mill, transported logs are debarked and bucked to length. In some cases, CT or laser technology is used to optimize sawing patterns and maximize fiber yield. Modern operations utilize merchandising to partition wood into multiple product streams based on quality. High-value fiber is destined for long-term durable uses, lower-grade sections are diverted to paper or engineered panels, and residues, such as bark, chips, and sawdust, are repurposed for bioenergy or products like insulation or wood composites. This ensures that nearly 100% of the harvested biomass is utilized.

Throughout this process, grading verifies that each species meets its legal structural or aesthetic requirements. In the seasoning phase, conifers are typically kiln-dried rapidly to meet structural standards, while dense hardwoods require precision-controlled air- or kiln-drying to prevent warping and internal cellular collapse.





## Making

Wood is processed into solid lumber or engineered products such as plywood, cross-laminated timber (CLT), glulam, oriented strand board (OSB), and many others. These are formed by layering or bonding wood fibers, veneers, or laminations using adhesives, typically urea- or phenol-formaldehyde resins, though bio-based alternatives from lignin or soy are emerging. Wood fibers are also refined into insulation boards and acoustic panels, often bound with natural or minimal synthetic binders. Finishes and coatings may include plant-based oils, waxes, or low-VOC sealants. In hybrid construction, timber is commonly combined with materials like steel, clay, or lime plasters to balance structure, durability, and fire performance.

## Featured Applications

Wood's versatility makes it suitable for nearly every building element, from structural framing to finishes, fixtures, and furnishings. Mass timber systems like CLT and glulam are increasingly used in mid- and high-rise buildings as low-carbon alternatives to steel and concrete. Insulation, sheathing, and acoustic panels can improve thermal and acoustic comfort while maintaining vapor permeability. Interior solid and composite wood products are used for flooring, millwork, and furniture.

Innovations such as transparent wood, bio-modified cellulose façades, robotic fabrication, modular design, and reclaimed

wood markets demonstrate the potential of wood to combine performance, beauty, technology, and circular design within innovative building practices.

### Structural and Envelope

- Solid sawn lumber (framing, joists, beams)
- Cross-Laminated Timber (CLT) panels
- Glued-Laminated Timber (Glulam) beams and columns
- Nail-Laminated Timber (NLT)
- Dowel-Laminated Timber (DLT) decking
- Laminated Veneer Lumber (LVL)
- Parallel Strand Lumber (PSL)
- Timber curtain walls and façade systems
- Exterior cladding and rainscreens (boards, shingles, panels)
- Timber-concrete or timber-steel hybrid structural systems

### Insulation:

- Wood-fiber insulation boards and batts

### Interior Finishes & Applications:

- Flooring (solid, engineered, parquet)
- Millwork and trim
- Wood-wool acoustic panels and ceiling tiles
- Plywood sheathing
- Oriented strand board (OSB) sheathing
- Interior wall and ceiling linings (solid or veneered panels)
- Built-in cabinetry, partitions, and shelving
- Prefabricated modular timber panels and wall systems
- Decorative veneers and laminates
- Acoustic wall and ceiling panels

### Miscellaneous:

- Furniture and joinery (tables, seating, cabinetry)

## Care & Maintenance

Wood longevity is affected by environmental conditions, with possible deterioration stemming from physical (UV, abrasion, etc), chemical (moisture, salt, etc.) and biotic (e.g. fungi, insect) influences. **Moisture is one of the most critical factors, and generally speaking keeping wood moisture content below 20% prevents conditions under which mold, fungi and insects thrive.** Detailing for drainage and ventilation reduces deterioration. Protective finishes, plant-based oils, or phosphate fire coatings extend durability. Regular inspection, refinishing, and repair sustain performance and retain the material's stored carbon over decades.

## End of/Next Life

At its end-of-use, timber can be disassembled, a crucial step that facilitates direct reuse or repurposing into new lumber, furniture, or panels. Reversible fasteners (screws, bolts) support future disassembly and reuse, while bio-based adhesives can ensure that components remain non-toxic through future remanufacturing, recycling, or energy recovery. Cascading material use prolongs carbon storage by maintaining a product at its highest value for as long as possible. Crucially, the carbon stored in wood products can be coupled with ecological forest management to support ongoing sequestration via the forest carbon cycle.

+ 0 - 3 months

+ 1 - 6 months

+ 1 - 3 months

Harvest/Felling &  
Transport to Mill

Sawmilling, Drying &  
Conditioning

Secondary Processing &  
Engineered Wood Manufacturing

Quality Control  
& Finishing

## Governing Regulations

Wood use in construction is governed by a combination of building codes, performance standards, and certification systems. The 2021 International Building Code (IBC) formally permits mass timber construction up to 18 stories (Types IV-A, IV-B, IV-C), reflecting growing confidence in timber's fire and structural performance.<sup>129</sup>

Many players influence the degree of sustainability embodied in wood products and buildings. The primary stakeholders include:

- Regulators (clean air and water, policy, code)
- Best practices (state planning, voluntary practices)
- Landowners and Managers (TIMO, REIT, Family, Large Private, Tribal, BLM, State, and other Gov.)
- Certification Entities (FSC, SFI, PEFC, CSA, ATFS)
- Lumber Mills
- Lumber yards, wholesalers and distributors
- Product manufacturers (e.g., LVL, OSB, mass timber, insulation)
- Secondary manufacturers / fabrication subcontractors
- Mass timber installers
- General Contractors
- Project Clients

*"Landowners and lumber mills have the biggest impact on the availability of sustainable mass timber. Landowners decide how to manage their forest... mills determine which landowners they will source timber from... As forests are owned and managed by many types of entities, including federal, state, tribal, private industry, and private non-industry groups, the goals and objectives of each vary. While forest managers are experts in a complex domain, many owners are motivated*

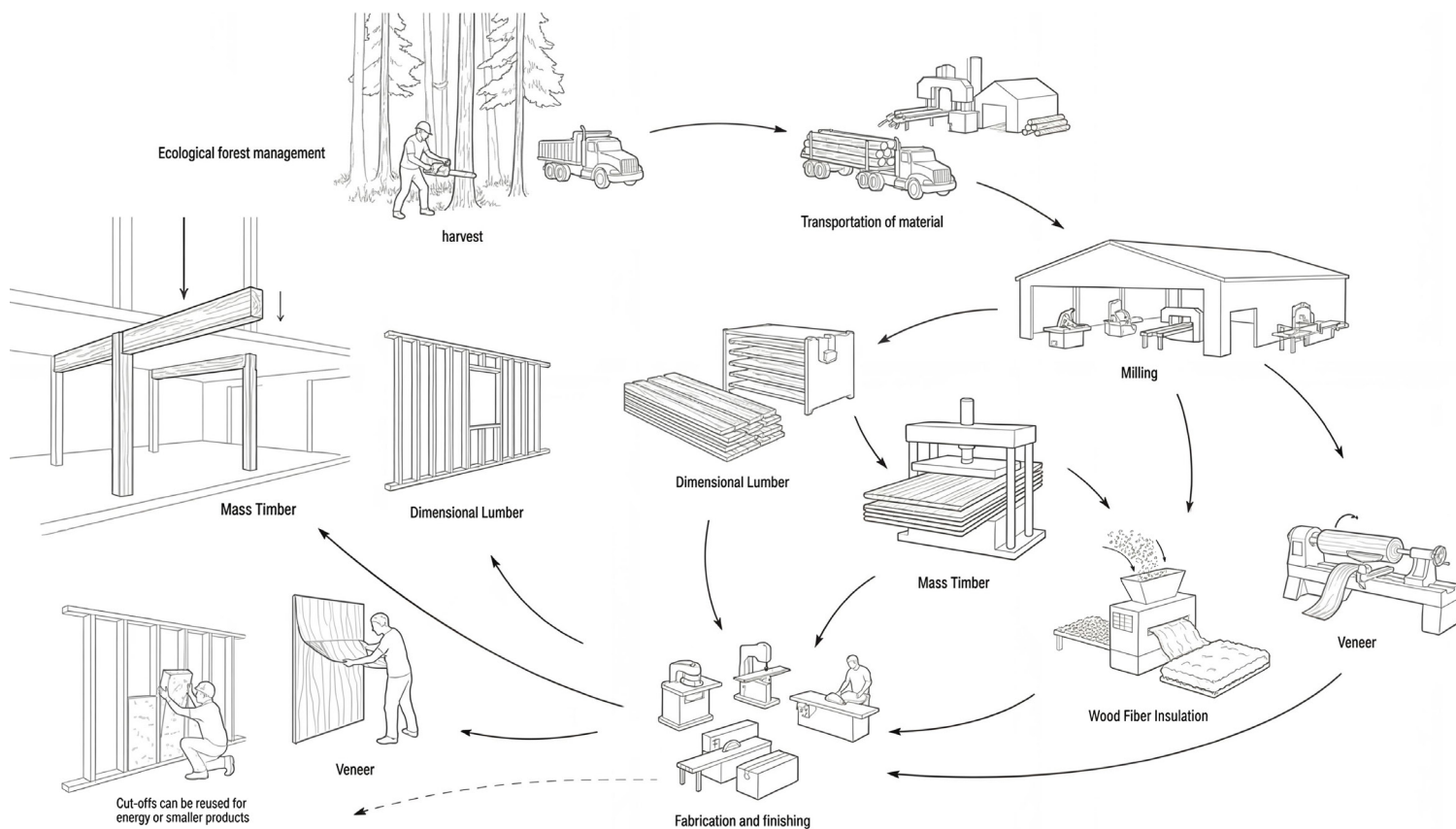
*to manage their land in response to regulations and market demand. A team may be able to secure timber that meets specific requirements through early planning. The earlier the engagement with suppliers sustainable wood sourcing partners, the easier this is to accomplish."*

- See the "Climate Responsibility" and "Sustainable Sourcing" in Getting to Craft in Mass Timber for more information on the forest carbon cycle and sourcing.

## Technical Design Data

Wood's performance varies by species, grade, density, and moisture content. Proper detailing and compatible finishes significantly influence durability and energy performance.

**Thermal:** Thermal resistance ranges from RSI-0.50 to 0.69/25mm (R-2.8 to 3.9/in) for wood-fiber insulation boards and approximately RSI-0.14 to 0.25/25mm (R-0.8 to 1.4/in) for solid softwood, providing moderate insulation and high heat storage capacity. Solid wood is anisotropic in



## Material Process Example

vapor diffusion, with  $\mu \approx 2\text{--}5$  along the grain and  $\mu \approx 20\text{--}50$  across the grain, while many wood-fiber products remain highly vapor permeable (e.g., insulation boards, which typically have  $\mu \approx 3\text{--}10$ ), allowing assemblies to regulate moisture.

**Density:** Varies widely by species; typical ranges include  $\sim 350\text{--}700\text{ kg/m}^3$  (22–44 lbs/ft<sup>3</sup>) for softwoods and  $\sim 600\text{--}900\text{ kg/m}^3$  (37–56 lbs/ft<sup>3</sup>) for hardwoods. Engineered products such as CLT or glulam typically fall within  $\sim 400\text{--}550\text{ kg/m}^3$  (25–34 lbs/ft<sup>3</sup>).

**Fire:** Structural timber chars at a predictable rate of  $\sim 0.65\text{ mm/min}$  (1.5in/hr), forming an insulating layer that protects the core. Wood-fiber boards can achieve Euroclass B reaction-to-fire ratings when treated, while timber assemblies can achieve 60-minute or greater fire resistance depending on assembly design.

**Moisture & Vapor:** Hygroscopic; equilibrium moisture content (EMC) depends on ambient conditions but is typically  $\sim 8\text{--}13\%$  in conditioned indoor environments ( $\sim 40\text{--}60\%$  RH). Moisture contents above  $\sim 20\%$  increase the risk of biological decay, so assemblies must be detailed to deflect, drain, and dry effectively. Wood-fiber insulation boards provide strong hygric buffering, allowing surface wetting to dissipate over time.

**Acoustic:** Wood-fiber acoustic panels typically achieve NRC  $\sim 0.5\text{--}0.8$ , with thicker boards capable of NRC  $\sim 1.0$ , providing strong sound absorption. Solid timber assemblies provide moderate sound insulation but typically benefit from layered or composite systems.

**Structural:** Average modulus of elasticity  $\sim 8\text{--}14\text{ GPa}$  (1150–2030 ksi), flexural strength  $\sim 60\text{--}90\text{ MPa}$  (8,700–13,000 psi), and compressive strength  $\sim 35\text{--}50\text{ MPa}$  (5,000–7,250 psi) parallel to grain, giving timber an excellent strength-to-weight ratio suitable for structural applications.

*\*Values represent typical ranges. Wood properties vary significantly by species, grade, density, and moisture content.*

### Strengths & Opportunities

#### Human health

- Natural, low-emission material that contributes to healthier indoor air when free of formaldehyde and synthetic binders.
- Supports biophilic design, offering sensory warmth and psychological well-being.
- Compatible with non-toxic, plant-based finishes and adhesives.

#### Ecosystem Health

- Responsibly managed forests maintain biodiversity, improve water and soil quality, and provide wildlife habitat.
- Mixed-species and continuous-cover forestry enhance resilience to fire, pests, and drought.
- Local sourcing reduces deforestation pressure and transportation impacts.

#### Climate Health

- Wood sequesters carbon during growth and continues to store it in buildings.
- Wood is roughly 50% carbon by dry weight, sequestering about  $1.83\text{ kg CO}_2/\text{kg}$  of wood. Long service life and reuse extend storage potential.

- Engineered timber replaces high-emission materials like steel and concrete.
- Cascading use and reuse extend carbon storage and delay emissions.

#### Social Health & Equity

- Certified and climate-smart forestry supports fair labor, Indigenous stewardship, and rural economies.
- Transparent certification systems (FSC, PEFC) uphold ethical sourcing and community benefits.
- Reinvestment in regional mills revitalizes local craftsmanship and jobs.

#### Circular Economy

- Design for disassembly and reuse allows timber elements to serve multiple life cycles.
- Bio-based adhesives and mechanical fasteners improve recyclability.
- Offcuts and residues can be upcycled into panels, insulation, or biochar, closing material loops.
- Mature supply chains with growing certification and traceability frameworks (FSC, PEFC, Climate Smart Wood).
- Engineered wood products enable tall, low-carbon buildings with excellent strength-to-weight ratios.
- Compatible with ecological forestry and polyculture, practices that enhance biodiversity and forest health.
- Vapor-open, hygroscopic, and thermally efficient; improves indoor comfort and reduces operational energy.
- Adaptable across structural, enclosure, and interior applications; offers natural warmth and biophilic value.

- Disassembly and reuse potential extends material life and preserves embodied carbon.
- Expanding innovation in bio-adhesives, transparent wood, and mass-timber modular systems.

### Challenges & Considerations

- Widespread use of synthetic adhesives (formaldehyde, isocyanates) can negatively impact indoor air quality and hinder recyclability.
- Unsustainable forestry and global demand risk overharvesting, habitat loss, and reduced biodiversity.
- Monoculture plantations deplete soils, increase pest vulnerability, and diminish ecosystem resilience.
- Fire safety and moisture control require careful detailing, coatings, or hybrid assemblies to meet code.
- Carbon benefits depend on long service life and verified forest regeneration; short-lived uses can negate sequestration gains.
- Certification costs and complexity limit access for small and Indigenous producers.
- Chemical treatments and finishes and hybrid assemblies composed of non-separable materials (e.g., concrete topping slabs) complicate reuse and circular recovery.

## Products

*Known bio-based products available at the time of writing. These products are a reference only; they have not been evaluated against the Common Materials Framework.*

### Structure

- CLT (Cross-Laminated Timber): [CRTC](#) (Advanced Cross-Laminated Timber / ACLT), [Crosswood](#) (hardwood CLT), [D.R. Johnson Wood Innovations](#), [Element5](#), [Evergreen CLT](#), [IB X-Lam/ International Beams](#), [Kalesnikoff](#), [Mercer Mass Timber \(Structurlam\)](#), [Nordic Structures](#), [SmartLam North America](#), [Sterling Structural](#), [Timber Age Systems](#) (forest-restoration CLT), [Timberlab](#), [Vaagen Timbers](#)
- DLT (Dowel-Laminated Timber): [Element5](#), [StructureCraft](#) (DowelLam), regional mass timber fabricators
- Glulam (Glue-Laminated Timber): [American Laminators](#), [Anthony Forest Products](#), [Art Massif](#), [Boise Cascade](#), [Element5](#), [FraserWood Industries](#), [Hampton Lumber](#), [Kalesnikoff](#), [Mercer Mass Timber \(Structurlam\)](#), [Nordic Structures](#), [RedBuilt](#), [Rosboro](#), [Spearhead Timberworks](#), [Timberlab](#), [Western Archrib](#), [Western Forest Products](#), [Weyerhaeuser](#)
- I-Joists: [Boise Cascade](#), [Pacific Woodtech](#), [RedBuilt](#), [Weyerhaeuser](#)
- MPP (Mass Ply Panels) / Veneer-Based Structural Panels: [Freres Engineered Wood](#)

- NLT (Nail-Laminated Timber): [Seagate Mass Timber](#), [StructureCraft](#), [Timberlab](#), [Western Archrib](#), regional mass timber fabricators
  - Other Engineered Wood Products (EWP), including LVL, LSL, and PSL: [Boise Cascade](#), [LP Building Solutions](#), [West Fraser](#), [Weyerhaeuser](#)
  - Solid Sawn Structural Lumber: (dimensional lumber and heavy timbers): Regional sawmills and timber frame suppliers including [Binderholz](#) (USA), [Canfor](#), [Hampton Lumber](#), [Interfor](#), [PotlatchDeltic](#), [Resolute Forest Products](#), [Sierra Pacific Industries](#), [West Fraser](#), [Western Forest Products](#), [Weyerhaeuser](#), and specialty timber frame suppliers including [Bensonwood](#), [New Energy Works](#), [Vermont Timber Works](#)
  - SRT (Structural Round Timber): [WholeTrees Structures](#)
  - Wood Structural Decking: [Boise Cascade](#), [Rosboro](#), [Western Archrib](#), regional mills
- ### Enclosure
- Modified Wood (thermally modified, acetylated, or furfurylated wood products): [Abodo](#), [Accoya](#), [Arbor Wood Co.](#), [Cambia](#), [CRTC](#), [Delta Millworks](#), [Kebony](#), [Lunawood](#), [reSAWN Timber Co.](#), [Thermory](#)
  - Naturally Durable Wood Cladding: [Atlantic White Cedar Company](#), [Black Locust Lumber](#), [Humboldt Sawmill](#), [Real Cedar member companies](#), Western Red Cedar producers (various mills)

- Structural Panels (Plywood and OSB): [Boise Cascade](#), [Georgia-Pacific, LP Building Solutions](#), [Roseburg](#), [West Fraser](#)
- Timber Façade and Wood Curtain Wall Systems: [Gutmann](#), [Nordic Structures](#), [Unicel Architectural](#) (RAICO), [Schüco](#), [Seagate Mass Timber](#), [StructureCraft](#), [Timberlab](#), [UNILUX](#)
- \* Wood Fiber Sheathing: [Gutex](#), [Pavatex](#), [STEICO](#), [TimberHP](#)

### Insulation

- \* Cellulose Insulation: [Applegate-Greenfiber Insulation](#), [Greenfiber](#), [National Fiber](#), [Nu-Wool](#)
- \* Rigid Wood Fiber Insulation Boards: [Gutex](#), [Soprema \(Pavatex\)](#), [STEICO](#), [TimberHP](#)
- \* Wood Fiber Insulation Batts: [STEICO](#), [TimberHP](#)
- \* Wood Fiber Loose-Fill Insulation: [TimberHP](#) (TimberFill)

### Interior Finishes

- Engineered Interior Panels (lowemitting plywood, MDF, particleboard with NAF binders): [Arauco](#), [Columbia Forest Products](#) (PureBond), [Roseburg](#), [States Industries](#), [Uniboard](#)
- Fiberboard Panels (compressed cellulose board): [Homasote](#)

- Solid Wood Flooring, Paneling, and Millwork: [Appalachian Woods](#), [Pioneer Millworks](#), [Urban Hardwoods](#), [Vermont Plank Flooring](#), reclaimed wood suppliers
- \* Wood Fiber Acoustic Panels: [Gutex](#), [STEICO](#), [Trolldtekt](#)
- \* Wood Wool Acoustic Panels: [Armstrong](#) (Tectum), [Trolldtekt](#)

### Other

- Prefabricated / Modular Mass Timber Systems: [BC Passive House](#), [b\\_solution](#) (Binderholz), [CRTC](#), [Green Canopy](#), [Node](#), [IDCUBED](#), [Innovative Structures](#), [Intelligent City](#), [Juno](#), [Kalesnikoff](#), [Nordic Structures](#), [P.A.T.H. Homes](#), [TMBR](#), [Unity Homes \(Bensonwood\)](#)
- Reclaimed structural timber and lumber: [Cambium Carbon](#), [Heritage Salvage](#), [Longleaf Lumber](#), [Pioneer Millworks](#), [TerraMai](#), [Urban Hardwoods](#), [Vintage Timberworks](#), and regional urban wood salvage networks and material reuse organizations.

*\* Residue-based wood products are often manufactured from sawmill byproducts, recycled paper fiber, or other wood processing residues. These materials extend the value of harvested biomass through cascading material use, converting lower-grade wood and manufacturing residues into durable building products before potential recycling, reuse, or energy recovery.*



# Children's Museum of Eau Claire

**Location:** Eau Claire, WI

**Climate Zone (ASHRAE):** 6A

**Year:** 2022

**Architect:** Steinberg Hart

**Fabricators:** Whole Trees Structures

**Materials:** Structural round timber

(Douglas fir, maple, ash)

**Source:** [WholeTrees](#)

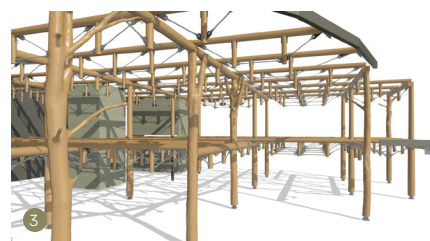
The Children's Museum of Eau Claire (CMC) realized a decade-long vision with a two-story, approximately 26,000-square-foot carbon-neutral building that places Structural Round Timber (SRT) at the center of both its structural system and visitor experience. Designed by Steinberg Hart with engineering by KPFF and fabrication by WholeTrees Structures, the project demonstrates how whole-tree construction can combine architectural expression, structural performance, and environmental responsibility.

CMC is the first known two-story building to use SRT trusses and branching columns to support concrete on metal deck, creating a canopy-like interior that evokes a forest environment and reinforces the museum's biophilic and educational mission. WholeTrees applied proprietary tree scanning and digital modeling processes to evaluate each log's geometry, fiber orientation, and strength characteristics, allowing naturally tapered,

unmilled timbers to be precisely engineered and integrated into a complex structural system. This technology enabled the team to optimize each tree's structural role while preserving its organic form.

The project sourced timber from three sustainably managed, single-origin forests: Douglas-fir truss material from Port Blakely in Washington, 30-foot-tall branched maple columns from Seven Islands Land Company in Maine, and ash columns from the Township of Sheboygan in Wisconsin. These materials form a visible narrative of regional forestry, renewable resources, and responsible sourcing.

Through the extensive use of SRT, the building sequesters approximately 159,000 kgCO<sub>2</sub> and supports the museum's goal of operating as a fully renewable-energy, carbon-neutral facility. The project demonstrates how whole-tree construction and digital fabrication can advance low-carbon, community-focused architecture.



1. Interior view. Image by Kleine Leonard Photography.
2. Roof trusses. Image by Kleine Leonard Photography.
3. 3D model of structure. Image by WholeTrees.
4. Interior view of column. Image by Kleine Leonard Photography.



# DC Southwest Neighborhood Library

**Location:** Washington, DC, USA

**Climate Zone (ASHRAE):** 4A

**Year:** 2021

**Architect:** Perkins&Will

**Structural Engineer + Fabricator:**  
StructureCraft

**Construction Manager:** Turner  
Construction

**Materials:** Dowel-laminated timber (DLT)  
panels (2×6 roof, 2×8 floor) supported by  
exposed glulam beams and columns

**Source:** [Perkins&Will](#)

The DC Southwest Neighborhood Library demonstrates how bio-based structural systems can be deployed in civic architecture through adhesive-free timber construction and prefabricated assembly. The approximately 20,000 ft<sup>2</sup> building replaces an outdated neighborhood library with a light-filled civic space designed to strengthen connections to the surrounding park while advancing sustainable construction practices. It is the first public building in Washington, DC to use dowel-laminated timber (DLT), a structural panel system composed entirely of dimensional lumber connected with hardwood dowels rather than synthetic adhesives.

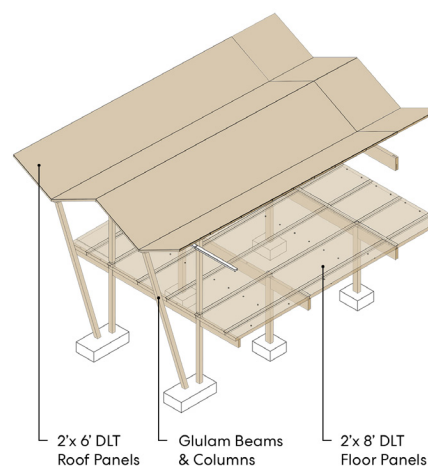
The DLT panels are fabricated from SPF (spruce-pine-fir) dimensional lumber, a widely available North American structural softwood resource. Roof panels constructed from 2×6 members and floor panels from 2×8 members are supported by glulam beams and columns and remain fully exposed throughout the interior and at exterior soffits. By allowing the timber structure to serve simultaneously as structure, finish, and architectural expression, the design reduces applied materials while highlighting the warmth and tactile qualities of wood.

The structural system works in conjunction with a hybrid timber-steel lateral system, demonstrating how bio-based structural elements can integrate with conventional structural strategies.

Prefabrication played a central role in the project's delivery. The folded-plate roof geometry was digitally modeled and fabricated off-site as large structural assemblies, with some prefabricated modules reaching roughly 70 feet in length. These timber components were transported to the site and installed rapidly by a small specialized crew, reducing construction time and minimizing jobsite disruption.

Through its glue-free timber panels, exposed structural system, and digitally coordinated prefabrication strategy, the project demonstrates how bio-based materials can support material efficiency, reduced construction impacts, and durable low-carbon civic buildings.

For more on this project, mass timber implementation, and sustainable wood sourcing, see [Getting to Craft in Mass Timber](#).



2



3

1. Exterior view. Image by James Steinkamp Photography.
2. Typical framing diagram. Image by Perkins&Will.
3. Roof canopy & column connection details. Images by James Steinkamp Photography.



# Massivhaus

**Location:** Bar Harbor, ME, USA

**Climate Zone (ASHRAE):** 6A

**Year:** 2024

**Architect:** OPAL

**Construction Manager:** AlliedCook

**Consultants:** Thornton Tomasetti, Taitem, Hedefine, Coplon Associates

**Materials:** CLT and glulam (NotchSB, KLH), wood-fiber insulation (TimberHP and STEICO), Eastern white pine siding and cladding

**Source:** [OPAL](#)

The Massivhaus project by OPAL Architecture is an innovative mass timber student housing building at the College of the Atlantic in Bar Harbor, Maine. It employs an all-wood structural system centered on cross-laminated timber (CLT), paired with wood infill walls, thermally modified ash cladding, and wood-fiber insulation to create a high-performance, low-carbon assembly that aligns with Passive House principles. The design team intentionally chose wood as the primary material to leverage its renewability, carbon sequestration potential, and indoor environmental quality benefits, resulting in a structure that is both durable and thermally efficient while expressing wood's natural warmth and tactile character. The overall approach reflects OPAL's firmwide emphasis on sustainable, human-centered architecture informed by ecology and performance.

Construction centers on prefabricated mass timber elements, with CLT serving as the primary structural system and wood-fiber insulation supporting enclosure performance. This predominantly wood-based assembly creates a highly insulated, vapor-permeable envelope that supports strong thermal and moisture performance while aligning with Passive House energy targets. The project demonstrates how engineered timber systems can meet rigorous performance criteria while reducing embodied carbon and enhancing occupant comfort through natural materials.

The whole-building life cycle analysis (LCA) carbon estimate, measured over a 60-year service life using the RICS methodology, is 351 kgCO<sub>2</sub>e/m<sup>2</sup>, assuming the proposed renewable energy installation. This represents a 90% reduction from baseline.



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1. Exterior view. Image by Trent Bell.
2. Interior view. Image by Trent Bell.
3. Wood fiber insulation board exterior. Image by OPAL.



## Pilefaçade

**Location:** Copenhagen, Denmark

**Climate Zone (ASHRAE):** 5A

**Year:** 2024

**Architect:** Schmidt Hammer Lassen (the Danish studio of Perkins&Will)

**Engineering + Fabrication:** Staticus, moow (Made out of Willow)

The Pilefaçade Project is an experimental façade system that explores how fast-growing bio-based materials can be integrated into contemporary building envelopes. Developed through collaboration between architects, material researchers, and façade engineers, the project investigates willow, one of the fastest-growing woody plants in the Northern Hemisphere, as a primary façade material within a modular curtain wall assembly.

Historically cultivated across Northern Europe, willow has often been directed toward low-value uses such as biomass fuel or agricultural applications. Pilefaçade reframes willow as a high-value building material by developing components from different parts of the plant. Thick branches are laminated into structural frame elements, shorter sections are CNC-milled into exterior rainscreen cladding profiles, and residues are processed into pressed boards. This cascading material strategy maximizes the value of harvested biomass while minimizing waste.

The façade is organized as a unitized wall assembly integrating glazing and opaque enclosure elements within a

**Cultivation and Harvest:** Pilebyg A/S

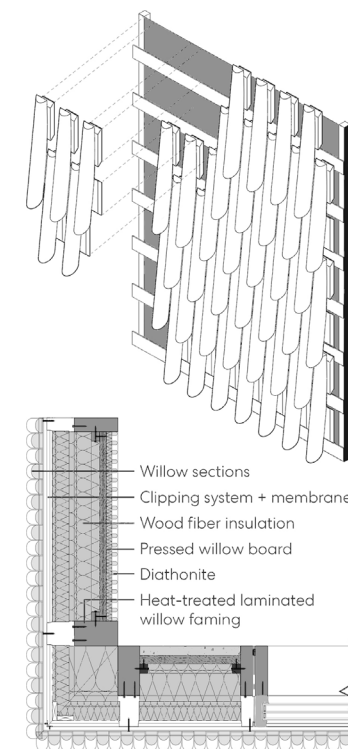
**Materials:** Willow structural elements, willow rainscreen cladding, pressed willow panels, cork-lime insulation plaster (Diathonite)

**Source:** [Pilefaçade Project](#)

laminated willow structural frame. From exterior to interior, the assembly begins with a ventilated rainscreen composed of clipped willow branch elements mounted to custom rails. This layer sits over a waterproof membrane attached to thermally modified laminated willow framing members that form the primary structure of the façade and accommodate an integrated insulated glazing unit (IGU).

Within the opaque wall areas, wood-fiber insulation provides the primary thermal layer. Pressed willow boards serve as a rigid interior substrate, finished with Diathonite, a cork- and lime-based insulation plaster that replaces several conventional enclosure layers while providing vapor permeability, acoustic insulation, and humidity regulation. This largely bio-based, high-performing wall assembly omits primary drivers of embodied carbon in envelope assemblies, such as opaque curtain wall modules and metal framing.

By pairing modular façade technology with rapidly renewable biomass, Pilefaçade demonstrates how underutilized plant resources such as willow could complement conventional timber in future low-carbon building systems.



1. Constructed modular assembly. Image by SHL / Perkins&Will.
2. Debarked willow stems (growth after 5 years). Image by SHL/Perkins&Will.
3. Wall assembly detail. Image by SHL / Perkins&Will.

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## Networks & Groups

### [American Wood Council \(AWC\)](#)

Develops the National Design Specification (NDS), which is the structural design standard referenced in the IBC for all wood construction.

### [APA – The Engineered Wood Association](#)

Trade association representing manufacturers of structural engineered wood products; develops the product standards (notably ANSI/APA PRG 320 for CLT and ANSI A190.1 for glulam) that are referenced in both the US International Building Code and the National Building Code of Canada.

### [BC Wood](#)

Trade association representing British Columbia’s value-added wood manufacturers, helping them expand into global export markets.

### [Canadian Wood Council \(CWC\)](#)

Primary resource for design standards, code development, and market promotion for wood products in Canada.

### [Cecobois](#)

Promotes wood construction in Quebec by providing technical support, education, and resources to architects and engineers.

### [Colorado Mass Timber Coalition](#)

Advances Colorado’s mass timber sector to address wildfire risks and housing needs while strengthening local forest product economies.

### [FPInnovations](#)

Canada’s national forest products research institute, responsible for much of the foundational CLT and mass timber research that underpins North American product standards.

### [New England Forestry Foundation](#)

Conserves forests and promotes sustainable management across New England, advocating for wood-based climate solutions and healthy, working woodlands.

### [Oregon Mass Timber Coalition](#)

Collaborative partnership driving Oregon’s mass timber industry forward through research, workforce development, and expanding sustainable wood product manufacturing capabilities.

### [Quebec Wood Export Bureau \(QWEB\)](#)

Promotes Quebec’s wood products internationally, connecting global buyers with regional manufacturers while emphasizing sustainable building and innovation.

### [Sustainable Northwest](#)

Bridges conservation and economy, supporting sustainable forestry and rural communities to ensure long-term environmental and economic health.

### [Think Wood](#) (Softwood Lumber Board)

The consumer and designer-facing education program funded by US softwood lumber producers. Less technical than WoodWorks but high visibility.

### [WoodWorks](#) (Wood Products Council)

Primary US resource for mass timber design support, education, and project assistance for architects and engineers.

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# Glossary

## Overarching Definitions

Term	Definition	Term	Definition
Binder	A substance used to create cohesion between aggregate or fiber particles, providing mechanical strength to a composite material.	Carbon Sequestration	The process of capturing and storing carbon dioxide (CO <sub>2</sub> ) from the atmosphere for extended periods of time. In biological systems, plants absorb CO <sub>2</sub> through photosynthesis and store it in their biomass. In biogenic carbon accounting, carbon sequestration values refer to the CO <sub>2</sub> removed during growth, while stored carbon values reflect the carbon retained within a material and may differ over its life cycle.
Bio-Based Materials	A material wholly or partly derived from living or recently living biological resources. Bio-based materials store biogenic carbon captured during plant growth, and can support low-carbon building systems when responsibly sourced and manufactured. This term refers to the origin of the material, not its end-of-use behavior. Bio-based feedstocks do not guarantee biodegradability, compostability, or low environmental impact, as these depend on how the material is manufactured, detailed, and managed throughout its life cycle.	Cast-in-Place	A construction technique where hempcrete, concrete, earth, or similar are poured into forms in situ on the job site rather than being prefabricated.
Biogenic Carbon	Carbon derived from biological sources (biomass) that was originally captured from the atmosphere via photosynthesis, rather than being fossil-based.	Chemicals of Concern (CoCs)	Substances commonly found in building materials that have been identified by government agencies or scientific organizations as harmful to human health, environmental health, or climate. These include formaldehyde-based resins (such as Melamine-Urea-Formaldehyde (MUF) and Urea-Formaldehyde (UF)), per- and polyfluoroalkyl substances (PFAS), and others.
Biophilic Design	An architectural framework that weaves natural materials, light, and vegetation into the built environment to improve occupant health and connectivity to nature.	Composite	A product which is made from a combination of two or more constituent materials with different properties.
Bioregion / Bioregional Sourcing	A bioregion is a geographically distinct area defined by its ecological characteristics like watershed, soil, climate, and native species rather than political boundaries. Bioregional sourcing refers to the practice of procuring materials from within or near this ecological region, reducing transportation impacts, strengthening local supply chains, and connecting material choices to the ecosystems and communities where a building is situated.	Culm	The hollow or pithy segmented stem of grasses, specifically referring to the structural “trunk” of bamboo or cereal grains.
Byproduct	A secondary material generated during the manufacturing or chemical processing of a primary product; it is often diverted from waste for secondary use.	Cultivate	The deliberate act of preparing land and tending to crops or biological organisms to encourage growth and improve yield.
Capillary Break	A physical gap or a non-porous layer (like a membrane or coarse gravel) placed within or between building assemblies to interrupt the wicking of liquid water through porous materials. Commonly used at the base of walls, beneath slabs, and at material transitions where moisture migration could compromise durability or performance.	Embodied Carbon	The total greenhouse gas emissions that are associated with material extraction, production, transport, construction, use (not including operational energy), repair/replacement, and end-of-use.
		Environmental Product Declaration (EPD)	A standardized, third-party verified document that quantifies the environmental impact of a product throughout its life cycle.
		Global Warming Potential (GWP)	A metric used to compare the heat-trapping ability of different greenhouse gases over a specific period (usually 100 years) relative to CO <sub>2</sub> .

## Overarching Definitions, Cont'd.

Term	Definition	Term	Definition
Grading	The classification of materials (like lumber, soil, or cork) based on structural integrity, quality, or aesthetic appearance according to industry standards.	Polyculture	The simultaneous cultivation of several crops or species in the same space, mimicking natural ecosystem diversity more closely.
Harvest	The act of gathering a plant from its environment for processing and use.	Polyurethane (PU)	Traditionally derived from petrochemicals, it is a key focus of green chemistry, where fossil-based polyols are increasingly replaced with renewable feedstocks like vegetable oils or lignin.
Health Product Declaration (HPD)	A standardized format for reporting product contents and associated health hazards, allowing for transparency regarding chemical ingredients and human toxicity.	Primary Product	The main material or good intended for production during a manufacturing or biological process.
Hurd / Shive	The woody, inner core of stalks (like hemp or flax) that remains after the outer bast fibers have been removed.	Regenerative	A design, land-use, and material approach that goes beyond reducing harm, striving for net-positive ecological and social outcomes. Where sustainability seeks to reduce harm, regenerative practice seeks to exchange resources with living systems in a way that supports soil health, biodiversity, water cycles, and community resilience over time.
Hygric Buffering	The ability of a material to absorb and release moisture in response to changes in humidity, helping moderate indoor humidity levels and reduce moisture fluctuations within building assemblies.	Retting	A controlled decay process (using moisture and microbes) to dissolve the cellular tissues surrounding bast fibers, allowing them to be separated from the stalk.
Hygroscopic	The physical property of a material that allows it to readily absorb and release moisture from the surrounding atmosphere in response to changes in humidity, reaching equilibrium with ambient conditions. In building assemblies, hygroscopic materials such as earth, wood, and hemp can moderate indoor humidity levels when properly detailed and vapor-open.	R-value / Thermal Resistance	A measure of a material's resistance to heat flow, expressed in units of hr·ft <sup>2</sup> ·°F/BTU (imperial) or m <sup>2</sup> ·K/W (metric). Higher R-values indicate greater insulating performance. R-value is additive across layers in a wall assembly and varies with material density, moisture content, and installation quality.
Inoculate	The intentional introduction of a microorganism (like mycelium or bacteria) into a substrate to initiate growth or a specific chemical reaction.	Shrinkage	The reduction in volume or dimensions of a material due to the loss of moisture during drying. Common in wood and earth, shrinkage can be controlled through proper particle grading, fiber addition, and mix design. In earthen construction, managing shrinkage is critical to preventing cracking in walls, blocks, and plasters.
Life Cycle Assessment (LCA)	A standardized methodology for quantifying the environmental impacts of a product or building across its full life cycle. LCA results are commonly expressed in Global Warming Potential (GWP). LCA informs Environmental Product Declarations (EPDs) and can be used to assess materials, products, or for whole building life cycle assessment (WBLCA).	Synthetic Material	Artificial, human-made products, often derived from petrochemicals.
Mineral-Based Materials	A material derived from abiotic, geological sources rather than biological ones. Many mineral-based materials, including earth, lime, and stone, can be used with minimal processing or chemical alteration, supporting low-carbon applications and circular end-of-life pathways such as reuse, reintegration into soil, or in the case of lime, the reabsorption of CO <sub>2</sub> released during its production.	Thermal Mass	The ability of a high-density material to absorb, store, and slowly release heat energy, buffering indoor temperature swings. Materials with high thermal mass, such as earth, stone, and concrete, are most effective in climates with significant diurnal temperature variation. High thermal mass does not equate to high insulation value; dense earthen walls can regulate temperature passively while still requiring additional insulation in colder climates.
Monoculture	An agricultural or forestry practice of growing a single species in a given area, often leading to lower biodiversity and higher pest vulnerability.		

## Overarching Definitions, Cont'd.

Term	Definition
Vapor Barrier vs. Vapor Retarder	A vapor barrier is a material with very low vapor permeability (typically less than 0.1 perms) that effectively blocks the movement of water vapor through a building assembly. A vapor retarder slows but does not stop vapor diffusion, allowing assemblies to dry in one or both directions. Many bio-based assemblies rely on vapor-open systems that can buffer and release moisture rather than blocking it entirely, making the distinction critical to proper detailing.
Vapor Permeability	The rate at which water vapor passes through a material, often measured in "perms," indicating how "breathable" a material is to gas-phase moisture.

## Bamboo Definitions

Term	Definition
Bahareque	A traditional construction system found in Latin America that combines bamboo (often <i>Guadua</i> ), earth, and plaster to create load-bearing or infill walls with good seismic performance.
Bamboo Node	The solid diaphragm within a bamboo culm that separates hollow sections. Nodes contribute to shear resistance and limit crack propagation.
Clumping Bamboo	A bamboo growth type characterized by tight, noninvasive rhizomes. Most construction-grade bamboo species, including <i>Guadua</i> and <i>Dendrocalamus</i> , are clumping varieties.
Engineered Bamboo	Bamboo products manufactured by bonding strips, chips, or fibers with adhesives under heat and pressure to create dimensionally consistent panels, beams, or boards. Engineered bamboo products mirror many engineered wood products such as CLT, LVL, and OSB, and offer greater dimensional stability than natural culms.
Esterilla	A flattened bamboo panel made by splitting and opening a culm longitudinally, then pressing it flat. Commonly used in Latin American construction for wall infill, ceilings, and formwork, and as a substrate for earth plaster.
Preservative Treatment	A process applied to bamboo or wood to protect against insects, fungal decay, and moisture degradation. Common methods for bamboo include boron salt solutions, smoking, and heat treatment, which neutralize natural sugars that attract pests and extend service life from a few years to several decades.

## Bamboo Definitions, Cont'd

Term	Definition
Rhizome	An underground stem system from which bamboo shoots grow. Rhizomes allow bamboo to regenerate without replanting and contribute to soil stabilization.
Running Bamboo	A bamboo growth type with aggressive, spreading rhizomes that can expand rapidly beyond intended boundaries. Running bamboo species, including <i>Moso</i> ( <i>Phyllostachys edulis</i> ), are widely cultivated in Asia for commercial and construction use, but are generally avoided in landscape planting in North America and Europe due to their invasive potential outside their native range.

## Biochar Definitions

Term	Definition
Activation	A secondary thermal or chemical process (e.g., steam or chemical treatment) that increases biochar's surface area and reactivity. Activated biochar differs from standard biochar.
Adsorption	The process by which molecules of a gas, liquid, or dissolved substance adhere to the surface of a solid material rather than being absorbed into its bulk. Biochar's extensive internal surface area makes it highly effective at adsorbing contaminants, nutrients, and moisture onto its pore walls, which underlies many of its soil amendment and building performance properties. Distinct from absorption, in which a substance is taken into the interior of a material.
Aromatic Carbon Structure	Ring-like molecular structures formed during pyrolysis that give biochar its chemical stability and resistance to oxidation.
Biochar	A stable, carbon-rich material produced by heating biomass in a low-oxygen environment (pyrolysis). Distinguished from charcoal by its intended use for carbon storage, soil improvement, or material applications.
Bio-oil	A liquid by-product of pyrolysis that can be used as fuel or chemical feedstock in some systems.
Biosolids/ Waste Water Sludge	Organic materials produced during the treatment of wastewater at treatment plants.

## Biochar Definitions, Cont'd.

Term	Definition
Carbon Black	A fossil-fuel-derived carbon product commonly used in pigments, plastics, rubber, and asphalt. Biochar can replace carbon black in some applications with lower embodied carbon.
Feedstock	Any organic material used to make biochar, such as wood waste, agricultural residues, manure, or food waste. Feedstock type strongly influences biochar properties.
Gasification	A high-temperature thermochemical process that converts biomass into a combustible gas mixture (syngas) in a low-oxygen environment. Unlike pyrolysis, gasification prioritizes energy production, with biochar as a secondary co-product rather than the primary output.
Porosity (Biochar)	The proportion of void space within a material relative to its total volume, expressed as a percentage. Biochar's highly porous structure, comprising micro-, meso-, and macropores, contributes to its insulation value, moisture buffering capacity, and ability to adsorb contaminants and nutrients.
Pyrolysis	A thermal decomposition process that heats biomass (typically 350–700 °C) in a low-oxygen environment, producing biochar, bio-oil, and syngas.
Recalcitrant Carbon	The chemically stable fraction of carbon in biochar composed largely of aromatic carbon rings. This fraction resists biological decay and enables long-term carbon storage.
Soil Amendment	A material added to soil to improve physical, chemical, or biological properties. Biochar is most commonly regulated and certified for this use.
Syngas	A combustible gas mixture (primarily CO, H <sub>2</sub> , and CH <sub>4</sub> ) released during pyrolysis. Often captured and reused as an energy source in well-designed systems.
Terra Preta	Meaning "black earth" in Portuguese, Terra Preta refers to highly fertile, charcoal-enriched soils found in the Amazon Basin, created by Indigenous peoples over centuries through the intentional addition of biochar, bone, and organic matter. It is one of the earliest known examples of biochar use for soil enhancement and long-term carbon storage.

## Cork Definitions

Term	Definition
Agglomerated Cork	Cork granules bound with polyurethane or another binder which accounts for around 10% of the product. Granules are ground from cork by-products, often from cork wine stoppers. Commonly formed using a compression mold.
Amadia Cork	The high-quality cork obtained from the third and subsequent harvests of a cork oak tree, typically starting when the tree is 45–50 years old. After multiple regeneration cycles, the bark becomes uniform, elastic, smooth, and dense, making amadia cork suitable for premium applications such as flooring, façade panels, architectural finishes, and high-grade products. It represents the highest commercial grade of natural cork.
Autoclave	An autoclave is used for industrial processes that require high temperatures and moist heat.
Expanded Cork	Low-density expanded cork panels or loose granules, typically around 7 lb/cu ft for concealed insulation applications. Expansion lowers the density of the cork but increases the insulation value by increasing the amount of trapped gas bubbles in the closed honeycomb cellular structure.
ICB (Insulation Cork Board)	Expanded cork panels produced without synthetic binders by heating cork granules with steam until they expand and self-bond through their natural suberin content. ICB is lightweight, vapor-open, and thermally stable, used in both concealed and exposed wall, roof, and floor assemblies.
Montado / Dehesa	The traditional agro-silvo-pastoral landscapes of Portugal and Spain where cork oaks are cultivated alongside grazing, seasonal agriculture, and native biodiversity. Recognized as among the richest ecosystems in Europe, these landscapes represent an integrated land-use system shaped by centuries of stewardship and are the primary source of the world's cork supply.
Phellem	The outermost layer of the cork oak's bark, composed of densely packed dead cells filled with suberin and air. Phellem is the commercially harvested cork material, growing at a rate of 1–3 mm per year and regenerating fully after each harvest.
Stripping	The careful removal of the outer bark of a cork oak tree during harvest, without cutting down or damaging the tree.
Subericulture	The regulated practice of managing and harvesting cork oak forests, including bark-stripping cycles.

## Cork Definitions, Cont'd.

Term	Definition
Suberin	A waxy polyester biopolymer found in the cell walls of cork and other plant tissues. Suberin gives cork its elasticity, water resistance, and ability to self-bond under heat, and is responsible for many of cork's key building performance properties.
Tannins	Naturally occurring organic compounds found in cork oak bark that help protect the tree from pests and decay.
Virgin Cork	The first layer of bark harvested from a cork oak tree, typically when the tree is about 25 years old. It is thicker, irregular, and less elastic than later harvests.

## Earth Definitions

Term	Definition
Adobe	Unfired earth bricks made from a mixture of clay, sand, and fibers (often straw), shaped in molds and air-dried. Adobe can be load-bearing where permitted by code.
Breathability (Earth)	The capacity of an earthen assembly to allow water vapor to pass through freely, supporting the material's ability to dry after wetting and regulate indoor humidity. As hygroscopic materials, earthen assemblies rely on vapor-open systems rather than moisture barriers, and perform best when properly detailed to absorb and release moisture over time.
Capillary Break (Earth)	A layer or detailing strategy that prevents ground moisture from wicking into earthen walls, typically achieved using stone, fired brick, concrete, or gravel at the base of walls.
Clay	The finest mineral particle in soil (<0.002 mm), responsible for plasticity and cohesion in earthen construction. Clay provides binding strength when mixed with water.
Cob	A hand-formed earth construction method using a stiff mix of clay, sand, and fibers placed monolithically without formwork. Cob walls are thick, load-bearing, and slow to build.

## Earth Definitions, Cont'd

Term	Definition
Compressed Earth Block (CEB)	Uniform unfired masonry units made by mechanically compressing damp earth in a block press. CEBs may be stabilized or unstabilized and can be used in load-bearing construction.
Earthen Binder	The component that holds particles together in an earthen mix. In unfired earth, clay acts as the primary binder; stabilizers such as lime or cement may be added to improve strength and durability.
Earthen Plaster	A finish material made from fine clay, sand, and fibers applied to interior or exterior surfaces. Earthen plasters are vapor-permeable and repairable.
Formwork	Temporary molds used to shape earthen materials during construction, most commonly used in rammed earth and light straw clay systems.
Gravel / Aggregate	Soil particles larger than 2 mm in diameter. Aggregates improve strength and reduce shrinkage but must be properly graded for earthen construction.
Light Straw Clay (LSC)	A non-structural infill system where straw fibers are coated with a clay slip and lightly compacted into formwork. LSC provides insulation and vapor openness rather than load-bearing capacity.
Loam	A well-balanced soil composed of a mixture of sand, silt, and clay in roughly equal proportions. Loam is considered ideal for agriculture and earth construction due to its workability, drainage, and structural stability.
Monolithic Construction	Building systems formed as a continuous mass rather than discrete units. Cob and rammed earth are monolithic earth systems.
Optimum Moisture Content (OMC)	The specific water content at which soil achieves maximum density when compacted. Critical for rammed earth and CEB performance.
Pozzolan / Trass-Lime	A pozzolan is a silica-rich material that reacts with lime in the presence of water to form a durable, hydraulic binder. Trass-lime is a specific pozzolanic mortar made from volcanic tuff (trass) mixed with lime, used historically and in contemporary earthen construction to improve weather resistance and surface durability without significantly reducing vapor permeability.

## Earth Definitions, Cont'd.

Term	Definition
Rammed Earth	An earth construction method where damp soil is compacted in layers inside formwork to create dense, load-bearing walls. May be stabilized or unstabilized.
Silt	Soil particles between clay and sand in size (0.002–0.06 mm). Silt contributes to workability but excessive silt can weaken earthen mixes.
Stabilizer	An additive used to improve the durability or strength of earthen materials. Common stabilizers include lime and cement; bio-based or chemical stabilizers are less standardized.
Wattle and Daub	A traditional wall system consisting of a woven lattice (wattle) coated with an earth-based plaster (daub). Typically non-structural infill.

## Flax Definitions

Term	Definition
Bast Fiber	The strong, cellulose-rich fibers found in the outer stem of certain plants, including hemp, flax, and jute. Bast fibers are separated from the woody inner core through retting and mechanical processing, and are used in textiles, insulation, composites, and plasters.
Field Retting / Dew Retting	The traditional flax processing method in which harvested flax stems are left on the field in windrows, allowing dew, rain, sunlight, and naturally occurring microorganisms to break down the pectins that bind the fibers to the woody core.
Heckling	The final combing step in flax processing in which cleaned flax fibers are drawn through progressively finer metal combs to separate long, high-quality fibers from shorter fibers (tow) and to align the remaining fibers parallel. This process removes residual shives and impurities, producing smooth, uniform fibers suitable for spinning into linen or for high-performance composite applications.
Linseed Oil	A drying oil pressed from flaxseed that polymerizes and hardens on exposure to air. Used for millennia as a natural wood finish, paint binder, and sealant, linseed oil is a primary ingredient in linoleum and natural oil paints, offering a low-toxicity alternative to petrochemical coatings.

## Flax Definitions, Cont'd

Term	Definition
Scutching	A mechanical step in flax processing that follows breaking, in which loosened flax stems are beaten or scraped to remove woody fragments (shives) from the bast fibers. The process further cleans and separates the fibers, preparing them for heckling and improving fiber purity and quality for textile and composite uses.
Tow	The short, coarser flax fibers separated from longer bast fibers during the heckling process. Lower in quality than long-line fibers, tow is used in insulation, composite reinforcement, and other applications where fiber length and uniformity are less critical.

## Hemp Definitions

Term	Definition
Bonding Coat	The initial thin layer of binder rich granulated plaster used in lined applications of hemp-lime construction to ensure adhesive and/or mechanical bonding.
Decortication	The mechanical process of separating the stalk, removing the outer fibers from the inner hurd.
Hand tamped	Packing hempcrete manually to infill structure, typically in place of insulation between structural framing members.
Hempcrete	Commonly used term for hemp-lime.
Hempcrete block	Modular blocks of hempcrete.
Hemp-lime	A bio-aggregate composite consisting of hemp hurd and a mineral-based binder, most commonly lime.
Lime Carbonation / Mineralization	The curing process by which lime-based binders absorb carbon dioxide from the atmosphere and convert back into calcium carbonate, hardening over time. In hempcrete, this process gradually mineralizes the hemp hurd particles, improving durability, pest resistance, and long-term structural stability.

## Hemp Definitions, Cont'd.

Term	Definition
Natural Hydraulic Lime (NHL)	A lime binder produced from limestone containing naturally occurring clay minerals, which give it hydraulic properties, meaning it can set and harden in the presence of moisture as well as through carbonation. NHL is widely used as a binder in hempcrete and earthen plasters, offering a balance of strength, flexibility, and vapor permeability.
Panelized Hempcrete	Premanufactured hempcrete panels cast or sprayed off-site and brought to the site for assembly.
Spray-Applied Hempcrete	Installation of hempcrete mix utilizing a mechanical sprayer or blower sprayed against one-sided forms and building out the material to complete the depth required.

## Straw Definitions

Term	Definition
Baling	The process of compacting straw into rectangular or round bundles for transport or construction use.
Internode	The hollow section of a grass or cereal stalk between two nodes. In straw, internodes form the air-trapping tubular structure that gives the material its insulating properties. Orienting straw so that heat travels across the internodes rather than along them significantly improves thermal resistance.
Load-Bearing vs. Non Load-Bearing Straw Bale	In load-bearing (Nebraska-style) straw bale construction, bales are stacked and compressed to carry the weight of the roof directly, without a separate structural frame. In non-load-bearing systems, bales serve as insulation infill within or adjacent to an independent timber or steel frame. Most contemporary and large-scale straw bale applications use non-load-bearing systems, which offer greater design flexibility and code compliance pathways.
Thatch	A roofing or cladding material made from tightly bundled and layered plant stems, most commonly water reed, wheat straw, or other grasses, applied in overlapping courses to shed rain. One of the oldest building envelope systems globally, thatch provides insulation, vapor permeability, and with proper detailing and maintenance, a service life of 30–80 years or more depending on species and climate.

## Wood Definitions

Term	Definition
Cascading Material Use	A resource management strategy in which materials are used sequentially across multiple product life cycles, prioritizing the highest-value applications first. For wood biomass, this may mean producing long-lived wood products that store carbon for decades, such as structural materials. After logs are processed to maximize lumber yield, by-products and residues can be used for durable products like wood-fiber insulation before being diverted to shorter-lived uses such as paper or bioenergy.
Chain of Custody (CoC)	A certification system that tracks forest products from their origin in a certified forest through processing, manufacturing, and distribution to ensure that certified material remains identifiable throughout the supply chain.
Deforestation	The permanent removal of forests when land is converted to another use such as agriculture, infrastructure, or urban development. This differs from timber harvesting, where forests are expected to regenerate and maintain long-term ecological functions.
Engineered Wood Products (EWP)	Wood products manufactured by bonding wood fibers, strands, veneers, or laminations together to improve strength, dimensional stability, or resource efficiency. Examples include plywood, oriented strand board (OSB), laminated veneer lumber (LVL), and mass timber products.
Felling	The specific process of cutting down a standing tree, typically the first stage in timber harvesting.
Forest Stewardship Council (FSC)	An international non-profit organization that establishes standards for responsible forest management. FSC certification verifies that wood products originate from forests managed to protect biodiversity, respect Indigenous rights, support fair labor practices, and maintain long-term ecological health.
Historic Range of Variability (HRV)	The natural range of ecological conditions, disturbance patterns, and species composition that occurred in a forest ecosystem prior to significant modern human alteration. Forest management approaches aligned with HRV aim to maintain ecological resilience and biodiversity.
Lignin	A complex natural polymer found in the cell walls of wood and other plants. Lignin binds cellulose fibers together, providing structural rigidity, compressive strength, and resistance to decay.

## Wood Definitions, Cont'd.

Term	Definition
Mass Timber	A category of engineered wood products created by laminating or fastening smaller pieces of wood together to form large structural components. Common products include cross-laminated timber (CLT), glued-laminated timber (glulam), dowel-laminated timber (DLT), and nail-laminated timber (NLT).
Programme for the Endorsement of Forest Certification (PEFC)	A global alliance that accredits national forest certification systems against its international sustainability standards. PEFC promotes sustainable forest management by supporting environmental stewardship, legal compliance, social responsibility, and traceable supply chains across diverse forest ownership structures. In the United States, the Sustainable Forestry Initiative (SFI) is the official PEFC national member organization, and the American Tree Farm System (ATFS) is also a PEFC-endorsed system. In Canada, PEFC Canada is the national member organization; the Canadian Standards Association's Sustainable Forest Management (CSA SFM) standard is also PEFC-endorsed.
Sapwood vs. Heartwood	Sapwood is the younger, outer wood of a tree that actively transports water and nutrients; it is lighter in color, higher in moisture content, and generally less durable than heartwood. Heartwood is the older, inner wood that has ceased active biological function, typically darker, denser, and more resistant to decay and insect attack. Species selection and the proportion of heartwood are key considerations for exterior and high-moisture applications.
Silviculture / Ecological Forestry	Silviculture is the practice of managing forest growth, composition, and structure to meet specified goals. Ecological forestry applies silvicultural principles with a primary emphasis on maintaining biodiversity, ecosystem function, and long-term resilience, favoring mixed-species stands, longer harvest rotations, and minimal soil disturbance over industrial monoculture approaches.
Thermal Modification	A process in which wood is heated to temperatures of approximately 160–230°C in a low-oxygen environment, altering its cell structure to reduce moisture absorption, improve dimensional stability, and increase resistance to decay and biological degradation. Thermally modified wood requires no chemical preservatives, making it a lower-toxicity alternative for exterior cladding and decking applications.

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## Case Studies:

*We are particularly grateful to the following project teams whose work is featured as case studies throughout this primer:*

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### Biochar

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### Cork

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- *Cork Houses in Catalonia*, López Rivera Arquitectos
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