Urban CDR Pathway Fact Sheet

Biomass for Construction

LEGEND

Application: Bio-based building materials can be used in load-bearing, non-load-bearing, insulation, and finishing components of buildings.

Permanence:

- 35–120 years for carbon stored in solid form in buildings for the lifetime of the product.*

**Cascading use and recycling of products can further extend the carbon storage time, while premature incineration and degradation, or the use of adhesives, coatings, and flame retardants, may limit the storage time.*

Infrastructure: Sawmills, kilns, drying chambers, storage, manufacturing and prefabrication facilities, using combined heat & power units powered with residues. Connecting supply chains from harvesting to buildings and ultimately reuse and recycling must consider requirements for transport infrastructure and services, as well as storage and warehousing.

Guidance: Assure that biomass is managed and harvested sustainably. Identify the relevant pathway steps, inputs, and outputs. Calculate the carbon sequestration impact according to building Life-Cycle-Analysis (LCA) standards. Report emissions impacts in the city's emissions inventory in accordance with the GHG Protocol for Cities.

PATHWAY

Bio-based building materials, such as wood, bamboo, straw, hemp, flax, reeds, and typha, are natural materials derived from living organisms and are therefore renewable. As plants grow, they absorb atmospheric CO_2 through photosynthesis and store it in their biomass. When this biomass is incorporated into buildings through the use of bio-based building components for periods exceeding the material's natural regeneration cycle, it effectively turns the structure into a carbon sink.

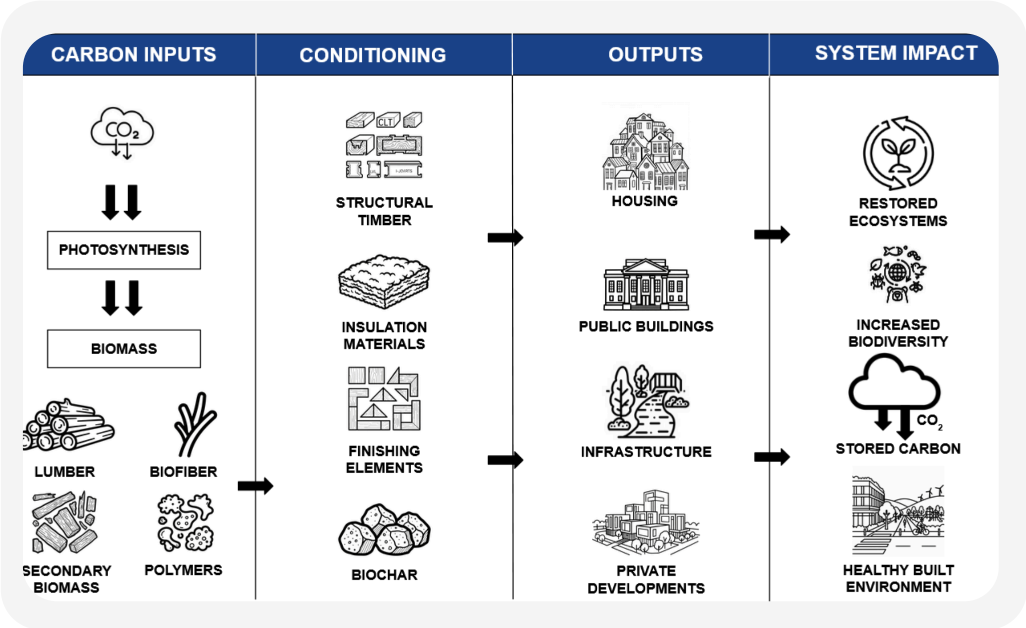

***Figure 1:** Simplified pathway overview*

This means that wood, bamboo, straw, hemp, flax, and other fibers do not only reduce CO_2 emissions through the substitution effect of conventional materials, but can become an active tool for Carbon Dioxide Removal (CDR). For example, engineered wood products consist of around 50% carbon by dry weight and store ~460–610 kg CO_2-eq/m^3 with the potential to directly replace emission-intensive materials like steel and concrete. The appropriate application of bio-based materials in construction depends on their specific properties. These materials can also be combined into functional building assemblies that serve the same purpose as traditional systems. Timber and bamboo are suitable for load-bearing structures like beams and columns, while straw, hemp, and other bio-fibers are suitable as infill-, insulation-, or finishing materials. Together, they can largely replace energy- and emission-intensive, conventional materials in construction , and act as a carbon sink.

ACCOUNTING

Emission risks: Challenges include quantifying the amount of carbon stored in bio-based materials, while taking into account the variations in durability by building component, material type, dimensions, and service life. The inefficient processing of biomass, resulting in high levels of offcuts that are directly incinerated or disposed of, can further reduce the carbon storage potential significantly. The lack of clear and consistent accounting works for bio-based materials is another challenge. Timber has some recognition under IPCC guidelines, but other materials such as hemp, straw, or bamboo lack clear treatment - the durability of their carbon storage remains debated and requires further research.

Accounting is further complicated by having to avoid double counting of removals and emissions when calculating across multiple system boundaries (forestry, construction, demolition, waste management), and taking into account leakage risks, where biomass use in construction may incentivize emissions elsewhere. This is, for example, the case when there is a displacement of conventional materials or land-use change. Additional risks arise from upstream forest management practices and natural disturbances such as wildfires or pests, as well as competition over biomass uses, which can affect biomass availability and hence supply stability. Finally, end-of-life scenarios are a source of uncertainty: reuse and recycling can extend storage, while incineration or uncontrolled disposal releases stored carbon back into the atmosphere. If carbon is released back into the atmosphere through incineration or decay before the regenerative cycle of the biomass is completed, the use of biomass in construction does not result in any net CDR.

Emission sources to account for in an LCA:

- Specific carbon storage potential of biomass;
- Emissions resulting from harvesting;
- Transport and logistics emissions;
- Emissions from drying, processing and manufacturing;
- Fossil-based adhesives, coatings, and flame retardants;
- Additional conventional building materials (e.g., concrete foundations); and
- End-of-life emissions from demolition, landfill, incineration and/or recycling of bio-based materials.

Mitigation Strategies:

- [ ] Sustainable forest and biomass management.
- [ ] Sourcing and processing biomass regionally to shorten transport.
- [ ] Electrification of processing and shifting to low-carbon transport.
- [ ] Improvement of emission intensities of adhesives, resins, and admixtures.
- [ ] Prefabrication and modularization of wood products to improve efficiencies, transport and logistics efficiency and reduce waste.
- [ ] Discourage demolition of buildings to extend buildings' life spans and carbon storage potential.
- [ ] Prioritize reuse and cascading of products to prolong carbon storage.

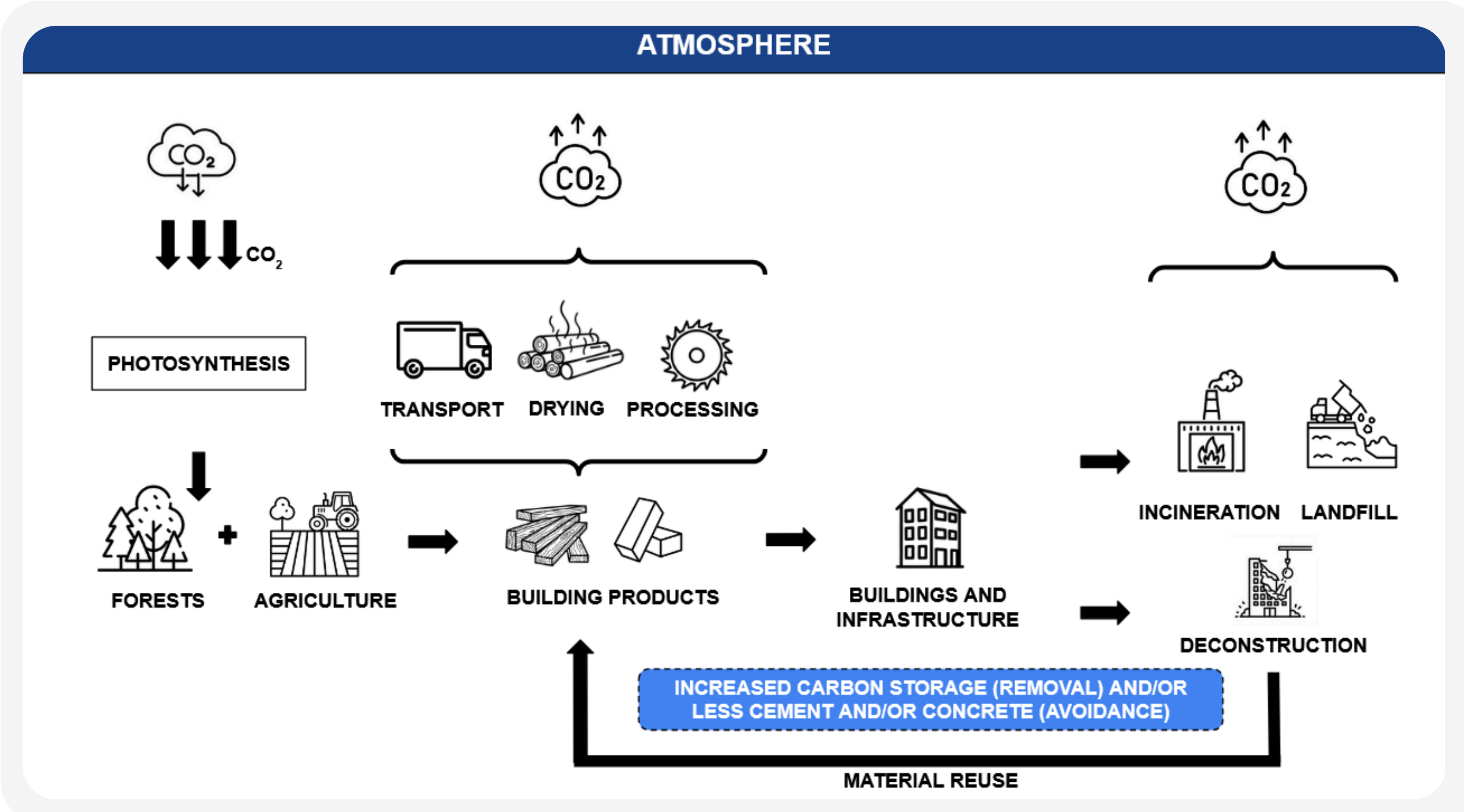

Figure 2: *Simplified carbon flow diagram*

Accounting Protocols, Standards and Certifications:*

- IPCC Harvested Wood Products Approach (HWP) credits storage over the average life of the building.
- **Standards:** International Standards such as ISO 14067 and ISO 21930 provide internationally recognized methods to quantify and report biogenic carbon content and storage duration, forming a basis for Environmental Product Declarations (EPDs). In Europe, EN 15084 serves as the key standard for construction products calculating GHG balances and global warming potential on the basis of Modules A1- C4, complemented with realistic assumptions about the end of life scenarios (Module D)
- **Protocols:** Emerging initiatives such as Rainbow Standard and Climate Cleanup are developing protocols to certify and standardize carbon removal in bio-based construction materials. Voluntary Carbon market standards such as Puro.earth or Verra do not explicitly cover bio-based construction materials or are in the process of developing methodologies.
- **Certifications:** There are sustainable building certification and protocols accounting for carbon emissions and storage, such as BREEAM, DGNB, LEED.

**Accounting of bamboo, straw, hemp and other fibers and non-wood materials is still evolving and mostly relies on LCA/EPD approaches as their CDR acknowledgement hinges on durability and future accounting rules.*

ALTERNATIVE DESIGNS

The urban CDR value chain illustrated in this fact sheet is a reference design based on common infrastructure types and waste streams. However, urban systems differ widely in their spatial form, governance, population density, and resource flows. Therefore, this model should be interpreted as adaptable, not prescriptive.

Possible variations: Prefabricated systems enable production in controlled factory environments, reducing waste and ensuring consistent quality. Owing to the lightness of bio-based materials, modules remain easy to transport. Compared to on-site construction, pre-fab greatly reduces the time, disturbance, and footprint of building activities, which is especially beneficial in urban areas. Furthermore, when factories are located near biomass sources, transport emissions can be minimized.

OPPORTUNITIES AND GAPS

Acceleration Opportunities:

- **Reduced Material Footprint:** Through the large-scale integration directly into existing building and construction supply chains, a scalable, durable, and cost-effective removal option can be created in which bio-based building materials replace more carbon intensive products, leading to lower environmental impacts and potential material cost reductions.
- **Carbon Market Entry Point:** Verified carbon negative materials in construction could generate financial value through green premiums or, in some cases, non- durable voluntary carbon credits. As carbon storage in these materials is not always permanent, reversal risks are high and market prices for such credits may be lower than for long-lived removals. Revenue could be generated for a range of stakeholders including farmers, forestry managers, agricultural producers, material processors and manufacturers and others depending on the project design.
- **Cascade Use of Demolition Wood** (reuse, recycling, pyrolysis, BECCS): Options like conversion to biochar and deep burial (also called direct biomass storage) are currently being developed to extend the carbon storage of building products for much longer periods of time even if buildings are prematurely demolished.

Gaps:

- **Unequal Market Conditions:** Bio-based materials face unequal market conditions when compared to conventional alternatives due to limited economies of scale, specialized certification requirements, complex handling processes, and the large amount of unaccounted negative externalities caused by conventional materials.
- **Supply Chain Fragmentation:** Production and distribution networks are underdeveloped and often fragmented, limiting consistent availability.
- **Regulatory Barriers:** Building standards, fire-safety codes, and high-rise approval frameworks are inadequate for bio-based materials, restricting broader adoption.
- **Data Gaps:** Limited regional information on supply, demand, and sustainable harvest potential constrains planning and scaling.
- **Feedstock Variability**: Biomass availability and quality may fluctuate seasonally or as a result of competing uses.
- **Public Perception:** In many regions, bio-based construction materials are associated with low quality and safety concerns, which can hinder market acceptance.
- **Traceability Needs:** Digital systems for monitoring material and carbon flows are largely absent, complicating credible accounting.

CORE RECOMMENDATIONS

- **Embed biomass for construction in climate and planning strategies. Use city GHG inventories and CDR targets to promote bio-based construction in housing, public buildings, and retrofits.**
- **Update building codes and procurement standards to recognize and prioritize carbon-storing materials. Fire safety regulations and performance testing must be updated to enable the safe use of timber and natural fibers in mid- and high-rise construction.**
- **Set performance-based standards to ensure materials meet functional, structural, environmental and safety standards when aiming for CO_2 storage, with flexibility in approaches. Set public procurement targets.**
- **Develop clear carbon accounting rules for temporary CO_2 storage in harvested wood products and especially for other bio-based materials, ensuring alignment between forestry and construction sectors and avoiding double counting.**
- **Capacity building and training for procurement officials to facilitate procurement of bio-based materials and bio-based concrete for public construction projects.**
- **Support lighthouse projects that demonstrate technical feasibility, cost-effectiveness, and social acceptance of bio-based construction.**
- **Support supply chain development, such as sustainable forestry, fiber production, industrial processing and component prefabrication.**
- **Use tools (LCA, Material Flow Analysis) to track embodied carbon.**
- **Renovation and demolition permits could enable tracking of carbon leaving a building and discourage pre-mature demolition.**

INNOVATION LANDSCAPE

Further breakthroughs are needed in the development of innovative products and testing, such as fire-safe coatings and recyclable adhesives, and standardized design-for-disassembly systems that support circular reuse. Equally important are innovations in city-scale monitoring and accounting protocols that ensure traceability, prevent double counting, and guarantee permanence across cascaded life cycles. Finally, policy innovations are needed to foster a more level playing field between bio-based building materials and conventional materials by fully incorporating externalities in the cost price. These developments need to be accompanied by training and incentives for designers and developers.

LEADING CITIES

- **Amsterdam, the Netherlands –** Green Deal Timber Construction mandates 20% of new buildings to be built with timber/bio-based materials.
- **Munich, Germany -** Subsidy program promoting timber construction / timber hybrid construction in new and current projects.
- Angermünde, Germany - Project Regenerative Commune combines different regenerative construction projects.
- Stockholm, Sweden - Stockholm Wood City, the world's largest urban wooden construction - 250,000m2 offering 2,000 new houses and 7,000 business spaces

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