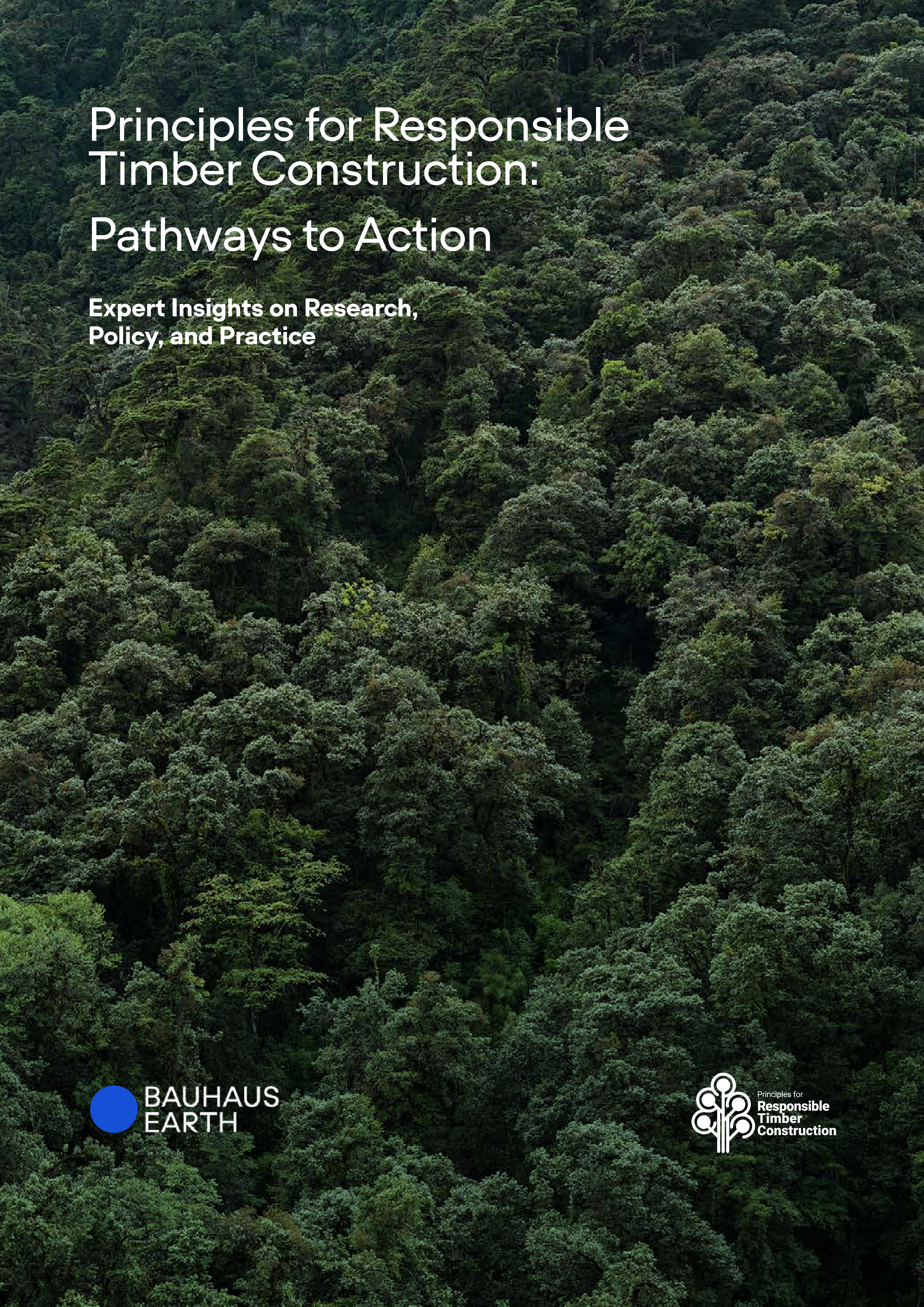

Principles for Responsible Timber Construction: Pathways to Action

Expert Insights on Research, Policy, and Practice

BAUHAUS EARTH

Principles for Responsible Timber Construction

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Foreword

The world stands at a critical crossroads: we must decarbonise rapidly, restore and adapt our landscapes, and at the same time provide housing and jobs for growing urban populations. At a global level, there has been a growing recognition of the role of a nature-based construction economy in addressing these interrelated global challenges.

As co-lead of the Forest & Climate Leaders Partnership (FCLP) initiative alongside the Governments of France and Kenya, Canada is committed to supporting the five *Principles for Responsible Timber Construction* as a global framework to ensure that increased timber demand is managed responsibly, maximising benefits for climate and biodiversity in our forests while supporting the livelihoods of Indigenous communities and at the same time helping to transform the built environment. The *Principles* will help us work towards thriving bioeconomies with positive outcomes for planet and people.

This *Guidance Report* underpins the five *Principles* with the latest scientific evidence, best-practice examples and regional contextualisation – a rich resource that will help countries and key actors understand the specific opportunities and challenges that exist in building with wood and other biobased materials in their countries, and draw on the Principles to drive change.

Canada is proud to endorse the *Principles* and this *Guidance Report* not only in words, but also through actions. As the third most forested country in the world, Canada holds great value in the role that forests play in addressing many of the societal problems the world faces. With new funding that supports novel timber products and low-carbon insulation for modular housing, coupled with actions to double the pace of new home building and catalyse affordable-housing programmes, the country hopes to send a powerful signal of commitment to increasing the use of wood from sustainably managed forests in the built environment.

I hope that the *Principles* and this *Report* inspire a growing coalition of governments to introduce policies and incentives in support of sustainable construction. Together, we can transform construction from a source of harm into a force for good, helping planet and people.

Maureen Whelan
Manager of Multilateral Affairs,
Canadian Forest Service
Co-lead, FCLP Action Area on Greening
Construction with Sustainable Wood.

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Executive summary

Underpinning the five *Principles*, this document offers practical references and pathways for countries to accelerate action responsibly, scale impact and sustain high-level political leadership on nature-based construction, forests, land use and climate.

During the coming decades, global demand for housing and infrastructure will rise sharply. Yet the building sector remains a major contributor to the climate, biodiversity and resource crises. Without a profound, systemic transformation of construction, these interlinked challenges of housing and planetary health cannot be met. The sourcing, processing and manufacture of construction materials are central to the problem but also part of the solution. Sustainably sourced timber, bamboo and other biobased materials offer an opportunity to shift from carbon-intensive, resource-depleting practices towards a regenerative, nature-based construction economy that benefits both people and the climate.

Although progress has been made worldwide, major barriers still impede change. These include systemic inertia, regulatory constraints and continuing concerns within the sustainability community about potential unintended consequences of a timber-led transition.

To support a responsible breakthrough, Bauhaus Earth and Built by Nature have partnered under FCLP's *Action Area on Greening Construction with Sustainable Wood* to develop the *Principles for Responsible Timber Construction* (see *Page 10*). The *Principles* provide a shared framework to build consensus and confidence across the value chain, guiding the alignment of policies, business models and sustainable forest management approaches in FCLP member States and beyond.

This *Guidance Report* complements the five *Principles* with insights from a global community of experts, researchers and practitioners. It highlights promising pathways, provides orientation in an evolving field of research and innovation, and identifies opportunities, good practice and safeguards to prevent risks or unintended outcomes. Each chapter concludes with policy pathways to enable responsible biobased construction at national and regional levels.

Five lead authors prepared the chapters, each addressing one *Principle*, with insights collected from a wider group of specialists working at the intersections of forestry, architecture and climate science. The report and its chapters are not intended as exhaustive summaries of a complex and evolving global landscape. They represent a first set of reflections and aim to stimulate informed debate and invite further contributions.

Key findings

Chapter 1
Lead author:
Dr Naomi Keena

Extending the life of existing buildings through renovation, repurposing and selective deconstruction is among the most effective strategies to reduce embodied carbon, conserve resources, and preserve cultural value, often cutting emissions by up to 75 per cent compared with new construction. Timber and other biobased materials are well suited to adaptive reuse, design for disassembly and modular construction. They enable lightweight retrofits, carbon storage and healthier indoor environments. Achieving this shift requires co-ordinated policies, training and financial incentives to replace entrenched demolition practices and outdated standards, positioning renovation as both a climate solution and a driver of more adaptive, resource-efficient and socially resilient cities.

Chapter 2
Lead author:
Stephanie Carlisle

Whole-life-carbon assessment (WLCA) is essential to ensure that the global expansion of timber construction reduces rather than accelerates environmental harm. WLCA promotes accountability, drives innovation and ensures that scaling biobased materials benefits forests and communities; however, inconsistent methods, data gaps and limited professional capacity still need to be addressed.

Chapter 3
Lead author:
Jamie Lawrence

Rising industrial-timber demand must remain within ecological limits so that forests continue to store carbon, support livelihoods and protect biodiversity. Scaling sustainable forest management (SFM) requires secure land tenure, inclusive governance and strong data and finance systems, supported by political will and public procurement that reward verified sustainable wood. This ensures that the construction sector's growing use of timber reinforces rather than depletes the world's forests.

Chapter 4
Lead author:
Prof Dr Matti Kuittinen

Responsible scaling of timber construction can meet housing needs while supporting climate goals. Realising this potential depends on extending building lifespans, reusing components and improving policy and reporting frameworks so that carbon storage is accurately measured, effectively incentivised and aligned with sustainable forest management and circular construction practice.

Chapter 5
Lead author:
Robyn van den Heuvel

A responsible timber-building bioeconomy reframes construction to respect ecological limits, support local livelihoods and enable equitable, locally led growth. Delivering this vision requires co-ordinated action across national and local governments, investors, foresters, researchers, construction professionals and manufacturers. Timber should be regarded not as a niche material but as part of a social, ecological and industrial system that enables a regenerative, climate-positive and community-centred economy.

Principles for Responsible Timber Construction

Extending the life of existing buildings

The potential for existing structures to be repurposed, renovated, and/or extended using timber, biobased, secondary and other low-carbon materials is prioritised over demolition

Accounting for whole life cycle

New timber buildings and renovations are designed and constructed to be safe and resilient, in ways that minimise whole life cycle impacts, optimising operational efficiency and minimising embodied carbon emissions and other environmental impacts from materials. Carbon is accounted for transparently, clearly differentiating between biogenic and fossil carbon.

Ensuring sustainable forest management

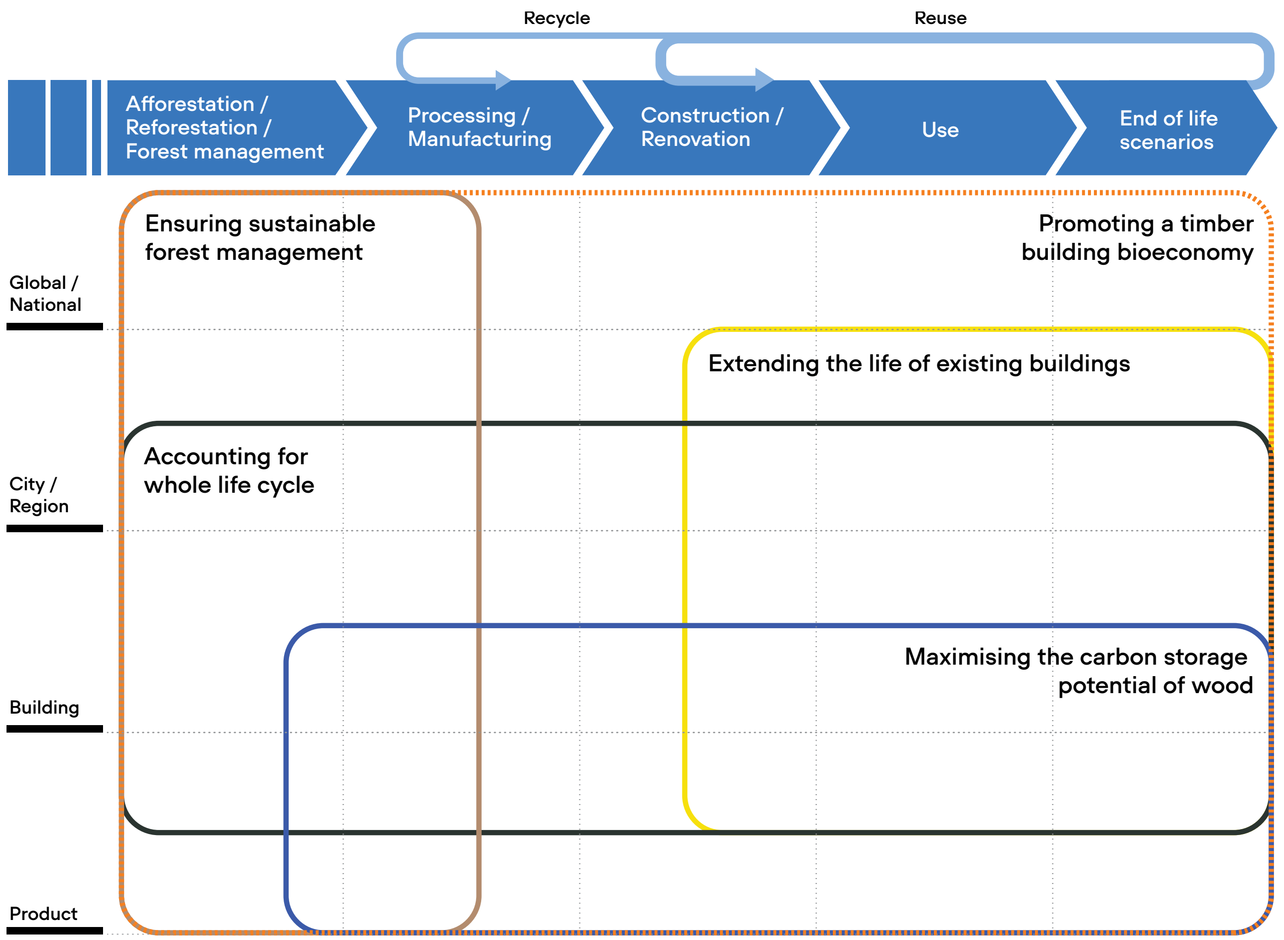
Wood-based construction materials are sourced from forests managed according to best practices in sustainable forest management which as 'a dynamic and evolving concept, aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations' [UN definition of SFM].

Maximising the carbon storage potential of wood

Wood is used efficiently, and its carbon storage potential is maximised by prioritising and incentivising its use for durable products such as construction where appropriate. Circularity of wood use for buildings is promoted, including design for disassembly to facilitate re-use and subsequent cascading of timber components in successive buildings to maximise the material's lifespan.

Promoting a responsible timber building bioeconomy

Information, education and training is provided for stakeholders across the 'forest to frame' value chain on the benefits and practices of responsible timber use in construction. Innovation, research and development is supported and encouraged to enable a timber construction economy and wood culture to thrive.



The Principles along the value chain
This diagram provides a graphical synthesis of the *Principles*' influence across the timber value chain, from forest management, including afforestation and reforestation, to end-of-life scenarios. It illustrates the specific stages and spatial scales – ranging from the product to the global level – where each *Principle* has the greatest impact and where synergies among *Principles* are most likely to emerge. The framework underscores the interconnectedness of the *Principles for Responsible Timber Construction* as complementary pathways towards advancing a regenerative and climate-resilient timber economy.

Opportunities and challenges

The challenge

Zhang, S. et al. (2024) "Estimation of global building stocks by 2070: Unlocking renovation potential," Nexus, 1(3). https://doi.org/10.1016/j.ynexs.2024.100019.

UNEP (2023). Building Materials and the Climate: Constructing a New Future. Dyson, A., Keena, N., Lokko, M., Reck, B.K., Ciardullo, C. United Nations Environment Programme, Nairobi, Kenya. https://wedocs.unep.org/xmlui/handle/20.500.11822/43293.

Churkina, G. et al. (2020) "Buildings as a global carbon sink," Nature Sustainability, 3(4), pp. 269–276. https://doi.org/10.1038/s41893-019-0462-4.

Global demand for housing and infrastructure is projected to rise sharply, potentially doubling the world's building stock by 2060 (Zhang et al., 2024). This era of rapid construction represents a critical – and possibly final – window of opportunity for meaningful climate action. At present, the building sector accounts for nearly 40 per cent of annual CO_2 emissions (UNEP, 2023). By 2050, half of these emissions are expected to be embodied, making construction materials a central challenge in reducing the sector's environmental footprint. If new urban construction proceeds using "business-as-usual" materials, the resulting emissions could reach up to 70 gigatonnes of carbon dioxide (Gt CO_2), depending on floor area per capita and the carbon intensity of material manufacture (Churkina et al., 2020). Without a profound, systemic overhaul of construction methods, the interlinked challenges of housing and planetary health cannot be addressed.

"It is crucial to ensure that increased demand for timber is managed sustainably and responsibly to maximize benefits for climate, nature, and people. The integrated approach of the Principles should set high standards of sustainable forest management, with appropriate safeguards and chains of custody to demonstrate transparency of supply. WWF looks forward to contributing to raising awareness and understanding of this commitment."

Jason Grant, Manager, Corporate Engagement, Forests, WWF-US

Curtis, P.G. et al. (2018) "Classifying drivers of global forest loss," Science, 361(6407), pp. 1108–1111. https://doi.org/10.1126/science.aau3445.

Secretariat of the Convention on Biological Diversity (2024) The Forest Factor: The role of protection, restoration and sustainable management of forests for the implementation of the Kunming-Montreal Global Biodiversity Framework. Montreal: Secretariat of the Convention on Biological Diversity. https://www.cbd.int/forest/doc/forest-factor-en.pdf

Decarbonisation is not the only concern. Global forest carbon sinks are under severe pressure from conversion to agriculture, disturbances such as wildfire and disease – all intensified by climate change – and degradation caused by unsustainable forestry practices (Curtis et al., 2018). Meeting rising timber demand will, in the near term, rely primarily on existing forests. Although deforestation rates have slowed in some countries in the last decades, the global extinction rate of species remains about 1 000 times above historical levels (Secretariat of the Convention on Biological Diversity, 2024). Given that 80 per cent of all land-based species rely on forest ecosystems, it is essential to accelerate forest and landscape restoration efforts to safeguard both the climate and biodiversity.

FAO (2024) The State of the World's Forests 2024. FAO. https://openknowledge.fao.org/handle/20.500.14283/cd1211en.

Foong, A. et al. (2025) "Forest Product Demand and Supply in a Bioeconomy Transition: The Possible Role of Timber for Climate Change mitigation," in World Conference on Timber Engineering 2025. World Conference on Timber Engineering 2025, Brisbane, Australia: World Conference On Timber Engineering 2025, pp. 5161–5170. https://doi.org/10.52202/080513-0635.

Global wood production has reached record levels, reflecting both opportunity and pressure within the expanding bioeconomy. While wood is increasingly viewed as a renewable alternative to carbon-intensive materials, growing demand requires careful management to ensure sourcing only from sustainable forests. Around 4 billion m³ of roundwood are harvested annually, of which industrial roundwood represents 2.04 billion m³ and woodfuel nearly half the total (1.97 billion m³) (FAO, 2024).

Projections indicate that global wood demand could rise by up to 49 per cent between 2020 and 2050, driven largely by industrial roundwood (FAO, 2024). The construction sector is a key driver through expanding use of engineered-wood products. Between 1961 and 2022, wood-use efficiency improved by about 15 per cent, meaning that by 2040 the same output could be achieved with 116 million m³ less industrial roundwood (FAO, 2024). Depending on adoption rates in residential construction, global demand for engineered-wood products could increase by 50–250 million m³ per year between 2030 and 2070 (Foong et al., 2025). These trends show that rising efficiency alone will not offset demand. This underscores the need for optimizing the use of wood and strategically combining it with other biobased materials to ensure a transition to a regenerative built environment – one that channels responsible market demand toward nature conservation, ecosystem restoration, and new forest creation.

The opportunity

Decarbonisation strategies that rely on unproven or resource-intensive carbon-capture technologies risk diverting attention and investment from scalable, nature-based solutions that deliver immediate and verifiable climate benefits in the built environment. Owing to their inherent carbon-storage potential and renewability, timber and other biobased construction materials offer a practical opportunity to harness the power of nature-based carbon capture.

"A timber bioeconomy shaped by intention and integrity isn't just about building better structures—it's about building better stories. It's where homes are more than shelter, forests are more than resources, and our future is something we craft with care. When done right, timber becomes the thread weaving together dignity, climate action, and rooted prosperity—with communities not on the margins, but at the core."

Nasra Nanda, Kenya Green Building Society

This opportunity was recognised by many States at the *Forests and Climate Leaders' Summit* at COP 27, where 32 founding member countries and the European Union formed the FCLP coalition committed to achieving the COP 26 *Glasgow Leaders' Declaration on Forests and Land Use*. The *Glasgow Leaders's Declaration* is a commitment by 144 nations the European Commission and the EU to end and reverse deforestation and land degradation by 2030. FCLP brings together governments and partners to maintain high-level political leadership on forests, land use and climate; to reduce forest loss, increase restoration and support sustainable development; and to ensure accountability for related pledges. For the first time at the global level, a clear window opened to align international and intergovernmental processes and lay the foundation for action.

At COP 28 in Dubai (December 2023), based on priorities identified by the FCLP founding members, a coalition of 17 FCLP nations launched *Greening Construction with Sustainable Wood*, signalling their intention to work with non-government partners to accelerate action responsibly and scale up impact. The coalition of 17 countries – the Commonwealth of Australia, Canada, the Republic of the Congo, the Republic of Costa Rica, the Republic of Fiji, the Republic of Finland, the French Republic, the Federal Republic of Germany, the Republic of Ghana, Japan, the Republic of Kenya, the Republic of Korea, the Kingdom of Norway, the Islamic Republic of Pakistan, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland, and the United States of America – endorsed the following statement:

"Recognising that wood from sustainably managed forests provides climate solutions within the construction sector, we commit to, by 2030, advancing policies and approaches that support low-carbon construction and increase the use of wood from sustainably managed forests in the built environment. Such policies and approaches will result in reduced greenhouse-gas emissions and an increase in stored carbon."

Joint Statement, FCLP *Greening Construction with Sustainable Wood*

A further step towards transforming the global construction sector was taken at the Buildings and Climate Global Forum in Paris (March 2024). Its final outcome, the Déclaration de Chaillot, supported by 70 countries, stated:

"Prioritising on-site assets, recycled and end-of-life use, local, sustainable, bio-/geo-sourced, low-carbon, energy-efficient materials, products and components ensuring easy maintenance and repair for life extension, aligned with circular-economy, eco-design, sufficiency and waste-prevention principles, enhancing carbon balance through storage and absorption in building materials."

Recognising the transformative potential of timber and other biobased materials, and the need to manage related risks, Bauhaus Earth and Built by Nature partnered with FCLP's *Greening Construction with Sustainable Wood initiative* to develop the *Principles for Responsible Timber Construction (see Page 10)*. Together, through a multi-stakeholder dialogue these *Principles* were distilled to provide a robust framework for scaling responsible timber use, offering a shared language to align policies, business models and sustainable-forest-management approaches across the value chain, among FCLP member States and beyond.

The *Principles* initiative

Officially launched at the 2025 *United Nations Climate Change Conference (COP 30)* in Belém, Brazil, the *Principles for Responsible Timber Construction* seek to mobilise broad international backing for sustainable construction using timber and other biobased materials, accelerating progress towards a resilient and sustainable biobased building economy. More than 280 organisations across the timber value chain have already endorsed the framework – from forest managers and manufacturers to investors, architects and engineers. National governments are likewise joining the movement and committing to responsible building and forest stewardship, with the *Principles* offering a practical framework for co-ordinated action.

Expanding upon the five *Principles*, this *Guidance Report* draws on insights from a global community of experts and researchers, outlining actionable pathways and supporting the mobilisation of knowledge and resources for transformative impact. Five lead authors contributed to the report, each addressing one *Principle* in a dedicated chapter, informed by a wide network of specialists across forestry, architecture and climate science. The report clarifies a rapidly evolving field of research and innovation, highlighting major opportunities, exemplary practice and persistent barriers, while emphasising safeguards to ensure that the growing use of biobased materials delivers credible, responsible climate benefits. The authors note that the chapters do not attempt to be exhaustive in such a complex and evolving global landscape of policy, research and practice, but rather seek to stimulate critical debate and invite further contributions.

Underpinning the five *Principles*, the report serves as both reference and resource to encourage countries to accelerate action responsibly, scale up impact and maintain high-level political leadership on nature-based construction, forests, land use and climate. It provides an entry point for governments and ministries seeking global insight and directs readers to additional research and tools in each thematic area.

The *Guidance Report* identifies workable pathways for systemic transformation in the construction sector and for redirecting financial capital to meet climate goals. Trillions of dollars must be shifted away from polluting industries towards nature-based solutions and regenerative business models in the coming decade. In response, global momentum for sustainable, biobased construction continues to build. Achieving responsible timber and biobased construction will require overcoming systemic barriers across governance, markets, knowledge, capacity and technology. Each chapter concludes with national-level policy recommendations to align forest management, building practice and finance systems for biobased-construction breakthroughs.

The *Guidance Report* also aligns with an Implementation Framework ↗ developed by *Built by Nature* – an actionable tool for demand-side stakeholders, including designers, developers, investors, insurers, asset managers, contractors and cities – to apply the *Principles* across the building life cycle, from feasibility to end of life, through structured strategies and curated resources.

"We need a new economic paradigm to transition from an extractive economy powered by fossil resources that develops at the expense of nature to a regenerative one powered by nature and thriving in harmony with it – a circular bioeconomy. Biodiversity is nature's life insurance, and valuing and investing in it within forestry and agricultural systems is key to a resilient world that prospers within a circular bioeconomy."

Marc Palahi, Circular Bioeconomy Alliance

Affordable housing development supporting regional timber value chain. Moyoni by studio OMT architects.
Zanzibar, Tanzania
Shortlisted Project, BbN Prize, 2025
© Volks.House

Expert perspectives

	Principles	Chapter title	Chapter author	
	Principle 1	Defining value: Extending the life of buildings through timber and low-carbon reuse	**Dr Naomi Keena** Assistant Professor, Peter Guo-hua Fu School of Architecture McGill University; Founding Director, McGill TRACE Lab	Dr Naomi Keena is an Assistant Professor and Professional Program Director at McGill University's Peter Guo-hua Fu School of Architecture, and the founding director of the McGill TRACE Lab (Think-tank and Research in Architecture and Circular Economy). Her research focuses on applying data-driven, life-cycle approaches and computational techniques to architectural and socio-ecological challenges — especially in the context of housing, circular economy, and environmental policy. She has published widely on topics such as circular housing, life-cycle assessment, sustainability, and built-environment materials. Notably, she has co-authored the UNEP report Building Materials and the Climate: Constructing a New Future (2023) and co-authored the book 'Sustainable Housing in a Circular Economy' (Routledge, 2024).
	Principle 2	Whole-life carbon in timber construction	**Stephanie Carlisle** Lecturer, Weitzman School of Design; University of Pennsylvania; LCA Practice Lead, C.Scale	Stephanie Carlisle is an architect and environmental researcher whose work investigates the interaction between the natural and built environment, including embodied carbon, LCA, urban ecology, landscape performance, environmental justice, and material supply chains. She currently serves as the LCA Practice Lead at C.Scale, where she guides whole-building life-cycle assessment, benchmarking, and innovation in biobased materials. As a lecturer at the University of Pennsylvania's Weitzman School of Design, she teaches graduate courses in LCA, materials, climate, and urban ecology. Previously, she led the LCA data and methods team at the Carbon Leadership Forum and was a principal at KieranTimberlake Architects, where she helped develop Tally LCA.
	Principle 3	Scaling responsible forest management for a low-carbon bioeconomy	**Jamie Lawrence** Xilva AG; Advisory Council, CSFEP; Director Forest Strategy, Bauhaus Earth	Jamie Lawrence is an adjunct member of the leadership team at Bauhaus Earth, focusing on forest strategy and the bioeconomy's role in social, environmental, and climate goals. He is co-founder and forest intelligence lead at Xilva, a due diligence provider for forest investment projects, and also co-founded the Climate Smart Forest Economy Programme (CSFEP), which promotes resilient forests and local economies. With three decades of experience in forest certification, auditing, traceability, and due diligence, he works to align the interests of companies and forest stewards by deploying safeguarding as a common language.
	Principle 4	Leveraging wood construction for long-term carbon storage: Insights from the EU	**Prof Dr Matti Kuittinen** Aalto University	Dr. Matti Kuittinen is Professor of Sustainable Construction at Aalto University´s Department of Architecture. His scientific work focuses on climate change mitigation by bringing together architecture, engineering and ecology. Dr. Kuittinen has worked as a Senior Ministerial Adviser at the Finnish Ministry of the Environment where he developed policies for whole life carbon assessment and the circular economy. As an architect, he designs carbon-efficient buildings and humanitarian construction.
	Principle 5	Promoting a responsible timber building bioeconomy: Learning from East Africa	**Robyn van den Heuvel** Program Director, CSFEP	Robyn van den Heuvel is the Program Director of the CSFEP, a global initiative that helps low- and middle-income countries in the Global South build regional forest product industries that support forest resilience, local prosperity, and climate goals. Robyn leads the strategic direction of the program, guiding its growth, partnerships, and implementation across regions. She oversees a multidisciplinary team and works closely with coalition partners, ensuring that CSFEP's work is grounded in local realities while contributing to global knowledge on regenerative forest economies.

Fully demountable, reusable timber office by Oslotre Architects.
Hasletre, Oslo, Norway
Commended Project, BbN Prize, 2025

Summary of key findings

Reclaiming value: Extending the life of buildings through timber and low-carbon reuse

In *Chapter 1*, Dr Naomi Keena describes how extending the life of existing buildings and avoiding demolition represents the lowest-carbon, most resource-efficient and least wasteful option. Renovation-centred pathways can cut greenhouse-gas (GHG) emissions by 50–75 per cent compared with new construction, while also limiting urban sprawl and conserving the cultural and social value embedded in existing structures. When timber, biobased, secondary and other low-carbon materials are applied in repurposing, renovation and extended building use, they help advance the shift to low-carbon construction. Extending building life and scaling timber innovation therefore work in tandem, creating pathways towards climate-positive development.

The chapter presents global examples of innovative biobased materials and design for disassembly (DfD) practices adapted to different climates. It highlights approaches to urban densification through mass-timber overbuild systems, insights from selective deconstruction, methods of material repurposing in informal housing and emerging digital tools that visualise circularity.

The principle of extending a building's life concerns not only the reduction of carbon emissions but also the preservation of collective memory, the strengthening of social cohesion and the promotion of more resource-efficient, adaptive and resilient urban environments. Yet systemic barriers – including entrenched demolition practices, limited technical capacity, weak financial incentives, socio-cultural bias and outdated standards – continue to impede wider uptake. Addressing these barriers calls for co-ordinated policies, training and incentives to grow markets for secondary materials, expand biobased alternatives and re-value existing buildings as vital climate assets.

Whole-life carbon in timber construction

A global rise in timber construction cannot be regarded as responsible or equitable if it accelerates global warming or causes irreversible environmental harm. To prevent such outcomes, the principles and tools of WLCA are indispensable for reducing the climate impacts of construction while protecting the function and integrity of productive landscapes as natural climate solutions.

In *Chapter 2*, Stephanie Carlisle examines the second *Principle for Responsible Timber Construction*, focusing on the reduction of carbon emissions. Comprehensive whole-life-cycle accounting is not merely a technical process; it underpins responsible timber construction by enabling accountability, driving innovation, supporting circularity and ensuring that the scaling of biobased materials strengthens – rather than undermines – forests and communities. The tools and knowledge required for responsible carbon accounting are already available. What remains is to expand their use, align incentives with verified performance and ensure that carbon accounting promotes both climate goals and social as well as ecological integrity.

Momentum is building: countries such as Denmark, France and the Netherlands now require WLCA in building codes, while procurement policies and corporate-reporting frameworks stimulate demand for verified data. Nonetheless, challenges persist – among them inconsistent methods, limited supply-chain transparency, insufficient data and a shortage of professional capacity. These weaknesses must be resolved to align timber's expanding role in construction with genuine climate performance.

While this chapter focuses primarily on carbon within whole-life-cycle accounting and across the full life cycle of timber products, it also acknowledges that broader environmental dimensions merit further analysis and dialogue. For biobased materials these include land-use change and effects on biodiversity; for mineral-based materials they encompass impacts such as mining, sand extraction and resource depletion.

IAAC © Adria Goula

Scaling responsible forest management for a low-carbon bioeconomy

Global demand for timber is rising quickly, driven by population growth and accelerating urbanisation. This demand must be aligned with governance systems that respect the Earth's carrying capacity and ensure that forests continue to provide essential ecosystem services. Not all wood delivers net climate benefits; its sustainability depends on how forests are managed and how timber is sourced and used. Understanding the link between forest-management systems and timber-based construction is central to achieving positive climate outcomes and directing finance effectively. The notion that all wood is good overlooks the complexity of forest ecosystems, the diversity of silvicultural practices and the absence of formal management across nearly half of the world's forests. Wood can act as part of a powerful climate solution, however, not all wood delivers net climate benefits; its sustainability depends on how forests are managed and how timber is sourced and used.

Chapter 3 situates SFM of production forests as the foundation of responsible timber construction and a cornerstone of the transition to a low-carbon, biobased economy. SFM enables productive forests and working woodlands to function as renewable, multifunctional systems that sustain livelihoods, store carbon and conserve biodiversity. Despite its significance, SFM remains under-recognised in current policy and finance frameworks, often eclipsed by narrower interventions such as forest-landscape restoration or conservation initiatives.

In this chapter, Jamie Lawrence brings together insights from leading experts to show that the tools, knowledge and examples needed to scale up SFM already exist. Governments must secure land tenure – particularly for Indigenous and local communities – reinforce forest governance and integrate forestry into wider land-use and climate strategies. Investment in forest finance, data systems, capacity-building and traceability tools is essential. Public procurement and awareness programmes can create stable markets for verified sustainable wood, consolidating responsible production. Best-practice examples demonstrate that legal clarity, accessible finance and inclusive governance can unlock sustainable and equitable outcomes.

Implemented effectively, SFM provides a holistic, place-based solution that aligns rising timber demand with environmental limits, ensuring that forests remain a pillar of a resilient, low-carbon economy.

Globally, SFM offers a comprehensive framework that balances ecological, economic and social objectives. It guarantees a reliable wood supply while contributing to national economies and human well-being. At the same time, it enhances carbon sequestration and storage, curbs deforestation and degradation, and reinforces conservation. Through integrated, adaptive management and continual improvement, SFM builds long-term forest resilience and sustainability. The necessary tools and knowledge are in place; what is still required is the political will and financial commitment to expand them worldwide so that the construction sector's growing reliance on timber strengthens – rather than undermines – the planet's forests.

"I believe in the power of markets to drive sustainable business. If demand for wood products is structured sustainably, it will increase demand for Sustainable Forest Management. This raises the economic value of keeping forests standing compared to converting them for agriculture, and it can create more positive economic and social dynamics around forest use. However, the scale of this demand must be managed with caution to avoid unintended consequences."

Thais Linhares-Juvenal, Senior Advisor Forest Governance, Economics, and Production, FAO

Leveraging wood construction for long-term carbon storage: Insights from the EU

Because industrial emissions remain difficult to abate, new ways of removing and storing carbon dioxide (CO_2) are urgently needed. *Chapter 4,* authored by Prof Dr Matti Kuittinen, underscores the importance of harnessing wood's potential as a durable carbon-storage reservoir within the built environment. Storing carbon in buildings provides a low-risk, cost-effective and immediately deployable approach to addressing both climate and housing challenges.

While rapid emissions reduction remains the foremost priority, embedding carbon in long-lived buildings offers a practical complement that can also help meet global housing demand. The chapter explores the potential of wood as a biogenic-carbon store, drawing on examples from the European Union to illustrate how much carbon can be locked within wooden buildings and cities when they are designed and maintained for long service lives.

Fragmented policy frameworks, inconsistent reporting of biogenic carbon, limited recognition of storage benefits, premature demolition and the absence of standardised certification systems continue to impede progress. The temporary nature of biobased-carbon storage reinforces the need for extended service lives, reuse and cascading use.

The chapter calls for embedding carbon-storage targets alongside emission limits in building codes and national climate policies. It proposes mandatory reporting of biogenic carbon in environmental-product declarations (EPDs), zoning measures for urban carbon sinks and public-procurement criteria that incentivise long-term storage. It further advocates DfD and circular-construction principles to prolong material lifetimes.

To realise these opportunities, the report recommends aligning EU regulations such as the *Energy Performance of Buildings Directive* (EPBD), the *Carbon Removals Certification Framework* (CRCF) and the *Construction Products Regulation* (CPR); strengthening coordination between forestry and construction ministries; developing data systems to monitor carbon stocks; establishing certification schemes to verify storage; and expanding green public procurement in parallel with regulation to drive innovation in the building sector.

The chapter presents wood-based construction as both a climate solution and a policy opportunity, urging governments to pair regulation with innovation and data transparency so that carbon storage becomes an integral element of national decarbonisation strategies. While its central focus is on carbon storage, the text also stresses the need to minimise wood waste and maximise the cascading use of timber products across their life cycle.

Locally sourced biobased materials, prototype for low-impact, circular architecture.
La Maison de la Réserve Ecologique by Archipel Zéro. Épinay-sur-Seine, France. Winner, BbN Prize, 2025
© Frédéric Denise

Affordable housing built using prefabricated timber systems sourced from local forests.Namabaale & Busibo Teacher Villages by Localworks.
Lwengo, Uganda
(c) Localworks

Promoting a responsible timber building bioeconomy: Regional lessons from East Africa

A timber bioeconomy is not only about choosing a low-carbon material; it is about enabling a new development pathway that respects ecological limits, centres community agency and reimagines how we design and build. The fifth *Principle for Responsible Timber Construction* invites us to move beyond carbon accounting and narrow built-environment frameworks, and to consider how timber construction can reshape landscapes and economies.

Drawing on global perspectives and insights from East Africa and beyond, Robyn van den Heuvel examines in *Chapter 5* the components, challenges and potential of a regenerative timber-building bioeconomy. Africa is home to more than a quarter of the earth's intact ecosystem and the Congo basin is the largest carbon sink on earth – apart from the world's oceans. The chapter highlights systemic constraints, including fragmented value chains, outdated building codes, under-developed manufacturing capacity and cultural bias against timber. It calls for policy interventions that strengthen regional coalitions, modernise governance, incentivise local innovation and ensure accountability beyond carbon metrics.

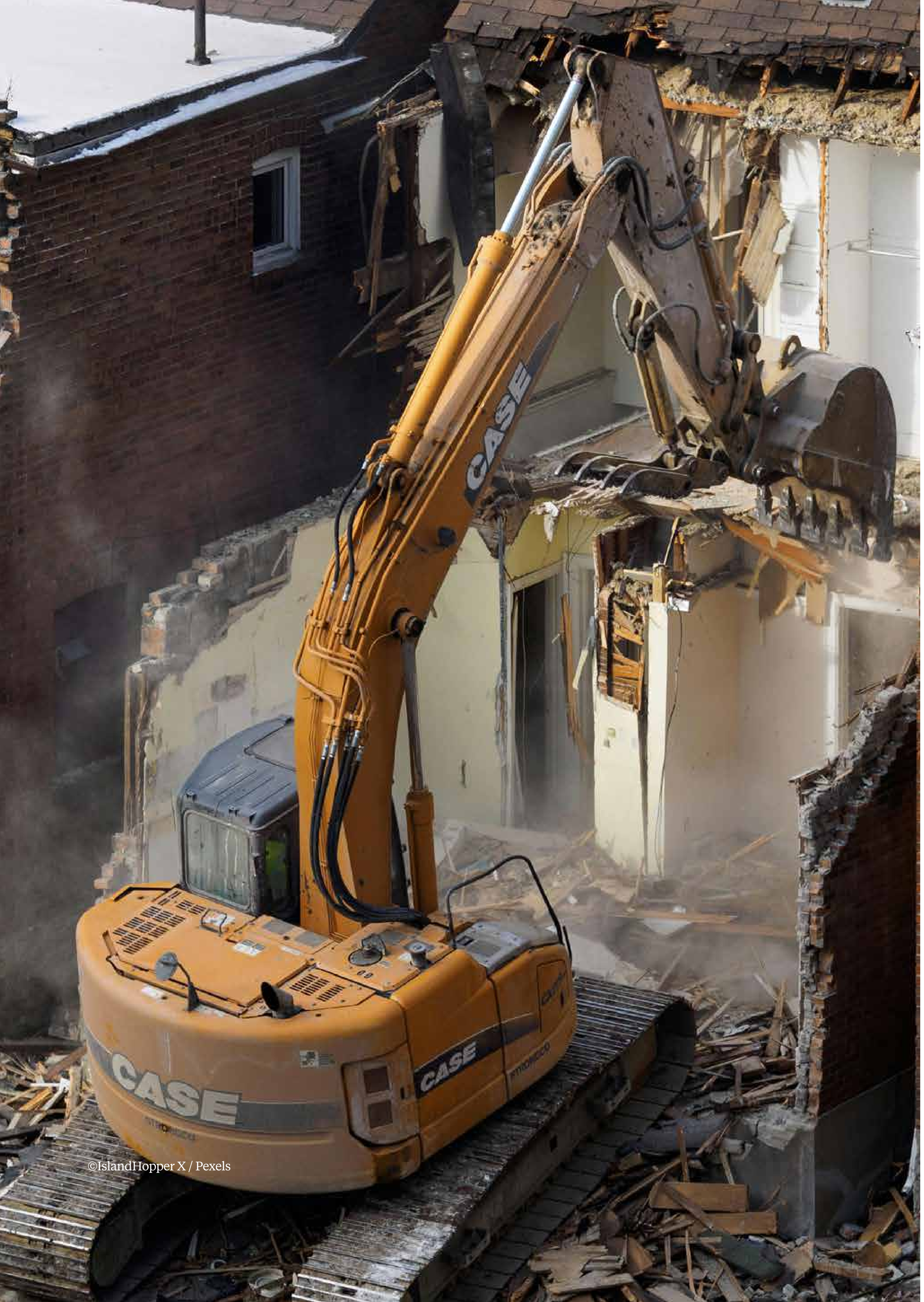
Demonstrated models confirm the viability of locally adapted timber systems that can reduce emissions by more than 70 per cent, create employment and empower communities. However, scaling such systems requires co-ordinated investment, inclusive governance and a narrative shift from timber as a niche material to timber as a mainstream development strategy. For resilient industries in the Global South, scalable impact can emerge from investing in community-driven systems.

A regenerative timber economy is not only about buildings; it is about transforming how we design, govern and relate to the natural systems on which we depend. For policymakers, this means aligning forest, housing and economic strategies to create value that is local, equitable and climate-positive.

While this chapter draws heavily on lessons from East Africa, it welcomes further contributions exploring how the *Principles* manifest in other regions around the world. Different political, social, and environmental contexts can create vastly different forms of a regenerative forest economy, where regulatory frameworks need to evolve to enable, rather than constrain, the use of natural materials, and where renewed knowledge and skills are needed for their effective application.

"Responsible timber construction has the potential to evolve into a regenerative industrial solution at scale. Achieving this transformation requires aligning local value creation with regional and global value chains, supported by manufacturing capacity, logistics and governance frameworks. Taken together, this provides the basis for a strong and responsible bioeconomy."

Dr Jörg Wiese, CEO, Kuehne Climate Center



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Chapter 1

Defining value: Extending the life of buildings through timber and low-carbon reuse

A reflection on Principle 1: Extending the life of existing buildings

"The potential for existing structures to be repurposed, renovated, and/or extended using timber, biobased, secondary, and other low-carbon materials is prioritised over demolition."

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Chapter overview

In *Chapter 1*, Dr Naomi Keena outlines how extending the life of existing buildings and avoiding demolition is the lowest-carbon, most resource-efficient and least wasteful option. Renovation-focused pathways can reduce greenhouse-gas emissions by 50–75 per cent compared with new construction, while also curbing urban sprawl and conserving the cultural and social value embedded in existing structures.

When timber, biobased, secondary and other low-carbon materials are used in the repurposing, renovation and extended use of buildings, they can support the transition to low-carbon construction. In this way, extending building life and scaling timber innovation are synergistic, offering pathways towards climate-positive development.

The chapter showcases global examples of innovative biobased construction materials and DfD practices adapted to local climates. It also highlights strategies for urban densification through mass timber overbuild systems, insights from selective deconstruction, approaches to material repurposing in informal housing, and emerging digital tools for visualising circularity.

The chapter emphasises that the principle of extending the life of a building is not only about reducing carbon emissions but also about preserving collective memory, supporting social cohesion and promoting more resource-efficient, adaptive and resilient urban environments. However, systemic barriers – including entrenched demolition practices, limited technical capacity, weak financial incentives, socio-cultural bias and outdated standards – continue to hinder wider adoption. Overcoming these barriers requires co-ordinated policies, training and incentives to develop markets for secondary materials, scale biobased alternatives and re-value existing buildings as critical climate assets.

From linear legacies to circular opportunities

“The earth’s layers remember geological ages, the rings of a tree recall past springs and autumns, and the archaeological mound is a reminder of the passage of cultures. The built structure remembers living habits and processes, contains information about historic vicissitudes, and forms the material basis of collective memory (...) The present intervenes in shaping the future by energetically making continuity more efficient than rupture, and renovation more efficient than demolition, through the persistence of boundaries, foundations, perceptual habits, and building traditions.”

Luis Fernandez Galiano, Fire and memory, 2000.

Linear legacies

Current construction practices often follow a linear model of resource use, progressing through extraction, construction, use and demolition. They rarely embrace a circular-economy approach. This linear logic leads to demolition instead of selective deconstruction and to material loss instead of recycling and reuse. New construction imposes additional environmental burdens through material extraction rather than reducing demand through renovation and efficiency improvements. Even when buildings or their components could be reused, renovated or retrofitted, technical standards, economic incentives and regulatory frameworks continue to favour new construction and linear pathways (UNEP, 2023). As a result, valuable materials are discarded, raw-material extraction increases and existing structures remain under-utilised.

Circularity in buildings refers to the sourcing, design, construction, operation and renovation of the built environment in ways that keep materials, components and spaces in continuous use, minimise waste and enable recovery at the end of service life (McDonough and Braungart, 2002; Ellen MacArthur Foundation, 2017; Khadim et al., 2023). Unlocking circular opportunities requires viewing existing buildings as assets rather than liabilities. Through targeted renovation and material substitution, these structures can be upgraded using low-carbon and biobased solutions while preserving, reusing or recycling existing elements. Prioritising reuse and life-extension of existing buildings over demolition, and favouring recycled or reused materials, are key strategies to reduce embodied carbon and advance the transition to circular construction.

Across the world, supply and demand for secondary building materials remain out of balance. With few circular business models and limited marketplaces for reused products, primary materials are still required for repair and renovation. In such cases, best practice is to incorporate low-carbon, renewable materials such as timber and other biobased options. Although biobased materials have low emissions during processing and use, their large-scale deployment must consider regional ecosystem capacity for carbon sequestration and storage (*see Chapter 2*). Biomaterial sourcing should also align with sustainable forest-management and farming practices (Keena, Duwyn and Dyson, 2022; *see Chapter 3*). Responsible material use includes cascading biobased resources, reusing and recycling biomass sequentially to maximise value before energy recovery (Jarre et al., 2020).

This chapter highlights the potential to avoid demolition by prioritising the repurposing, renovation and extension of existing structures using timber, biobased, secondary and other low-carbon materials. Global examples show how responsible biobased construction enables renewal of the built environment through deconstruction instead of demolition. Circularity shifts the sector away from wasteful practices while unlocking new design, economic and social value within existing assets. Timber systems are especially suited to DfD, allowing buildings to adapt over time and components to be reused at end of life. Extending building life and scaling timber innovation are therefore mutually reinforcing pathways towards climate-positive, resource-efficient development.

Rethinking building longevity: prioritising reuse over demolition

In OECD countries, existing buildings account for about 65 per cent of the total building stock projected for 2060 (UN Environment and International Energy Agency, 2017). Building stocks are expected to continue expanding towards 2070. Without renovation, floor area could more than double in developing economies, while renovation-focused pathways can significantly reduce carbon intensity and limit urban sprawl (Zhang et al., 2024). Globally, demand for repair and renovation will rise, particularly in regions with ageing mid-century stock. In the coming decades, many buildings, especially concrete structures, will reach a critical age and require system repairs or upgrades (Vilches et al., 2017). Early design decisions are therefore crucial to reducing environmental impacts by reusing existing structures and components. This helps to avoid the emissions associated with to demolition, waste generation and the energy-intensive manufacture of new materials. Global estimates from 2019 indicate that the material stock embedded in buildings totals roughly 550 gigatonnes. Mineral-based products such as concrete, steel and brick comprise nearly 90 per cent of this stock, while biomass materials, including timber, represent less than 4 per cent (Haberl et al., 2025). This dominance of mineral-based materials reflects historical trends but also highlights a major opportunity to reuse existing mineral products and scale up low-carbon, biobased and renewable alternatives. Material choices ultimately determine how buildings are valued. They influence whether a building's life is extended or its materials discarded.

Extending the use of existing structures supports decarbonisation

Extending the life of existing buildings and avoiding demolition is the lowest-carbon, most resource-efficient and least wasteful option. It preserves the carbon stored in existing biogenic materials, such as wood, thereby preventing premature release and avoiding emissions from new sourcing. Renovating existing buildings generates approximately 50 to 75 per cent fewer greenhouse-gas emissions than demolition and new construction, largely because it reuses the structure and envelope, components that contain most of a building's carbon-intensive materials, including concrete, steel, aluminium and brick (Strain 2017; Keena et al. 2023b).

Retrofit strategies often target operational carbon through efficient lighting, appliances, ventilation and heat pumps. Common envelope upgrades, such as insulation, glazing and shading, also contribute significantly to energy savings (Ang et al. 2023). These interventions involve material choices that can reduce embodied carbon and should be assessed within a whole-life-cycle framework, recognising that embodied impacts represent a growing share of a building's overall climate footprint. When timber, biobased, secondary and other low-carbon materials are used in repurposing, renovation or extended use, they support the transition to low-carbon construction (Keena et al. 2022a).

Alongside sectoral shifts towards whole-building life-cycle thinking, circular strategies such as adaptive reuse, shared-use models and behavioural changes away from demolition-led practices further support decarbonisation by lowering material demand and energy use. Adaptation strategies that promote more intensive use of existing buildings through space sharing have been shown to reduce environmental impacts by up to 50 per cent compared with conventional retrofitting, mainly by limiting new construction and maximising the use of existing structures (Shahmohammadi et al. 2024).

Research aimed at lowering embodied-carbon emissions associated with building materials (Carcassi et al. 2022; UNEP 2023) underscores the urgent need to reconsider how materials are selected and used. Although the steel and cement industries are improving manufacturing processes to advance decarbonisation (UNEP 2023), the use of low-carbon materials such as timber and bamboo remains limited globally. Biobased products offer multiple benefits, including the ability to store carbon throughout their service life and reuse cycles, while supporting lightweight, modular construction (*see Chapter 2*). Integrating these materials as a priority in the repurposing, renovation or extension of buildings enhances resource efficiency and reinforces climate resilience within the built environment.

Extending the life of buildings is a key strategy to reduce emissions in the built environment, particularly for timber construction. Maintaining or reusing timber structures keeps carbon stored and avoids emissions from demolition and new construction (Churkina et al. 2020). Demolition releases this stored carbon back into the atmosphere (*see Chapter 2*).

The potential to mitigate greenhouse-gas emissions increases when biobased resource use is planned to maximise its lifetime. Ensuring that materials first serve long-term applications before being down-cycled into shorter-term uses enhances carbon-storage potential across successive life cycles (Lafleur and Fraanje 1997). In such design processes, resource quality and suitability across subsequent uses are optimised, maximising carbon storage through each cycle. Research shows that extending the use of existing buildings and undertaking selective deconstruction to recover secondary materials can reduce carbon emissions by up to 75 per cent compared with demolition and new construction (Rondinel-Oviedo et al. 2024; Di Maria et al. 2018; Keena et al. 2023b).

Despite their high mitigation potential, circular end-of-use approaches remain limited. Realising their full impact requires policies and technical guidance that emphasise building-life extension and material recovery at the end of use. As outlined in Section 2, a circular-economy framework advances these aims by standardising components for disassembly and reuse and by providing technical guidance on circular construction (UNEP 2023).

1.1. Best practice: La Maison de la réserve écologique by Archipel Zéro, France (2025)

© Frédéric Denise

The project demonstrates an outstanding commitment to circularity and regenerative construction practices. It integrates reused materials and a wide range of natural resources beyond timber (e.g., straw, raw earth) within a low-impact construction process. This process also served as an educational tool, involving both local residents and professionals through hands-on workshops focused on sustainable construction techniques. The building's minimal physical footprint, enabled by screw pile foundations and thoughtful site placement that respects local wildlife and ecological conditions, demonstrates a comprehensive commitment to environmental stewardship. Additionally, all timber used is certified and sourced locally within France.

Further information:
BbN Prize, 2025 ↗

Current trends in research, policy and practice

Research

Adaptive reuse and building performance during the use phase

Engineered biobased materials such as cross-laminated timber, together with rapidly renewable resources like bamboo, offer viable alternatives to conventional concrete and steel, especially in renovation or repurposing scenarios. For example, in adaptive reuse of ageing commercial buildings, especially offices, adding lightweight timber floors can support the provision of new housing units. Replacing concrete façades with biobased assemblies can significantly reduce upfront embodied emissions while improving thermal performance, lowering operational energy demand and enhancing occupants' thermal comfort. Biobased panels show strong potential as alternatives to drywall partitioning, given their effective acoustic and indoor air quality properties (Keena et al., 2022a). Locally sourced biobased products often perform well in the climatic conditions in which they are found, offering inherent thermal and hygric advantages. They contain properties which meet occupant comfort requirements in their specific location. For example, panels made from coconut products exhibit intrinsic evaporative cooling and dehumidifying properties essential in hot, humid climates (Lokko 2016; Lokko et al. 2016; Lokko and Rempel 2018). Research indicates that opting for biobased or other low-carbon and biodegradable finishes, such as cork or cellulose-based tiles, can further reduce the environmental impact while supporting healthier material choices and habitats (Zimmerman et al., 2020). 1.2. Best practice highlights the potential to mitigate greenhouse gas (GHG) emissions through the use of novel biobased materials that incorporate DfD principles.

Replacing fossil-based binders with bio-binders can improve air quality and reduce energy use over the course of a building's life. These materials demonstrate potential as evaporative cooling systems and humidity-buffering technologies (Maalouf et al., 2015; Nguyen et al; 2018; Zimmerman et al., 2020). Research into bio-binders is crucial since biobased products with synthetic resin are difficult to recycle at end-of-life, as noted in 1.3. Best practice.

Integrating Forestry and Construction for Circular Design

Biobased materials integrate most effectively within circular design frameworks when supported by systemic coordination between the forestry and construction sectors (Dzhurko et al., 2024). Connecting the ecological characteristics of tree species with the functional requirements of buildings can enhance long-term sustainability (Osborne et al., 2023). Such integration also allows better anticipation of how climate change and biodiversity objectives may affect the future viability of timber supply, while addressing carbon-uptake accounting and the alignment of harvest rotations with building lifetimes (Hoxha et al., 2020).

1.2. Best practice: opportunities of novel biobased construction materials and DfD practices to reduce greenhouse gas emissions and respond to local climatic conditions

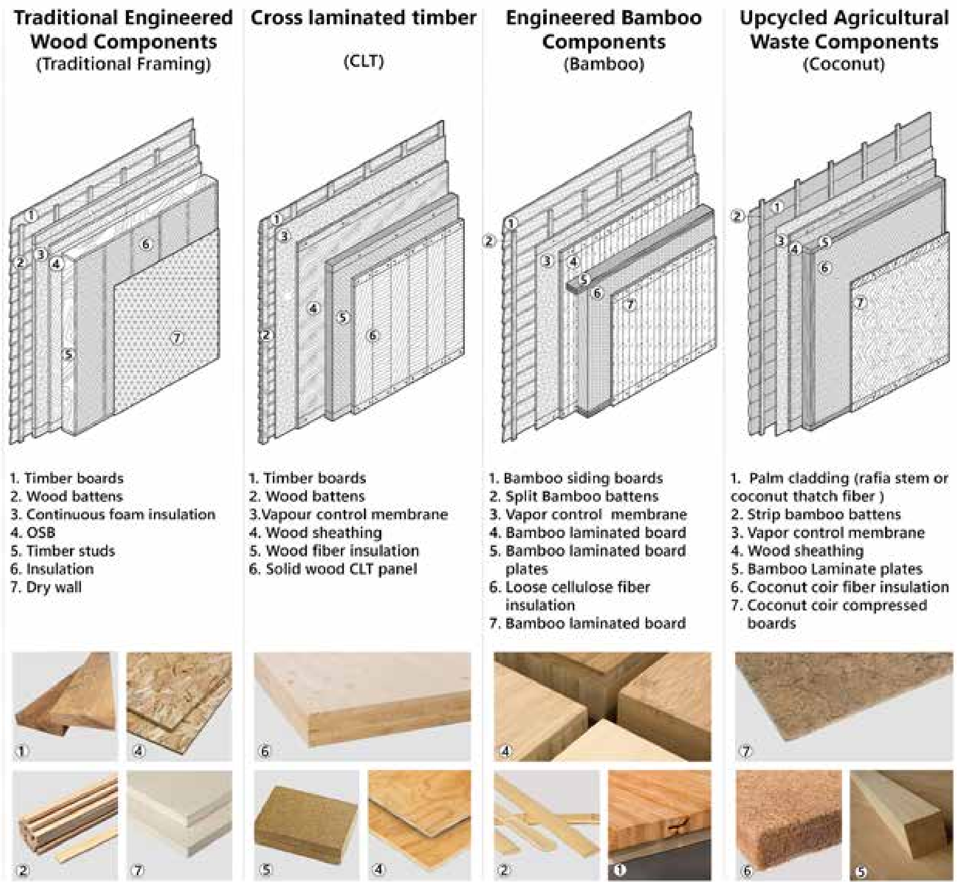

Figure 1: Wall assembly types for traditional framing, CLT, bamboo, and coconut, showing the construction assemblies designed to respond to the local climatic conditions in which they are found (Keena et al., 2022b).

Description: This case explores emerging high-performance biobased construction materials, produced sustainably and/or using waste agricultural byproducts, to reduce environmental impacts in the built environment. A life-cycle assessment (LCA) compares three wall assemblies using local biobased materials in Montreal, Canada, Nairobi, Kenya, and Accra, Ghana with a traditional assembly using gypsum boards and rockwool insulation. The study assesses global warming potential (GWP), non-renewable cumulative energy demand, acidification potential, eutrophication potential, and freshwater consumption (FWC). Scenarios include options for DfD and potential future alternatives for electricity supply in Kenya and Ghana. Results indicate that all biobased alternatives have lower (often significantly so) life-cycle impacts per functional unit, compared to the traditional construction. DfD strategies are also shown to result in -10 per cent to -50 per cent impact reductions. In Kenya and Ghana, results are influenced by electricity sources, revealing both opportunities for decarbonisation and trade-offs in acidification and eutrophication (Keena et al.,2022b).

Further information:
Keena et al., 2022 ↗

1.3. Best practice: Recycling challenges of engineered biobased products

Description: This case study (Keena et al., 2023b) examines extending the life of buildings through selective deconstruction and the associated recycling challenges of engineered biobased products' life cycle assessment, which found that the GHG emissions from recycling engineered biobased boards were higher than from landfilling them. The study highlights the need for further research into biobased resins to prevent mixing biological and technical nutrients, enabling better recovery or composting and reducing the need for virgin timber. Stable bio-binders can also enhance long-term carbon storage. The study calls for research and development into durable biobased adhesives to improve recyclability (Calvez et al., 2024; Kumar and Leggate, 2022; Liu et al., 2022). It also emphasises designing structural systems for longer service life, incorporating moisture protection, maintenance and repair strategies to extend use beyond current limits (Bergsagel et al., 2025). Designing more efficient structural systems, such as standardised components and mechanical rather than chemical joints, can simplify disassembly and promote reuse of large elements in new buildings (Akinade et al., 2017; O'Grady et al., 2021).

Further information:
Keena et al., 2023 ↗

Policies

Reusing biobased products

In Europe, wood salvaged from deconstruction and reuse faces regulatory challenges under the European Harmonised Standard EN 14081 series, particularly regarding source identification. Ongoing discussions are considering whether dedicated standards may be required for reclaimed timber (Porteron and Ridley-Ellis, 2025). These requirements complicate reuse and recycling, but could be resolved through a new framework specific to reused timber. Comparable challenges also arise in fire-resistance testing under the European Standard BS EN 13501 series (Kissinger, 2025).

In the United Kingdom, Regulatory Position Statement (RPS) 291, introduced in late 2023, temporarily permitted 'amber' waste wood from pre-2007 buildings, previously classified as potentially hazardous, to be processed and stored as non-hazardous, provided quarterly testing was carried out and results shared with the Wood Recyclers Association (WRA). This measure alleviated testing bottlenecks that followed the withdrawal of the earlier RPS 250. RPS 291 has since been withdrawn after extensive testing confirmed that amber wood is no longer hazardous. It is now formally recognised as non-hazardous, removing the need for a regulatory position statement for its movement and processing (UK Environment Agency, 2024; Kissinger, 2025).

Whole-life-cycle approaches to decarbonising the built environment

A strong emphasis on whole-life-cycle assessment is now evident in international policy and industry guidance. This includes dynamic models to capture biogenic carbon pools in forests and buildings, and a growing focus on embodied carbon. A UNEP report (2023) on building materials and climate highlighted the importance of tackling embodied carbon and applying whole-building life-cycle thinking to the built environment. A recent OECD policy framework aimed at national and local governments recommends embedding whole-building life-cycle assessment in regulations and gradually introducing embodied-carbon performance limits, meaning maximum permitted levels of embodied emissions (OECD, 2025). Similarly, UNEP's *Guidance for Responsible Banking* (2024) outlines how financing for the buildings and construction sector can integrate circular-economy strategies by emphasising whole-life-cycle approaches and reducing embodied emissions through 'avoid, shift, improve' material-efficiency actions.

At the EU level, the 2050 vision for a decarbonised building stock moves beyond the current focus on operational emissions. The European Commission's 2025 guidance elaborates on the new directive requiring Member States to calculate and disclose the life-cycle global-warming potential of new buildings by 2028 for large buildings and by 2030 for all buildings. They must also prepare national roadmaps for introducing limit values. Together, these initiatives mark a clear shift from an exclusive focus on operational energy efficiency towards a systemic approach that embeds embodied carbon, circularity and material sustainability in future policy and building-sector practice.

Practices

A circular economy approach offers opportunities for design, reuse and recycling at each phase in a building's life. The following sections outline key practices at each phase.

Early decisions during the planning and design phases

A circular economy approach provides a practical framework to guide decisions across a building's life cycle. At its core, circularity in the built environment depends on time-sensitive planning and integrative design decision-making (UNEP 2023). Early planning and design choices have repercussions for the ability to extend a building's life, and to reuse or recycle materials either later within the same lifespan or in subsequent uses. Design choices regarding building form, layout, material selection, construction assemblies, and how the building will be maintained and eventually adapted or dismantled can substantially reduce embodied carbon. During the planning phase, one should first consider whether anything new needs to be built at all, and what alternatives can be explored. During the early design phase, opportunities to reduce carbon involve building less by maximising the use of existing assets. For example, densification using a mass timber system overbuild offers new solutions to extending the life of existing assets while meeting additional space demands, without the need for extensive new construction. One example is Haven in Canada that offers prefabricated overbuilds using mass timber - transforming standard class b and c office buildings into high performance rental housing - towards reduced delivery time and cost (Haven, 2025). During the construction phase, a circular approach involves building efficiently by using low-carbon construction technologies and eliminating waste (HM Treasury, 2013; Programme for Energy Efficiency (PEEB), 2021; World Green Building Council, 2019). Here, biobased materials offer excellent low-carbon alternatives. See **1.4. Best practice** for an example of densification and reduction in carbon emissions by extending and reusing an existing structure.

1.4 Best practice: Densification using mass timber system overbuild solutions

Description: The Lighthouse building in Amsterdam's District West – developed by TPG Angelo Gordon and APF International – has been transformed from a 1997 reinforced-concrete office into a modern grade-A workspace. Led by Benthem Crouwel Architects, the project focused on extending and upgrading the facility while significantly reducing its carbon footprint. Key sustainability measures included the use of demountable mass timber, upgraded connections to the district's ground-source heat (GSH) network, reuse of the original cladding and most of the mechanical ductwork, and implementation of smart energy-management technology.

A post-completion ESG assessment by the Whitby Wood Group of companies showed that extending and reusing the existing structure is expected to save 40 per cent of lifetime (to 2079) carbon emissions compared with demolition and rebuild. Energy performance has improved by up to 30 per cent compared with the original 1997 building, creating a low-carbon, efficient workspace for the future.

Key Facts:

- Whole-life embodied carbon was reduced from 312 kg CO_2e/m^2 to 270 kg CO_2e/m^2 (–16 per cent) through the use of demountable timber.
- 658TCO2e stored in the timber frame.
- Timber extension saves 47 per cent structural embodied carbon vs. RC frame.
- 52 per cent of A1-A5 emissions (130 kgCO_2e/m^2) from MEP systems; structure largely reused.
- GSH upgrade cuts energy use by 35 per cent and total carbon by 48 per cent versus air-source systems

Further information:
Whitby Wood by Benthem Crouwel Architects ↗

Design for disassembly, modularity and prefabrication during the construction phase

When designing to extend a building's life or planning new construction, promoting the use of DfD can facilitate reuse at a building's end of use. DfD allows building components to function as adaptable systems rather than fixed elements, enabling their reuse, refurbishment or relocation within circular material loops (O'Grady et al., 2021). When combined with broader strategies such as deconstruction and resilience planning, DfD further enhances the circularity of existing buildings (Joensuu et al., 2022), increasing carbon savings. In addition, the benefits of adaptive reuse and repurposing with biobased materials are multiple, given their lightweight properties, rapid construction time and suitability for prefabrication. Digitalisation also supports prefabrication and modular construction by resolving issues before materials reach the worksite, reducing waste by 23–100 per cent (Jaillon, Poon and Chiang, 2009; Lu and Yuan, 2013; Chen, Msigwa et al., 2022).

Selective deconstruction and avoiding landfilling
A potentially lower-carbon approach to the end-of-use of a building is selective deconstruction, which involves dismantling the structure rather than demolishing it. Practices of reuse, repair and recycling help retain the value of building components and materials. As mentioned above, research demonstrates the significant carbon reduction potential of selective deconstruction over demolition and landfill. See 1.5. Best practice for an example of selective deconstruction in practice, including key lessons from real-world applications.

1.5. Best practice: Selective deconstruction in a Montreal triplex: Lessons from circular renovation practices and analysis

Description: This case presents an evaluation of the selective deconstruction and renovation of a typical Montreal triplex, a three-unit urban residential typology. The project, led by social enterprise SURCY in collaboration with the Association of Construction and Housing Professionals of Quebec (APCHQ) and McGill TRACE Lab, analyzed how to maximise material recovery and apply circular strategies in renovation. The project preserved the existing basement and foundation, made of concrete and wood beams, while upgrades focused on the wood-based structure and building envelope. Integrating LCA and life-cycle costing (LCC) into the design process provided evidence to support a circular approach outlining the environmental and economic benefits and trade-offs. Outputs of this collaboration include a Salvage Materials Design Guide for the Quebec Construction Sector.

Further information:
Guide to Recyclable Materials, Surcy. ↗

Key challenges and opportunities

Mitigating risks and safeguarding the future of the built environment requires rethinking how existing buildings are valued, maintained, and transformed. This section outlines the technical, operational, social, cultural, regulatory and economic limitations and opportunities to overcome linear processes of waste production and demolition. It outlines the challenges and opportunities that exist in integrating a circular economy approach, including the use of secondary and biobased materials.

Overcoming an entrenched linear approach which promotes demolition

Technical, operational, socio-cultural, economic, and regulatory limitations regarding the use of secondary and biobased materials pose a barrier to their use.

Extending the life of existing buildings and using recovered and biobased materials face four overarching barriers, but within these also lie opportunities, as outlined below:

- overcoming technical challenges and addressing funding gaps
- developing economic incentives to drive a reuse marketplace
- improving socio-cultural acceptance
- strengthening policies and regulatory frameworks, including standards, regulations and certifications

Technical and operational challenges and opportunities

Challenge

Construction practices rely on landfill as a waste management strategy
Demolition followed by landfill remains the dominant method for handling construction and renovation waste. This linear approach reinforces a disposal-oriented mindset and leads to the loss of valuable materials. Globally, around 35 per cent of construction waste still ends up in landfill (Z. Chen et al., 2022), underscoring the need for stronger regulatory shifts, industry engagement, and circular waste management infrastructure. In Montreal, for example, construction, renovation, and demolition (CRD) waste accounts for up to 30 per cent of the solid waste stream, with most still landfilled (Keena and Rondinel-Oviedo, 2022). The issue is even more critical in developing regions: in Peru, 94 per cent of construction sites involved demolition, with 66 per cent of waste landfilled, most handled by unregistered operators, reflecting limited oversight and low recovery rates (Rondinel-Oviedo, 2021). Even in contexts with higher diversion rates, a significant share of waste wood is not reused or recycled into higher-value products but instead diverted to energy recovery.

Challenge

Lack of knowledge and skills regarding deconstruction and material reuse

A major barrier to circular construction is the limited availability of training and practical knowledge—particularly in selective deconstruction, material sorting, and reuse. While circular practices are increasingly recognised, they are rarely implemented on-site due to insufficient technical capacity. For example, staff training on construction waste sorting was the least reported current practice in a survey of Peruvian construction sites, despite being the most cited future priority (Rondinel-Oviedo, 2021). Across the sector, education and training on using secondary materials remain inadequate, and many professionals lack the technical expertise to safely and effectively reuse materials.

Challenge

Funding constraints for technical innovation

Material degradation, fire resistance, and seismic performance affect the reusability of buildings and materials, particularly in regions reliant on reinforced concrete or exposed to seismic risks. Insufficient investment by governments in research and innovation is still constraining progress towards practical solutions. Similar challenges exist for introducing biobased materials, which must compete with established construction products.

Opportunity

Partnerships in research and development

Partnerships among public institutions, academia and the private sector advance research and innovation in sustainable construction materials, helping to close knowledge gaps. Initiatives such as technical training, scholarships and centres of excellence support innovation and encourage behavioural change across the building life cycle (Keena et al., 2022a). Funding mechanisms that strengthen local value chains for recycled and biobased materials are also essential. Examples include the EU's Horizon Europe programme; particularly the New European Bauhaus Facility and Cluster 6 on Food, Bioeconomy, Natural Resources, Agriculture and Environment. National initiatives such as the Netherlands' Topsectors programme and Canada's CMHC Housing Supply Challenge likewise promote sustainable biobased construction.

Opportunity

Training and knowledge in circular design and construction practices

Circular design in existing buildings includes adaptive reuse, lightweight retrofitting, targeted conservation, and the use of timber, engineered wood, and other biobased materials to extend building lifespans. Scaling these approaches requires a trained workforce with practical knowledge of circular design principles—evaluating reuse potential, specifying biobased materials, and planning interventions that minimise disruption while maximising performance. Technical training should also emphasise selective deconstruction methods, which can recover components for reuse and reduce emissions by up to 70 per cent in urban contexts (Di Maria et al., 2018; UNEP, 2023). In this context, human factors such as effective communication among teams, access to appropriate tools, and targeted training are critical to successfully promoting selective deconstruction and design for disassembly (Akinade et al., 2017). Government support for education and research on selective deconstruction and disassembly remains essential (Cruz Rios and Grau, 2020; Deplazes, 2012; Hossain et al., 2020; McClure et al., 2007; Rondinel-Oviedo and Schreier-Barreto, 2019). Designing for future disassembly—including modular timber systems and reversible connections—can enable component recovery and reuse, cutting life-cycle impacts by up to 50 per cent (Keena et al., 2022b). Embedding these skills in architectural curricula, trade training and procurement policies can help steer the sector towards sustainable construction. Address the decline of craftsmanship to extend building lifespans by valuing trades through apprenticeships, vocational programs, government support, better pay, and public appreciation.

Economic Challenges and Opportunities

Challenge

Limited economic incentives

Government support for the reuse of secondary materials and the uptake of new biomaterial products, such as those derived from agricultural waste, remains limited or absent. This gap discourages the development of reuse markets and innovative biobased building products, slowing the broader adoption of circular practices. Without regulatory frameworks or procurement policies that promote reused components, technical and operational barriers remain unresolved (Knoth et al., 2022). The lack of institutional leadership contributes to the perception that secondary materials and novel biobased products are marginal rather than part of mainstream practice. Because steel and concrete benefit from mature supply chains and large-scale production, biobased building materials tend to be costlier and less competitive. Without fiscal or policy incentives, their adoption in the market remains limited (Keena et al., 2022a).

Opportunity

Economic Frameworks and Public Procurement

To build a circular marketplace for material reuse and accelerate the adoption of low-carbon, biobased materials, economic and policy frameworks must enable innovative enterprises to scale and contribute to local economies. Fiscal and financial instruments, including tax incentives, grants and concessional loans, can promote the development and adoption of sustainable materials and stimulate emerging markets.. Incentives like green public procurement and tax benefits can also encourage stakeholders in the building sector to integrate life-cycle thinking in design and construction. Advancing research and development in biobased materials requires targeted funding, while national-level policies should promote public–private partnerships that blend public and private financing to drive innovation and applied research. Ongoing collaboration between research institutions and industry is essential. This partnership helps to advance progress in this field.

Socio-cultural Acceptance

Challenge

Social resistance to biobased material and secondary material use

In many contexts, biobased materials are still perceived as outdated, unsafe, or unsuitable for modern architecture (Galmarini et al., 2022). Their use is often limited to informal settlements and non-load-bearing applications, as concrete and steel are viewed as more durable, safe, and low maintenance (Salzer et al., 2016). Such views are rooted in prevailing ideas that link modern design with the use of concrete, steel and glass. For centuries, global folklore and children's literature (Choplin, 2023) have portrayed wooden or straw homes as weak, while brick and cement houses represent beauty and protection. In contexts where concrete and brick signify permanence and social status, such narratives reinforce the idea that traditional biobased materials are less desirable.

In many parts of the Global South, housing develops progressively (see 1.6. best practice). Construction begins with reused or temporary materials—often wood, straw, or adobe—and gradually transitions to more durable options like concrete and brick as resources become available (Sarmiento-Pastor et al., 2025). This incremental process reflects adaptation and long-term investment, while also deepening the association between permanence, safety, and social value.

These cultural messages, transmitted through stories, education, and everyday building practice, perpetuate the belief that concrete is inherently superior while traditional materials are linked to poverty or vulnerability. Awareness campaigns, design competitions, and awards can help shift these perceptions by showcasing reused and vernacular materials as resilient, desirable, and compatible with contemporary aesthetics (Keena et al., 2022a). Such initiatives can demonstrate how local identity can be preserved while promoting climate-responsive and culturally appropriate design.

Challenge

Broader cultural biases against biobased and secondary materials

Cultural biases also contribute to resistance, as secondary materials are often associated with poor quality or unreliability, while biobased products are viewed as less progressive than glass or steel. Architect Rem Koolhaas famously described this shift as the global conformity of contemporary architecture and the loss of national and vernacular identities (Venice Biennale, 2014). This homogenisation reflects linear thinking. As a result, reused elements may be dismissed not for technical reasons but due to perceptions of complexity, higher cost, or deviation from the industry's preference for mass customisation.

1.6. Best practice: Repurposing materials, a case of informal housing in Lima, Peru

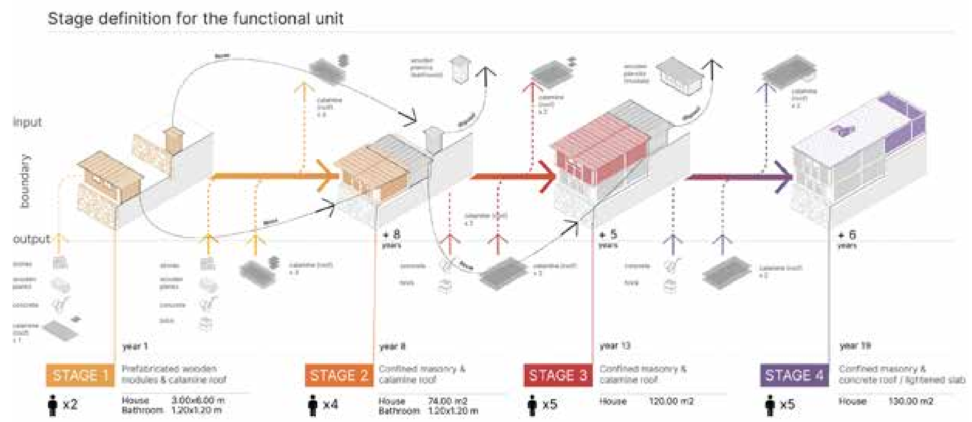

Figure 2: Incremental building and circular practices in informal housing in Lima, Peru. Rondinel et al., 2025 Source image 1: Sarmiento-Pastor, J., Lira-Chirif, A., Rondinel-Oviedo, D.R., Keena, N., Dyson, A., Raugei, M., Acevedo-De-los-Ríos, A., 2025. Source image 2: © Rondinel-Oviedo, D. R. & Acevedo-De-los-Ríos, A. 2019.

Description: In Lima's informal settlements (Peru), housing is built incrementally using available and reused materials. Corrugated metal sheets and timber panels are repurposed repeatedly across multiple stages of home expansion. While the overall process remains linear, this extended reuse enhances short-term circular performance by reducing material turnover and delaying environmental impact (Sarmiento-Pastor et al., 2025). Despite repeated reuse, these practices occur within a largely linear system: materials circulate locally for years but are eventually discarded without formal recovery. In early housing stages, timber is used for 15–20 years before being replaced by concrete, reflecting both the potential of timber and the prevailing preference for industrial materials. Reuse practices are concentrated in informal contexts, driven by necessity, while formal construction continues to favour demolition over conservation. Establishing local material recovery hubs linked to neighbourhood supply chains can help formalise these processes. This example illustrates how municipal incentives—such as tax reductions and fast-track permits—can integrate circularity principles into urban upgrading and land regularisation programmes.

Further information:
Sarmiento-Pastor et al., 2025 ↗

Opportunity

Buildings with socio-cultural connections are the last to be demolished

Buildings that last are often those with strong emotional or cultural meaning. The lifespan of a structure is not defined only by its physical durability but also by how connected people feel to it (Cao *et al*., 2021). When buildings are valued socially and culturally, owners and developers are more likely to preserve, maintain, or repurpose them rather than demolish them. Prioritising these connections in design and renovation can extend building life by transforming spaces into places of meaning.

While iconic heritage buildings, such as Japan's Ise Shrine, demonstrate how emotional and cultural attachment can promote material reuse (Adams, 1998), this principle also applies to everyday structures such as housing. When people live, gather, and form memories in a space, that building gains value beyond function. Architecture and thoughtful design play key roles in creating such memorable environments. Even functional settings, like airports, can foster attachment when designed to support human interaction (Oyarzún *et al*., 1999).

Conversely, buildings of poor quality often fail to inspire connection.

Socio-cultural ties may also erode when communities are displaced or excluded from planning decisions. Strengthening these connections requires inclusive, long-term design processes that build belonging and trust. A sense of place arises from the interplay of physical, social, cultural, and institutional factors and can both reflect and reinforce housing sustainability (Safarkhani, 2025).

Policy and Regulatory Frameworks - Standards, regulations and certifications

Challenge

Uncertainty and risk in secondary and novel material use due to the absence of quality standards

The absence of recognised standards and certification mechanisms for secondary materials and emerging biomaterials – such as those incorporating bio-binders – creates uncertainty and risk. Without clear criteria to ensure compliance with building codes, architects and contractors are reluctant to specify these materials. This regulatory ambiguity undermines confidence and discourages investment in reuse infrastructure. Until reliable assessment standards are developed for composition, structural performance, and code compliance, the use of secondary materials will remain limited (King, 2021; UNEP, 2023). Recent attempts to draft such standards demonstrate particular complexity for reused timber, due to its variable properties (Porteron and Ridley-Ellis, 2025).

Opportunity

Implement performance-based building standards and regulatory reform

National building codes can be updated to broaden material options and support low-carbon construction. Such reforms would enable the integration of biomaterials and secondary materials in mainstream practice. A notable precedent is the International Code Council (ICC) ad hoc committee on tall wood buildings, which examined the building science of high-rise timber structures. Their work resulted in a code amendment permitting mass timber construction up to 82.3 metres in height, adopted in the 2021 ICC building code.

For secondary material use, the establishment of robust standards and certifications is critical. Developing assessment frameworks that ensure safety and performance can encourage selective deconstruction and material recovery. Clear policies should guide approval procedures before secondary materials enter the market. These materials must meet recognised benchmarks for composition and performance and comply with existing building codes. To overcome legal and social barriers, they should be assessed to demonstrate equivalence with virgin materials. Transitioning from prescriptive to performance-based standards is key to enabling innovation in biobased and secondary material use (Keena et al., 2022).

Opportunity

Promote evidence-based material selection

Reducing long-term waste and carbon risk begins with early material choices. Raising awareness among construction professionals about alternative, low-carbon materials is essential. These materials may be biobased or secondary. Such awareness enables informed decisions that minimise environmental burdens throughout a building's life cycle. LCA and carbon accounting can support evidence-based design, while EPDs provide transparent data on material impacts for architects and specifiers.

Training programmes, procurement guidelines, and public-sector codes and standards should embed evidence-based design to align early-stage decisions with sustainability and circularity goals. This awareness is particularly important for retrofitting projects, where extending the life of existing structures depends on selecting compatible, low-impact materials that enhance performance without triggering extensive structural changes or waste. Growing awareness of the need for data transparency along both primary and secondary supply chains is vital to ensure ethical and sustainable sourcing practices.

Opportunity

Accelerate the digitalisation of buildings and promote social awareness

Digitalisation is a key enabler of circularity and an effective tool for reducing material waste and inefficiency. Tools such as building information modelling (BIM), the Internet of Things (IoT), and building and material passports support systematic documentation of material stocks, monitor component performance, and identify when elements are nearing the end of service life. This enables timely intervention for reuse, safer dismantling, and landfill diversion (UNEP, 2023).

Beyond tracking and recovery, digital tools mitigate quality-related risks when reintroducing secondary materials by maintaining records of specifications, maintenance, and exposure. This documentation supports reuse decisions and builds trust across supply chains. While BIM is particularly useful for complex or large-scale projects, material passports offer a simpler, scalable solution for smaller or residential buildings by storing life cycle data that supports renovation, reuse, and maintenance (GlobalABC and UNEP, 2021).

Encouraging use of these tools, especially in public and institutional projects, can accelerate adoption and extend building lifespans. As digitalisation expands across the housing sector, tools like Data Homebase's Digital Passports (see 1.7. Best practice) can help mainstream circular practices while raising social awareness of the material value embedded in homes.

1.7. Best practice: Data homebase digital housing passports visualising circularity

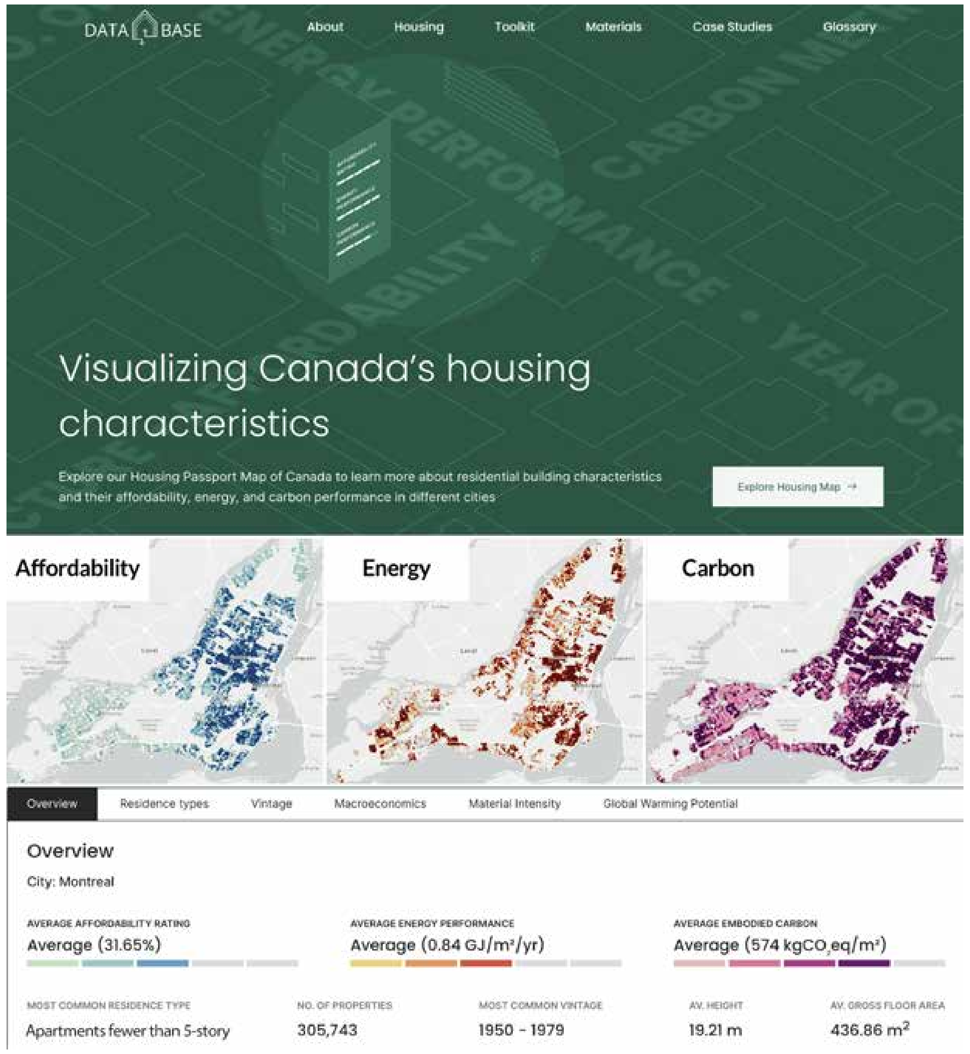

Figure 3: DataHomebase web application: homepage (top). Color coded scales visualize affordability blue-green scale; energy performance red-yellow scale; carbon footprint purple-pink scale (bottom). Source image: Keena, N., Friedman, A., Parsaee, M., & Klein, A. (2023).

Description: Data Homebase is a web application that standardises housing data and supports circular decision-making in Canadian cities through a new Housing Passport Knowledge Graph (HPKG) (Keena et al., 2025, 2023a). Housing data is fragmented, limiting insights into building lifespans, material reuse, and environmental performance. Accessible at multiple scales, from individual buildings to entire cities, the Canadian digital housing passport compiles data on emissions, energy performance and housing affordability. It visualises environmental impacts of deconstruction and recycling versus landfill, aiding informed decisions for municipalities and homeowners.

Further information:
Keena et al., 2023 ↗;
McGill TRACE lab, DataHomebase ↗

Ecological limits and material supply risks for timber-based strategies

Rising demand for biobased construction must still contend with structural limits on sustainable timber use, particularly those related to land management, governance and biodiversity protection. Combining timber with fast-regenerating materials such as agricultural residues (e.g., straw) and purpose-grown biomass from lignocellulosic crops (e.g., bamboo, hemp, miscanthus, switchgrass) can broaden supply and reduce pressure on forests (Röck et al., 2023). Crop diversification also enhances resilience, as biomass yields and fibre quality vary with environmental conditions.

Although timber can serve as a long-term carbon store, global supply may meet only a fraction of the projected demand for new floor area by 2050, raising concerns about deforestation and ecosystem strain (Pomponi et al., 2020). Research indicates that climate change will significantly affect global timber supply by shifting and shrinking the distribution of major species (Dyderski et al., 2018; Mauri et al., 2022)—an area warranting further study. A timber-only strategy is therefore neither feasible nor desirable. Regionally adapted approaches that integrate complementary biobased materials are essential. The production and use of biomaterials must be governed by robust sustainability criteria to prevent unsustainable practices—from deforestation and land-use change to biodiversity loss (*see Chapter 3*). Given physical and ecological constraints, hybrid strategies that combine recovered mineral-based components with regionally sourced biobased materials provide a more pragmatic, scalable approach. This integrative pathway reduces pressure on ecosystems while aligning with circular design principles and material reuse objectives.

Selective deconstruction and renovation to extend life of buildings
© Rondinel-Oviedo, D. R., TRACE lab (2025).

From principle to action

The *Action Pathways* summarised below outline key policy pathways and enabling mechanisms for extending the life of existing buildings and avoiding unnecessary demolition, waste, and related life-cycle emissions. These recommendations aim to establish a regulatory and market environment that supports the adoption of socially accepted biobased and secondary materials and promotes building life extension. Targeted policies are essential to ensure the effective and widespread integration of these materials and practices across the building sector.

Action pathways

Key challenge	Policy pathway	Enabling strategies
Entrenched linear approaches promote demolition and loss of valuable materials.	**Avoid Demolition**	• Extend the life of existing buildings to preserve embodied carbon, reduce waste, and reduce emissions. • Enact legislation during the planning and design stages to discourage unnecessary new construction and prioritise the reuse of existing buildings. • Introduce 'renovation-first' requirements in permits and planning. • Set reuse and recovery targets at the municipal and regional level • Offer financial incentives or coding benefits for retrofitting and deconstruction.
Socio-cultural biases associating secondary and biobased materials, and vernacular architecture, with outdated or undesirable aesthetics.	**Shift public perception to recognise these materials and design traditions as compatible with modern, innovative, and sustainable lifestyles, challenging the dominance of concrete, steel, and glass as symbols of contemporary design.**	• Launch awareness campaigns (competitions, awards, etc.) to make reuse and biobased products attractive and mainstream, debunking myths regarding durability, properties, lifespan and health impacts. This can help inform the public and decision-makers about the benefits of reuse. • Support demonstration projects that showcase reliable and desirable reuse in real buildings. • Promote the use of biomaterials and vernacular design in refurbishment and heritage buildings. As highly visible and frequently visited sites, these buildings can serve as powerful demonstrations of sustainable, locally adapted construction solutions. • Create attractive and accessible marketplaces for reused materials, including dedicated hubs or sections within major retailers.

Action pathways

Key challenge	Policy pathway	Enabling strategies
Uncertainty and risk regarding the safety and performance of reused and novel biobased materials.	**Build Trust and Security in the use of secondary and biobased materials**	• Develop assessment standards and certification for biobased and secondary materials to ensure safety and efficacy. • Policies to develop and regulate the government approval process for re-used materials before they enter the marketplace • This will support selective deconstruction and may act as a catalyst for the development of reuse marketplaces.
Economic and market barriers to scaling biobased and secondary material industries, and to enabling circular design and construction.	**Promote Economic Incentives and Sustainable Public Procurement**	• Economic drivers—such as grants, tax benefits, and subsidies—can be as effective as legislation in promoting material reuse in design and construction, as well as stimulating the development of a reuse marketplace in the construction sector. • Financial incentives should support the growth of new architecture and engineering practices conducting circular design, as well as specialised deconstruction contractors capable of carefully dismantling buildings and preparing secondary materials for resale. • Establishing centralised reuse hubs or 'one-stop shops' for end-of-use materials can facilitate the recovery and resale of high-value components before they are sent to sorting facilities. • By enabling biobased and circular economies in construction, economic and government incentives - tax incentives and public procurement - can generate new employment opportunities and foster local economic development.

Action pathways

Key challenge	Policy pathway	Enabling strategies
Lack of awareness and technical know-how in circular design and construction.	**Revive Craftsmanship and Embrace Circular Training in Design and Construction**	• Reviving craftsmanship via apprentice and trade schools will facilitate repair, which is vital in the maintenance of existing buildings and in the renovation process. • Support training on selective deconstruction for contractors and building inspectors. • Integrate adaptability and disassembly principles into architectural and engineering university curricula and professional training. • Promote design competitions and awards that highlight circular design approaches. • Support pilot projects that demonstrate adaptable and disassemblable timber systems. • Develop context-specific guidelines showcasing best practices at the regional and country level
Prescriptive building codes and regulations constrain innovation.	**Building codes and regulations that focus on performance rather than prescription-based standards enable the use of alternative materials.**	• Revise building codes to expand material options, enabling the use of innovative, low-carbon, and circular materials in construction. • Mandate the use of construction materials that safeguard human and environmental health, ensuring compliance with health, safety, and sustainability standards. • Incorporate guidance in building codes, certification systems, and material passports to discourage toxic materials and promote non-toxic alternatives like bio-resins and bio-glueing agents. These measures can improve indoor air quality and protect the health of both construction workers and building occupants. • Provide targeted training for professionals on implementing performance-based codes.

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Chapter 2

Whole-life carbon in timber construction

A reflection on Principle 2: Accounting for Whole Life Cycle

"New timber buildings and renovations are designed and constructed to be safe and resilient, in ways that minimise Whole Life Cycle impacts, optimising operational efficiency and minimising embodied carbon emissions and other environmental impacts from materials. Carbon is accounted for transparently, clearly differentiating between biogenic and fossil carbon."

Lead Author:
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Chapter overview

A global increase in timber construction cannot be considered responsible or equitable if it accelerates global warming or causes other irreversible short-term environmental damage. To safeguard against such risks, it is essential to adopt the principles and tools of WLCA to reduce the climate impacts of construction while protecting the function and integrity of productive landscapes as natural climate solutions.

In the *2nd Chapter*, Stephanie Carlisle reflects on the second principle for responsible timber construction, which is grounded in the goal of tangibly and measurably reducing carbon emissions. Comprehensive whole-life-cycle accounting is not simply a technical tool; it forms the foundation for responsible timber construction. It enables accountability, drives innovation, supports circularity, and ensures that scaling biobased materials strengthens, rather than undermines, forests and communities.

The tools and knowledge required for responsible carbon accounting already exist. The remaining task is to scale their application, align incentives around verified performance and ensure that carbon accounting serves not only climate goals but also social equity and ecological integrity. Global momentum is building, with countries such as Denmark, France and the Netherlands now requiring WLCA in building codes, while procurement policies and corporate reporting frameworks drive demand for verified data. Nonetheless, gaps remain: inconsistent methods, limited supply-chain transparency, insufficient data and a lack of professional capacity. These weaknesses must be addressed to align timber's growing role in construction with genuine climate performance.

While the focus of this chapter is on the critical role of carbon in whole-life-cycle accounting and in assessing the full life cycle of timber products, it is equally important to recognise the broader environmental impacts. For biobased materials, these include land-use change and impacts on biodiversity; for other construction materials, they include pressures such as mining, sand extraction and resource depletion.

Why a whole life carbon approach matters

The climate impacts of construction

The climate impacts of the built environment are staggering. The built environment currently accounts for nearly 40 per cent of global energy-related CO_2 emissions, with 11 per cent arising from embodied carbon in building materials (UNEP, 2023). While the sector has traditionally focused on operational carbon, the shift to decarbonised energy sources and improved efficiency means embodied carbon will become the main source of emissions by mid-century (Architecture 2030, 2022). Achieving ambitious climate targets and staying within planetary boundaries while providing safe, liveable, and flourishing communities for all people will require a radical redesign of our built environment. It also requires reimagining the landscapes, industries, labor, and economies on which our built environment depends. We cannot meet these targets without action to address climate impacts of material choices – including rapidly decarbonising high-emission industries such as concrete and steel, while expanding the use of low-carbon, biobased alternatives from sustainable sources (UNEP, 2023). A whole life cycle approach helps us bring the full range of climate strategies into play, enabling a path for meaningful action in every country and on every project.

The biobased materials opportunity

When sourced responsibly, biobased materials offer significant opportunities to decarbonise construction through both substitution and carbon storage. Immediate substitution benefits from replacing high-emission materials such as concrete and steel with biobased alternatives can reduce embodied carbon by about 30–40 per cent (Andersen et al., 2022; Duan et al., 2022). Beyond timber, many underutilised wood- and fibre-based materials could further reduce near-term environmental impacts (Bukauskas et al., 2025; Pomponi et al., 2020).

Biobased materials differ fundamentally from conventional construction materials in their carbon dynamics. While concrete and steel production involves one-way fossil carbon emissions, biobased materials operate within biological carbon cycles characterised by carbon removal and sequestration during plant growth, temporary storage in biomass and products, and eventual re-emission upon material decay or combustion. This cyclical process allows biobased materials to act as temporary carbon sinks, with storage duration dependent on product lifespan and waste avoidance at the end of life.

When incorporated into long-lived building applications, biobased materials transfer carbon from the atmosphere into the built environment while enabling continued carbon sequestration through regrowth. Agricultural residues such as wheat straw or corn husks also extend carbon storage beyond natural decomposition or immediate use as biofuels (Tripathi et al., 2019; Miner et al., 2014; Guest et al., 2012). To realise these benefits, accounting frameworks must distinguish regenerative from extractive sourcing and capture the temporal dynamics of forest carbon and material use. Without robust accounting, large-scale biobased construction could unintentionally undermine forest carbon storage or shift impacts to other materials or regions.

Why comprehensive carbon accounting matters for biobased materials

Whole-life carbon (WLC) accounting tracks greenhouse gas emissions across an entire building lifecycle—from raw material extraction to construction, operation, and end-of-life. For renewable resources such as wood and other biobased materials, extraction extends into managed landscapes, including forests and agricultural systems that actively participate in the global carbon cycle. WLC broadens the scope of environmental understanding beyond the building site, linking design and construction decisions with their landscape-level consequences. It links forest growth, management practices and wood markets with building performance, material use and end-of-life outcomes.

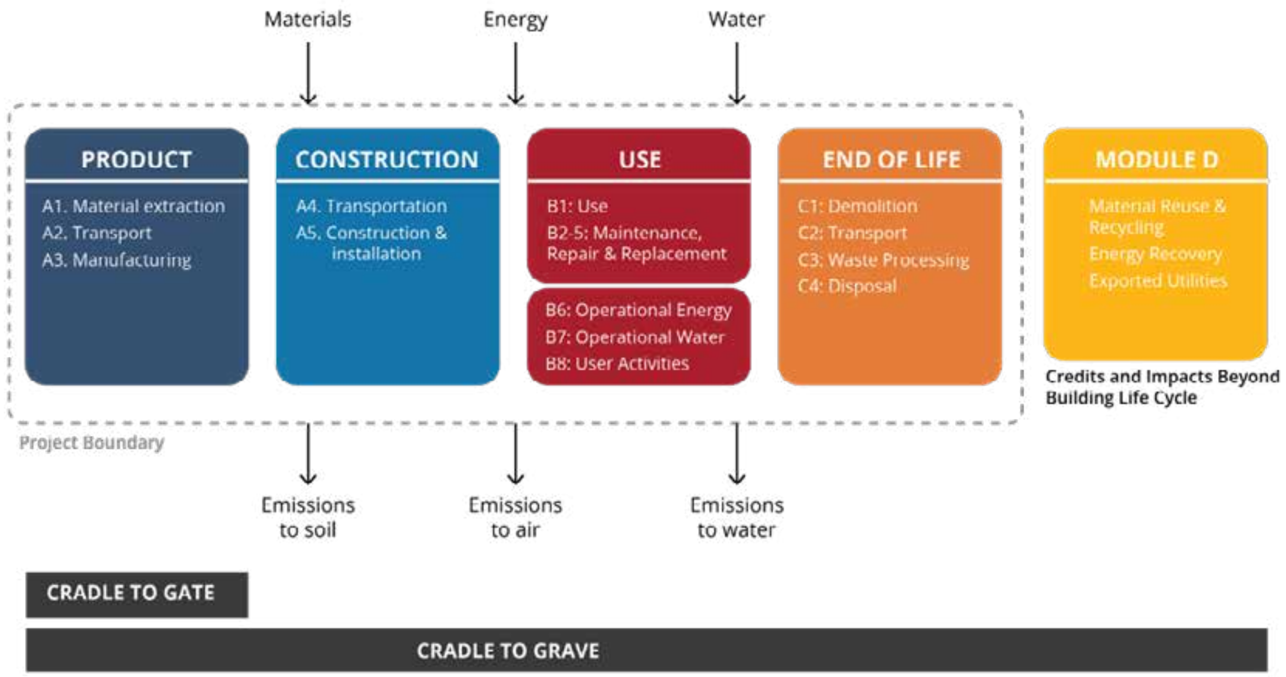


Figure 1: Stages of Whole-life carbon accounting. Diagram by Stephanie Carlisle

This landscape connection is particularly complex because forests and agricultural lands face competing demands for carbon storage, biodiversity conservation, food production and material supply (Searchinger, 2023; Foley et al., 2005). Forest management must balance economic, cultural and environmental services, integrating carbon impacts with wider effects on biodiversity, water quality and climate resilience. Without comprehensive accounting, material choices for buildings may inadvertently undermine landscape carbon storage, underscoring the need to understand the full carbon consequences of sourcing decisions.

Comprehensive approaches are essential for both new construction and renovation. Renovation decisions involve trade-offs between the embodied carbon of renovation materials and the operational savings from avoided demolition emissions. End-of-life decisions are equally critical: sending biobased materials to landfill or incineration releases stored carbon, reducing their climate benefit. Keeping these materials in use through reuse, recycling and cascading strategies extends carbon storage in the built environment and maximises climate benefits (*see Chapter 1*). Such trade-offs can only be evaluated through comprehensive accounting that tracks all carbon flows over time.

What is life cycle assessment (LCA)?

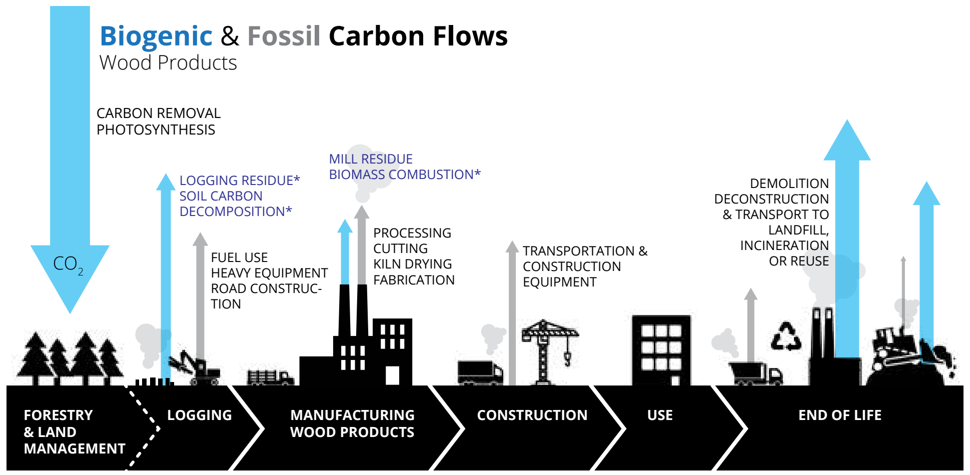


Figure 2: Biogenic and fossil carbon flows for wood products. Diagram by Stephanie Carlisle

LCA provides the analytical framework for measuring carbon emissions and other environmental impacts, following established international standards (ISO 14040/44, ISO 14025, ISO 21930, EN 15804+A2, EN 15978) that enable systematic comparison across materials and design strategies. LCA can be applied at multiple scales—from individual materials and products to buildings, economic sectors, or nations—providing flexibility for different decision-making contexts. Increasingly, WLC assessment is being integrated into policy frameworks, including building codes that set embodied carbon limits, public procurement policies that prioritise low-carbon materials, and carbon pricing mechanisms that account for lifecycle emissions.

Key carbon accounting terminology:

- **Embodied carbon:** Emissions from material extraction, manufacturing, transportation, construction, maintenance, and end-of-life processes (demolition, disposal, recycling or re-use)
- **Operational carbon:** Emissions from building energy use during occupation
- **Biogenic carbon emissions (GWP-biogenic):** Greenhouse gas emissions from carbon that originates from recently living organic matter (plants, trees, agricultural residues). This carbon is first sequestered from the atmosphere during plant growth, temporarily stored in landscapes and materials, and eventually re-emitted to the atmosphere through decay or combustion.
- **Fossil carbon emissions (GWP-fossil):** Greenhouse gas emissions from carbon that has been stored underground for millions of years in coal, oil, and natural gas. When fossil fuels are extracted and burned, these emissions represent a permanent addition to the active carbon cycle, contributing directly to atmospheric CO2 accumulation.

What comprehensive carbon accounting enables

Comprehensive carbon accounting reveals intervention points across the entire value chain, enabling coordinated climate action from land management through manufacturing, urban planning, and construction. This holistic view shows that the greatest climate benefits often stem from coordinated improvements across multiple stages rather than optimising individual components in isolation. By examining emissions across the complete life cycle, comprehensive accounting allows for the identification and prioritisation of decarbonisation strategies that are relevant, actionable and effective across all building types and regions.

These capabilities engage stakeholders across diverse sectors and scales. For architects and engineers, comprehensive accounting quantifies the climate benefits of specifying biobased materials, supporting design decisions that balance performance, cost and carbon outcomes. At the supply-chain level, it reveals opportunities to reduce near-term emissions through improved forest residuals management and to shift biomass toward long-lived products such as engineered wood rather than short-lived applications like biofuels or pulp and paper (Figure X). Forest resources are renewable, but increasingly scarce. By tracking carbon flows across production pathways, comprehensive accounting helps land managers, manufacturers, designers, and communities optimize both climate impact and economic value, demonstrating how material-use decisions ripple through entire supply chains.

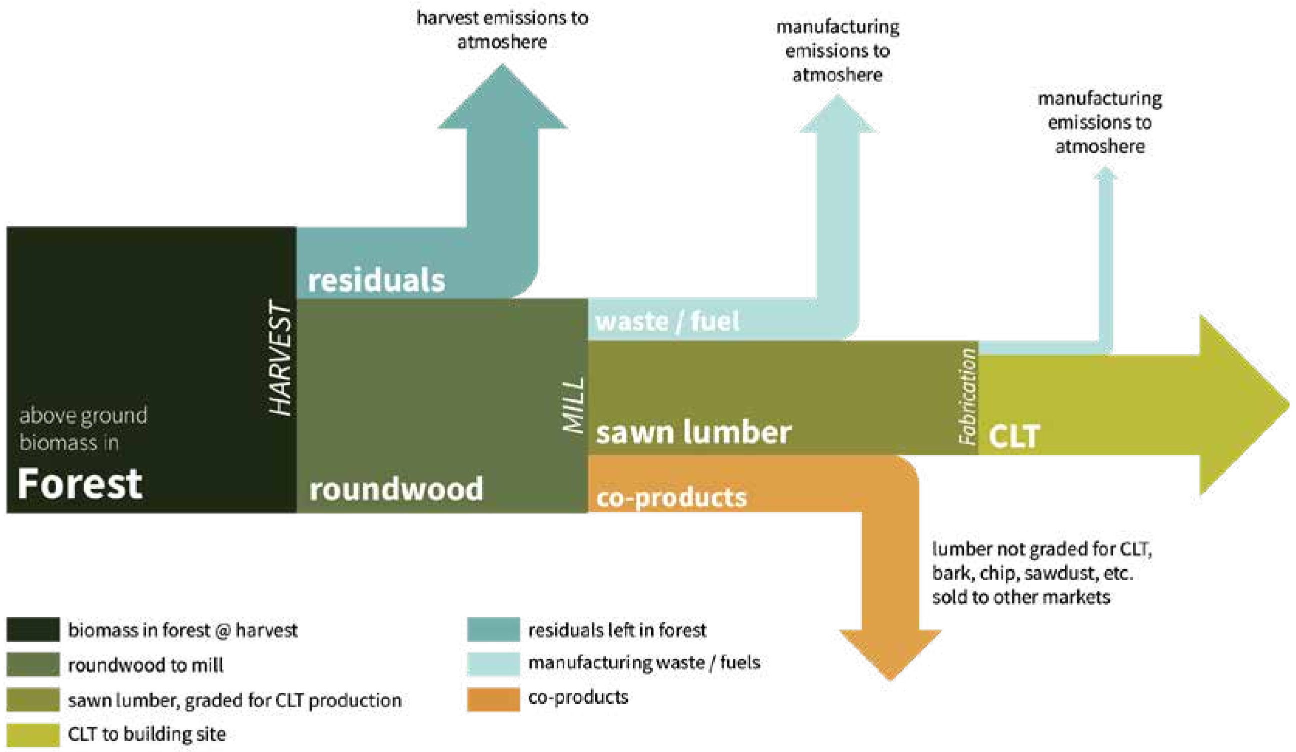


Figure 3: Carbon flows in mass timber production from forest to building site. Diagram by Stephanie Carlisle, based on data from the American Wood Council and CORRIM North American Forestry LCAs.

This expanded perspective underpins evidence-based policy frameworks that drive market transformation, including building codes that set embodied-carbon limits rather than prescriptive material requirements, procurement policies that create stable demand for verified low-carbon products and carbon-pricing mechanisms that accurately reflect life-cycle emissions. Comprehensive accounting also establishes systems of accountability that extend beyond voluntary commitments to verifiable performance, enabling the tracking of sectoral progress against science-based targets and identifying emission hotspots that require intervention (Lewis et al., 2023).

The foundation that comprehensive accounting provides is essential for implementing building-retention and renovation strategies while ensuring that the scaling of biobased construction delivers genuine, verifiable climate benefits. By creating accountability systems that reward proven performance, comprehensive accounting ensures that the growth of biobased construction contributes to global decarbonisation while supporting forest conservation and community well-being.

Current trends in research, policy, and practice

Comprehensive carbon accounting for biobased materials represents an emerging field characterised by rapid development across research, policy, and industry practice, though not always in coordination. This dynamic environment creates both opportunities for innovation and risks of fragmented approaches that could undermine the goal of ensuring verified carbon benefits from timber construction. Understanding current trends reveals where the field stands today and identifies the gaps that remain between theoretical capabilities and widespread implementation.

Research trends and methodological developments

Static vs dynamic LCA

Traditional lifecycle assessment approaches use static snapshots that treat carbon emissions and sequestration as instantaneous events. However, both landscapes and buildings require an understanding of timing effects that unfold over many decades (Sohn et al., 2020). Although methods for dynamic LCA have been in use for over a decade (Levasseur et al., 2012), recent research has shown that inconsistencies in biogenic-carbon calculations can lead to significant variations in results, potentially compromising decision-making (Hoxha et al., 2020). The most contentious issues concern how to evaluate trade-offs between near-term emissions from forest disturbance, long-term storage in durable wood products and buildings, and temporal trade-offs between harvest and regrowth in light of increasing wood demand (Searchinger et al., 2023; Peng et al., 2023).

Reflecting this growing recognition of temporal dynamics in responsible timber sourcing at product, building and sectoral scales, an expanding body of research has developed increasingly sophisticated dynamic-LCA models. These demonstrate that forest-rotation cycles, species mixes, product allocation, manufacturing efficiency, building lifespans and end-of-life scenarios all significantly affect net climate benefits when temporal dynamics are properly modelled (Anderson et al., 2024; Hawkins et al., 2021; Lan et al. 2020; Head et al., 2020).

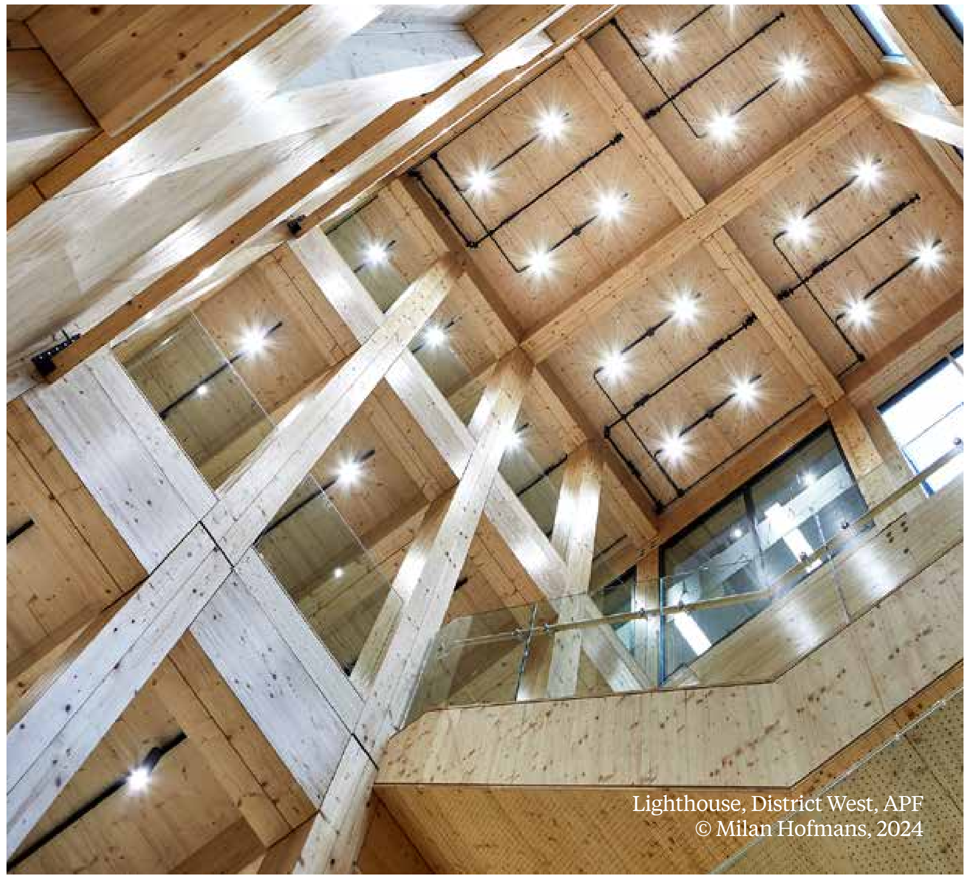
Beyond "carbon neutrality"
Current product lifecycle assessment standards are based in mass-balance approaches to biogenic carbon accounting that systematically excludes forest-level biogenic carbon dynamics from analysis, assuming that the biogenic carbon emissions from managed forests are approximately carbon neutral. Life-cycle assessment standards mandate that assessments begin at the point of harvest, treating biogenic carbon as a removal as it enters the product system (–1 kg CO_2e) and as an emission when it leaves the system (+1 kg CO_2e) through decomposition, incineration or material reuse at end-of-life (ISO 21930; EN 15804; EN 16485). The "–1/+1" mass-balance approach categorises material reuse and circular-economy strategies as emissions, due to a strict reliance on the product- or building-level boundary, thereby limiting the ability of traditional accounting to incentivise waste reduction and circularity.

LCA standards generally limit use of this approach to wood from "sustainably managed forests," a term that would benefit from greater clarity, as it can be interpreted as ranging from certified wood, legal wood, or any wood products from a country in which forest carbon stocks are stable on average, regardless of the management and harvest practices of the specific forest area. There is currently a lack of consensus on the most useful and feasible scale in which to assess wood sourcing, with some using national-level accounting, and others developing methodologies that align carbon removal claims with specific forest management unit in order to communicate the value of exceptional forest management and explore the variability of climate impacts across diverse woodsheds.

This static method avoids consideration of the timing of biogenic-carbon sequestration and release and, in its adherence to product boundaries, omits relevant biogenic-carbon exchanges within the forest system (Hoxha et al., 2020; De Rosa et al., 2017; Levasseur et al., 2013). Recent research by Andersen et al. (2024; 2022) and Hansen et al. (2024) highlights this limitation, revealing wide variability in forest-management impacts on net emissions, with outcomes ranging from significant carbon benefits to substantial carbon burdens depending on rotation length, species selection and silvicultural practice. Such variability remains invisible under conventional wood product LCAs, which treat all harvested wood as equivalent regardless of management regime.

A new international standard (ISO 13391:2025) was recently published to provide a comprehensive framework for evaluating the GHG dynamics of wood and biobased products, including the emissions, removals and storage in the forest as a result of specific forest management practices, carbon storage in products, and the avoided emissions associated with substituting biobased materials for conventional construction materials. This new standard should provide a pathway for forest owners, or product manufacturers, or consumers of biobased construction materials to more clearly understand and communicate the climate benefits of sustainable forest management and responsible timber construction.

Supply-chain research increasingly emphasises the need for traceability systems linking forest-management practices with building-material performance. Existing chain-of-custody certification frameworks track material origin through manufacturing, yet rarely extend to final product installation or end-of-life (Stäuble et al., 2024). Emerging research exploring the integration of holistic carbon-accounting data within these traceability systems shows promise for creating accountability frameworks that reward verified long-term carbon storage rather than theoretical potential (Stopfer et al., 2024; Kaulen et al., 2023).


Lighthouse, District West, APF
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Policy developments and regulatory trends
Integrating comprehensive carbon accounting into building codes and regulations marks one of the most significant policy advances in the transition to low-carbon construction. Globally, the EU is a leader in performance-based whole life carbon accounting, with multiple countries implementing frameworks for whole life carbon accounting and robust systems for data collection and benchmarking over the last decade. Over time, what began as independent national programs, have begun to harmonize into a more consistent approach through the considerably slower process of EU-wide directives and incorporation of whole life carbon accounting into international building code.

Typically, policy progression follows a phased approach: initial voluntary disclosure and data collection, transition to mandatory reporting, and eventual introduction of embodied-carbon caps.

2.1. Best practice: National whole-life carbon regulation in buildings in the EU

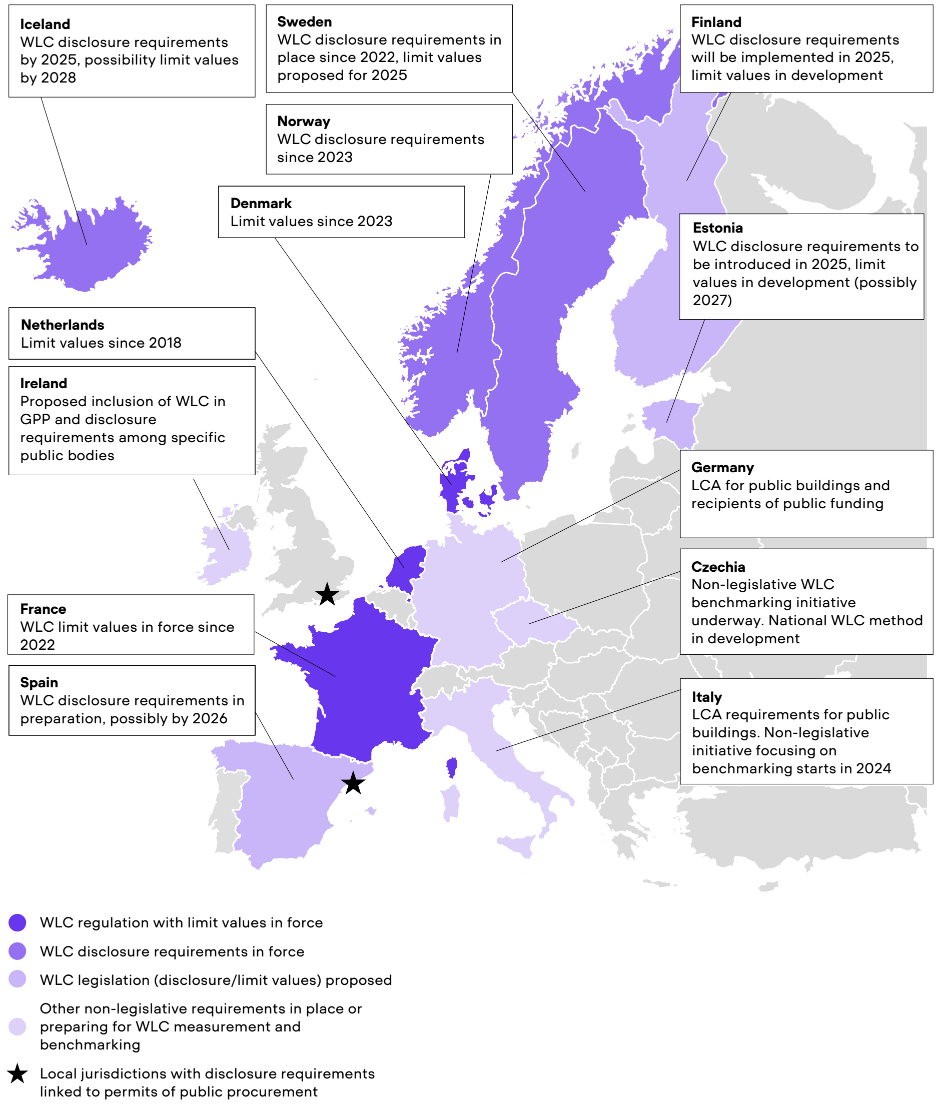


Figure 4: Overview of WLC regulations and initiatives across Europe Bauhaus Earth (2025) based on BPIE (2024)

Several countries in the EU are leading the transition toward performance-based whole life carbon regulation. The Netherlands pioneered embodied-carbon disclosure in 2013, establishing mandatory disclosure thresholds. Since 2023, Denmark's building code has required whole-life-carbon (WLC) assessments for new construction, with limits applying to buildings larger than 1,000 m². France's RE2020 regulation remains the most advanced integration of biogenic-carbon accounting and dynamic LCA into codes, requiring developers to incorporate temporal-carbon effects rather than assuming immediate neutrality.

Across the EU, the recast EPBD requires member states to require collection of life-cycle Global Warming Potential (GWP) for all new buildings, signalling a shift toward comprehensive carbon accountability that incentivises innovation and transparency throughout the construction value chain.

Further information:
How to establish whole life carbon benchmarks, BPIE (2024) ↗
GHG limits for buildings, Bauhaus Earth (2025) ↗

In countries without national mandates, subnational actors—states, provinces and municipalities—have driven regulatory innovation. In the United States, where no national building code exists, federal standards for public buildings (P100), California's CalGreen regulations and city-level policies together form a framework for broader adoption. Similarly, the City of Vancouver has introduced whole-building life-cycle assessment (WBLCA) requirements that are being incorporated into Canada's national building code. In the United Kingdom, London has required WLC assessments for all major projects since 2021 and is testing their inclusion in the forthcoming Net Zero Carbon Building Standard. These examples signal a wider policy shift from prescriptive material specifications to performance-based standards, encouraging innovation while maintaining environmental integrity and alignment with local design culture.

Public-procurement policies are increasingly generating market demand for verified low-carbon products rather than broad sustainability claims. *Buy Clean* programmes in several US states require embodied-carbon disclosure for state-funded projects, creating strong incentives for manufacturers to provide robust data. Internationally, similar measures are emerging: New South Wales (Australia) mandates embodied-carbon reporting for projects exceeding AU $7.5 million (as of July 2024), while the EU's Green Public Procurement framework encourages member states to prioritise goods and services with lower life-cycle impacts. Sweden has achieved roughly 60 per cent inclusion of environmental criteria in public tenders. Requirements for EPDs in government procurement establish expectations for third-party-verified data, stabilising demand for transparent carbon-accounting systems and enabling material differentiation based on actual performance.

Corporate-carbon-accounting frameworks are reshaping market dynamics by complementing regulatory drivers. Historically, most corporate disclosure systems excluded biogenic carbon from Scope 1, 2 and 3 inventories due to inconsistent methods and limited data. The draft *Greenhouse Gas Protocol Land Sector and Removals Guidance (2024)* introduces methodologies for recording fossil, biogenic and land-use emissions, as well as carbon storage in products and land. It encourages developers and asset owners to assess specific sourcing pathways rather than rely on generic factors. The Corporate Sustainability Reporting Directive (CSRD) and European Sustainability Reporting Standards (ESRS) further require detailed life-cycle emissions disclosure. Together, these frameworks create demand for verified carbon-storage accounting, aligning private-sector reporting with regulatory expectations.

Finally, international coordination efforts are essential to ensure comparability across markets. Mutual-recognition agreements between national EPD programmes are helping to harmonise data standards and avoid trade barriers. The OECD's work on embodied carbon in trade and border-carbon adjustments supports the inclusion of life-cycle emissions in global commerce. The EU is exploring expanding life-cycle emissions requirements beyond deforestation regulations to include additional material categories. These developments present opportunities for harmonised approaches but also challenges for producers in developing countries who may lack the capacity to provide detailed carbon data.

Practice gaps and implementation challenges

Despite strong methodological progress and increasing policy momentum, notable gaps remain between research capability and the widespread application of whole-life-carbon (WLC) assessment in practice. Many practitioners still apply generic carbon-neutrality assumptions to wood products, masking critical variations in forest management and sourcing. These limitations stem from insufficient supply-chain data, unclear guidance on assessing forestry emissions and gaps within building-sector life-cycle-assessment (LCA) tools. Continued reliance on simplified approaches creates false equivalencies between high- and low-performing supply chains, weakening market signals that should reward exemplary forest management. It also frustrates designers and building owners who intentionally source responsibly managed timber but cannot clearly communicate its climate benefits. The gap between sophisticated research methods and simplified practice assumptions constrains differentiation between timber products based on verified carbon performance rather than broad material categories.

Industry practice often focuses narrowly on manufacturing emissions while overlooking forest and end-of-life impacts that contribute significantly to total life-cycle carbon flows. Manufacturing typically accounts for only 15–40 per cent of total life-cycle emissions for wood products, depending on sourcing and end-of-life fate (ref). Yet, many assessments stop at the factory gate. This emphasis on upfront carbon overlooks the storage benefits that represent a key advantage of biobased materials over conventional alternatives.

Current practice also reveals oversimplified comparisons between material categories that ignore supply-chain specificity and the rapid decarbonisation of conventional materials. Generic “wood good, concrete bad” assumptions fail to capture variations in sourcing quality within biobased materials or improvements in low-carbon steel and concrete production. Studies of substitution effects frequently rely on static emissions factors that omit the decarbonisation trajectories of conventional materials, potentially overestimating the relative benefits of biobased alternatives.

A persistent lack of supply-chain transparency further limits verification of sustainability claims and prevents market differentiation based on actual climate performance. Without traceability systems that connect forest management practices to final building products, consumers and specifiers cannot distinguish between products from exceptionally managed forests and those from degraded or less sustainable sources. This transparency gap undermines the market mechanisms needed to reward responsible forest management.

Building-sector LCA tools and adoption trends

As policy requirements and voluntary sustainability programmes expand, whole-life-carbon (WLC) assessment is gaining ground across the building industry. Tools such as OneClick LCA, Tally, eTool and C.Scale are increasingly integrated into design workflows, enabling architects and engineers to analyse carbon performance alongside other building metrics. The growth of national and regional materials databases has accelerated adoption by improving access to digital EPDs and region-specific manufacturing data. However, these platforms still lack consistent methods for biogenic-carbon accounting, creating challenges for practitioners comparing biobased materials across tools or aligning project-level assessments with broader reporting frameworks. Novel materials such as compressed-straw panels, hempcrete and mass timber from reclaimed wood remain under-represented or excluded from WBLCA tools and databases.

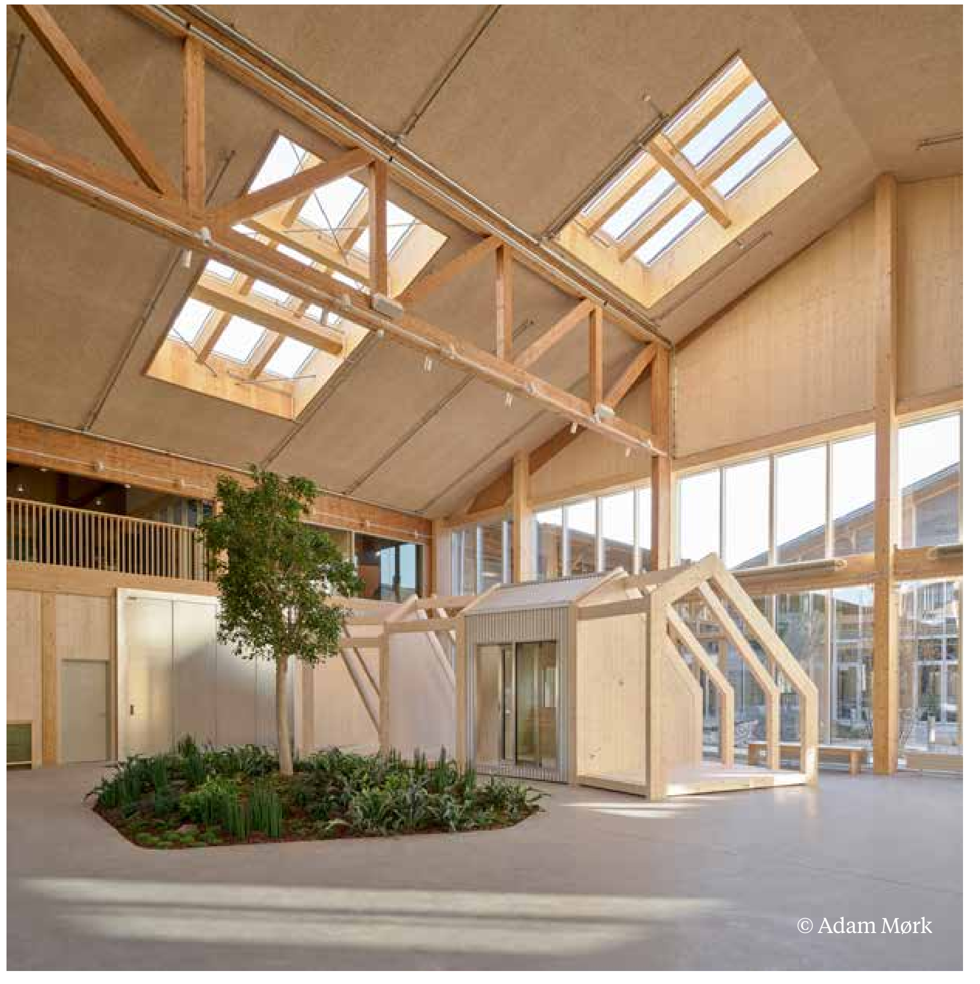
Professional capacity-building initiatives

Professional-capacity-building efforts increasingly recognise that technical training alone cannot overcome implementation barriers. Collaboration programmes linking forestry, manufacturing and construction sectors through demonstration projects and peer-learning networks are helping bridge disciplinary divides. Educational institutions are integrating carbon-accounting concepts into architecture, engineering and forestry curricula, though coordination across these programmes remains limited.

The convergence of research, policy and industry practice creates opportunities to scale comprehensive-carbon-accounting approaches. Yet barriers persist in data availability, professional capacity and market alignment. Addressing these challenges will be essential for enabling timber construction to deliver verified climate benefits rather than theoretical potential. Progress depends on coordinated action across disciplines to ensure that comprehensive accounting supports wider objectives of climate action, forest conservation and social equity.

LKR Innovation House, VELUX (C) Adam Mørk

2.2. Best practice: LKR Innovation House, VELUX, Østbirk, Denmark, 2025



© Adam Mørk

The LKR Innovation House has transformed a 9,500 m² timber warehouse into a 14,000 m² commercial hub, housing over 500 employees in design and product development. It proves that large-scale adaptive reuse can replace demolition to meet modern workplace requirements. The project addresses demand for sustainable offices by delivering a healthy, daylight-filled, and inclusive environment, while advancing biodiversity and indoor climate goals.

More than 55 per cent of materials were reused, including glulam frames, façades, and concrete floors. PEFC-certified timber from Austria, Germany, and the Czech Republic was combined with façade innovation and constructive wood protection, ensuring durability without chemicals.With a carbon footprint of 4.6 kg CO_2e/m²/year—far below Danish 2029 targets—the project sets news global possibilities for circular, low-carbon construction.

Further information:
BbN Prize, 2025 ↗

Key Challenges and Opportunities

Gaps between comprehensive-carbon-accounting capability and widespread implementation present transformation opportunities rather than insurmountable barriers. Each challenge highlights intervention points where coordinated action can drive systemic change across the forest-to-building value chain. The goal is not perfect accounting but accountable progress towards verifiable carbon benefits that can be measured, tracked and improved over time.

1. Challenge: Methodological inconsistencies

Biobased materials are still assessed using differing methods across regions, tools and regulatory frameworks. Standards such as ISO 21930, used widely in North America, and EN 15804 + A2, prevalent in Europe, apply different biogenic-carbon-reporting approaches, producing results that cannot easily be compared. These inconsistencies increase compliance costs for companies active in multiple markets, reduce confidence in carbon claims among buyers and policymakers, and slow adoption through uncertainty over which methods to apply.

At the same time, these inconsistencies are creating new pressure for coordination specialists. International organisations, standards bodies and industry associations increasingly recognise that fragmented approaches hinder the market transformation required to scale biobased construction. A methodological foundation for harmonisation already exists through research that links forest-to-building accounting approaches, bridging ecosystem and technical boundaries. These extend beyond traditional harvest-to-end-of-life analysis to include forest growth, management practices and regeneration cycles.

1.1 Transformation opportunity

The transformation opportunity lies in aligning technical capability, market demand and institutional recognition around coordinated approaches that serve all stakeholders better than fragmented systems. Frustrations caused by inconsistent methods are now generating the political and economic momentum needed for international coordination. This coordination preserves regional flexibility while enabling global comparability and supporting trade.

2. Challenge: Data availability and transparency

Comprehensive carbon accounting depends on reliable data covering forest management, manufacturing, transport and end-of-life processes. Forest-management information often remains commercially sensitive or inaccessible, supply-chain transparency is limited in fragmented timber markets, and long-term forest-carbon monitoring is scarce in many resource-rich but low-capacity regions. These data gaps impede differentiation between high- and low-performing supply chains and disadvantage smaller producers and forest communities.

Nevertheless, these limitations have catalysed collaboration around shared data infrastructure that benefits entire value chains. Public and private stakeholders increasingly recognise that isolated data-development efforts cannot resolve systemic information gaps. Innovative partnerships are emerging that share costs and benefits among participants. Digital traceability platforms now extend chain-of-custody certification from forest harvest through building end-of-life, while supply-chain-specific EPDs record actual sourcing and manufacturing conditions rather than relying on generic regional averages.

2.1 Infrastructure opportunity

The infrastructure opportunity lies in developing systems that verify carbon claims without requiring each producer to maintain a complete monitoring programme. Regional sourcing strategies can reduce information demands while enabling more detailed verification of environmental performance, suggesting that decentralised approaches may prove more effective than centralised ones for scaling transparency.

3. Implementation complexity and capacity

Comprehensive carbon accounting spans multiple disciplines yet must remain practical for broad adoption across the building sector. Specialised expertise remains concentrated in consultancies and research institutions rather than embedded in everyday design and construction practice. Barriers multiply when practitioners collaborate across sector boundaries: forest managers and building designers often have limited mutual understanding, while trust gaps between environmental advocates and industry further hinder communication.

These complexity challenges are prompting new approaches that link technical accessibility and cross-sector collaboration as shared objectives. Recognising that carbon accounting cannot remain a specialised pursuit, emerging collaborative platforms combine simplified tools with relationship-building across professional domains. Training initiatives increasingly emphasise joint problem-solving rather than one-way instruction, and automated assessment platforms deliver reliable results without requiring deep technical expertise from individual users.

3.1 Transformation opportunity

The transformation opportunity lies in building professional ecosystems that treat carbon accounting as a collaborative practice rather than an isolated skill. Regional demonstration projects serve as essential testbeds for integrated approaches, strengthening technical capability and professional relationships under real-world conditions. Well-documented case studies of successful collaborations provide replicable models that accelerate adoption through proven implementation pathways.

4. Challenge: Policy and market misalignment

Policy and market systems often treat carbon accounting as voluntary, provide weak incentives for transparency, and fail to reward exemplary forest management. Because of this misalignment, markets send mixed signals, reducing incentives to invest in sound accounting systems and making it harder to distinguish between stronger and weaker supply chains. These policy gaps are stimulating innovation that aligns incentives around verified carbon performance rather than generic sustainability compliance. Procurement policies increasingly require demonstrated environmental outcomes rather than process documentation, while new financial instruments incorporate comprehensive carbon assessments into lending and investment decisions. Carbon-pricing mechanisms are gradually expanding to include life-cycle emissions, creating economic drivers for material selection based on total environmental performance.

4.1 Alignment opportunity

The alignment opportunity draws on lessons from other sectors where measurement systems have enabled market differentiation and continuous improvement. The convergence of regulation, corporate commitments and investor expectations is generating strong demand for verified performance data, allowing policy frameworks to reward excellence rather than penalise underperformance.

5. Challenge: Systemic transformation potential

These challenges are interrelated. This creates opportunities for coordinated action that addresses multiple barriers at once. Methodological harmonisation enables data exchange across regions and tools, shared infrastructure supports capacity-building across sector boundaries, and performance-based incentives create market demand for simplified, scalable tools that expand access to comprehensive carbon accounting.

5.1 Transformation opportunity

The greatest transformation opportunities arise from recognising these interconnections and designing responses that target systemic rather than isolated issues. Regional demonstration projects can test integrated approaches that combine technical innovation, policy development and market design within specific contexts. Effective progress relies on integrating technical capability, regulatory frameworks and market mechanisms as mutually reinforcing elements of the broader transition.

From Principle to Action

Whole life carbon accounting represents more than a technical improvement in how we measure building materials—it provides the foundation for a fundamental shift toward regenerative construction practices. By revealing the true climate performance of different sourcing and design strategies, a comprehensive carbon assessment enables the built environment sector to become a driver of forest conservation rather than degradation.

The path forward requires coordinated action across multiple domains: harmonising accounting methodologies, building professional capacity, creating supportive policies, and investing in transparency systems. While these challenges are significant, the alternative—continuing to build without understanding our climate impact—risks undermining both decarbonization goals and forest conservation efforts.

The tools and knowledge needed for responsible carbon accounting already exist. The remaining task is to scale their application, align incentives around verified performance, and ensure that carbon accounting serves not just climate goals but also social equity and ecological integrity. When done well, whole life carbon assessment becomes a pathway to construction practices that actively contribute to climate stabilisation while supporting forest-dependent communities and biodiversity conservation. The second principle for responsible timber construction grounds all other efforts in measurable climate benefits, ensuring that the growth of biobased construction truly serves the urgent goal of global decarbonization.

The opportunities identified in this *Chapter* require co-ordinated policy implementation to transform comprehensive carbon accounting from a specialised practice into a standard procedure. The following actions, supported by enabling strategies, can guide policymakers in the building sector and forest or land management ministries to realise these transformation opportunities through systematic policy change.

Action pathways

Key challenge	Policy pathway	Enabling strategies
Methodological inconsistencies	**Harmonise Global Accounting Standards**	• **Establish national positions on biogenic carbon reporting** that distinguish fossil and biogenic emissions. • **Lead or participate in international harmonisation** efforts between ISO and CEN. • **Support industry pilots** of harmonised approaches through demonstration projects. • **Provide technical assistance and funding** for developing countries, enabling their participation in global carbon-accounting programs.
Data availability and transparency	**Invest in Shared Data Infrastructure**	• **Enhance national forest inventory systems** to include carbon-accounting capabilities. • **Fund collaborative platforms** for supply-chain-specific EPDs. • **Extend** chain-of-custody certification systems from forest harvest through building end-of-life. • **Coordinate data sharing agreements** with international partners to support cross-border supply chain transparency.
Implementation complexity and capacity	**Mandate disclosure while building capacity**	• **Implement phased disclosure requirements** starting with public projects before expanding to private sector. • **Establish embodied carbon limits** in building code based on performance standards rather than prescriptive material requirements. • **Link public procurement policies** to demonstrated carbon benefits through verified supply chain performance data. • **Fund capacity-building programs** that help domestic producers and practitioners develop comprehensive carbon-accounting capability. • **Support integration** of carbon accounting into education and training programs through collaborative curriculum development.
Policy and market misalignment	**Align Incentives with Verified Performance**	• **Reform public procurement policies** to create premium markets for materials sourced from sustainably managed forests and landscapes. • **Work with financial regulators** to encourage carbon assessment in lending. • **Develop tax incentives** that reward long-term carbon storage. • **Establish verification frameworks** that connect forest resilience and building performance. • **Incentivise regional sourcing,** reducing traceability complexity and strengthening domestic forest economies.

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Chapter 3

Scaling responsible forest management for a low-carbon bioeconomy

A reflection on Principle 3: Ensuring sustainable forest management

"Wood-based construction materials are sourced from forests managed according to best practices in sustainable forest management, defined by the United Nations as 'a dynamic and evolving concept that aims to maintain and enhance the economic, social and environmental values of all types of forests for the benefit of present and future generations."

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Chapter overview

While global demand for timber is rising rapidly, driven by a growing global population, this demand must be aligned with governance systems that take account of the Earth's carrying capacity and ensure that forests continue to provide key ecosystem services. Not all wood delivers net climate benefits; its sustainability depends on how the forest is managed and how the timber is sourced and used. A clear understanding of the relationship between forest management systems and timber-based construction is central to delivering favourable climate outcomes and steering finance. The assumption that "all wood is good" overlooks the complexity of forest ecosystems and the diversity of silvicultural approaches — as well as the complete absence of any formal management across nearly half of the world's forests.

This chapter positions the SFM of production forests as the foundation for responsible timber construction and a cornerstone of the transition to a low-carbon, biobased economy. SFM enables productive forests and working woodlands to function as renewable, multifunctional systems that support livelihoods, store carbon and conserve biodiversity. Despite its relevance, SFM remains under-recognised in current policy and funding frameworks, often sidelined by a focus on specific interventions within a broader discipline, such as forest landscape restoration or conservation efforts.

In this Chapter, Jamie Lawrence draws from a wide range of experts in the field to demonstrate that we have the tools, knowledge and examples needed to scale up SFM as the foundation for a responsible bioeconomy. To do so, governments must secure land tenure, especially for Indigenous and local communities, enforce forest governance and integrate forestry into broader land-use and climate strategies. Investment in forest finance, data systems, capacity-building and traceability tools is also critical. Public procurement and awareness campaigns can help create stable markets for verified sustainable wood, reinforcing responsible production. Best-practice examples demonstrate that legal clarity, finance and inclusive governance can unlock sustainable and equitable outcomes.

When implemented effectively, SFM offers a holistic, place-based solution to align growing timber demand with environmental limits, ensuring that forests remain a pillar of a resilient, low-carbon economy. On the global stage, SFM remains highly relevant. It offers a comprehensive framework that balances ecological, economic, and social objectives. It ensures a reliable supply of wood while contributing to national economies and human well-being. At the same time, SFM can enhance carbon sequestration and storage, curbs deforestation and forest degradation, and strengthens forest conservation efforts. By promoting integrated, adaptive management and ongoing improvement, SFM supports long-term forest resilience and sustainability.The tools and knowledge for implementing SFM already exist; what is urgently needed is the political will and financial commitment to scale them globally, ensuring that the construction sector's growing reliance on timber strengthens rather than undermines the world's forests.

We depend on forests

This chapter builds on the UN definition of SFM to examine what it means for governments to promote, support, and enforce it in practice. It reviews current trends in research, policy, and implementation, supported by best practice examples and expert insights. Rather than offering yet another toolkit, it aims to provide decision-makers with a clear overview of the critical issues and opportunities to consider when scaling SFM in their jurisdiction. The main takeaway of this chapter is that ensuring SFM is not only essential for preserving our forests but also foundational to a responsible bioeconomy. In this context, timber construction, along with other biobased materials, serves as a central pillar of the global transition to a low-carbon future.

Every building is, at its core, a territorial project shaped by the landscapes that supply the resources used in its construction. The construction sector must recognise the environmental and social value of sourcing materials from sustainably managed forests and agricultural areas. Achieving this requires appropriate infrastructure to process and integrate such materials effectively. The industry also needs to move beyond treating construction inputs as generic, placeless commodities and instead acknowledge their connection to the regions from which they originate.

"Nature-based solutions such as protecting and restoring forests can contribute over one third of the total climate change mitigation required by 2030 to keep temperature rise below 2˚C."

Inger Andersen, Director General, IUCN

Without strong national and international action to promote and enforce SFM, the world risks accelerating deforestation, forest degradation and biodiversity loss while depleting forest carbon stocks, undermining global climate goals and increasing the frequency of forest disturbances. Weak governance can exacerbate land-use conflicts, undermine the rights of Indigenous Peoples and local communities (IPLCs), and destabilise rural economies that depend on forests. In the absence of effective implementation of SFM, forests could shift from being critical carbon sinks and providers of key ecosystem services to net sources of emissions, threatening environmental stability and human well-being.

The expansion of forest-based climate solutions should be integrated with strategies that advance inclusive economic growth and long-term sustainable development. Achieving this connection demands a deeper understanding of domestic and international forest resources and an action-oriented commitment to protect, restore and manage them sustainably while preventing deforestation and degradation. Within this wider context, the chapter highlights the sustainable management of production forests as a core principle underpinning *Principles for Responsible Timber Construction*.

Forests and other terrestrial ecosystems currently capture around 31 per cent of human-generated CO_2 emissions (Mosandl, 2024). Globally, forests are distributed across various climatic zones, with tropical forests comprising the largest area at 45 per cent, followed by boreal forests at 27 per cent, temperate forests at 16 per cent, and sub-tropical forests accounting for the remaining 11 per cent. Management objectives and income distribution differ widely: high-income countries control most temperate forests, while tropical forests lie mainly in lower-income regions. In boreal zones, nearly half of the forest area is managed for production, whereas tropical forests have the smallest share designated for production and the largest share for biodiversity conservation. Roughly a third of tropical forests do not have clear or known management goals (Shono and Jonsson, 2022). Because forest types and local contexts vary widely, governments need strategies tailored to their specific ecological, economic and social circumstances.

Production forest in Brandenburg © Bas Princen for Bauhaus Earth, 2024

Framing sustainable forest management

The underlying argument of SFM is that forests are not just wilderness to be preserved, nor simply sources of commodities to be extracted. When managed sustainably, forests function as regenerative habitats and land-use assets that provide lasting benefits for communities and economies while supporting society as a whole through climate-change mitigation and essential ecosystem services.

Wood can act as a powerful climate solution only when it is sourced from sustainably managed forests and used to replace fossil fuels or carbon-intensive materials, ideally in long-lived applications that store carbon over time. A clear understanding of the relationship between forest management systems and timber-based construction is central to delivering favourable climate outcomes and steering finance towards low-emission building pathways. The assumption that “all wood is good” overlooks the complexity of forest ecosystems and the diversity of silvicultural approaches — as well as the complete absence of formal management across nearly half of the world’s forests.

Forestry practices vary widely, reflecting both local conditions and diverse management priorities, ranging from biodiversity conservation and carbon sequestration to timber production for economic gain. With 55 per cent of the world's forests (2.13 billion ha) under a form of management plans that are documented and periodically revised which is an important indicator of the intention to sustainably manage forest resources (FAO, 2025b). Yet the gap that remains — and the diversity of approaches — makes it essential to understand the origins of wood, the management systems that shape it, and the kinds of practices being reinforced in each region. SFM provides a scientifically and operationally grounded framework to reconcile the demand for wood products with the need to maintain healthy ecosystems, while also safeguarding the livelihoods and well-being of the communities that depend on them.

SFM has served as a foundational concept for a range of evolving forestry approaches designed for specific ecological and socio-economic outcomes. Notable examples include climate-smart forestry, regenerative forestry and continuous-cover forestry. Each builds on SFM principles while introducing new strategies to address emerging environmental and societal challenges. These approaches are at varying stages of research and application within both academic and professional forestry contexts, reflecting a shared commitment to integrated, place-sensitive and forward-looking forest management.

“It is crucial to ensure that increased demand for timber is managed sustainably and responsibly to maximize benefits for climate, nature, and people. The integrated approach of the Principles should set high standards of sustainable forest management, with appropriate safeguards and chains of custody to demonstrate transparency of supply. WWF looks forward to contributing to raising awareness and understanding of this commitment."

Jason Grant, Manager, Corporate Engagement, Forests, WWF-US

3. 1. Examples of emerging forest management approaches based on SFM

Climate-smart forestry (CSF)
An emerging concept built on three pillars: (1) adaptation to climate change, (2) mitigation of climate change, and (3) the integration of social dimensions. Its core objective is to improve the forest carbon balance. To support this goal, CSF is also supported by the 3S framework - Sink, Storage, and Substitution - which emphasises increasing carbon sequestration in forests, extending carbon storage in harvested wood products, and substituting carbon-intensive materials with renewable, forest-based alternatives. (Weatherall et al., 2022; Lawrence, Wishnie and Zimmer, 2023; McLoughlin et al., 2025)

Regenerative forestry
Focuses on adapting sustainable management practices to local contexts, guided by a broader commitment to "doing more good." It seeks to generate net positive outcomes not only in terms of carbon but also across socio-economic, cultural, and ecological indicators. (Soil Association, 2022)

Continuous-cover forestry (CCF)
Umbrella term that comprises several Forest-management approaches (FMAs): unmanaged forest nature reserve, multi-objective, and closer-to-nature FMAs. The main idea of CCF is that forests are managed in a way that the vegetation land cover (tree stock, forest canopy) is always maintained at least to a minimum, to avoid negative impacts (e.g., direct exposure of forest soils to sunlight or rain to avoid loss of fertility and erosion), and uses continuous regeneration versus large-scale clear-cut felling (Mason, W.L. et al., 2022). This FMA aims to create more diverse forests, both structurally and in terms of species composition, by avoiding clear felling. Developing more diverse forests is expected to reduce the risks posed by future and present climate change and by biotic threats.

New Generation Plantations
New generation plantations are a concept for SFM that aspires to create well-managed, inclusive, and profitable forest plantations that are in harmony with both people and nature. They are a shift from traditional intensification efforts by incorporating a wider approach than profit generation and economies of scale that includes protecting high conservation value areas, restoring ecosystems on a landscape scale, engaging local communities, and integrating social and environmental considerations alongside economic viability.

Repositioning SFM within Environmental and Climate Policy Frameworks
Forests are increasingly recognised as vital nature-based solutions for addressing the climate and biodiversity crises. Despite this, SFM – as a comprehensive framework integrating conservation, production, restoration, socio-cultural and economic functions – has lost prominence in national and international policy discourse. While its core principles remain relevant, they are now often addressed in isolation. For example, the Food and Agriculture Organisation of the United Nations (FAO) highlights conservation, protection, restoration, production and innovation, but seldom frames these under the unifying concept of SFM. On the global stage, SFM remains highly relevant, while complementary approaches such as forest landscape restoration, highlighted during the United Nations Decade on Ecosystem Restoration, are gaining broader visibility. On the one hand, there is concern that a fragmented approach risks diluting the integrative value of SFM; however, on the other hand, proponents of a more segmented strategy argue that breaking down forest-related pathways allows for more targeted and effective focus.

At the same time, policy and funding priorities have shifted towards restoration and afforestation, catalysed by initiatives such as the UN Decade on Ecosystem Restoration and finance instruments like REDD+. Although such interventions are urgent and necessary, reducing SFM to a collection of isolated actions risks weakening its holistic perspective. The emerging bioeconomy narrative – focused on material production – has further displaced SFM in political language. Donor funding often favours protection-oriented activities rather than the complex requirements of sustainable wood-production systems and forest-based value chains. As a result, while SFM remains a valid and essential concept, it currently lacks sufficient political and financial recognition at both global and national levels.

"We need a new economic paradigm to transition from an extractive economy powered by fossil resources that develops at the expense of nature, to a regenerative one powered by nature, thriving in harmony with it- a circular bioeconomy. Biodiversity is the life insurance for Nature and therefore valuing and investing in it within our forestry and agricultural systems is key for a resilient world that prospers within a circular bioeconomy."

Marc Palahi, Circular Bioeconomy Alliance

Relevance of sustainable forest management

Global demand for wood is projected to rise substantially across all sectors, driven by population growth, higher per capita consumption and policies promoting carbon-neutral construction as a response to climate change (Nepal, Johnston and Ganguly, 2021; Gardiner and Moore, 2014; Forster, Styles and Healey, 2025). Meeting this demand without undermining forest ecosystems requires strong government commitment to implementing, enforcing and monitoring SFM practices. **Only by aligning wood sourcing with the ecological, social and economic dynamics of forests can societies remain within a safe operating space – one that safeguards forest-carbon stocks and supports biodiversity.**

SFM should not be viewed merely as a defensive response to over-exploitation risks but also as a mechanism through which responsible demand for forest products can drive the restoration of degraded forest landscapes. Regenerative approaches seek to restore and enhance ecological processes, positioning regeneration as both an ethical commitment and a practical necessity for meeting society's long-term material needs. Advancing this transition requires sustained investment in nature-based initiatives with defined objectives, scalable climate solutions and demonstrable positive outcomes. Forests are central to this narrative. Well-managed forests, and restoration itself, emerge from informed, accountable and responsible demand.

SFM provides a holistic framework that:

1. Ensures wood supply security
2. Contributes to GDP and well-being
3. Promotes carbon sequestration and storage
4. Reduces deforestation and forest degradation
5. Supports forest conservation and protection
6. Enables integrated management grounded in adaptive learning and continuous improvement

1. Ensures wood supply security

Security of supply refers to the long-term assurance of resource provision and remains a key driver of SFM In many countries, however, this security is threatened by overharvesting, illegal logging, deforestation and forest degradation – all of which reduce ecosystem services, weaken economic resilience and endanger livelihoods.

When managed sustainably, wood supply can support forest conservation. In the construction sector, stakeholders across the wood value chain face the growing challenge of securing sufficient resources to meet future needs. The FAO estimates that three major product categories for substituting non-renewable materials – cross-laminated timber, cellulosic fibres and woodfuel for bioenergy – could together raise roundwood demand by up to 272 million m³ annually by 2050 compared with 2020, an increase of approximately 49 per cent (FAO, 2024).

To achieve these goals, while contributing to conservation efforts (Dieterle and Karsenty, 2020), environmental equilibrium, economic security and social equity, SFM builds on more than 300 years of practice aimed at ensuring that harvests do not exceed regrowth (Carlowitz, 1713).

This principle, combined with demand-side measures such as using wood where it is structurally most suitable and complementing it with other biobased materials through innovative construction systems, can reduce pressure on forest ecosystems, broaden the biobased material palette and strengthen the resilience of the construction sector, allowing forests time to recover and meet future demand.

2. Contributes to GDP and well-being

SFM contributes significantly to global GDP and human well-being by ensuring forests provide enduring economic, environmental and social benefits. In 2015, the formal forest sector contributed over USD 1.52 trillion to national economies, including USD 663 billion in direct value added, and employed around 33 million people (FAO, 2022; ILO, FAO and Thünen-Institute of Forestry, 2022).

Forests underpin rural livelihoods, particularly for IPLCs, generating income through timber, non-timber products and ecotourism. They also provide ecosystem services – clean air, water regulation and climate mitigation – that sustain public health and overall quality of life. By linking forest stewardship with economic opportunity and social equity, SFM reinforces its role as a foundation for both national development and community resilience. Recognising the contribution of forests to the global climate system and their connection to the products used in everyday life shows that all societies are, in some way, forest dependent.

3. Promotes carbon sequestration and storage

The capacity of forests to sequester carbon and store it in biomass and soils is central to whole-life-carbon accounting (see Principle 2). By maintaining forest cover, supporting natural regrowth and reducing degradation and wildfire risk, SFM helps forests remain effective carbon sinks. When wood is harvested and used in long-lived products, carbon storage extends into the built environment (see Principle 4).

Forests absorb roughly 7.6 billion tonnes of CO_2 each year – nearly three times the annual emissions of the European Union – making them one of the planet's largest carbon sinks (Harris et al., 2021). Terrestrial ecosystems capture about 25 per cent of human-induced CO_2 emissions, with forests accounting for most of that uptake (Hurteau, 2021). This underscores the urgency of reforestation and SFM implementation for climate mitigation, especially in tropical and subtropical regions where targeted investments can deliver significant results in short timeframes (Mosandl, 2024). Regionally adapted SFM strategies, responsive to ecological and socio-economic conditions, can amplify these benefits and secure the dual role of forests as carbon sinks and renewable material sources.

4. Reduces deforestation and forest degradation

SFM is crucial for combating deforestation and forest degradation, particularly when integrated within broader land-use governance frameworks (Krawchenko and Tomaney, 2023). Most large-scale forest loss occurs in tropical and subtropical regions, driven largely by agricultural expansion and informal activities. Strengthening SFM in these contexts promotes forest protection and long-term stewardship.

Halting deforestation to achieve reductions in carbon emissions requires appropriate economic incentives. Reforestation in humid tropical zones delivers exceptional climate gains by capturing carbon rapidly (Mosandl, 2024). These results show why it is important to invest in sustainable forest management approaches that are tailored to local environmental and economic realities.

Deforestation releases an estimated 8 billion tonnes of CO_2 each year, while global forests absorb about 15.6 billion tonnes annually, maintaining a significant net carbon sink (Harris et al., 2021). Forest degradation alone contributes nearly 17 per cent of global carbon emissions (Baccini et al., 2012), underscoring the need for effective forest conservation and sustainable management as complementary, although sometimes territorially separate, strategies.

5. Supports forest conservation and protection

Preserving primary, old-growth and close-to-nature secondary forests is fundamental to conserving biodiversity and mitigating climate change. Forests host most of Earth's terrestrial species, yet degradation, deforestation and fragmentation continue to drive unprecedented biodiversity loss (Beck-O'Brien et al., 2022). Market dynamics can either reinforce responsible management or undermine it. Uncontrolled expansion of mass-timber demand could lead to unsustainable harvesting, infrastructure intrusion and the conversion of natural forests to plantations, fragmenting habitats, reducing ecosystem connectivity and threatening species dependent on mature-forest conditions (Pasternack et al., 2022). SFM must provide a balance — responding to market pressure while incentivising and complementing forest conservation and protection.

Legal protection of forest areas remains a cornerstone of conservation policy, yet its effectiveness depends heavily on the level of funding, monitoring and enforcement capacity. High-income countries often combine protected-area networks with broader strategies that promote multifunctional management and sustainable production, rather than classifying large proportions of forest land as strictly protected (Shono and Jonsson, 2022). These approaches are not mutually exclusive; applied in tandem and informed by local socio-economic realities, they can deliver stronger conservation outcomes.

Emerging tools such as natural-capital accounting now make it possible to measure and manage the multiple values of forests with greater accuracy (Grover et al., 2025). Applied effectively in tropical regions, these tools can enhance biodiversity protection while reducing reliance on strict legal designation as the sole means of conservation.

6. Enables an integrated approach

FMAs vary from intensive models maximising short-term yield and profitability to low-intensity systems prioritising conservation and low operational input (Duncker et al., 2012a). Defining objectives at both forest-management-unit and landscape levels determines the silvicultural practices required.

Because forests provide a wide spectrum of goods and services, management strategies can prioritise, optimise or integrate these functions in diverse ways (Duncker et al., 2012b). SFM enables a holistic approach that balances productive, ecological and socio-cultural dimensions, recognising forests as interconnected systems supporting both people and nature. Beyond timber production, SFM encompasses biodiversity conservation, non-wood forest products, watershed protection, carbon sequestration and the safeguarding of cultural values and livelihoods, especially for IPLCs. Sustainably managed production forests support protected areas by linking habitats and acting as buffers that strengthen ecosystem resilience and conservation outcomes.

"Today, the sustainable forest sector is presented with unprecedented opportunities, driven by the urgency of climate action, growing awareness of the biodiversity crisis and the recognised potential of sustainable wood value chains to deliver positive environmental and socio-economic outcomes. However, realising this potential will be challenging without addressing the sector's social licence gap. Integrating ecological restoration into planted-forest systems offers a pathway to overcome this challenge – by not only contributing to climate mitigation, biodiversity conservation and community development, but also by demonstrating that such systems can restore ecosystem services across landscapes while supplying renewable resources for a thriving bioeconomy."

Mark Wishnie, Chief Sustainability Officer, BTG Pactual Timberland Investment Group

Enablers of sustainable forest management

Practitioners, policymakers and advocates of SFM must extend their focus beyond conservation by embedding policies and tools that actively restore and regenerate forest landscapes. Responsible procurement, a long-standing ally of SFM, should evolve to reflect this regenerative approach, shifting from merely preventing harm to actively creating ecological and social value. Although the enablers of SFM differ by region, several overarching factors consistently influence its implementation worldwide, with their relative significance varying by context.

To promote and support SFM effectively, governments should consider the following enabling factors:

Examples of enabling factors for SFM

Integrated legal and policy frameworks	**Clarity and security of land tenure:** Ambiguities and overlapping claims often undermine legal certainty and discourage long-term investment in SFM.
	National forest policies with enforcement capacity: Strong national forest policies depend not only on clear legal frameworks but also on the ability to enforce them effectively
	Spatial land-use planning: Spatial planning provides the framework for reconciling competing land uses and safeguarding the ecological functions of forests. By adopting integrated spatial planning approaches, policymakers can designate priority zones for conservation, timber production, ecosystem restoration, and community access.
Forest finance	**Economic incentives and innovative financial mechanisms** are essential to unlock SFM, given its need for upfront investment and often delayed financial returns. The stark disparity between "gray" and "green" finance[1] represents one of the most pressing challenges in global environmental policy. For long-term effectiveness, SFM requires financial frameworks that support forest protection, sustained forest cover, and integrated land-use planning. These frameworks include public subsidies from national funds, carbon finance, green investment instruments, and blended finance approaches.

1 "Grey finance" refers to financial flows that support sectors and activities with limited or no consideration for environmental and social impacts, potentially contributing to unsustainable forest use and degradation. "Green finance" (in this report also forest finance) refers to financial flows directed toward activities that enhance ecological and environmental sustainability, including SFM (e.g. forest restoration, biodiversity conservation, and climate change mitigation through forests)

Knowledge, data, and capacity	**Public awareness of ecosystem services and SFM benefits:** In many developing countries, rising public awareness of the ecosystem services provided by forests, such as clean water, soil protection, carbon sequestration, and biodiversity, has fostered stronger community support for forest conservation. This awareness often translates into local resistance to deforestation and greater acceptance of SFM practices, demonstrating the potential of bottom-up approaches to drive sustainable outcomes.
	Forest inventory and monitoring systems: Reliable data on forest cover, biomass, and land-use change are critical for evidence-based SFM. Innovations such as satellite monitoring, drones, and digital traceability platforms enhance transparency, enable rapid detection of deforestation or illegal logging, and strengthen law enforcement.
	Local technical capacity and education: Sustained investment in forestry education, vocational training, and context-specific digital extension services. Building local expertise is a foundational prerequisite for effective, adaptive, and inclusive forest management. Strengthening local capacity must be recognised as a strategic priority and treated as a precondition for meeting national and global SFM objectives, including climate mitigation, biodiversity conservation, and rural development.
Inclusive governance and community engagement	**Recognition of IPLC rights and roles:** Particularly important in regions with high forest dependency (e.g., Amazon, Congo Basin, South East Asia). Recognising the rights and roles of IPLCs not only enhances forest stewardship but also strengthens social equity and conflict resolution, key to SFM. Empowering communities through participatory planning and co-management agreements fosters long-term commitment to sustainable practices.
	Social license to operate: SFM is, in essence, a social issue. A "social license to operate" (Wang, 2019) in forestry refers to the ongoing acceptance and approval of forestry operations by the local community and stakeholders who are affected by them, both directly and indirectly. Social license is a cross-cutting issue across all aspects of SFM. It underpins the stakeholder engagement strategies of forest industry companies and the success of forest carbon projects, which depend on strong community participation for implementation. SLO is not a formal legal or regulatory license, but rather an informal, dynamic, and context-specific process that requires long-term engagement and trust-building.
Forest Certification Schemes[2]	**Certification should be understood not as a stand-alone solution,** but as one component within a broader policy and governance framework that ensures SFM is implemented effectively across diverse regional contexts. The role of certification schemes, as independent verification systems, is to confirm that wood products originate from forests managed in line with SFM principles. Through chain-of-custody systems, certification provides an initial level of supply chain transparency. In the context of timber construction, requiring certification should be considered the minimum market norm.

2 Forest certification has developed into a key market-based tool, expanding from 51 million hectares in 2000 to 435 million hectares in 2020 (FSC and PEFC). While it plays a valuable role in promoting responsible forest management, certification cannot be seen as a comprehensive guarantee of sustainability beyond the borders of the forest management unit. Most schemes establish baseline requirements, and their effectiveness depends on their scope, enforcement, and the specific context in which they are applied. Uptake has been more extensive in temperate and boreal regions, accounting for 84% of all certified areas in 2020, yet remains limited in tropical forests, where the risks of deforestation and degradation are highest (Shono and Jonsson, 2022) . Over-reliance on certification may also mask deeper governance challenges, unresolved tenure disputes, or unregulated domestic markets where forest governance is weak or absent.

Myths and misconceptions

Advancing policies and practices that support SFM requires raising awareness grounded in scientific evidence and fostering context-specific understanding. This involves recognising trade-offs, avoiding oversimplified narratives and bridging the often fragmented perspectives that shape forest debates.

“We must challenge our assumptions about scale, industrial models are not the only path. Community-led, small-scale management in tropical forests proves that meeting local needs while preserving integrity is a valid form of sustainability.”

Peter Graham, Managing Director of Policy and Research, Climate Advisers

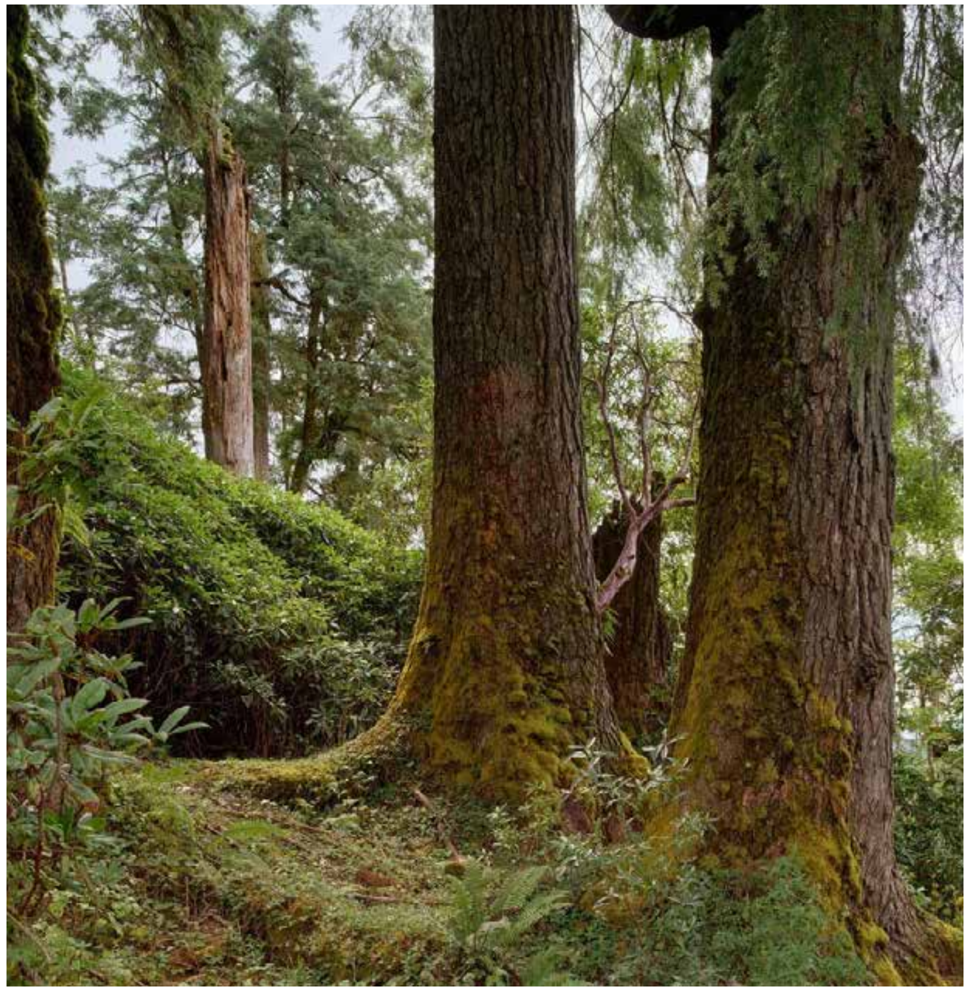
Myths and misconceptions	
All wood is good	While wood is a renewable resource and can support climate goals, its true sustainability depends on how it is sourced and used. The use of wood delivers climate benefits only when it comes from responsibly managed forests (Gibson and Pomponi, 2025; Arehart et al., 2021) and is used in long-lived products such as construction materials (Van Roijen, Miller and Davis, 2025; Pramreiter et al., 2023). In the absence of SFM, logging can drive higher carbon emissions, forest degradation, biodiversity loss and social harm, particularly in regions with weak governance or land-use-change pressures. To ensure sustainability over time, harvest rates must reflect the productive capacity of forests rather than being dictated by consumer demand. Achieving this balance requires context-specific approaches that align supply and demand at the system level.
One size fits all	The assumption that a single model of SFM can be applied uniformly across all regions overlooks the ecological, socio-economic and political diversity of the world’s forested landscapes. Differences in forest types, ecosystem functions, land-tenure systems, governance structures and cultural relationships with forests, particularly between developed and developing countries, require context-specific approaches. Imposing top-down or standardised models risks being ineffective. Decontextualised approaches can weaken local governance, displace IPLCs and lead to unintended negative outcomes. Tailored strategies that recognise regional complexity and foster inclusive decision-making are therefore essential to achieving meaningful sustainability on the ground. This need for place-based adaptation is reflected in forest certification systems, which have developed national and regional standards to account for local conditions.
Forest protection and harvesting are opposites	Public debates often conflate forest harvesting with deforestation, which can obscure the potential of well-managed production forests to contribute simultaneously to biodiversity conservation, climate goals and rural development. Management approaches such as Climate-Smart Forestry, Close-to-Nature Forestry and harvesting methods including selective logging, group selection and shelterwood systems demonstrate that forest protection and wood production are not mutually exclusive. When guided by SFM, production forests can function as ecological buffers, strengthen habitat connectivity and reduce pressure on primary forests. Nonetheless, a divide persists between those advocating strict protection and those supporting multifunctional management, reflecting limited recognition of the wide range of practices between illegal logging at one end of the spectrum and SFM at the other. As a result, the benefits of responsible harvesting for ecosystem care are often overlooked. When properly managed, forests under SFM can protect biodiversity while supporting timber production, climate goals and local livelihoods.
Plantations[3] and intensification aren’t necessary	Planted forests and well-managed plantations can play a strategic role in ensuring a sustainable wood supply. By producing timber more efficiently, they can reduce harvesting pressure on natural forests and support the restoration of degraded or deforested areas. Despite their relatively small area share, plantations are important for wood production, with projections indicating they will provide approximately half by 2040 (Kanninen, 2010). Although the impact of planted forests on biodiversity, water resources, local communities, and other ecosystem services varies by context, their significance in meeting global wood demand is expected to grow in the coming years (FAO, 2025c). There is a sufficient body of evidence to show monoculture plantations that have been poorly executed and have drawn criticism of social imposition, biodiversity loss, soil degradation, and vulnerability to pests and diseases. If global demand is to be met and plantations and intensification play a clear role, we must do better. However, more sustainable alternatives are gaining traction both working within the sector (NGP, 2025) and proposing parallel models such as mixed-species plantations (Guo et al., 2025; Depauw et al., 2024) and agroforestry systems (Báder et al., 2023; Minini et al., 2024), which incorporate ecological diversity and multifunctionality. These advances can offer more resilient approaches and hold promise for reconciling wood production with broader sustainability goals.

3 According to the Global Forest Resources Assessment (FRA 2020), planted forests are those predominantly established through planting and/or deliberate seeding (FAO, 2018). This category is broad and includes, but is not limited to, plantation forests. Plantations, by contrast, represent a specific subset of planted forests: they are intensively managed, typically consist of one or two species of the same age class, and are characterized by regular tree spacing. Forests established for ecosystem restoration or protection, or those that resemble natural forests at maturity, are not classified as plantations. (FAO, 2025)

Harvesting reduces the carbon sink

The more intensive the harvesting, the higher the resulting carbon emissions from the timber sector, to the point where, in the extremes of land use change and deforestation, they can offset any climate benefits typically expected from substituting wood for more carbon-intensive materials. However, balancing productive areas with conservation areas, applying sensitive harvesting techniques, not harvesting to the point where the forest carbon stock is reduced over-time are all possible and common trade-offs. For example, studies indicate that longer rotation periods generally enhance in-forest carbon sequestration and support greater biodiversity, contributing to more resilient forest ecosystems (e.g., Soimakallio, et al., 2022, Schulte et al., 2022, Felton et al., 2024).

The debate over the optimal balance between forest carbon sink and material substitution in construction remains unresolved, in large part due to the different assumptions and timeframes used in modelling studies. Some evidence suggests that less intensive harvesting regimes may achieve greater net CO_2 sequestration than intensified harvesting and feedstock utilisation strategies, particularly over the next decade, a critical window for climate action (Soimakallio et al., 2021; Brown et al., 2024). The debate highlights the need for context-specific approaches based on accurate data that take into account forest ecology, regional dynamics, and the intended use and longevity of harvested wood products.



Untoched Hemlock Forest in Central Bhutan © Bas Princen for Bauhaus Earth, 2024

Key implementation challenges and opportunities

Implementing SFM faces several persistent challenges: ensuring business and financial viability, addressing illegal activities and resource conflicts, fostering local participation, improving silvicultural practices and clarifying tenure and property rights (FAO, 2025). This section outlines eight interconnected areas of opportunity. Addressing them is critical to safeguarding forest ecosystems and ensuring that SFM contributes meaningfully to national and international goals on climate mitigation, biodiversity conservation and rural development.

1. Challenge:
Fragmented legal frameworks, weak enforcement,and insecure tenure

Weak and poorly enforced legal frameworks undermine long-term forest stewardship. In many countries, forest, agriculture and land-use laws are misaligned, allowing unsustainable practices to persist. Insecure tenure and limited recognition of IPLCs further reduce incentives for sustainable management and exclude local actors from decision-making. These conditions fuel land-use disputes, speed up deforestation and reduce accountability. The problem is made worse by policies developed in isolation, with forestry often separated from agriculture, infrastructure and urban planning. This fragmentation increases land degradation and deforestation, especially where agriculture is expanding. Strengthening legal foundations – supported by credible enforcement and integrated, cross-sectoral planning – is essential for SFM to realise its potential for climate, biodiversity and livelihoods.

Weak governance and insecure land tenure are major barriers to scaling up SFM, particularly in low-income tropical countries. Although many national policies appear robust on paper, implementation often fails due to limited political will, inadequate institutional capacity and weak oversight in remote regions. Protected areas may also be exempt from the monitoring applied to managed forests, leading to inconsistent enforcement. In many cases, forests managed sustainably are better at preventing encroachment and illegal logging than formal reserves. However, limited adoption of long-term forest management plans and insufficient stakeholder participation continue to constrain investment and weaken stewardship.

1.1. Opportunity:
Establish legal and policy foundations with enforcement

Integrating SFM into national development and climate strategies is essential for maximising the role of forests in addressing climate change, biodiversity loss and socio-economic development. Embedding forestry in cross-sectoral planning and inter-ministerial dialogue positions SFM as a strategic tool for meeting national development goals and raising the political and economic profile of the sector.

Governments should treat SFM not only as an environmental goal but as an integral component of national socio-economic policy. Forest-management plans serve as key mechanisms to translate SFM principles into on-the-ground practice but require strong legal frameworks, state support and mechanisms for accountability. Secure land tenure and recognition of IPLC rights, backed by enforceable mechanisms, are critical. Where tenure is absent or unclear, local communities are often excluded from decision-making. Effective SFM depends on inclusive processes that empower communities, smallholders and marginalised groups to co-design and co-manage forest initiatives.

Recognising community land rights and ensuring secure tenure – supported by adequate funding, monitoring and governance – can significantly improve forest sustainability. When communities gain legal control, they are more likely to protect and invest in forests.

“Security of tenure is one of the most important preconditions for forest investment. Without it, even the most promising financial mechanisms and ownership models won’t be attractive for investors.”

Shauna Matkovich, The ForestLink

3.2. Best practice: Gabon’s model of forest governance

The government has mandated that all logging concessions achieve Forest Stewardship Council (FSC) certification by 2025, with penalties for non-compliance that include license revocation. This policy, supported by a 2020 government – FSC cooperation agreement, is reinforced by fiscal incentives that adjust forest tax rates based on certification status. The country’s 2021 climate regulation and REDD+ strategy also establish a legal foundation for performance-based climate financing. Notably, Gabon became the first African nation to receive REDD+ payments under a $150 million agreement with the Central African Forest Initiative. Source: FSC, 2020; Fair & Precious, 2022; UNDP, 2021

3.3. Best practice: First Nations forestry partnership in British Columbia

In 2023, the Tlowitsis, We Wai Kai, Wei Wai Kum, and K’ómoks First Nations reached a landmark agreement with Western Forest Products Inc. to acquire a 34per cent interest in a new forestry partnership worth CAD $35.9 million. Facilitated by the Province of British Columbia through Incremental Treaty Agreements, the partnership covers approximately 157,000 hectares of forest land on Vancouver Island with an allowable annual cut of over 900,000 m^3.

This initiative represents a significant step toward reconciliation by restoring Indigenous participation in forest ownership, management, and benefit-sharing. For the Nations, who have been stewards of these forests for millennia, the agreement strengthens economic self-determination, supports job creation, and enables long-term stewardship aligned with cultural values.

The model demonstrates how recognition of Indigenous rights and roles can create mutually beneficial outcomes by combining sustainable forest management with economic reconciliation. It also serves as a replicable pathway for integrating IPLCs into the governance and value chains of forest industries. Source: BC Gov News, 2023

3.4. Best practice: Maya Biosphere Reserve in Guatemala

The Maya Biosphere Reserve in Guatemala exemplifies best practices in tropical forest management through legally defined community concessions and strong governance. In the reserve’s multiple-use zone, 25-year extraction concessions, mandating FSC certification, are granted to community cooperatives. These concessions integrate sustainable practices like low-impact logging, fire control, and agroforestry, while channelling shared revenue into education, health, and infrastructure. Backed by local and international NGOs such as Rainforest Alliance, and with funding from international donors such as USAID, the initiative has maintained near-zero deforestation (0.4per cent) over two decades, created over 12,000 jobs, and generated $69.6 million in sales between 2013 and 2021. Less than 1 per cent of forest fires affect concession areas. The program effectively aligns community incentives with forest conservation, demonstrating how policy-supported local stewardship can deliver both ecological and economic benefits, though recent proposals for private development threaten to undermine these gains. Source: Balta, 2021; Nerger, 2022

Sawmill in Brandenburg
© 414films for Bauhaus Earth

2. Challenge:
Chronic underfunding of SFM

SFM continues to face economic disadvantages compared with competing land uses such as commercial agriculture, resulting in ongoing deforestation pressures. Forest managers—particularly in the Global South—confront structural financing gaps because key ecosystem services such as carbon sequestration and biodiversity conservation remain difficult to monetise. Even with forest certification, these services seldom yield lasting market premiums.

While many initiatives have attempted to implement payment for ecosystem services (PES), few have achieved meaningful economic returns. Only a few, such as Costa Rica's national PES program, have delivered consistent financial benefits (UNFCCC, 2020). In parallel, demographic shifts are weakening the socio-cultural foundations of forest stewardship. Younger generations of IPLCs are increasingly migrating to urban areas in search of more lucrative opportunities, eroding the cultural and economic ties that historically sustained forest management.

"We need to economically valorise natural forests beyond protection measures, ensuring their long-term preservation through viable economic models."

Michelle Stede, Network Manager Construction & Circular Economy, FSC

2.1. Opportunity:
Scaling forest-positive finance

Scaling forest-positive finance requires innovative mechanisms, cross-sectoral partnerships and catalytic philanthropy. According to the United Nations Environment Programme (UNEP, 2025), private finance for nature has surged to USD 102 billion, an elevenfold increase from 2020 levels (USD 9.4 billion). Financial tools such as forest bonds, blended finance, carbon markets and debt-for-nature swaps can monetise ecosystem services while directing investment toward conservation with equitable community benefits. Collaboration with actors such as insurers or water authorities—whose financial risk exposure is linked to forest degradation—strengthens the economic rationale for SFM and builds shared value.

Philanthropic capital should be deployed strategically to de-risk early-stage investments, fund capacity-building and support policy reform, thereby unlocking larger flows of private finance. A coordinated mix of public, private and philanthropic funding can enable long-term transition toward forest-positive economies.

"In recent years, governments, NGOs, large companies, and major investment banks have begun working together. This convergence is promising as this is the kind of collaboration that can drive systemic change towards a sustainable forest sector."

Gary Bull, Professor of Forestry, University of British Columbia

3.5. Best practice: Examples of forest-positive finance

Forest bonds

Forest bonds and sustainability-linked instruments are increasingly used to attract private investment by mitigating financial risk and addressing upfront capital needs. These tools distribute investment risk across multiple projects, making forest conservation more appealing to traditional investors.

Examples:

Sustainability-Linked Bond, Uruguay (IDB, 2022)
Sovereign biodiversity sukuk[4] "Islamic Bond", Malaysia (IFC and Amundi, 2024)

Blended finance approaches

Blended finance approaches leverage public and philanthropic capital to crowd in private investment, though uptake in forest contexts has historically lagged behind infrastructure and energy projects. The emerging trend shows these instruments increasingly targeting forest-specific goals, with mechanisms like the Central African Forest Initiative partnership enabling derisked loans backed by funding entities.

Examples:

Tropical Asia Forest Fund 2 (TAFF2) (Convergence Blended Finance, 2023)
Restoration Seed Capital Facility (RSCF, 2023)
Ireland's Silva Fund
Germany's Waldumbau-Programme
Austria's Forest Funds demonstrate

National forest funds

Country-led financial instruments that enhance the ability of forest nations to mobilise and manage resources for forest-related activities. Typically financed through dedicated revenue streams (e.g., environmental fees, levies, or taxes designed to discourage unsustainable practices), these funds may also incorporate development aid or project-based contributions. This financial mechanism can operate either as a transfer platform, facilitating the flow of funding from diverse sources to local actors, or as a catalytic mechanism, strategically addressing economic barriers and fostering sustainable enterprise development within the forest sector.

Examples:

Central African Forest Initiative (CAFI)
Amazon Fund
Tropical Forests Forever Facility (TFFF)

4 According to the Global Forest Resources Assessment , planted forests are those predominantly established through planting and/or seeding (FAO, 2025b). This category is broad and includes, but is not limited to, plantation forests. Plantations, by contrast, represent a specific subset of planted forests: they are intensively managed, typically consist of one or two species of the same age class, and are characterized by regular tree spacing. Forests established for ecosystem restoration or protection, or those that resemble natural forests at maturity, are not classified as plantations. (FAO, 2025c)

Payments for ecosystem eervices (PES)
Through these schemes, landholders and communities are compensated for maintaining forest cover and safeguarding ecosystem services such as carbon sequestration, water regulation, soil fertility, and biodiversity. By translating environmental benefits into direct financial value, PES can make stewardship a viable and attractive choice for landowners, embedding sustainability into everyday decision-making.

Example:
Costa Rica's National PES Program (UNFCCC, 2020)

Carbon markets
These are financial mechanisms that put a price on greenhouse gas emissions by enabling the trade of carbon credits, which represent verified reductions or removals of CO2. These markets operate in two forms:

- **Compliance markets,** where governments set legally binding caps on emissions and regulated entities must purchase credits to meet their targets. Examples include Australia, New Zealand, and California, where forestry-related carbon activity is almost entirely compliance-driven.
- **Voluntary markets,** where companies and organisations buy credits to meet corporate climate commitments or offset emissions beyond legal requirements. These markets dominate in the global south.

In the forestry sector, carbon markets reward SFM by monetising the carbon sequestration benefits of well-managed forests. Beyond REDD+ (which has faced credibility challenges), a growing share of credits now comes from ARR (Afforestation, Reforestation, and Revegetation) projects that establish new forests, and IFM (Improved Forest Management) projects that improve management of existing forests to increase carbon storage. Verified credits from these activities can provide new revenue streams for forest managers, landholders, and communities, while supporting national climate commitments and corporate net-zero goals.

Debt reduction instruments
Debt-for-nature swaps are financial agreements in which part of a country's external debt is forgiven or restructured in exchange for commitments to channel equivalent resources into conservation. This mechanism provides fiscal relief while securing long-term investments in forests and other ecosystems. For forest-rich developing countries, such instruments offer a pathway to ease fiscal constraints that often incentivise resource exploitation. While they may not significantly reduce overall sovereign debt, debt-for-nature swaps can act as a stepping stone toward broader debt restructuring, creating fiscal space for sustained forest protection.

Example:
Peru's debt-for-nature agreement with the United States (WWF, 2023)

Private funding through TIMOs
Today, Timberland Investment Management Organisations (TIMOs) play a central role in structuring investments, offering pooled funds or separately managed accounts (SMAs) tailored to different investor profiles. While experienced investors often prefer SMAs, new entrants, driven by climate goals and net-zero commitments, rely on funds with predefined strategies. These funds prioritise steady, lower-risk returns alongside carbon, biodiversity, and sustainability outcomes rather than purely financial gains. Governments can unlock much greater investment by ensuring a stable regulatory environment: strong forest legislation, credible enforcement, and secure land and carbon tenure. Without these, even well-designed policies fail to attract capital.

Example:
Large-Scale Forest Investment Strategy in Brazil's Cerrado (Irvin, 2025)

3. Challenge:
Capacity and skills deficit in forestry

Many forest owners, wood-sector actors, and community members have limited awareness or understanding of SFM. Public and community institutions often lack trained professionals and expertise in ecological monitoring, participatory planning and integrated land management. In many developing countries, forestry actors lack access to modern silvicultural training and inclusive governance systems, leaving frontline workers – essential for implementation – underserved.

The sector also faces a growing workforce gap. Demographic decline, limited remuneration and restricted career pathways have reduced the sector's appeal to younger professionals. With education systems emphasising academic over vocational learning, operational capacity remains underdeveloped. This disconnect has produced a structural skills gap in a sector increasingly shaped by digital technologies, precision management and advanced supply-chain logistics. Without targeted investment in education, training and workforce development, the sector will struggle to deliver the transformation required for sustainable forest management (Owuor et al., 2021).

> *"Many stakeholders, including governments and certified companies, believe their current practices are adequate, representing a significant knowledge barrier"*
>
> *Dr Michael Galante, Founder, Secretary-General, ARFM*

3.1. Opportunity:
Building skills, capacity, and attractive career pathways in forestry

Building capacity in the forest sector should go hand in hand with technical support and the adoption of innovative systems that enhance livelihoods, social well-being, resource conservation and ecological resilience, rather than focusing solely on economic returns (FAO, 2024). Innovation in forestry is most effective when grounded in local contexts, traditional knowledge and community priorities (FAO, 2024).

Expanding forestry education and vocational training, particularly for frontline workers, can close persistent skills gaps in silviculture, ecological monitoring and participatory governance. Training programmes should go beyond compliance, integrating traditional ecological knowledge with emerging technologies such as digital monitoring, precision forestry and landscape mapping. Clear career pathways, improved working conditions and youth engagement are essential to attract the next generation of professionals.

Inclusive governance and social innovation can further empower local actors. Community-based forest management, Indigenous mapping platforms and women-led restoration initiatives have strengthened accountability and equity, while cooperative models and hybrid governance institutions expand participation. Interdisciplinary networks and digital platforms can connect youth, entrepreneurs and local communities to knowledge exchange, innovation and forest-based enterprise opportunities.

To enhance sector capacity, key actions include strengthening professional training in silviculture, forest inventory, digital monitoring and ecosystem-based management. Expanding extension services and establishing innovation hubs – especially in rural and tropical areas – remains crucial where technical support is limited. The preparation of practical, context-responsive forest management frameworks enables practitioners to manage trade-offs effectively and harness emerging policy and market opportunities. Together, these measures illustrate essential pathways for building capacity and advancing SFM.

3.6. Best practice: Global training network for SFM

Initiatives such as the Alliance for Responsible Forest Management (ARFM) exemplify promising approaches to strengthening SFM in Africa, Asia-Pacific, and Latin America. As an international non-profit, ARFM develops region-specific training frameworks that combine theory and practice. Its intensive 28-day program equips practitioners, auditors, government personnel, and community representatives with the skills needed to manage diverse forest ecosystems effectively. Its approach also underscores the potential of global training networks to accelerate the adoption of best practices, reduce emissions, conserve biodiversity, and bolster local economies. Source: ARFM, 2025

4. Challenge:
Data collection and gaps in monitoring, verification, and carbon accounting.

The science of SFM relies on robust data collection and analysis—covering species growth rates, yield tables, soil profiles, stakeholder mapping and biodiversity indicators. SFM is fundamentally a planning tool, and effective planning depends on accurate data. At a national scale, assessing whether various demand scenarios can be met under current management practices requires detailed productivity data. For example, calculating backwards from the annual allowable cut (AAC) can help determine whether a timber products facility is viable. To ensure a reliable supply for specific wood-based value chains, sustained yield and 'market equilibrium' figures must be established.

Effective climate action in the forest-based sector also depends on sound monitoring, verification and carbon accounting systems. Yet significant gaps remain. Although forest certification and traceability schemes exist, adoption and enforcement are inconsistent. Real-time monitoring technologies are underutilised, and carbon accounting methodologies are fragmented, lacking standardised, transparent and user-friendly tools. Such gaps reduce confidence in sustainability claims and in the proven climate advantages of timber sourced responsibly.

4.1. Opportunity:
Prioritise data collection to support forest management, market equilibrium, certification, traceability, and carbon accounting

Recent advances in monitoring technology now enable real-time assessment of sustainable harvest levels, allowing forest-management systems to become more adaptive and responsive. Effective management depends on policy frameworks that can adjust to ecological and market shifts. Assessments comparing sustainable supply and demand must consider variables such as growth, age-class distribution, species composition and operable area. Accurate estimates rely on localised, real-time inventories of harvestable stands.

As demand for climate-smart and sustainably sourced forest products increases, supply-chain actors must demonstrate credible sustainability practices. Achieving this – and thereby rewarding SFM – requires addressing three key questions:

1. **Where did the wood come from? – Traceability[5]**
2. **Was the forest sustainably managed? – Certification**
3. **Does the forest maintain or increase its carbon stock? – Carbon accounting**

5 Effective traceability systems combine field verification, audits, and digital data management to ensure transparency and accountability. They help governments combat illegal logging, improve revenue collection, and support law enforcement, while enabling private-sector actors to meet legality requirements, improve supply chain management, and demonstrate compliance with sustainability standards. (Nogueron et al., 2022)

Traceability and forest certification systems are relatively well established but require stronger enforcement and cross-market consistency[6]. The critical remaining gap lies in forest-carbon accounting.

Despite the availability of several methodologies, a universally recognised and accessible framework for verifying forest carbon stability remains absent. This deficiency is critical, as robust carbon accounting underpins evidence of the net climate benefits achieved when wood substitutes for carbon-intensive materials such as steel and concrete. Establishing consistent and practicable measurement standards will be pivotal to reinforcing the integrity of sustainable forest management and advancing the role of forests in global mitigation frameworks.

“At the EU level, carbon dominates the SFM debate—but forests are more than carbon. Their health and resilience depend on biodiversity, and policymakers must embrace this broader understanding.”

Samy Porteron, Senior Programme Manager, ECOS

Data required to inform forest-related policy, investments and interventions based on an accurate understanding of a domestic ‘forest to market equilibrium’ and thereby:

1. Definition of types of stakeholders and investors (including their objectives and requirements)
2. Define sourcing areas’ economic viability, in relation to transport costs and emissions.
3. Description of the capacity of defined FMUs to supply the expected timber volumes by species, age-class and DBH, including each FMU that is within transport reach of a target market.
4. FMU, rotation and stand-level data of the relevant species, or group of species/target forest type, is essential for accuracy.
5. Estimation of the volume committed to any other uses, e.g. traditional, customary needs.
6. Estimation of leakage (e.g. illegal deforestation, damage, waste) and correction of the supply capacity accordingly.
7. Analysis of risks to forest permanence.
8. Implications on the supply of human resources capabilities and skills.

6 A range of technological solutions have emerged to support companies in tracing and reporting the origins of their timber imports. These include log marking, DNA testing, cloud-based supply chain compliance platforms, blockchain systems, government-sponsored timber traceability systems, as well as technologies such as RFID tags and QR codes.

3.7. Best practice: Examples on building capacity and data collection

In Peru, Indigenous Tech Camps bring together communities, NGOs, and officials to co-develop and pilot data-driven forest conservation approaches, such as DNA-based wood tracing systems via World Forest ID, equipping remote guardians with advanced mapping and monitoring skills. (Rainforest Foundation US, 2023)

In Southeast Asia, Indigenous groups in Borneo are using GPS, GIS, and drone mapping to formalise land claims and detect encroachment by plantations. (MK, 2023)

The LandMark platform provides a global, open-source tool for Indigenous mapping, boosting tenure security and forest stewardship across borders. (WRI, 2024)

5. Challenge:
Aligning demand with forest supply

A central challenge in advancing responsible timber construction is balancing industrial demand with the ecological limits of a sustainable wood supply. In many industrialised regions, forest management has long been shaped by short-lived wood products from intensively managed forests – such as paper, packaging and pellets (Nabuurs et al., 2019). Transitioning toward balanced supply and demand is constrained by entrenched industrial priorities, climate impacts affecting species suitability and the financial risks of shifting from short-rotation monocultures to longer-rotation, mixed-species forests (Bozzolan et al., 2024; Lerink et al., 2023).[7]

Domestic markets for certified wood remain weak in many countries, and public awareness of ecosystem services and sustainability is limited. This reduces demand for verified sustainable timber, perpetuates reliance on uncertified or illegal wood and discourages adoption of SFM. Without stronger procurement standards and awareness campaigns, incentives for responsible production remain inadequate. Governments play a critical role in strengthening markets for certified wood by shaping demand and influencing consumer preferences.

“There is a need to link forest management to realistic demand projections for wood products; forest management models should be guided by anticipated demand and substitution potentials.”

Maximilian Schulte, PhD, Wageningen Environmental Research, Team Sustainable Forest

7 Harvest levels vary across regions. The gap between a country’s maximum sustainable harvest (not to be confused with its net annual increment) and the current level can serve as a buffer of under-utilised forest area that helps maintain carbon storage. A healthy buffer allows countries to absorb shocks such as fires or storms and accommodate temporary increases in harvesting without depleting stocks. Where the buffer is narrow, extending rotation periods can add carbon-storage benefits, but an excessive biomass reserve may heighten wildfire risk and reduce the carbon sink. Balancing carbon storage and climate resilience will remain a key function of SFM.

5.1. Opportunity:
Balancing and expanding markets for sustainable wood products.
Policymakers can unlock the climate-mitigation potential of forests by fostering markets that prioritise long-lived wood applications such as engineered-wood products. Aligning procurement standards, fiscal incentives and supply-chain regulations can encourage the construction and design sectors to favour sustainable timber over high-carbon alternatives. Collaboration between demand- and supply-side actors can also create adaptive markets that use a wider diversity of species, enhancing forest resilience. By rebalancing product-value hierarchies and supporting financial innovation, SFM can simultaneously deliver stronger climate outcomes, biodiversity protection and long-term wood security.

“I believe in the power of markets to drive sustainable business. If demand for wood products is structured sustainably, it will increase demand for Sustainable Forest Management. This raises the economic value of keeping forests standing compared to converting them for agriculture, and it can create more positive economic and social dynamics around forest use. However, the scale of this demand must be managed with caution to avoid unintended consequences.”

Thais Linhares-Juvenal, Team Leader Forest Governance and Economics, FAO

3.8. Best practice: Sustainable timber trade - Verifikasi Legalitas Kayu, Indonesia

In Indonesia, the Sistem Verifikasi Legalitas Kayu (SVLK) has become a central element of the country’s VPA with the European Union. By aligning national legality verification with EU import requirements, the scheme has opened up new opportunities for Indonesian timber producers to access more environmentally sensitive markets. This recognition through the FLEGT licensing scheme not only secured international market access but also reinforced domestic governance by improving transparency, monitoring, and accountability in the forestry sector. Over time, SVLK has enhanced recognition of verified wood products within Indonesia itself, demonstrating how market access can drive governance reforms (Obidzinski et al., 2014).

“Urban populations are just as forest-dependent as rural ones—especially as we move away from fossil-based materials. The demand they create should be seen not as a threat, but as the very driver that can deliver restoration and sustainable supply at scale. Nations and industries must clearly communicate the benefits of forests to people at the end of the supply chain, showing that demand is part of the solution.”

Lars Laestadius, Forest Policy and Sustainability Adviser, The Eco-innovation Foundation

6. Challenge:
Market demand and differentiation
Growing market demand for verified sustainable wood is creating strong incentives for SFM, particularly in countries where consumers and companies require deforestation-free and responsibly sourced products. Certification schemes such as FSC and Programme for the Endorsement of Forest Certification (PEFC) play a central role in meeting these expectations. They establish minimum standards for SFM, facilitate access to international markets and can deliver reputational benefits and, at times, modest price premiums. However, demand in many domestic markets, especially in developing economies, remains limited, reducing incentives for producers.

6.1. Opportunity
Governments and local authorities can help shape markets by requiring certified materials in public construction. Forest certification, regardless of the specific system, remains essential for validating SFM practices, particularly where policy frameworks are unstable or enforcement capacity is weak. It provides continuity and reliable oversight even amid political fluctuations.

Upcoming revisions to certification standards present an opportunity to integrate climate-smart objectives more fully. At the same time, growing market demand for transparency creates scope for countries to lead efforts toward harmonising standards, such as through the United Kingdom Woodland Assurance Standard (UKWAS).

"Waldwirtschafterei" -Project, Berlin-Brandenburg
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From principle to action

The evidence and consensus supporting SFM, not only as an essential framework for sustained production but also as a central paradigm in the global climate-solutions toolkit, is now well established. Sustainable forest management supports sustainable development, creates employment, drives economic growth and strengthens rural resilience. For the expanding construction sector, it provides a renewable and readily available material for long-lived, low-carbon products.

A wide range of technological solutions, standards and regulatory systems already enable the monitoring and verification of sustainable forest use, with new tools developing rapidly — for example, geospatial biomass-tracking systems driven by demand from voluntary carbon markets. In short, mechanisms exist to meet demand-side requirements and to provide supply-chain actors with the two pieces of information needed to realise the carbon-sequestration and storage potential of forest products: the origin of the wood and confirmation that the source forest is being managed sustainably.

Much of the knowledge, science and technology required for scaling SFM are in place. What remains are the enabling political and economic conditions, alongside education systems capable of building the skilled workforce to deliver SFM at scale. Skills will follow investment and political commitment. The *Principles* respond to this emerging demand from the construction sector for reliable, sustainable forest products. A biobased economy is taking shape, and progress now depends on the political will to incentivise action and support the concerted expansion of SFM worldwide.

The following actions provide starting points for governments to enable, encourage and support SFM in production forests. Successful implementation requires drawing on globally recognised best practices while tailoring approaches to local capacities, ecological conditions and socio-economic contexts.

Action pathways

Key challenge	Policy pathway	Enabling strategies
Fragmented legal frameworks, weak enforcement, and insecure tenure Siloed policymaking disconnects forestry from agriculture, infrastructure, and urban planning, driving degradation and deforestation. IPLCs often lack secure tenure and recognition, excluding them from decision-making.	**Establish legal and policy foundations with enforcement**	**Integrate SFM in National Development and Climate Strategies** such as Nationally Determined Contributions (NDCs), National Biodiversity Strategies and Action Plans (NBSAPs), and national forest programs. **Embed forestry in cross-sectoral planning:** Position SFM within agriculture, infrastructure, water, and energy strategies; foster inter-ministerial dialogue. **Promote multi-objective forest management plans:** Balance ecological, economic, and social goals with legal frameworks, government backing, and accountability mechanisms. **Secure land tenure and recognise IPLC rights:** Provide clear tenure rights, harmonise legal frameworks, and strengthen enforcement. **Institutionalise participatory planning:** Ensure inclusive governance through co-design and co-management with communities, smallholders, local and marginalised groups.
Chronic underfunding of SFM Financial flows driving deforestation outweigh green finance. Ecosystem services such as carbon sequestration and biodiversity remain undervalued, leaving communities and managers without viable long-term incentives.	**Enabling forest-positive finance**	**Mobilise innovative forest finance mechanisms:** Forest bonds, blended finance, national forest funds, carbon markets, and debt-for-nature swaps to monetise ecosystem services. **Align with strategic funding partners:** Engage insurers, water utilities, and other stakeholders exposed to forest-related risks to co-invest in SFM. **Leverage catalytic philanthropy:** Deploy philanthropic capital to support policy reform, capacity building, monitoring, and early-stage project development, de-risking private investment.

Action pathways

Key challenge	Policy pathway	Enabling strategies
Capacity and skills gaps hinder SFM. Many regions lack trained forestry professionals, technical expertise, and access to modern silvicultural and monitoring tools.	**Scaling capacity building, technical support, and innovation**	**Expand training, innovation, and technical support for SFM:** Strengthen forestry education and vocational training. Provide technical support and extension services. Promote innovation grounded in local contexts, traditional knowledge, and community needs. Deploy modern tools (digital monitoring, carbon assessment, ecosystem-based management) to improve effectiveness.
Gaps in monitoring, verification, and carbon accounting undermine climate credibility. Adoption of traceability and certification is inconsistent, real-time monitoring tools are underused, and carbon accounting remains fragmented and non-standardised.	**Supporting measurement, reporting, and verification systems**	**Strengthen traceability, certification, and carbon accounting for climate credibility:** Scale up adoption and enforcement of traceability and certification systems across jurisdictions. Develop and deploy user-friendly, standardised tools for forest carbon accounting. Ensure procurement systems answer three fundamental questions: Where did the wood come from? (traceability); Was the forest sustainably managed? (certification); Does the forest maintain/increase carbon stocks? (carbon accounting).
Weak domestic demand for certified wood, and limited consumer awareness of ecosystem services and sustainability.	**Developing markets and increasing consumer awareness**	**Prioritise certified wood in public procurement:** Require public construction and infrastructure projects to source wood from sustainably managed forests. **Educate consumers on ecosystem services and sustainability:** Launch awareness campaigns to highlight the climate, biodiversity, and cultural benefits of forests, and build trust in certification as a guarantee of responsible sourcing.

Phased Strategy for Scaling SFM

Step 1
Establish the policy environment
Create and/or understand the enabling policy framework for SFM. Clarifying where spatial land-use priorities may conflict—for example, balancing food security with reforestation objectives—and ensuring that forest departments have the mandate, resources, and authority to implement and enforce SFM.

Step 2
Minimise waste and losses in harvesting and processing
Reduce material losses across the value chain. This can be achieved by promoting reduced-impact logging, upgrading transport systems, and improving sawmilling efficiency. Such measures increase resource-use efficiency while lowering environmental impacts.

Step 3
Improve productivity within existing FMUs
Sustainable productivity gains should be sought within existing FMUs before considering expansion. Enhancing silvicultural practices and applying adaptive management can increase output while safeguarding biodiversity, carbon storage, and other ecological functions.

Step 4
Invest in forest data and inventories
Robust, species-level forest data and inventories are essential to identify which forest areas can be sustainably managed as FMUs. Investing in reliable data improves planning, supports enforcement, and strengthens transparency in forest governance.

Step 5
Explore new FMUs
Expansion should only be pursued once existing FMUs are managed effectively and sustainably. New FMUs should be established primarily in degraded or secondary forests, where restoration-based management can generate ecological recovery alongside socio-economic benefits. Any expansion must be integrated into national spatial planning frameworks to ensure alignment with other land-use priorities.

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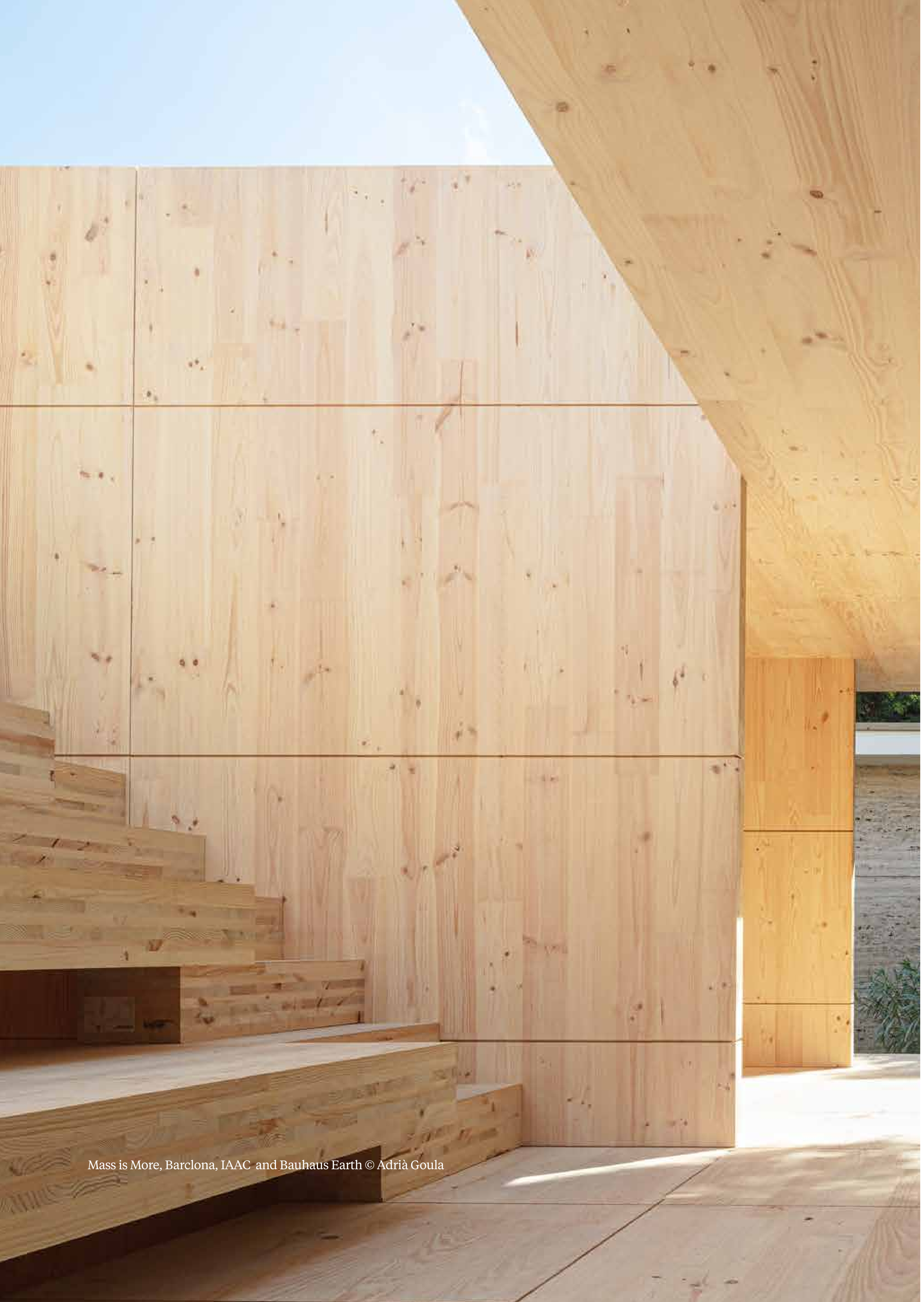

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Chapter 4

Leveraging Wood Construction for Long-Term Carbon Storage: Insights from the EU

A reflection on Principle 4:
Maximising the carbon storage potential of wood

"Wood is harvested efficiently to minimise waste and its carbon storage value is maximised by prioritising and incentivising its use for durable products such as buildings. The circularity of wood used for buildings is promoted, including design for disassembly to facilitate re-use and subsequent cascading of timber components in successive buildings to maximise the material's lifespan"

Lead Author:
Prof Dr Matti Kuittinen, Aalto University, Finland

Chapter Overview

Due to hard-to-abate industrial emissions, new ways of removing and storing CO_2 are urgently needed. *Chapter 4*, authored by Prof. Dr. Matti Kuittinen, underscores the need to harness wood's potential as a durable carbon-storage reservoir within the built environment. Storing carbon in buildings offers an inexpensive, low-risk and readily deployable means of addressing growing global housing needs. The chapter argues that while rapid emissions reduction remains the primary goal, storing carbon in long-lived buildings is a practical and cost-effective complement—one that can also address global housing needs.

The chapter explores the potential of wood as a biogenic carbon store, highlighting examples from the European Union to demonstrate just how much carbon can be locked away in wooden buildings when they are designed and maintained for long service lives.

Fragmented policy frameworks, inconsistent reporting of biogenic carbon, limited recognition of storage benefits, premature demolition, and the absence of standardised certification frameworks hinder progress. The temporary nature of biobased carbon storage also underscores the need for long service lives, reuse, and cascading use.

The chapter calls for integrating carbon-storage targets alongside emission limits in building codes and national climate policies. It proposes mandatory reporting of biogenic carbon in EPDs, zoning policies for urban carbon sinks, and public procurement criteria that reward long-term carbon storage. It also advocates for DfD and circular construction principles to extend material lifetimes. To unlock these opportunities, the report recommends aligning regulations such as the European Union's EPBD, CRCF and CPR,

cross-sectoral coordination between forestry and construction ministries, data systems to monitor carbon stocks, certification schemes to verify storage and

green public procurement in parallel with regulation to accelerate new approaches in the building sector. Finland's introduction of a "carbon handprint" in building declarations is highlighted as an example of policy innovation.

The chapter frames wood-based construction as both a climate solution and a policy opportunity, urging governments to combine regulation, innovation, and data transparency to make carbon storage an integral part of national decarbonisation strategies. The key focus of this chapter remains on carbon storage, while the importance of minimising wood waste and maximising the cascading use of timber products until end of life must also be acknowledged.

Note: In this chapter, carbon storage is quantified as the corresponding amount of CO_2, although only carbon atoms are stored in woody biomass. This reporting approach eases comparison with GHG emissions expressed as CO_2 equivalents (CO2e).

Introduction: Unleashing the carbon storage potential of wood construction

The imperative of removing carbon from the atmosphere

Carbon storage should never be used as an excuse for, or an alternative to, emission reductions. Cutting GHG emissions remains the most cost-effective way to mitigate climate change. Yet global emission reductions are proceeding too slowly, and atmospheric GHG concentrations continue to rise (IPCC, 2021a). To keep warming well below 2°C, significant, additional efforts to remove CO_2 from the atmosphere are now required alongside deep emission cuts (IPCC, 2022a, 2022b).

Carbon dioxide poses a long-term risk because a substantial fraction of it persists in the climate system for centuries to millennia. Even if all emissions ceased today, elevated atmospheric CO_2 would continue to drive warming for many centuries (IPCC, 2021a; Archer et al., 2021). This committed warming increases the risk of crossing climatic tipping elements, beyond which impacts may accelerate and become more difficult to manage (McKay et al., 2022a).

What is carbon removal?

Carbon removal refers to taking CO_2 from the atmosphere – or from industrial point sources – and storing the carbon in durable reservoirs. A carbon "sink" is the process that causes net removal; "storage" is the reservoir that holds the carbon. Natural sinks include the land biosphere and the oceans (via photosynthesis and geochemical processes such as weathering), while technological approaches include afforestation, reforestation, biochar, enhanced weathering, direct-air carbon capture and storage (DACCS), bioenergy with carbon capture and storage (BECCS), ocean alkalinity enhancement, and long-lived wood use in construction (IPCC, 2022b; Smith et al., 2023; Smith et al., 2016).

Other GHGs can also be targeted. Methane (CH_4), for example, has a much higher warming impact per unit mass than CO_2 over relevant timeframes (IPCC, 2021a). Some emerging approaches seek to convert methane to CO_2 or accelerate its oxidation, thereby lowering near term warming and potentially easing removal. However, such methods are currently costly, technically challenging, and not yet deployable at scale; consequently, most near term attention is on CO_2 removal and durable storage (IPCC, 2022b; Minx et al., 2018).

The urgency partly reflects the persistence of hard to abate emissions in sectors such as cement, steel, aluminium and plastics. Even with strong efficiency gains and electrification, these sectors are expected to emit between 500 and 900 $GtCO_2e$ through mid-century under current policies (IPCC, 2022a; Material Economics, 2018). As the remaining carbon budget compatible with 1.5 °C has rapidly diminished, and the 1 100 $GtCO_2e$ budget for a 2°C pathway is also shrinking, scalable and responsible carbon removal is increasingly necessary in the construction sector, to complement rapid mitigation (IPCC, 2021a, 2022a).

Carbon removal carries risks, including moral hazard (for example, signals that continued pollution is acceptable), as well as environmental and social trade-offs depending on method and location. Policy must therefore embed CDR within a mitigation-first framework. Such a framework should be accompanied by robust standards for durability, monitoring, reporting and verification (MRV), LCA, environmental safeguards and equity considerations (IPCC, 2022b; Smith et al., 2023; Minx et al., 201. At the same time, additional warming increases the likelihood of feedbacks such as permafrost-carbon release, including widely discussed hazards such as large-scale destabilisation of deep-sea methane hydrates (Schuur et al., 2015; Ruppel & Kessler, 2017). These prospects reinforce the case for deploying proven mitigation and carefully governed carbon removal now.

Achieving climate goals requires accelerating emission reductions while establishing responsible, durable CO_2 removal at meaningful scale. Strategic policy support – for research, standards, MRV, cascading use of wood, and integration into long term decarbonisation plans – can help ensure that carbon removal complements, rather than displaces, aggressive mitigation (IPCC, 2022a, 2022b; Smith et al., 2023).

More buildings = more emissions or more carbon storage?

As the global population grows and urbanisation continues, demand for new construction will increase. Analyses project very large additions to the global housing stock – by 2100 we may need to build two billion new homes (Smith, 2018), in addition to renovating a significant share of the existing building stock.

If global construction needs are met using conventional methods and materials, cumulative GHG emissions would increase substantially, heightening the risk of crossing climate tipping points (McKay et al., 2022b). Without changes in practice, rising construction demand will drive higher GHG emissions, undermining efforts to keep warming well below 2°C (IPCC, 2022a). Material choice strongly influences both embodied emissions and the mass of materials required to meet societal needs. Lower density materials such as engineered timber can deliver structural performance at lower mass, whereas dense materials such as concrete and clay brick typically require greater mass per unit of functional output (for example, floor area), with consequential impacts on life-cycle emissions (Churkina et al., 2020; Harbert et al., 2020). At regional scale, the built environment is dominated by mineral-based materials by mass. Analyses show concrete, aggregates and masonry comprise the bulk of material stocks with wood a comparatively small share, although percentages vary by country and building type (Miatto et al., 2017). Currently, in the European construction sector, concrete makes up more than 72 per cent of construction materials by mass, whereas the share of wood is less than one per cent (Circular Buildings Coalition, 2024).

Conversely, growing demand can be harnessed to accelerate innovations and business models that reduce embodied emissions and store carbon in long-lived building products particularly through wider use of sustainably sourced, long-lived wood products that ideally would follow the principles of the circular economy (*see Chapter 1*) (Churkina et al., 2020; De Wolf et al., 2017; Pomponi & Moncaster, 2017; Allwood et al., 2012). To safeguard and extend the valuable storage of biogenic carbon, wooden building components should be designed for multiple life cycles. Enablers for multi-cycle use include design for disassembly, standardised joints and connections, modularity and thorough documentation (Piccardo & Hughes, 2022). Pursued alongside strong reductions in operational and embodied emissions (*see Chapter 2*), such strategies can help align the construction ecosystem with climate goals.

Cleaning the atmosphere is costly

Today and in the foreseeable future, natural sinks and storages remain more practical than complex, capital intensive technological alternatives in which CO_2 is captured directly from air or industrial processes. A key challenge for technological carbon capture from ambient air is dilution: atmospheric CO_2 averaged roughly 427–431 ppm in monthly values during 2025, meaning that CO_2 constitutes about 0.043% of air by volume – approximately one CO_2 molecule per 2,300 air molecules (NOAA, 2025). While capture from point sources (for example, industrial flue gas) benefits from higher CO_2 concentrations, any separation process requires energy, materials, maintenance and capital, which remain expensive (McQueen et al., 2021). Although technologies are improving, ambient-air dilution and system-wide energy requirements limit efficiency and complicate large-scale deployment. Moreover, capture, transport and storage infrastructures entail embodied emissions and environmental footprints that must be managed.

Photosynthesis provides a foundational ecosystem service for carbon dioxide removal (CDR), and elevated CO_2 can stimulate plant growth. However, responses are constrained by nutrients, water, temperature and ecosystem dynamics, and such CO_2 fertilisation does not offset anthropogenic emissions (IPCC, 2021a, see sections on CO2 fertilisation and ecosystem limits). Warming also affects terrestrial carbon stocks: a large share of forest carbon is held in soils, where microbial decomposition accelerates with higher temperatures, releasing CO_2. Furthermore, climate-related disturbances such as drought and wildfire increase plant mortality and reduce photosynthetic capacity (Crowther et al., 2016; IPCC, 2021c).

The costs of atmospheric GHG removal vary widely across approaches. Biological processes (for example, plant growth, algae) and geochemical pathways (for example, carbonate formation through weathering) remove carbon without direct financial outlays, though their rates, durability and land-use impacts require careful governance (IPCC, 2022c). By contrast, engineered CDR remains expensive: direct-air capture (DAC) currently costs in the range of 200–1,000 USD per tonne CO_2, while bioenergy with carbon capture and storage (BECCS) or industrial point-source capture can be somewhat lower due to higher CO_2 concentrations and process efficiencies (Smith et al., 2023; Rubin et al., 2015). Achieving net-zero and stabilisation goals will require substantial investment in carbon-capture, utilisation and storage (CCUS) systems. The International Energy Agency estimates annual funding in the order of hundreds of billions of US dollars by 2030 to develop and deploy CCUS at the scale implied by net-zero pathways (IEA, 2023a).

The potential of wood as a biobased carbon storage

Building products offer a major opportunity for carbon storage. Several assessments indicate that construction materials and practices could contribute materially to CDR, with multi-gigatonne potential under ambitious yet plausible deployment scenarios, though exact figures depend on method, durability and governance (IPCC, 2022b; Smith et al., 2023). Pathways to store carbon in the built environment include the wider use of biobased materials, urban green infrastructure, enhanced weathering of minerals in soils, biochar, carbonation of cementitious materials (passive and accelerated), direct-air capture (DAC) integrated into building systems, artificial photosynthesis, carbon-cured concrete and CO_2-based plastics, each with distinct potentials and constraints (see Figure 1, *Options for storing carbon in the built environment and their current maturities*) (Kuittinen et al., 2021; Woolf et al., 2010; Beerling et al., 2020; Xi et al., 2016; Aresta et al., 2013; Keith et al., 2018; Li et al., 2022). Among these pathways, biobased construction materials and biochar currently offer the strongest CO_2-reduction potential and the most direct applicability to buildings (Kuuttinen et al., 2021).

Climate potential in the built environment / Current applicability to construction	Low	Medium	High
High	• Emerging biobased composites	• Biobased composites • Vernacular biobased materials	• Wood, bamboo and straw for construction • Biochar for landscaping
Medium	• Enhancing weathering in urban soils and landscaping	• CO2-cured concrete • Air-conditioning with DAC in offices	• Carbonation of concrete rubble or unsealed cement-based products • Urban soils • Urban trees
Low	• Living building materials • Capturing carbon from municipal bio-waste energy plants • Enhanced or artificial photosynthesis	• CO2-based plastics • Biochar for asphalt and concrete • Air-conditioning with DAC in shops and residential buildings	• Carbonation of concrete structures • Urban lawns and herbaceous plants • Biobased plastics

Figure 1: Different options for storing carbon into the built environment and their current maturities (Kuittinen, et al. 2021).

Quantifying the biogenic carbon content of construction products can be achieved using established methods (see Figure 2, *Calculating the biogenic carbon content stored in a product*). In wood products, roughly half of the dry mass of typical lignocellulosic materials is carbon fixed through photosynthesis. Empirical measurements for common wood species average about 47–55 per cent carbon by dry mass (IPCC, 2006; Lamlom & Savidge, 2003). Thus, approximately half the product's dry biobased mass represents biogenic carbon stored for as long as the product remains intact and does not decompose, burn or otherwise oxidise.

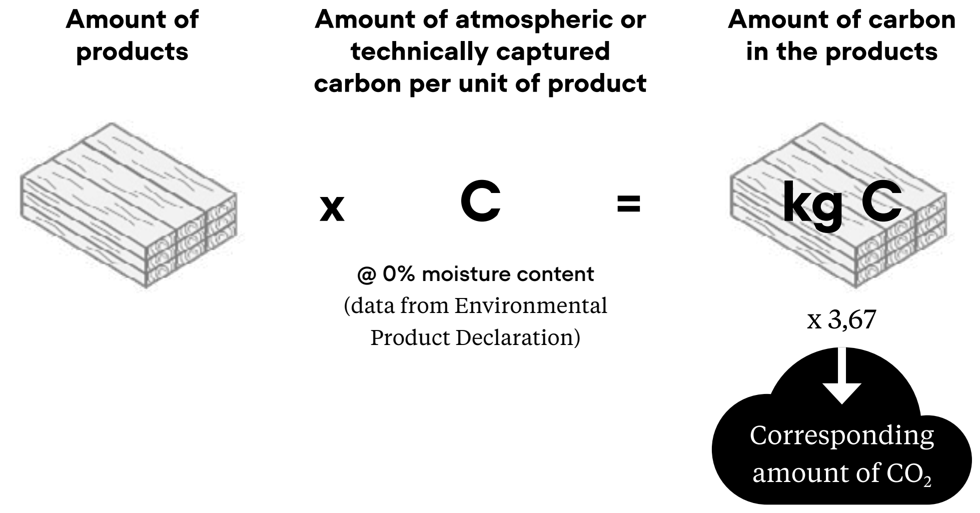

Figure 2: Calculating the biogenic carbon content stored in a product (Diagram by Matti Kuittinen).

The carbon content of biobased construction materials varies widely (see Figure 3, *Share of carbon in different biobased materials used in construction*). Depending on the plant, this can exceed 60 per cent (for example, bamboo or cork) or remain closer to 40 per cent (for example, straw or cotton). This carbon stays locked in the biomass until decomposition or combustion occurs. In the latter case, capture from exhaust gases is technically possible through bioenergy with carbon capture and storage (BECCS).

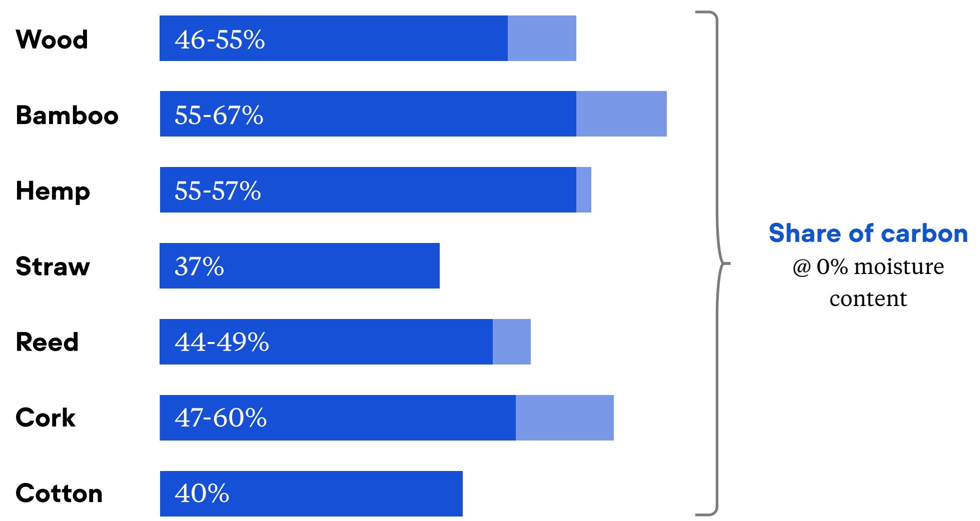

Figure 3: Share of carbon in different biobased materials that can be used in construction (Häkkinen, 2020).

The potential of wood as a biobased carbon store has been well documented. On average, wood-framed buildings can store around 100–300 kg CO_2 per square metre of floor area, depending on product mix, design life and accounting boundaries (Vares, Häkkinen & Vainio, 2017; Hafner & Schäfer, 2018). The largest storages occur in buildings that use massive-wood systems such as cross-laminated timber (CLT) or logs. Biogenic carbon storage can also be achieved in concrete, masonry or steel structures by incorporating biobased insulation, boards, trusses, cladding and other components containing biogenic carbon (Kinnunen et al., 2022).

Globally, constructing new residential buildings from timber could yield carbon storages between 0.04 and 2.5 Gt CO2 per year, depending on the share of new construction that is timber-based. Over 30 years, cumulative storage could range from roughly 7 to a theoretical maximum of 60 Gt CO2, increasing urban carbon pools by about 25–170 per cent across scenarios (Churkina et al., 2020). To safeguard forest health and biodiversity, harvesting should remain below sustainable thresholds (for example, less than 70 per cent of annual growth increment). In regions where forest management is constrained, fast-growing biomaterials such as bamboo, straw or hemp provide complementary options (Pomponi et al., 2020).

A review of scientific literature finds that the most prominent methods for carbon capture and storage in residential areas include carbon uptake into vegetation and soils, and wood construction. Other methods, such as green roofs, biochar or other biobased building products, currently have smaller evidence bases or more limited potentials (Kinnunen et al., 2022).

Given their inherent storage potential and renewability, biobased construction materials can help address three linked challenges: meeting growing construction demand, reducing embodied emissions, and providing durable carbon storage in long-lived products and structures. When deployed with appropriate design and end-of-life strategies, sustainably sourced biobased materials and biochar offer comparatively near-term, scalable storage opportunities, provided deployment respects limits related to land, biodiversity, water and social safeguards.

The carbon storage potential of timber buildings in cities

Evidence from Europe illustrates the substantial potential of timber construction to store carbon over the long term, with measurable impacts at both building and city scales.

In Munich, Germany, the carbon stored in 566 timber-built flats equals more than 12500 tonnes of CO2 (Hafner et al., 2020).

In Helsinki, Finland, analyses show that in some districts the carbon stored in wooden buildings can exceed nearby forest carbon stocks; in optimal cases, the storage of wooden buildings equals up to 170 tonnes CO2 more per hectare than forested areas. This finding does not justify unnecessary logging or land-use change and must be interpreted under strict sustainability safeguards (Talvitie et al., 2023).

In Switzerland, annual carbon storage in the building stock by 2050 could reach 2.5 Mt CO_2 if wood is widely used in new construction and renovation, almost matching corresponding emissions from these activities. By 2050, cumulative biogenic carbon storage could reach 300 Mt CO_2 and exceed 400 Mt CO_2 if demolition is avoided through life-extension measures (Priore et al., 2025).

4.1. Best practice: The Black and White Building, Waugh Thistleton Architects. London, UK, 2022


© Geoff Major

London's tallest engineered timber office building, a seven-storey, 4,480 m² workplace. It combines laminated veneer lumber and cross-laminated timber, delivering open, flexible floorplates.

The project highlights mass timber's capability for commercial offices. With 80% fewer deliveries and a six-month faster build than concrete, it reduced urban disruption while creating adaptable, light-filled spaces that enhance wellbeing.

The structure uses 1,330 m³ of FSC/PEFC-certified timber from Germany, Austria, and storm-felled US tulipwood. Prefabricated, barcoded components minimised waste, with 95% designed for reuse or recycling. Delivering 37% lower embodied carbon than concrete and storing 231 $kgCO_2e/m^2$ biogenic carbon, the building has created a new global standard for circular urban timber design.

For further information:
BbN Prize, 2025 ↗

Timber structure designed for disassembly, The Black and White Building by Waugh Thistleton architects
© Andy Stagg

Key challenges and opportunities

Policies for supporting carbon storages in the built environment

Challenge:

Fragmented and missing policies

Wood construction is affected by policy domains spanning forestry, construction, the bioeconomy and industrial regulation. As a result, regulatory incentives are often dispersed or misaligned, producing uneven outcomes across jurisdictions and value chains. For example, relevant EU frameworks include the recast EPBD, the Union CRCF, the EU Forest Strategy, the EU Bioeconomy Strategy and land-sector climate rules (LULUCF). These frameworks interact but are administered by different bodies and instruments (Directive (EU) 2024/..., 2024; Regulation (EU) 2024/..., 2024; European Commission, 2021, 2018; Regulation (EU) 2018/841, amended by Regulation (EU) 2023/839).

Policies that directly address carbon storage remain rare. However, following the IPCC call for developing novel CO_2 removals at scale, such initiatives are increasingly needed. This is particularly relevant in countries where construction demand is high, such as in the Asia-Pacific region, Africa and South America. Reconstruction efforts after wars or natural disasters also provide opportunities to improve living standards while increasing carbon storage.

Opportunity

Sectoral legislation for carbon storage

Given the potential of biobased carbon storage, policy incentives are needed to accelerate the use of biogenic materials in buildings. Challenges such as fragmented policy frameworks and incomplete or inconsistent reporting of biogenic carbon in product declarations must be addressed, and frameworks for identifying optimal carbon-storage options established (*see Chapter 2*).

In the built environment, there are several opportunities for developing legislation for addressing carbon storages:

- Design of buildings and infrastructure
- Construction works
- Production of building products
- Maintenance of buildings and infrastructure
- Public procurement of the activities listed above,
- Green financing or insurance
- Cross-sectoral climate policies that would require sector-specific quotas for reduction of GHG emissions and increase of GHG removals

Although developing cross-sectoral legislation is demanding, it can effectively prevent burden-shifting between sectors of society.

4.2. Best Practice: Hasletre, Oslotre Architects. Oslo, Norway


© Oslotre Architecture & Construction Technology • Oslotre

The new headquarters for Save the Children Norway is found in Hasletre, a 2,772 m², four-storey office building built entirely built from timber, and the world's first demountable and fully reusable mass-timber office.

CLT and glulam form the structure, with prefabrication cutting assembly time by 75%. Dry timber-to-timber joints eliminate glues, silicones, and most steel, enabling disassembly and reuse. Reused interior elements and salvaged equipment enhance circularity. With 60% lower emissions than traditional offices and a design-for-disassembly model, HasleTre defines a global model for circularity in timber architecture.

For further information:
BbN Prize, 2025 ↗

4.3. Best practice: Examples of evolving policies

In the European Union, two key frameworks are increasing demand for reporting GHG removals: the EPBD and the CRCF (Directive (EU) 2024/..., 2024; Regulation (EU) 2024/..., 2024).

The revised EPBD introduces a requirement for new buildings to declare whole-life-cycle GHG emissions using a standardised life-cycle-assessment methodology. It also specifies that Member States "shall address carbon removals associated with carbon storage in or on buildings," guiding the inclusion of biogenic-carbon accounting in building assessments (Directive (EU) 2024/..., 2024). Technical guidance for reporting biogenic carbon in construction products is provided in European standard EN 15804, which sets rules for compiling EPDs and defines product-category rules for life-cycle-assessment reporting (CEN, 2019). As a result, EU Member States will need to address carbon storage in buildings from 2028 onwards under the EPBD framework (Directive (EU) 2024/..., 2024).

The CRCF establishes a legal framework for certifying carbon removals and storage across multiple sectors, including agriculture, forestry and construction. Wood-based building products and harvested-wood products are key areas of focus. Rather than setting mandatory quotas, the CRCF defines principles and requirements for robust monitoring, reporting and verification, additionality, sustainability and long-term storage, thereby enabling market development for certified removals and storage.

In addition, the proposed recast of the CPR lays down common rules for declaring product environmental performance, including carbon-related information, in harmonised product standards and EPDs. The recast aims to harmonise reporting of GHG emissions and carbon storage across the single market, improving comparability and transparency (European Commission, 2022).

Need for novel carbon storage

Challenge

Removing massive amounts of CO_2

The IPCC concludes that CDR is required in addition to deep emissions mitigation to achieve net-zero and temperature-stabilisation goals (IPCC, 2022d). To support the 40 Gt CO_2 of emission reduction needed by 2060, the IPCC calls for around 8 Gt of new removals by mid-century, delivered through a portfolio of approaches with differing costs, risks and co-benefits (IPCC, 2022d, 2022e).

The scale-up challenge is particularly evident for carbon capture, utilisation and storage (CCUS). In net-zero-aligned pathways, the IEA projects CO_2 capture rising to approximately 1.2 Gt per year by 2030 and about 6 Gt per year by 2050, with geological storage providing most permanent abatement (IEA, 2023b). Current project pipelines and financing fall short of these levels, underscoring a delivery gap that demands stronger policy, investment and infrastructure development (IEA, 2023b; IEA, 2024). Moreover, real-world performance at several large projects has been below design expectations, revealing technical and operational issues that must be addressed. For example, early operation at the Gorgon CCS project in Western Australia captured significantly less CO_2 than planned because of injection-system problems and regulatory constraints (Government of Western Australia, Department of Mines, Industry Regulation and Safety, 2021–2023; Leeson et al., 2017).

Opportunity

Storing carbon into the built environment

Part of the required new removals can come from land-based sinks, but a substantial share must rely on other durable options. Embedding biologically or technically captured carbon in long-lived buildings and infrastructure can contribute to CDR when supported by robust sustainability safeguards and end-of-life management (Beerling et al., 2020). While CCUS is likely to remain part of the overall climate solution, complementary, effective and cost-efficient CDR pathways, including long-lived wood use, biochar with durable sequestration and mineralisation routes, need accelerated development and deployment alongside demand reduction and rapid emissions cuts (Woolf et al., 2010; IPCC, 2022d, 2022e).

Safeguarding carbon storages

Challenge

Premature demolition

The built environment already contains significant amounts of biogenic carbon (*see Chapter 1*). Although exact figures are uncertain, it is vital to maintain this stock and to accumulate additional carbon in new and renovated buildings. Where possible, demolition should be postponed.

Obsolescence is the usual cause of demolition. A building may become obsolete for technical, physical, functional, legal, economic or stylistic reasons. Unless protected as heritage, few buildings are covered by policies that prohibit demolition. However, architects and engineers have recently published “demolition maps” identifying demolished or threatened structures (Architects Climate Action Network, 2025). When buildings are demolished, stored carbon is lost if biobased products are not reused or recycled.

Challenge

The temporary nature of biobased carbon storage

Biobased building products offer only temporary carbon storage. Over time, their carbon content is likely to return to the atmosphere through energy recovery, incineration or decomposition. Even when the delay between carbon uptake during photosynthesis and its release exceeds the regrowth period of harvested forests, this merely buys time for mitigation efforts. Maximising the duration of biogenic carbon storage therefore remains important.

When a building is eventually demolished, both the invested capital and embodied emissions are lost. Even a structure that endures for 200 years – an uncommon exception – has a lifetime shorter than the atmospheric lifetime of the GHG emissions released during product manufacture. From a mitigation perspective, the amortisation period of embodied emissions should ideally be far longer, though this is rarely achieved because of various forms of obsolescence.

Challenge

Burning or landfilling of biobased building products

The carbon stored in biobased products should be safeguarded beyond a building’s first use. When such materials are removed during renovation or demolition, they are typically burnt. Even when this produces bioenergy, CO_2 – apart from the rare exception of BECCS – returns to the atmosphere, contributing to warming. The risk is higher where landfilling of organic matter is allowed: in anaerobic conditions, biobased materials decompose to methane, which has a much higher global-warming potential than CO_2.

Opportunity

Designing for multiple lifecycles

Designing for reuse and high-value recovery increases benefits after a building’s first life and lowers whole-life emissions when substitution effects are credible and verifiable. International standards such as EN 15804 provide clear rules for accounting benefits and burdens beyond the system boundary, including potential environmental gains when components are reused, recovered or recycled after end of life (CEN, 2019).

A multi-life-cycle approach is central to reducing the risk that carbon stored in biobased products is lost prematurely. Prioritising reuse over recycling, recovery or disposal, and advancing circular-economy policies that promote durability, reparability and reusability of construction products and assemblies, are key enablers. These principles are embedded in regulatory schemes such as the EU Waste Framework Directive (Directive 2008/98/EC, as amended; European Commission, 2020). Achieving practical reuse at scale requires conformity assessment, traceability and structural verification for reclaimed elements, supported by clear PCRs and EPD rules that document the performance history of reused components (CEN, 2019).

Designing buildings and components for reversibility – including disassembly, adaptability and reconfiguration – greatly improves the likelihood of multi-life use. International guidance such as ISO 20887 sets requirements for DfD and adaptability, enabling component recovery, remanufacturing and reuse through standardised interfaces, accessible fasteners and modular detailing (ISO, 2020; Durmisevic, 2019).

For wood and other biobased materials, reuse depends on robust grading and performance verification (for example, strength, stiffness, moisture content, durability and fire safety), contamination checks (for example, coatings and preservatives) and suitable connection systems that allow non-destructive removal. Planning for deconstruction at the design stage, protecting elements during use and maintaining material passports or digital twins to record provenance and properties can materially improve recovery yields and environmental performance across multiple life cycles (Pomponi & Moncaster, 2017; ISO, 2020; Durmisevic, 2019).

4.4. Best practice: Appelweg, Moos. Amsterdam, Netherlands, 2024

Appelweg is a four-storey, 3,186 m² residential complex delivering 63 modular social housing units for Ymere housing corporation. The project responds to the Dutch housing crisis by providing high-quality, affordable homes for students, refugees, and families. Conceived as “flex” housing with a 15-year initial use, its permanent-quality modules are fully reusable, ensuring long-term adaptability and minimal waste.

CLT forms the primary structure, paired with recycled brick, thermo-wood, and plastic façades. Prefabricated, demountable modules support relocation and closed-loop material cycles. With digital twins and material passports ensuring traceability, Appelweg locks carbon in timber, reduces emissions, creates local jobs, and establishes a practical blueprint for climate-positive housing.

For further information:
BbN Prize, 2025 ↗

Management of information

Challenge

Incomplete product data

Information on the amount of biogenic carbon stored in a construction product is often difficult to locate or compare across EPDs or databases. Although standard EN 15804 sets core rules for reporting biogenic carbon and whole-life modules, EPD-programme requirements and product-category rules vary, and some operators do not systematically require or harmonise the reporting of biogenic carbon (CEN, 2019; ISO, 2017, 2016). In addition, accounting conventions differ on whether biogenic carbon associated with packaging is reported, which can cause confusion unless clearly distinguished from product contents in module reporting (CEN, 2019) (*see Chapter 2*).

Opportunity

Carbon storage as mandatory product information

Existing standards already enable the documentation of biogenic carbon content in EPDs[8]. There are therefore no technical barriers for manufacturers to report the quantity of biogenic or technical carbon stored in their products. Procurers could also require such information for green public procurement purposes, and EPD-programme operators could make the reporting of carbon storage a mandatory element of their rules.

4.5. Best practise: Paradise building, Bywater, London, UK, 2025

London’s largest timber office is a six-storey, 7,694 m² building constructed using CLT floors and glulam beams on a hybrid frame. It pioneered fire safety with a comprehensive load-bearing test, establishing new levels of certainty for exposed timber offices. The building is fully demountable with bolted connections and removable fire boards for reuse. Prefabrication reduced waste and minimized disruption on the constrained urban site. In addition, the building stores 1,884 tonnes of CO_2.

For further information:
BbN Prize, 2025 ↗

8 Note: The climate implications of a product´s carbon storage (i.e., delayed emissions) are beyond the scope of EPDs.

Challenge

Missing data on building stock carbon storages

Maintaining existing biobased carbon storage in the built environment is important, yet there are no coordinated efforts to estimate its scale at global or national levels. As a result, policies that prevent demolition cannot easily be linked with those that extend or expand biogenic carbon storage in buildings.

Legal requirements for declaring the carbon footprint of construction products are emerging. In the EU, the recast CPR introduces harmonised rules for declaring product environmental performance, including carbon-related information, while the EPBD requires Member States to address carbon removals associated with storage in or on buildings and to declare whole-life GHG emissions for new construction (Directive (EU) 2024/..., 2024; European Commission, 2022). This creates a situation where carbon storage must be addressed at the building-stock level under the EPBD, but biogenic-carbon reporting at product level may remain voluntary or programme-specific under the EPD framework—potentially leading to inconsistencies if the two are not coordinated (CEN, 2019; Directive (EU) 2024/..., 2024; Regulation (EU) 2024/..., 2024).

Opportunity

Building-level carbon monitoring

Building-permission authorities and national statistical agencies could assume a central role in documenting and tracking carbon storage within the building stock. Most buildings already produce sufficiently detailed bills of quantities and are increasingly designed through BIM. As a result, biogenic-carbon storage may be estimated directly from each building's whole-life-carbon assessment.

Statistical information on prevalent construction materials by building age can also be compiled. When combined with registry data, such information offers an overview of the carbon held in the existing stock. Connecting attributes such as a building's age, use and principal materials can further indicate its likelihood of renovation or demolition. This insight supports regional strategies that encourage the reuse or recycling of biobased products, helping to prolong their biogenic-carbon storage.

4.6. Best practise: Carbon handprint in new Finnish legislation

In Finland, most new buildings will require a climate declaration consisting of two indicators: the carbon footprint and the carbon handprint. The footprint describes climate impacts over the building's life cycle, while the handprint represents the potential benefits that would not occur without the project.

The carbon handprint includes both biogenic and technical carbon storage, surplus renewable energy, and benefits from reuse, recycling and carbonation of cement-based products. Its calculation follows international and European standards. The aim is to provide designers and builders with an incentive and a harmonised method for achieving positive climate outcomes.

4.7. Best practise: Declaring carbon storages of buildings

The EU has enabled real-estate owners to declare the amount of removed or stored carbon in the building. This will be done through the Energy Performance Certificate, and principles for the declaration are based on the Energy Performance of Buildings Directive. Furthermore, EU member states are required to address carbon removals that are associated with carbon storage in or on buildings.

From principle to action: policies for enabling carbon storages and cascading uses

Achieving global climate goals depends on pairing rapid emission reductions with the responsible and durable removal of CO_2 at scale. Coordinated policy action, supporting research, standards, monitoring and the cascading use of wood within long-term decarbonisation strategies, will ensure that carbon removal strengthens rather than substitutes mitigation efforts. A range of policy instruments offers potential to scale carbon storage in the built environment and promote the cascading use of wood materials.

Set minimum levels for carbon storages in buildings

In addition to legally binding GHG limits for buildings, policies should address the complementary aspect of GHG removals. It is essential to set limits for operational and embodied emissions in new buildings while simultaneously establishing incentives or minimum thresholds for carbon storage. If GHG limits are already defined, as in the EU, declaring carbon storage would not add administrative burden.

The quantification of carbon storage is already integrated into LCA. Current tools and databases are sufficient for this purpose (*see Chapter 2*). In practice, the declaration of stored carbon would only require a bill of quantities, an existing practice for project costing, and the combination of product quantities with their carbon contents. The additional effort is therefore minimal.

Monitor the accumulation of carbon in the built environment

Building inspection authorities and statistical agencies are well positioned to document and track the accumulation of biogenic or technically captured carbon in the built environment. Such data can be obtained from building permission applications and registration records. Information on long-term changes in carbon stocks can also support timely renovation measures that maintain these storages.

Declare the carbon stored in products

To enable the construction value chain to design buildings with optimal carbon storage, product-level information is essential. Policymakers should establish requirements or incentives for manufacturers to declare the amount of biogenic or technically captured carbon in products. To avoid inconsistent reporting or greenwashing, clear guidance, ideally through recognised standards, is required. Complementary information, such as the technical service life of products under different conditions, would further support the development of solutions that maximise the duration of carbon storage in the built environment.

Zoning for carbon storages
Including carbon-storage objectives in city planning can complement building- and product-level policies. When new plans are prepared or existing ones updated, incentives or requirements for area-based carbon storage can be introduced. Comparing the organic carbon removed from a site before construction, such as forest clearing or soil removal, with the carbon stored in buildings and sequestered in vegetation after development can be an effective policy instrument for growing urban areas.

Prolonging carbon storage
Building policies should require designs that enable long service lives and facilitate disassembly. Extending service life can be achieved, for example, by mandating a minimum design life of 100 years for buildings with significant carbon storage. Design for disassembly can be required at the building-permission stage to ensure future recovery and reuse of components. Manufacturers should also be encouraged to implement take-back and remanufacturing systems, creating incentives and secondary markets for reused products and their embedded carbon.

A progressively lowering real-estate taxation scheme could discourage the demolition of carbon-containing buildings. In addition, compensation markets could recognise and reward long-term carbon storage in buildings.

Certification schemes for carbon storage in products and buildings
To level the playing field for city planners, designers and manufacturers, policymakers should develop science-based certification systems for verifying carbon storage in products and buildings. The CRCF policy scheme of the EU may serve as an example.

Public procurement for carbon storage
Green public procurement can accelerate new approaches in the building sector before, or in parallel with, regulation. Depending on context, procurers can establish incentives or requirements for biogenic or technically captured carbon storage in public projects. Incentives may include scoring tenders according to the amount of stored carbon, for example per unit of floor area or per year. Requirements can specify minimum storage amounts for the subject of procurement, such as a school building, or exclude tenders that fail to address carbon storage.

In all cases, project agreements should include clear reward and sanction clauses, and contracting entities should ensure compliance during execution. It should also be emphasised that overconsumption of wood or other materials for carbon-storage or circularity gains must be avoided.

Action pathways

Key challenge	Policy pathway	Enabling strategies
Urgent need for new ways of removing and storing CO_2	**Policies for carbon storage in buildings**	Set minimum levels for carbon storage in buildings Publish guidance for the quantification and a common reporting format
Incomplete data and information on carbon storage	**Monitor the accumulation of carbon in the built environment**	Require information on the carbon storage of the building as part of the building permission application Develop guidance for authorities for sorting, storing and following the data in a comparable process
Incomplete data and information on carbon storage	**Provide information on carbon storage in building products**	Declare the amount of biogenic or technically captured carbon in the products Include carbon storage as a mandatory of information in an EPD programme
Urgent need for new ways of removing and storing CO_2	**Policies for carbon storage in zoning**	Set minimum levels of carbon sinks and storage in city plans
Short building lifespans and prevailing demolition practices	**Prolong carbon storage**	Set incentives for avoiding demolition Require long design service lives for buildings that have high carbon storage Develop financial and tax incentives for maximising the duration of carbon storage Require buildings and products to be designed for disassembly and reuse Develop fluent product recognition processes for reused building products
Lack of standardised and credible certification frameworks	**Develop certification schemes for carbon storage in products and buildings**	Policymakers should develop clear, science-based certification schemes to enable the certification of carbon storages in products and buildings. The CRCF policy scheme of the EU may serve as an example.
Need for stable demand and market incentives for low-carbon and carbon-storing building products.	**Public procurement for carbon storage**	Include the amount of carbon storage as a comparison criterion to green public procurement of buildings Include carbon storage as a selection criterion to green public procurement of building products

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Chapter 5

Promoting a responsible timber building bioeconomy: learning from East Africa

A reflection on Principle 5: Promoting a responsible timber building bioeconomy

“Information, education and training is provided for stakeholders across the ‘forest to frame’ value chain on the benefits and practices of responsible timber use in construction. Innovation, research and development is supported and encouraged to enable a timber construction economy and wood culture to thrive.”

Lead Author:
Robyn van den Heuvel, Program Director, Climate Smart Forest Economy Programme (CSFEP)

Chapter Overview

A timber bioeconomy is not only about choosing a low-carbon material; it is about enabling a new development pathway, one that respects ecological limits, centres community agency, and reimagines how we design and build. The fifth Principle for Responsible Timber Construction challenges us to move beyond carbon accounting and narrow built-environment frameworks and to rethink how timber construction can reshape landscapes and economies.

Drawing on global perspectives and insights from East Africa and beyond, Robyn van den Heuvel examines in this chapter the components, challenges and potential of a regenerative timber-building bioeconomy. It highlights systemic challenges, including fragmented value chains, outdated building codes, under-developed manufacturing capacity and cultural bias against timber. It calls for policy interventions that fund regional coalitions, modernise governance, incentivise local innovation and ensure accountability beyond carbon metrics.

Successful models demonstrate the viability of locally adapted timber systems that reduce emissions by more than 70 per cent, create jobs and empower communities. However, scaling such systems requires co-ordinated investment, inclusive governance and a shift in narrative – from timber as a niche solution to timber as a mainstream development strategy.

Ultimately, a regenerative timber economy is not only about buildings but about transforming how we design, govern and relate to the natural systems on which we depend. For policymakers, this means aligning forest, housing and economic strategies to create value that is local, equitable and climate-positive.

Illustrative examples from East Africa showcase the opportunity for this as a regenerative solution. This represents a more immediate opportunity than in some areas in the Global North, where decades of reliance on concrete and steel have diminished timber expertise and shaped regulatory frameworks that unintentionally restrict the use of natural materials.

Introduction: beyond buildings to systems

Timber is re-emerging in global consciousness as a lever for climate mitigation and sustainable development. In a world racing to decarbonise, wood is increasingly recognised as a renewable material that reduces the embodied emissions of buildings, substitutes fossil-intensive resources and stores carbon for decades (UNEP, 2022). Life-cycle assessments indicate emission reductions of about 20–30 per cent at whole-building scale and more than 60 per cent for specific structural elements when timber replaces conventional materials of comparable performance (Myint et al., 2024; Abushama et al., 2025).

Yet timber is more than a material. It is part of living ecosystems, land-tenure systems, knowledge traditions and rural livelihoods. The transition to a timber-building bioeconomy must therefore move beyond lowering carbon to building a truly regenerative system. **A timber bioeconomy is not simply a low-carbon choice; it represents a new development pathway – one that respects ecological limits, centres community agency and reimagines how we design and build.**

The fifth *Principle for Responsible Timber Construction – Promoting a Timber Building Bioeconomy* – challenges stakeholders to look beyond carbon accounting and narrow built-environment frameworks to consider how timber construction can reshape landscapes and economies. This requires systemic change: a shift from linear, extractive models to circular, regenerative ones that prioritise people, forests and climate.

A timber bioeconomy connects land management, architectural expression, industrial policy and environmental justice. In doing so, it can transform not only buildings but also economies and relationships with forests.

> *“Right now, timber is still seen as an extractive commodity, not as part of a regenerative and responsible system. But if we shift the lens and position it as a tool, something that can drive dignity for communities, prosperity for businesses, and legacy for government, then we can fundamentally shift the narrative, unlock its full potential, and create systemic change.”*
>
> Nasra Nanda, CEO of Kenya Green Building Society and Chair of the World Green Building Council’s Africa Regional Network

Amid global climate commitments and net-zero targets, countries face growing pressure to identify credible decarbonisation pathways. The timber sector holds significant potential but is often misunderstood or treated too narrowly, limited to material substitution or reliant on global supply chains that undermine local value. This chapter promotes a more holistic vision of a timber-building bioeconomy, asking what is possible, what is at stake and what is needed for this transition to benefit forests, communities and the planet.

A well-designed timber economy can catalyse durable development outcomes across multiple domains:

Forest resilience
Responsible timber markets can provide direct economic incentives for SFM. In regions vulnerable to illegal logging or degradation, regulated timber markets can reverse incentives for deforestation. Forest revenue can fund ecosystem monitoring, reforestation and climate-adaptation measures – all critical under rising climate stress. Evidence from Nepal and Tanzania shows that forests under community-based management often outperform state or private forests on both biodiversity and carbon outcomes (Chhatre and Agrawal, 2009).

Livelihoods and equity
Globally, more than 880 million people depend on forests for some aspect of their livelihoods (World Bank, 2021). The timber value chain – from harvesting to processing to construction – can provide dignified employment, particularly in rural areas where formal jobs are scarce. Millions of livelihoods in sub-Saharan Africa depend on forest-based activities, from woodfuel to smallholder forestry (FAO, 2020). When paired with skills development and inclusive market mechanisms, timber can offer economic agency and resilience in underserved communities.

Affordable, climate-smart and resilient housing
Africa is projected to add nearly 950 million urban residents by 2050, underscoring the immense construction demand ahead (OECD/SWAC, 2020). If current building patterns persist, this will trigger surges in concrete and steel use – with associated emissions and waste. Biobased materials such as timber and bamboo can deliver affordable, thermally comfortable and structurally resilient homes. In East Africa, early-stage prototypes demonstrate that timber-framed structures can compete on cost with concrete-block buildings while providing superior insulation and easier expansion.

Drawing on global experience and grounded insights from East Africa and beyond, this chapter examines the components, challenges and opportunities of a regenerative timber-building bioeconomy. It identifies common misconceptions, outlines key pathways and highlights the risks of inadequate implementation. **Done responsibly, timber construction can power locally led, climate-smart development – but only if we move beyond business-as-usual and embrace an ambitious, inclusive and place-based vision.**

"It's not just about reducing impact — it's about increasing value. Every decision we make must add value to the local forest economy."

Felix Holland, Director and Principle Architect, Localworks

Current trends in research, policy and practice

A truly regenerative timber bioeconomy is more than simply constructing buildings from wood. It is a place-based, regenerative system that aligns decisions across forests, industry and the built environment, guided by principles that prioritise the health of forest ecosystems, the rights and livelihoods of local communities and the adaptive capacity of systems under a changing climate. When done well, this approach avoids the misconceptions in research, policy and practice that risk narrowing timber's potential to a story of material substitution.

Over the past decade, construction events and architectural magazines have often portrayed timber construction as a recent innovation emerging from the Global North. The projects showcased and the architects most visible often reflect a northern perspective – advanced engineered timber products, multi-storey buildings and high-profile "green" towers. The rise of engineered mass timber technologies such as CLT and glue-laminated timber (glulam), combined with climate urgency and a wave of demonstration projects during the 2010s, helped position timber as a climate solution for construction. These advances are important, but they do not represent the full picture. They overlook centuries of knowledge and craftsmanship in tropical timber use and biobased construction. Across South-East Asia, Latin America and Africa, communities have long used renewable materials to build climate-responsive structures. Frequently dismissed as "informal" or "traditional", these systems in fact embody sophisticated environmental intelligence and adaptive capacity refined over generations.

"We don't want to copy global best practices; we want to learn from them and adapt. The most interesting innovations come when you combine global insights with local experimentation. That's how we design timber systems that actually work in our climate, with our materials, for our people."

Prof Schalk Grobbelaar, Associate Professor and Chairperson of the York Timbers Chair in Wood Structural Engineering, University of Pretoria

A responsible timber bioeconomy is therefore not only about substituting materials with lower-carbon alternatives; it is about enabling a new development pathway – one that respects ecological limits, centres community agency and reimagines how we design and build. It connects land management, architectural expression, industrial policy and environmental justice. In doing so, it has the potential to transform not only buildings but also economies and the ways in which societies interact with forests.

It is "responsible" not just because it reduces potential harm, but because it:

1. **Puts forests first** – sourcing in ways that sustain biodiversity, support climate adaptation and ensure long-term forest health (*see Chapter 3*).
2. **Creates value across the whole tree** – building circular, optimised manufacturing with cascading value chains that maximise efficiency and minimise waste to ensure that every part of the tree goes into a long-life product.
3. **Is truly local** – rooted in the ecosystems, materials, labour and traditions of a specific place, ensuring that revenue flows to local actors.
4. **Builds equity** – by centering IPLCs, securing land rights and sharing economic benefits.
5. **Delivers for people** – through buildings that are affordable, appropriate, adaptable and maintainable over time.

"We are not just using timber to build buildings – we are using timber to build economies. If we do it right, then the entire supply chain becomes more sustainable and more local. If not, we just create new forms of extraction that look greener but are still harmful. For us, the idea is that sustainability should live at every node of the chain – from forest to site."

Caleb Brown, EcoPrefab Production Manager, Localworks

Ugandan Tree Growers Association partners outside Kampala, 2025
© BbN/ CSFEP

Put forests first

At the core of a responsible timber bioeconomy is a *forest-first logic* — meaning that sourcing decisions begin with the needs of the forest ecosystem, not the needs of the market. This includes protecting old-growth and primary forests, selecting species based on resilience and regeneration, and adapting harvesting practices to changing climatic and ecological conditions. In climate-vulnerable regions, this may mean prioritising species and forest systems that can withstand altered rainfall patterns, increased desertification, pests, pathogens or fire.

Too often, sustainability or responsibility in timber is equated solely with forest certification standards – such as the FSC or the PEFC. These schemes are essential, setting baseline requirements for legality, ecosystem protection and social safeguards. For those seeking to build sustainably, they are an important tool to prevent harm.

However, forest certification is only one instrument within a broader system. It was designed to strengthen existing value chains, not to transform them. Relying on certification alone risks oversimplifying complex governance realities and ecological contexts. Sourcing from certified forests should remain the goal, but where that is not possible, responsible alternatives can still deliver regenerative outcomes. Even where forest certification is achieved, stakeholders should look further – considering chain of custody, circularity, impacts on IPLCs and wider ecological benefits. Standards bodies such as FSC and PEFC are invaluable but should not become mere box-ticking parameters for procurement.

Beyond certification, organisations such as FSC can help shape a truly regenerative forest economy. Their multi-stakeholder platforms already convene diverse actors to define what good sustainability looks like. Expanding those deliberations could transform forest value chains, aligning them with the systems thinking required for a timber bioeconomy.

Whole-tree value chains

Many timber operations still waste significant portions of each harvested tree – discarding bark, branches and offcuts. A regenerative bioeconomy maximises the utility of all components by fostering diverse product streams: structural lumber, engineered wood, panels, biomass energy, compost inputs and artisanal goods. Such integration extends material life and reduces pressure on forests.

For instance, a tree felled for poles in Tanzania may generate offcuts compressed into particleboard, while sawdust fuels brick kilns. This integration enhances financial viability and deepens local value chains. As Felix Holland, Director at Localworks, says:

"We need to think beyond just timber buildings to timber-based value chains that are clean, circular, and rooted in the places they emerge from."

Truly local manufacturing

Timber construction is often portrayed as if it looks the same everywhere. Media coverage tends to feature high-rise timber towers in Global North cities – multi-storey buildings made from CLT and glue-laminated pillars. While these innovations are important, they represent only a fraction of global timber construction. In much of the Global South, timber is used in single-storey or low-rise buildings, often in hybrid systems combining wood with earth, stone or metal. In Kenya, for example, informal housing in peri-urban areas frequently uses eucalyptus poles with iron sheeting and earthen floors to remain functional, flexible and affordable.

Regions have their own distinct development pathways and construction is shaped by the preferences, resources and values of each society. Because these differ across contexts, the resulting building solutions will also differ. There is no universal model to replicate – not even modular or prefabricated systems suit every place. Instead, locations should develop solutions that respond to their specific climate, geography and community priorities.

Too often, timber production remains centralised and export-oriented. Regenerative timber economies, by contrast, promote decentralised, community-rooted processing infrastructure. This includes mobile sawmills, prefabrication workshops and biomaterial laboratories, which enable local actors to shape materials that meet local needs. Distributed manufacturing not only creates jobs and reduces transport emissions but also develops infrastructure that reflects cultural and environmental contexts. Within this, it is essential that value addition – and thus profit generation – occurs within the country rather than through raw-material export of roundwood.

CPS Africa, Fumba Town, 2025 © BbN/ CSFEP

5.1. Best practice: redesigning timber's role in African housing, OMT Architects:

© Volks.House

When a client in Zanzibar could not find an architect willing to build with timber, OMT Architects accepted the challenge – despite having no prior experience with the material. A decade later, the firm has become a regional leader in timber construction, using design to challenge perceptions and redefine urban housing in East Africa. Their breakthrough project, *Moyoni Homes*, introduced a compact two-storey timber design that reduced costs while improving liveability. Residents quickly favoured the timber units over concrete alternatives, citing comfort and better indoor climate. As Wekesa George from Studio OMT Architects explained: "The timber homes sold better because people didn't like the smell of drying concrete. It shifted perception." Since then, OMT has built more than 80 Moyoni units and expanded into affordable housing, balancing cost, safety and material performance. They use locally sawn pine for framing, CLT selectively for long spans, and adapt ground floors for fire and functional requirements. Their CheiChei apartments combine timber with concrete cores and ground-level commercial spaces, directly responding to local demand. Beyond individual buildings, OMT invests in systemic change – supporting local sawmills to grade timber, educating clients and embedding sustainability in design. "You can't just throw new materials into an old system," Wekesa George said. "You have to build the ecosystem as you go."

Further information:
BbN Prize, 2025 ↗

Building equity
A regenerative approach ensures that IPLCs are not merely participants but leaders in decision-making and, where possible, owners of land and enterprises. This involves strengthening tenure security, recognising customary governance, ensuring fair benefit-sharing and integrating traditional knowledge in forest management and building design. Studies show that forests managed by Indigenous Peoples with secure rights store more carbon and support higher biodiversity than those managed by state or corporate entities (Rights and Resources Initiative, 2020). Recognising regenerative forest economies as opportunities to restructure value chains also allows for greater local ownership and long-term wealth retention.

"Communities aren't just labour; they are co-owners in creating a green economy. Until people see themselves as co-designers in the process, it won't feel real. A responsible timber economy must speak in ways people understand – it's about dignity, heritage and shared prosperity. That's what makes it truly regenerative and locally grounded."

Nasra Nanda, CEO, Kenya Green Building Society, and Chair, World Green Building Council Africa Regional Network

5.3. Best practice: Easy Housing Concepts Uganda Ltd. Kampala, Uganda, 2024


© Easy Housing

A model for affordable, modular Sub-Saharan housing. It showcases low-cost sustainable housing for Sub-Saharan Africa. The project addresses housing shortages and climate resilience by providing affordable, modular, and self-sufficient homes. It benefits local communities by creating jobs, training carpenters, and building a domestic timber supply chain. Constructed from FSC-certified pine sourced from Ugandan plantations, the home uses modular timber frames, plywood walls, and screw-based assembly for full disassembly and reuse. Prefabrication reduces waste and land disturbance.

Further information:
BbN Prize, 2025 ↗

5.2. Best practice: Building community, not just buildings, Busibo teacher's village, Localworks


©Localworks

Across Uganda, rural schools struggle with high teacher turnover, partly due to a lack of safe, affordable housing near schools. In Lwengo District, this challenge prompted an integrated solution addressing not only housing but broader sustainability, resilience and local economic development.

Localworks, a Uganda-based design–build firm, created the Busibo and Namabaale Teachers' Villages – 52 dignified homes built using prefabricated timber systems sourced from local forests. The design prioritised comfort, durability and affordability while minimising environmental impact and strengthening forest-positive value chains.

The construction system combines light-frame timber structures with lime–sawdust bricks, corrugated-iron roofing and passive ventilation. These design choices draw on vernacular traditions, local materials and circular-economy practices – ensuring low energy use and easy maintenance. Timber is sourced from sustainably managed, small-scale growers.

The results speak for themselves. Preliminary assessments show 75 per cent reduction in total carbon emissions per unit compared to conventional housing, and 1.5 tonnes of carbon stored in each timber structure

In addition to reducing emissions, the project created jobs, transferred skills in modern timber construction and provided teachers with healthy, comfortable homes – improving retention and community integration. Localworks intentionally designed for replicability, demonstrating a scalable model that can be adapted across Uganda and beyond.

For further information:
BbN Prize, 2025 ↗

Delivering for people
Buildings must not only be sustainable; they must also be liveable, maintainable and affordable. Regenerative timber buildings are designed to adapt over time, be repaired with locally available tools and respond to changing family or climatic needs. This approach avoids the trap of expensive "green" buildings that exclude the very communities they aim to serve.

Key challenges and opportunities

Building a regenerative timber bioeconomy is a complex undertaking. It involves reshaping entire value chains that span forests, factories and construction sites, while navigating entrenched perceptions, policy silos and infrastructure gaps. The challenges are substantial: fragmented systems and incentives, weak or missing manufacturing capacity, outdated governance, cultural bias and the persistent risk of "green extraction". Added to these are the practical constraints of logistics and finance, making it clear that scaling timber construction is as much about redesigning systems as it is about designing buildings.

Yet within each challenge lies opportunity. Weak governance can become a platform for collaboration. Gaps in manufacturing can inspire investment in research, prototyping and innovation. Cultural stigma can shift towards market confidence once communities experience dignified timber buildings. Finance, often poorly aligned, can be redirected to the right actors at the right time. By reframing these challenges as entry points for transformation, it is possible to chart a pathway that expands the use of timber while regenerating forests, empowering communities and delivering climate-smart housing at scale.

From fragmentation to coalition

The challenge

A pervasive barrier to building a responsible timber bioeconomy is the misalignment of expectations across the system. Many governments, funders and investors still view timber construction as a straightforward material substitution – a technical fix that can be scaled quickly by replacing concrete with wood. Forestry actors, meanwhile, often regard timber primarily as an export commodity, valued for volume rather than regeneration or local use. These limited perspectives highlight the need for clearer alignment on goals, timelines, and responsibilities.

The result is fragmentation. Forest agencies may prioritise plantation expansion without considering market demand. Construction ministries might champion prototypes without ensuring supply-chain readiness. Donors may fund pilots too small or short-term to yield policy insights. In the absence of a shared theory of change, actors work at cross-purposes – one optimising for speed, another for ecological restoration, a third for foreign exchange. Each acts rationally within its own paradigm, but collectively these assumptions stall transformation.

Unlike other construction materials, timber supply chains are highly dependent on ecological and spatial conditions. Even in forest-rich regions, supply and demand frequently fail to align – a problem compounded by storms, wildfires or pest outbreaks. Such disruptions can flood markets with low-quality salvage wood, halt harvesting entirely or depress prices elsewhere, creating instability for producers. They expose the logistical complexity of timber systems: urban construction sites often lie far from production forests, and the journey from standing tree to building-ready product involves multiple stages – harvesting, drying, milling, manufacturing and storage – each with technical and temporal constraints. Without strong coordination, these steps become disjointed, inflating costs, delaying projects and reducing flexibility.

Another recurring challenge is the tendency to replicate success stories from Europe or North America without contextual adaptation. This creates unrealistic expectations about what "modern timber" should look like – industrial, engineered and technologically complex. In many parts of the Global South, such models are capital-intensive, inaccessible and disconnected from local building cultures and labour markets. Emerging countries have the opportunity to shape timber construction so it aligns with local building culture, budgets, and labour markets. With the result being place-specific pathways that reflect local ecosystems, social structures and housing needs, which have too often remained undervalued or underdeveloped.

A regenerative timber economy requires a fundamental shift in mindset: from quick wins to patient systems-building; from extraction to stewardship; from importing solutions to enabling local ingenuity. Without this shift, efforts will remain scattered, uncoordinated and fragile.

"Fragmentation isn't just a challenge — it's the reason we formed this coalition. If we want timber construction to deliver real, positive gains for people and forests, we need spaces where housing experts, forest managers, millers, and communities can plan and work together."

Bongiwe Shongwe, Program Manager, East Africa Biobased Construction Coalition

The Opportunity

Regenerative timber systems demand coordination across sectors and geographies. No single actor – whether a forestry department, housing ministry or private firm – can align forests and buildings alone. Systemic change requires durable, inclusive and empowered coalitions.

Recommendation

Support regional "forest-to-frame" coalitions that bring together IPLCs, urban planners, millers, financial institutions and land-use experts. These coalitions should co-develop national forest-product strategies and establish context-specific standards.

Lwengo ©Localworks

5.4. Best practice: The Biobased Construction East Africa Coalition

Launched in 2024, the Biobased Construction East Africa Coalition – managed by the CSFEP– brings together more than 25 public, private and civil-society actors across Kenya, Uganda and Tanzania. Members include tree-growing associations, urban planners, government agencies, architects and timber processors. Their shared goal is to enable a responsible timber-construction sector that builds thriving local businesses, creates jobs, reduces emissions and restores forest ecosystems.

Rather than promoting timber use in isolation, the coalition adopts a systems perspective, aligning land-use planning, industrial development, skills training and housing policy. Partners co-design national strategies and technical pathways for producing, processing and building with biobased materials in ways that are inclusive, circular and climate-aligned. The approach is deeply local, recognising that successful bioeconomies must be rooted in place – shaped by local materials, capacities and needs.

By building trust and shared ownership across the value chain, the coalition is turning fragmented initiatives into a coherent ecosystem – one capable of stewarding forests while meeting the region's growing demand for dignified, climate-smart housing. It represents an emerging model of collaborative governance with lessons that extend well beyond East Africa.

Further information:
Biobased Construction East Africa Coalition ↗

From import dependence to place-based innovation

The challenge

A thriving timber bioeconomy relies on more than forests and builders – it depends on the manufacturing layer in between. In many regions, this "missing middle" remains one of the most critical yet overlooked gaps. Manufacturing infrastructure is often lacking near forest areas, particularly for primary processing – such as milling, drying and grading – and for early-stage product development. As a result, forest owners and local businesses are excluded from higher-value supply chains. As a result, forest owners and local businesses are excluded from higher-value supply chains. They sell raw or minimally processed timber into volatile markets, capturing only a fraction of potential value and leaving little scope for reinvestment or innovation.

A further gap lies in product development, testing and research. In many contexts, builders and engineers lack knowledge of the timber they use – its structural properties, durability, moisture behaviour or design limitations. This leads to overdesign, underuse or reliance on imported alternatives. Consequently, locally grown timber – in both the Global North and South – is often regarded as risky or unfit for construction, even when it could perform well if better understood and properly processed.

Logistics compounds these challenges. Even where timber is harvested responsibly, it rarely moves efficiently from forest to processor to construction site. Narrow or poorly maintained forest roads, inadequate transport capacity and fragmented supply coordination inflate costs, delay projects and undermine builder confidence. Climate shocks such as storms can create sudden surpluses of damaged timber, overwhelming local systems, while urban demand may divert material away from nearby markets. Without integrated logistics and manufacturing, value chains remain fragile and easily disrupted. Timber's transport advantage—its lower weight compared with steel or concrete—can be offset by long-distance haulage. Strengthening regional value chains is therefore essential to reduce emissions and build resilient, place-based timber systems.

Brandenburg, Germany, offers a telling example. The region produces large volumes of pine, yet much of it is exported – sometimes as far as China. This is not due to scarcity elsewhere but to domestic constraints: building codes and species preferences limit local use. The issue is not simply transport – it is the lack of alignment between regulation, infrastructure and market demand.

This is not a purely technical issue but a systemic bottleneck. Without investment in manufacturing equipment, prototyping and reliable logistics, even the best-managed forests cannot support a sustainable construction sector. Schalk Grobbelaar of the University of Pretoria highlights the need for experimentation in local contexts:

"If we don't test what we have, we won't know how to use it. We need space to try things out, to take risks and to fail safely."

Yet current systems and standards are risk-averse, underfunded and oriented around international building codes that rarely reflect local species or vernacular techniques. Strength-grading standards often fail to accommodate smaller, localised resources.Closing this gap requires investment in machinery and laboratories, alongside improved supply-chain integration – not equipment in isolation. Universities, public laboratories, logistics providers and private manufacturers all have roles in co-developing new products suited to local materials and markets. These may include engineered timber, hybrid assemblies, lime–sawdust bricks and other innovations that expand the potential of biobased materials.

If the manufacturing sector remains underdeveloped, countries will continue exporting raw timber and importing finished products – foregoing local value creation. A responsible timber bioeconomy must therefore build a stronger, more experimental manufacturing backbone, connecting forest stewardship to high-performance construction, supported by logistical systems that make those connections viable.

As Aman Chode, Senior Programme Manager at *Gatsby Africa, observes:*

"The challenge isn't just growing trees - it's what happens in between the forest and the building site. Right now that middle layer is thin: we don't have enough local kilns, sawmills, or labs to process, grade, and test our own timber. That means builders have no confidence in the material, so they overdesign or import instead. If we can build that manufacturing backbone, we not only add value locally, we prove that African timber is reliable, competitive, and ready to be part of the future economy."

The opportunity

High-tech, imported products such as CLT from Austria or glulam from Finland may perform well in temperate regions but are not automatically suited to tropical or subtropical conditions. In many cases, local materials – indigenous species, bamboo or compressed wood fibre – offer viable, lower-cost alternatives if technical capacity is developed to process and build with them.

Recommendation

Establish regional biobased-construction innovation hubs to test and develop construction materials and typologies suited to local ecosystems, labour markets and housing needs.

5.5. Best practice: From testing to transformation - University of Pretoria's Timber Innovation Hub

The University of Pretoria is emerging as a regional hub for research, testing and innovation in timber construction – addressing one of the bioeconomy's most pressing gaps: the missing middle in manufacturing and materials science.

Through the Growing Timber Connections initiative, the University's York Timbers Chair in Wood Structural Engineering partners with industry, government and academia to foster a culture of experimentation. Schalk Grobbelaar, who leads the programme, describes it as an effort to "test what we have, so we know how to use it". The team collaborates with sawmills and engineers to study indigenous and plantation-grown species, identify their properties and develop practical design methods for the South African context, including fire performance, structural capacity and hybrid assemblies.

A growing suite of public events reinforces this ethos of collaboration. In September 2025, the University will host a Timber Construction Colloquium, industry conference, exhibition, workshops and a full-scale timber-frame assembly, giving students, professionals and policymakers a chance to build, test and learn side by side. These initiatives are helping to build both the technical foundation and human capacity required to scale local timber construction in ways attuned to climate, culture and context.

As Grobbelaar notes:

"If we want to get timber into mainstream construction, we need to do more than talk about it. We need to show it, measure it, try it – and yes, sometimes fail at it. But we must create room to learn."

Further information:
York Timbers, University of Pretoria ↗

From policy gaps to enabling governance

The challenge

Even where timber supply is emerging, demand-side systems are rarely ready to absorb it in a regenerative, scalable way. In many markets, construction codes still exclude or restrict the use of timber and other biobased materials due to outdated safety standards or limited familiarity among regulators. Even where codes are permissive, other barriers persist: few trained designers and contractors, limited awareness of timber's benefits, and ongoing concerns about fire safety, durability and termite exposure. These gaps suppress demand – not because timber is unviable, but because the system surrounding it remains incomplete.

A critical gap persists between those driving construction demand, architects, engineers and public procurement authorities, and the forest value chain, limiting coordination across production and use. Design choices are driven by cost, speed and compliance rather than by an understanding of how those decisions affect ecosystems, local economies or forest regeneration. This disconnect leads buyers to default to imported certified wood, bypassing local producers who may lack credentials but are deeply rooted in place and practice.

Logistical barriers reinforce this divide. Urban construction projects are typically distant from forest regions, and without coordinated infrastructure – from harvest planning to grading, storage and transport – local timber struggles to enter mainstream procurement. In some regions, mismatches between forestry and construction policies exacerbate the problem: forests may be managed primarily for export while building codes and public tenders favour imported materials. These challenges go beyond regulation – they reflect the governance of entire value chains, including how materials move through them.

This fragmentation arises from a common misunderstanding: many policymakers and professionals treat forestry and construction as separate fields, without recognising that timber building is part of the overall forest economy. Like other materials, timber depends on well-coordinated value chains that link forest production with building demand, supported by shared goals and quality management. When these links are missing, policies and investments remain fragmented, and the system fails to reach its potential.

What is needed is long-term, predictable demand that builds confidence among local processors, manufacturers and builders. Co-ordinated procurement – especially by public actors – can aggregate demand, standardise specifications and anchor domestic supply chains. Beyond regulation, governments must take on a convening role bringing together ministries, departments and disciplines to govern timber construction as a system rather than a silo. This convening function should also extend to infrastructure planning, ensuring that transport, storage and processing capacity are treated as public priorities, not left to fragmented market forces.

If this coordination fails, a vicious cycle will persist: weak demand discourages investment in supply, and weak supply reinforces perceptions that timber is not yet viable. Breaking that cycle requires more than building a few green structures – it requires a new mindset about what it means to build with nature.

The opportunity

Outdated building codes, unclear forest-use rules and siloed ministries create uncertainty. Investors hesitate, builders improvise and foresters navigate competing mandates. Governance must become more proactive and better aligned with climate and development goals.

Recommendation

Update building codes to explicitly permit timber and other biobased materials; develop procurement incentives for public timber construction; and create enforcement tools to monitor legality and sustainability across the value chain.

> *"Timber construction should not be understood solely as a technical solution, but as a system that cuts across multiple ministries – including forestry, construction, housing, land use, and trade. At present, policies and regulations are often developed in silos: forestry frameworks may encourage plantation expansion while building codes still restrict the use of timber, or procurement policies remain narrowly focused on cost and speed with no mandate to prioritise local materials. What is needed is a coherent, integrated policy and regulatory framework that recognises timber as part of a broader system – one that links what happens in the forest with what happens on construction sites."*
>
> Caroline Ray, Regional Director, Arup East Africa

From cultural bias to mainstream adoption

The challenge

Even where material availability and systems are improving, public perception remains one of the most persistent barriers to timber construction. In many East African contexts, wood is still perceived as a "poor man's material", suitable only for temporary or secondary applications. By contrast, concrete and steel have come to symbolise modernity, permanence and social status within prevailing construction cultures. This perception gap not only slows market adoption but also undermines efforts to build a viable timber value chain. As Felix and Caleb from Localworks explained, many community members initially questioned the safety and longevity of timber buildings.

"There's a cultural belief that if a house is not concrete, it's not a real house," they noted. "We've had to build to prove otherwise."

Leander Moons, founder of Studio OMT Architects, echoed this sentiment:

"In Africa we still have a bias in how we see timber – as an inferior, simple building material. People aspire to what they associate with affluence in places such as Dubai or Europe, where concrete dominates. To shift that perception, we began by designing timber homes for middle-income buyers. Once we were able to show that people with money actually want timber houses, the local population got interested. They started asking, 'Why are people with money buying these houses?'"

The strategy worked. OMT's *Moyoni Homes* – timber-frame fourplexes – have since become the most popular product in Zanzibar's Fumba Town, demonstrating that timber can be modern, comfortable and desirable. However, this underscores a wider challenge: perception does not shift through a single project or pilot, no matter how successful. The broader market only evolves when there are enough visible, mainstream examples to build confidence. For timber, scale is not merely an economic question; it is the key to cultural acceptance.

Changing perception will take time. It requires more than marketing or awareness campaigns – it demands real-world demonstrations that challenge assumptions and reflect social aspirations. Timber must not only be sustainable but must also be seen as safe, aspirational and worthy of investment. Yet scaling such demonstrations is difficult, as public scepticism restricts access to the capital required to deliver them. Developers hesitate to take risks on materials that buyers do not trust, and financiers hesitate to back projects that the market doubts. The result is a self-reinforcing cycle: without more buildings, perceptions stay negative; but without shifting perceptions, financing remains constrained.

This makes the early scaling phase uniquely challenging. A few pioneering developers, architects or NGOs can demonstrate feasibility, but without supportive finance and policy, they struggle to replicate success at scale. Real transformation occurs when timber buildings are no longer exceptions – when they are schools in every district, housing developments in every city and public buildings commissioned by governments. Only then does timber move from being viewed as experimental or aspirational to being accepted as mainstream.

The opportunity

Building a responsible timber bioeconomy requires investment – not only in forests or flagship buildings, but across the entire value chain: from smallholder producers and artisanal millers to mid-sized manufacturers and project developers. Yet, finance is often poorly matched to need. Impact investors seek short-term returns that emerging value chains cannot yet deliver. Public funding prioritises large-scale infrastructure, while early-stage actors remain invisible to mainstream capital markets. The result is a fragmented funding landscape that rewards maturity over potential and fails to foster a regenerative system.

Recommendation

Develop blended-finance vehicles and tailored financial instruments that align capital with context – providing early-stage grants for community enterprises, concessional loans for mid-scale manufacturers and guarantees or offtake agreements to de-risk sustainable construction. These mechanisms should be coordinated with public procurement and regulatory reforms, ensuring that finance does not simply follow the market but actively shapes it.

> *"Finance is the critical bottleneck. The actors closest to the forest and the small manufacturers who could anchor new value chains are the very ones locked out of capital. Meanwhile, investors chase scale and quick returns, which doesn't align with forestry's 20- to 30-year business. Without patient, fit-for-purpose finance that bridges this missing middle, we risk building an economy where the most essential players are excluded – and the promise of a regenerative timber system never materialises."*
>
> Aman Choda, Senior Programme Manager, Gatsby Africa

From metrics to social and ecological accountability

The challenge

One of the most urgent risks in scaling timber construction is that it could evolve into a new form of "green extraction" – a superficially sustainable practice that reproduces the same patterns of ecological harm, social exclusion and value concentration found in conventional extractive industries. Without careful design and governance, the drive to decarbonise buildings using timber could inadvertently fuel deforestation, displace communities and degrade ecosystems under the banner of climate action.

This risk is greatest where forest governance is weak, land rights are insecure or demand for timber outpaces sustainable supply. As markets seek greater volumes of biobased materials, and carbon accounting frameworks begin to reward wood over carbon-intensive alternatives, the pressure to scale rapidly can incentivise shortcuts – harvesting from intact forests rather than managed plantations, bypassing local consultation or relying on monoculture plantations that erode biodiversity and water systems. In such cases, timber becomes a "green" input on paper but a destructive force in practice.

Green extraction is also a matter of social equity. Forest-proximate communities often face a dual burden of environmental degradation and economic marginalisation: their forests supply distant low-carbon cities, yet they experience few tangible benefits. The language of sustainability can obscure this imbalance, presenting timber as a global public good while local realities remain unchanged or continue to decline. This dynamic mirrors the extractive patterns of mining, industrial agriculture and fossil fuel industries, where ostensibly "clean" outputs can conceal exploitative supply chains.

Carbon markets further complicate the picture. Although timber construction yields genuine carbon benefits, these can be overstated, poorly verified or used to justify unsustainable sourcing. Timber risks becoming another offset mechanism – a tool to balance emissions rather than transform systems. Seeing timber only as a carbon product, rather than as part of the living systems that sustain people and nature, risks repeating the mistakes of earlier environmental markets.

Avoiding green extraction requires more than safeguards; it requires a new theory of change – one that centres local control, long-term forest health and equitable benefit-sharing over rapid material throughput. The transition to a regenerative timber bioeconomy demands more than emission reduction – it calls for a fundamental reconfiguration of the relationships linking natural resources, human well-being and territorial systems.

The opportunity
Carbon accounting remains essential but insufficient. A low-carbon building constructed with illegally sourced timber from an insecure community is not a success. Accountability in timber economies must encompass equity, tenure rights, biodiversity and governance, even when these dimensions are harder to quantify.

Recommendation
Complement carbon standards with holistic accountability frameworks that incorporate benefit-sharing provisions, Indigenous oversight and measurable indicators for biodiversity and livelihoods.

"Carbon is important, but it cannot be the only measure. A timber system that reduces emissions but leaves forests degraded or communities excluded is not responsible. The risk is that we chase narrow targets and call it progress, while overlooking whether forests are healthier, communities are stronger, and rights are protected. True accountability means measuring not just tonnes of CO_2 saved, but whether the whole system is delivering value for people and landscapes alike."

Bongiwe Shongwe, East Africa Biobased Construction Coalition

From principle to action

Choosing to pursue a timber-building bioeconomy is not simply a matter of substituting materials – it is a commitment to redesigning an entire system. Timber is not merely a low-carbon alternative; it is a product of a living forest ecosystem, a carrier of cultural and architectural traditions, and the backbone of value chains that can either regenerate or deplete the landscapes and communities they affect. Whether timber construction becomes a tool for ecological justice and local prosperity, or another mechanism of extractive development, depends on how deliberately the system around it is designed.

Building a responsible timber bioeconomy invites us to look beyond procurement checklists or flagship projects. It demands holistic thinking – aligning governance, finance, logistics, design and land use; embedding equity and circularity into every stage of the value chain; and rooting solutions in local contexts rather than replicating global templates. This also involves confronting difficult trade-offs – between acting quickly and acting responsibly, scaling up and remaining inclusive, pursuing innovation and preserving tradition – with openness and care.

Getting the balance right is difficult, but failure would be far more costly. A poorly designed timber economy could lower carbon emissions while deepening inequality and forest degradation. Yet if done well, it can create something far more ambitious: an economy in which housing, climate action and forest protection reinforce – rather than undermine – one another.

This transformation is already under way. Across regions, diverse actors are piloting governance, finance, design and land-use frameworks that integrate social equity and ecological integrity as core principles. The challenge ahead is to connect these efforts into a coherent, enduring and just system. A responsible timber bioeconomy, built with care and courage, offers a tangible pathway towards that future.

> *"We can't solve today's problems with yesterday's thinking. Timber opens a door – but only if we design the entire system around justice, community and care. That's where the real innovation lies."*
>
> Leander Moons, OMT Architects

What will it take to make regenerative timber economies a reality? What does that look like in practice – across policy, finance and implementation? Drawing from regional experience, five interdependent shifts stand out. These are not isolated actions but coordinated movements that must be reinforced through policy alignment, investment flows and cultural change. As these shifts occur, a responsible timber bioeconomy will take shape.

Action pathways

Key challenge	Policy pathway	Enabling strategies
Fragmented value chains and siloed initiatives prevent coordination across forestry, housing, and construction.	**Fund and empower durable, inclusive "forest-to-frame" coalitions that co-develop national strategies and standards.**	• Support multi-stakeholder platforms (incl. IPLCs, industry, government, finance) • Provide long-term funding and secretariat capacity • Mandate integration of land use, industrial development, skills, and housing policies
Reliance on imported timber products limits innovation and ignores local materials and contexts.	**Establish regional innovation hubs for biobased construction tailored to local ecosystems and markets.**	• Fund applied R&D and product testing for local species • Develop context-specific building standards • Promote hybrid systems and indigenous material use • Build partnerships between universities, industry, and government
Outdated codes, siloed ministries, and unclear forest rules block investment and scale-up.	**Modernise governance frameworks to integrate forestry, construction, housing, and procurement policies.**	• Update building codes to explicitly allow timber/biobased materials • Create green public procurement incentives • Develop monitoring and enforcement mechanisms for legality and sustainability. • Establish cross-ministerial coordination bodies.
Finance is mismatched to needs, excluding smallholders and early-stage manufacturers from capital.	**Design fit-for-purpose, blended finance systems that align with the long timelines and risks of timber economies.**	• Provide grants for early-stage/community enterprises • Offer concessional loans for mid-scale manufacturing • Use guarantees/offtake agreements to de-risk projects • Link finance instruments to procurement and regulatory reforms
Carbon-focused metrics risk overlooking equity, biodiversity, and governance.	**Complement carbon accounting with holistic accountability frameworks that include social and ecological safeguards.**	• Incorporate benefit-sharing requirements • Ensure Indigenous oversight and tenure recognition • Develop biodiversity and livelihoods impact indicators • Embed carbon accountability into certification and procurement processes

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Call to action

Nations across the globe are encouraged to endorse the *Principles*, embed them in policy, investment, and practice, and to adapt and scale successful biobased construction value chains in their regional contexts. The following section summarises key challenges, policy pathways and enabling strategies identified in the five chapters that are needed to align forest management, building practice and finance systems to achieve a transition towards a regenerative, circular and just bioeconomy.

Achieving responsible timber and biobased construction requires overcoming systemic barriers that span governance, markets, knowledge and technology and therefore depends on the involvement of many actors. The recommendations in this chapter outline how coordinated action across levels of government can accelerate the shift toward responsible timber and biobased construction. The use of wood and other biobased materials is shaped by several policy domains – land-use planning, forestry, construction, bioeconomy, and industrial regulation – with responsibilities often distributed across ministries and tiers of government. Governments at all levels have instruments to influence the transition to biobased construction, each with distinct jurisdictional authority over discrete areas of action.

The challenges identified across the chapters include fragmented governance, underfunded SFM, limited technical capacity for industrial processing, socio-cultural bias, methodological inconsistencies in carbon accounting and incentives to redirect investment flows towards biobased building products that are cost-competitive in local markets. These systemic constraints hinder the alignment of the forest and construction sectors and the mainstreaming of biobased and circular-design practices. Addressing them requires a coordinated reconfiguration of policy incentives, data infrastructures and market instruments guided by regenerative-design principles.

Kissinger, G. (2025). Public policies promoting forest-positive buildings: A review of twenty one countries, Lexeme Consulting and Forests & Climate Leaders' Partnership Initiative

Taxonomies of political-support measures for the bioeconomy and "forest-positive buildings" are typically organised along the forest-to-building value chain, from supply to demand side measures (Kissinger, 2025). This report adopts a similar approach, organizing key challenges and policy pathways according to their position within the timber construction value chain. In response to shared challenges across regions and markets, the proposed policy pathways highlight priority areas for government action to accelerate responsible timber construction. The *Policy Pathways Map* provides a synthesized overview, grouping the challenges and policy pathways discussed in the five chapters into thematic clusters that influence different stages of the supply chain (*see Page 30-31*). This map serves as a practical tool for matching challenges with their corresponding policy pathways and indicating which chapter of the report provides more detailed enabling strategies.

The pathways and strategies outlined throughout the report are not exhaustive nor prescriptive. Instead, they are intended to provide a foundation for inter-sectoral policy dialogue and coordinated action toward a systemic approach to implementing the *Principles for Responsible Timber Construction*.

Key challenges and pathways

Ensure efficient, integrated and accountable governance

Fragmented legal frameworks, outdated regulations, unclear mandates, siloed working and weak intersectoral coordination impede the integration of forest and construction data needed for systemic change. Strengthening institutional coherence and embedding accountability across all governance levels are essential for climate credibility and traceability throughout the value chain.

Pathways to action

- Establish legal and policy foundations with enforcement mechanisms to enable SFM in production forests (*see Chapter P3*).
- Fund and empower durable, inclusive "forest-to-frame" coalitions that co-develop national strategies (*see Chapter P5*).
- Modernise governance frameworks to integrate forestry, construction, housing, and procurement policies (*see Chapter P5*).
- Adopt building codes and regulations that focus on performance rather than prescription-based standards and enable the use of alternative materials (*see Chapter P1*).
- Avoid demolition, with 'renovation-first' requirements in permits and planning (*see Chapter P1*).
- Implement policies for carbon storage in buildings and zoning (*see Chapter P4*).
- Promote economic incentives and sustainable public procurement (*see Chapter P1*).
- Include the amount of stored carbon as a comparison or selection criterion in green public procurement of buildings and products (*see Chapter P4*).

Fund technical innovation and industrial production

Adapting biobased materials to twenty-first-century construction and optimising value chains require sustained investment in research and innovation. Current constraints include limited resources for R&I, insufficient testing infrastructure to verify material performance and a lack of industrial capacity to produce cost-competitive biobased materials at scale. Strengthening research, standardisation, and verification systems is critical for safe, traceable adoption in building codes and for faster market uptake.

Pathways to action

- Invest in research and shared data infrastructure (*see Chapter 2*).
- Support monitoring, reporting and verification (MRV) (*see Chapter 3*).
- Complement carbon accounting with holistic accountability frameworks that include social and ecological safeguards (*see Chapter 5*).
- Harmonise global accounting standards (*see Chapter 2*).

Incentivise finance and market transformation

Misaligned financial mechanisms and limited access to capital for smallholders and early-stage manufacturers restrict the scaling of SFM, biobased materials and circular systems. Weak domestic demand for verified biobased materials, outdated standards and fragmented innovation ecosystems further slow adoption.

Pathways to action

- Enable forest-positive finance (*see Chapter 3*).
- Design fit-for-purpose, blended finance systems that align with the long timelines and risks of timber economies (*see Chapter 5*).
- Align incentives with verified carbon performance (*see Chapter 2*).
- Create markets and certification schemes for carbon storage (*see Chapter 4*).

Invest in capacity building and training

Skills and knowledge gaps across design, engineering, and forestry impede uptake of circular and biobased construction. Expanding technical expertise and professional networks is central to mainstreaming responsible timber practices.

Pathways to action

- Scale capacity building, technical support, and innovation in SFM (*see Chapter 3*).
- Establish regional innovation hubs for biobased construction tailored to local ecosystems and markets (*see Chapter 5*).
- Build collaborative capacity for comprehensive carbon accounting (*see Chapter 2*).
- Support craftsmanship and training in circular design and construction (*see Chapter 1*).

Build social acceptance

Socio-cultural bias and misconceptions about biobased materials remain key barriers to market growth. Although biobased materials have been part of all traditional building cultures around the world, materials often do not appeal to the aspirations of consumers seeking status. Shifting public perception and building of biobased materials professional culture is necessary to normalise reuse, refurbishment, and low-carbon design traditions.

Pathways to action

- Develop markets and increase consumer awareness of ecosystem services and sustainability (*see Chapter 3*).
- Build trust and security in the use of secondary and biobased materials (*see Chapter 1*).
- Shift public perception through on-the-ground demonstrators to recognize biobased and secondary materials, and design traditions as compatible with modern, innovative, and sustainable lifestyles (*see Chapter 1*).

Policy pathways map

Supply side

Key challenges

Fragmented legal frameworks, weak enforcement, and insecure tenure (see Chapter 3)

Fragmented value chains and siloed initiatives across forestry, housing, and construction (see Chapter 5)

Outdated codes, siloed ministries, and unclear forest rules block investment and scale-up (see Chapter 5)

Chronic underfunding of SFM (see Chapter 3)

Finance is mismatched to needs, excluding smallholders and early-stage manufacturers from capital. (see Chapter 5)

Capacity and skills gaps hinder SFM (see Chapter 3)

Reliance on imported timber products limits innovation and ignores local materials and contexts (see Chapter 5)

Gaps in monitoring, verification, and carbon accounting undermine climate credibility. (see Chapter 3)

Carbon-focused metrics risk overlooking equity, biodiversity, and governance (see Chapter 5)

Policy pathways

Establish legal and policy foundations with enforcement (see Chapter 3)

Fund and empower durable, inclusive "forest-to-frame" coalitions that co-develop national strategies and standards (see Chapter 5)

Governance frameworks to integrate forestry, construction, housing, and procurement policies (see Chapter 5)

Enabling forest-positive finance (see Chapter 3)

Design fit-for-purpose, blended finance systems that align with the long timelines and risks of timber economies (see Chapter 5)

Scaling capacity building, technical support, and innovation in SFM (see Chapter 3)

Establish regional innovation hubs for biobased construction tailored to local ecosystems and markets (see Chapter 5)

Supporting measurement, reporting, and verification systems (see Chapter 3)

Complement carbon accounting with holistic accountability frameworks that include social and ecological safeguards (see Chapter 5)

Pathway clusters

- Ensure efficient, integrated and accountable governance
- Fund technical innovation and industrial production
- Incentivise finance and market transformation
- Invest in capacity building and training
- Build social acceptance

Demand side

Key challenges

Weak domestic demand for certified wood, and limited consumer awareness of ecosystem services and sustainability (see Chapter 3)

Socio-cultural biases/ Lack of awareness and know-how in the building sector to conduct circular design (see Chapter 1)

Implementation complexity and capacity (see Chapter 2)

Uncertainty associated with the safety and efficacy of re-use materials and novel biobased materials (see Chapter 1)

Methodological inconsistencies (see Chapter 2)

Data availability and transparency (see Chapter 2)

Entrenched linear economic model promoting demolition (see Chapter 1)

Economic and market barriers to the development and scaling of bio-based and secondary material within circular building practices (see Chapter 1)

Prescriptive building codes and regulations hamper innovation (see Chapter 1)

Policy and market misalignment (see Chapter 2)

Policy pathways

Developing markets and increasing consumer awareness (see Chapter 3)

Build trust and security in the use of secondary and biobased materials. (see Chapter 1)

Shift public perception to recognize biobased- , secondary materials, and design traditions as compatible with modern, innovative, and sustainable lifestyles (see Chapter 1)

Mandate disclosure while building capacity (see Chapter 2)

Support craftsmanship and training in circular design and construction (see Chapter 1)

Harmonize global accounting standards (see Chapter 2)

Invest in shared data infrastructure (see Chapter 2)

Building codes and regulations: Focus on performance rather than prescription-based standards (see Chapter 1)

Avoid demolition, 'renovation-first' requirements in permits and planning (see Chapter 1)

Policies for carbon storages in buildings and zoning (see Chapter 4)

Promote Eeconomic incentives and Sustainable Public Procurement (see Chapter 1)

Public procurement for carbon storages (see Chapter 4)

Align incentives with verified performance (see Chapter 2)

Markets for carbon storages (see Chapter 4)

Imprint

About Bauhaus Earth

The mission of Bauhaus Earth is to transform buildings and human settlements from drivers of climate and societal crises into creative forces for systemic regeneration. Only a complete systemic overhaul of our built environment will prevent a global climate catastrophe. As an independent make-and-think tank, we address the re-entanglement of buildings and cities with Earth's natural systems. Our fields of action extend from material innovation, transformation studies, and quantitative research to the demonstration of solutions in the built environment, policy advisory, and education. Through our multidisciplinary approach, we aim to bridge the persisting.

About the initiative

The *Principles for Responsible Timber Construction* initiative is a collaborative effort of Bauhaus Earth and Built by Nature in support of the Forest and Climate Leaders' Partnership (FCLP) *Greening Construction with Sustainable Wood* working group. Since COP28, this initiative has worked closely with FCLP and its working group; however, this report represents the independent authors' research findings and does not represent government positions on the topic.

The *Principles and its Guidance Report* have been built on a foundation laid by many organisations over many years. It was shaped by a diverse group of co-authors and stakeholders from across the value chain. One of the key inspirations was "Securing the Future of Our Forests and Cities"[1] which outlined a set of recommendations for responsible timber sourcing and use, co-authored by Bauhaus Earth, Built by Nature and Pilot Projects.

Methodology

The report is the product of internet based desk research, interviews and workshops with key stakeholders along the forest to frame value chain. Given its global scope, the report does not claim to be exhaustive, but rather seeks to demonstrate and highlight key illustrative examples of the opportunities, risks and risk mitigation strategies of a biobased construction industry.

1 Policy Guidelines for Securing the Future of Our Forests and Cities. Available at: https://www.bauhauserde.org/articles/policy-guidelines-securing-future-forests-cities

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List of Abbreviations

AAC	Annual Allowable Cut
BECCS	Bioenergy with Carbon Capture and Storage
BIM	Building Information Models
CCUS	Carbon Capture, Utilisation and Storage
CDR	Carbon dioxide removal
CLT	Cross-Laminated Timber
CO_2	Carbon dioxide
CO2e	Carbon Dioxide equivalent
CPR	Construction Products Regulation (EU Regulation)
CRCF	Carbon Removal Certification Framework (EU Regulation)
CRD	Construction, Renovation, and Demolition (CRD)
CSFEP	Climate Smart Forest Economy Program
CSRD	Corporate Sustainability Reporting Directive
DAC	Direct-air capture (of CO2)
DACCS	Direct-air carbon capture and storage
DfD	Design-for-disassembly
EPBD	Energy Performance of Buildings Directive (EU Regulation)
EPDs	Environmental Product Declarations
ESRS	European Sustainability Reporting Standards
FMAs	Forest-management approaches
FWC	Freshwater consumption
GHG	Greenhouse gas
GIS	Geographic Information System
GLT	Glue-Laminated Timber
GSH	Ground-source heat
GWP	Global Warming Potential
IFM	Improved Forest Management
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IPLCs	Indigenous Peoples and Local communities
LCA	Life-Cycle Assessment
LCC	Life-cycle costing
MRV	Monitoring, Reporting and Verification
PCRs	Product Category Rules
PES	Payment for Ecosystem services
RPS	Regulatory Position Statement
SFM	Sustainable Forest Management
SLO	Social license to operate
SMAs	Separately managed accounts
TIMOs	Timberland Investment Management Organisations
UNEP	United Nations Environment Programme
WBLCA	Whole-building life-cycle assessment
WLC	Whole-Life Carbon
WLCA	Whole-life-carbon assessment

Principles initiative

BAUHAUS EARTH

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