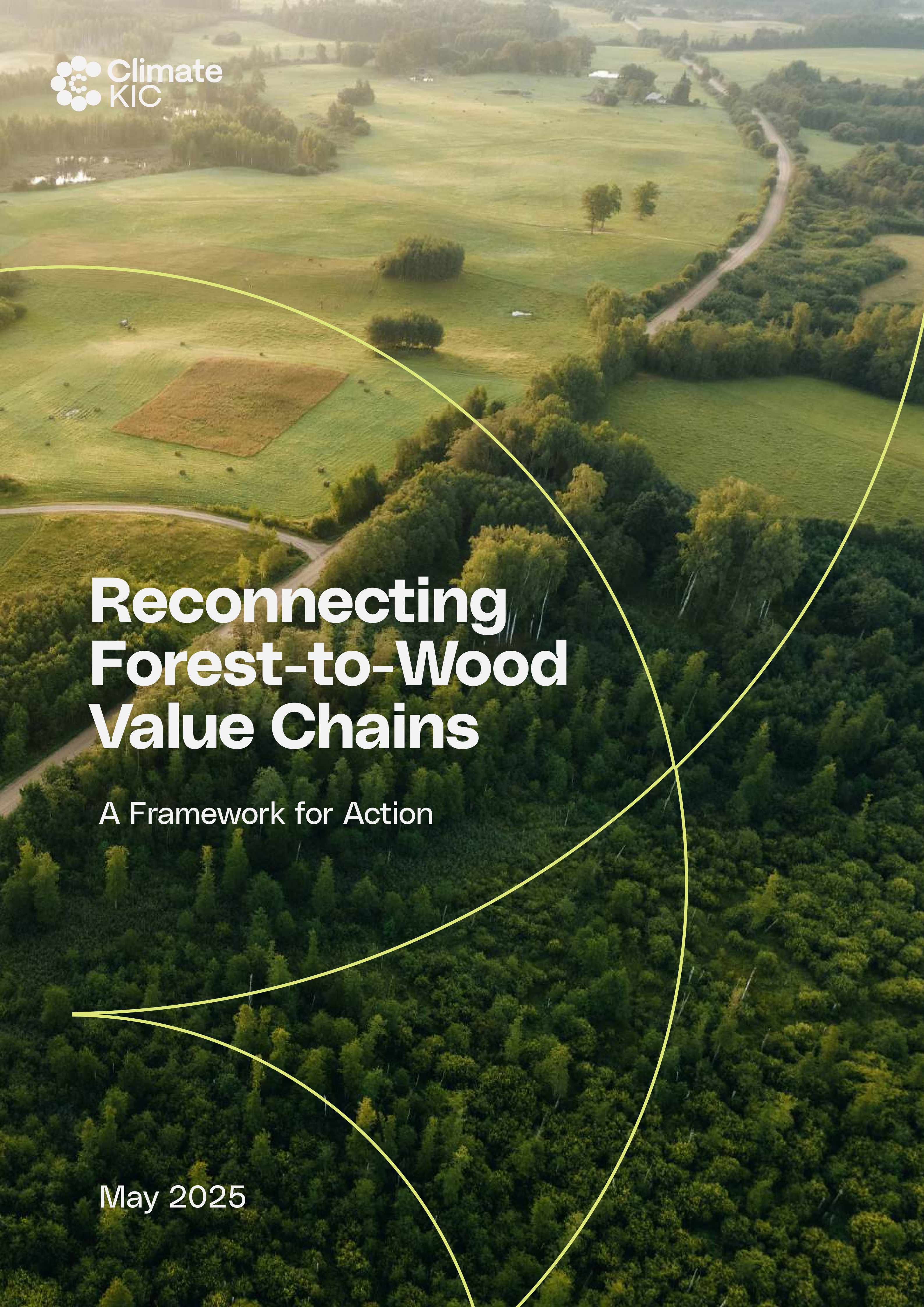

Climate KIC

Reconnecting Forest-to-Wood Value Chains

A Framework for Action

May 2025

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Foreword

Jamie Lawrence
Xilva AG and CSFEP Advisory Council

The built environment is both a marvel of human ingenuity and one of the greatest contributors to our planetary crisis—currently responsible for nearly 40% of global greenhouse gas emissions. As populations continue to grow and urbanize this impact will only deepen. Consider this: every half hour, the world adds the floor area equivalent of eleven Roman Colosseums. By 2050, global floor space will increase by 70%.

Historically, we have expanded our cities by drawing down on Earth's finite natural capital—depleting forests, mining the earth, and overlooking the communities and ecosystems displaced in the process. Forests continue to be destroyed for gains in agriculture or development, their less tangible values—clean water, air, carbon storage, biodiversity, and cultural heritage—rarely accounted for in our economic models. In this equation, the forest is rendered invisible, and construction, extractive.

But what if there were another way?

What if construction could become part of the solution and markets could fund forest-positive pathways at scale?

Around the world, a growing movement of scientists, architects, foresters, and policymakers have begun to ask this question—not rhetorically, but with rigor. They are exploring the potential of wood and other bio-based materials to build not only more sustainably, but regeneratively. They are examining how forest products, when sourced from well-managed ecosystems, can sequester carbon, reduce dependence on high-emission materials, and contribute to circular economies that respect both nature and people.

This inquiry was sparked by a pivotal moment in climate science: a quantitative understanding of the role forests could play in climate mitigation—through reforestation, avoided deforestation, and improved forest management. While the numbers mattered, what mattered more was the awakening they inspired.

We came together—across disciplines and continents—to explore this collective inquiry.

This study stands on the shoulders of that global inquiry, learning from inquisitive stewards of our forests, concerned architects, climate scientists, standard-setters and sustainability professionals to whom the term sustainability seemed misused or ill-equipped to grapple with the many aspects of forest value chains that could be maximised to generate positive outcomes.

Ironically, in this context, the very term "sustainability" has its origins in forestry's role providing props and beams to the mining industry. The term was first used in 1713 by a German tax accountant and Saxon mining administrator (Hans Carl von Carlowitz) who approached forest management as a response to a fear of a shortage of wood and created a regional plan for the sustained yield of timber reserves. Yet as the bioeconomy movement convened, a new regenerative narrative, ultimately inspired by hope, not fear, has allowed for a higher aspiration to achieve more than just sustained yield, to imagine more than just a stemming of our losses.

Thus, the movement and science to recognise the role that forests and forest products have to play in tackling climate change has been steadily growing in support along with a solid body of evidence. Organisations such as Climate-KIC, Potsdam Institute, Michigan State University, EFI, Bauhaus Erde, Built by Nature, Project Drawdown, FAO, Dalberg, Axum, WEF, WBCSD, to name but a few, all have active strategies focused on forest bioeconomies as a climate solution. It is also being reflected in regulatory initiatives such as the EU's Forest strategy 2030 and incentivized legislations in countries like France.

The Climate Smart Forest Economy Program (CSFEP) was one of the precursors bringing in an approach to this collaborative inquiry into when and under which conditions forest products could form part of the solution.

The use of wood is only a climate solution if the forest is maintained, its carbon sink remains intact over time, biodiversity is enhanced or protected, and its benefits are felt by its people.

Whilst we have learned much together and no doubt there will be much more to learn, we have been pushed to recognise that an over-enthusiastic, one-size-fits-all fast scaling of any market-led solution could likely entail unintended consequences. We have learnt from the Global South that social license, jobs and well-being are more pressing aspects of the same solution. We have learnt of the fears and perceptions surrounding wood use, the timber industry and its role and been reminded of potential pressures on other land use types. And while a lot of work has been done market side to encourage sustainable wood use and uptake, we all too often find ourselves trapped back in the very siloes that we try to escape. Indeed it would seem that although the much used quote of John Muir's thoughts on nature "When we try to pick out anything by itself, we find it hitched to everything else in the Universe" – is understood well enough, we are yet to build our societies (nor our built environment) in such a way that these natural interactions can be maximized for the benefit of people and planet. Lest we forget that the use of wood is only a climate solution IF the forest is maintained, its carbon sink remains intact over time, biodiversity is enhanced or protected, and its benefits are felt by its people. Without looking to the forest, sourcing from deforested areas where the carbon and indeed the ethical deficit is simply too large to offer any contribution to climate efforts- is a risk.

Yet the reality, on the construction side is just as stark: each week, 1.5 million people move to urban areas—many into informal settlements, victims of an urban housing crisis. Meanwhile, the default path remains one of destruction: forests cleared, concrete poured, carbon released. It is easy to imagine a new neighbourhood built as we do today—with concrete, steel, and carbon debt, illegally harvested wood, cleared from indigenous lands, leaving behind a scarred ecosystem and sub-optimal housing. But this trajectory is not destiny. We can refuse to accept that future.

Instead, now imagine a neighbourhood built from responsibly sourced wood, harvested from forests stewarded with care where the building materials are designed to be deconstructed and reused, storing carbon for generations. A neighbourhood and a market that gives back to the forest, that greens the city, that dignifies its inhabitants.

That vision is happening—in pockets, in projects, in policies. We know the potential of forests and forest products to serve societal, climate and environmental needs. We know that a balance between the carbon functions of a forest, the storage capacity of a forest product and the substitution potential of end use can be achieved to produce a positive impact. We know it can be done. It has been done. Many times. Scale comes from embedding these practices not only in the landscapes from which we source our materials and not only in the cities we build but in our own minds. Embracing John Muir's view of nature requires a mental shift for us and a paradigm shift for our markets.

This much our collective inquiry has taught us.

While we must continue to stand on scientific rigor and embrace continuous learning, it is clear that our time for collaborative inquiry, is running short. We must now move to scale through collaborative effort.

This study is one contribution to that collaborative effort—to move from inquiry to implementation. It recognizes the scale of the challenge, but also the vastness of the opportunity. If we get it right, the built environment could become a carbon sink rather than a source. Forests could thrive not in spite of market pressures but rather because of market demand… the right type of demand. And people—Global South & Global North —could find dignity and pride not just in housing, but in the landscapes from which those homes arise.

I am proud to have participated in these efforts alongside many brilliant minds and resolute colleagues across the forest to frame professions with a deep belief in what is possible when science, policy, design and practice come together. I am hopeful of the contribution that this document can make to the implementation of the solutions that we have in front of us. May this work serve as both a guide and a call to action.

Let us build .. and grow..
the future .. differently.

Executive Summary

Forests and their associated wood value chains provide a wide range of ecosystem services—regulating the water cycle and its quality, cooling the air, supplying biomass and countless other resources, and contributing to human prosperity. **However, the current divide between forest management (or a lack thereof) and wood value chains prevents the full realisation of these multiple benefits.** Fragmentation creates tensions, reduces efficiency, and limits the contribution of forests and wood to climate action, biodiversity conservation, and local economic development. These systems must be reconnected to unlock their full potential, ensuring that local communities and foresters generate sufficient value for sustainable forest stewardship.

Reconnecting Forests and Wood Value Chains – A Framework for Action sets out a practical way to realign the entire forest-to-wood system so that it delivers climate mitigation and other environmental amenities, circular material flows, and equitable local bio-based prosperity. This document explains the theory of change and provides policymakers, investors, land managers, industry, designers, and community leaders with inspiration, ideas, and practical guidance to initiate and drive action.

By strengthening the connections between forests and wood value chains, the Framework supports landscape regeneration, the creation of long-lived, low-carbon products, and the development of resilient local economies. The result is a system capable of sequestering carbon and delivering tangible social, economic, and environmental benefits for future generations.

Seeing the whole picture
Before acting, stakeholders need a clear view of how their system affects the climate, other ecosystem services, and dependent economies. The Framework, therefore, begins with a diagnostic that follows the forest-to-wood value chain, which also tracks the way carbon is handled in this continuum:

- **Sink** – the amount of carbon removed from the atmosphere and sequestrated in the forest as a result of forest management and harvest.
- **Storage** – the share of harvested carbon that remains locked in products as a result of wood transformation and utilisation.
- **Substitution** – the greenhouse gas emissions avoided when wood-based products replace more carbon-intensive materials or fuels.

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By applying the Sink–Storage–Substitution lens across the entire forest-to-wood continuum, the Framework reveals barriers and leverage points, guiding interventions and innovations that raise the system's performance as a whole.

From insight to implementation
Nine iterative stages translate that diagnosis into delivery of forest-wood value change transformation: convening committed actors, mapping the baseline, analysing cross-system interdependencies and feedback loops, shaping a sequenced portfolio of projects, securing governance and finance, carrying the work through, and learning as conditions evolve. Structured key action items clarify the process further.

Embedding regeneration into the system
Achieving lasting impact requires going beyond sustainability toward a regenerative forest and wood economy—one where economic activities strengthen ecosystems and communities' health, resilience, and vitality. Regeneration is guided by principles such as holistic system thinking, prioritising material avoidance and circular use, enhancing carbon storage across the entire forest-product lifecycle, and tailoring actions to local ecological and social contexts. Drawing from established frameworks, this approach offers a coherent foundation for aligning actors across the value chain toward practices that sustain, actively renew and activate the living systems we depend on.

Outcomes and call to action
Success depends on more than isolated improvements; every stakeholder must see their role in the broader system and understand how their decisions create ripple effects, both upstream and downstream, across the forest-to-wood value chain. Working in a complex, rapidly changing world, especially under the pressures of climate change, demands adaptive, iterative approaches that can respond to uncertainty.

Progress will require innovation across many dimensions, from new financing models such as payments for ecosystem services to radical forms of collaboration that unite land managers, industries, policymakers, investors, and communities around shared goals. The tools are in place. What is needed now is bold, coordinated action on a local level to shift from fragmented interventions towards a regenerative, socially-just and future-proof forest economy.

By strengthening the connections between forests and wood value chains, the **Framework supports** landscape regeneration, the creation of long-lived, low-carbon products, and the development of resilient local economies.

Abbreviations

CO_2	Carbon Dioxide
CSFEP	Climate Smart Forest Economy Program
EEA	European Environmental Agency
EFI	European Forest Institute
EIT	European Institute of Innovation and Technology
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization
GHG	Greenhouse Gas
GCR	Glasgow City Region
HWP	Harvested Wood Products
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre (European Commission)
KPI	Key Performance Indicator
LULUCF	Land Use, Land Use Change and Forestry
MEL	Monitoring, Evaluation and Learning
NPP	Net Primary Production
UN	United Nations
WBCSD	World Business Council for Sustainable Development
WEF	World Economic Forum

Acknowledgements

This report is the outcome of four years of work under the Climate Smart Forest Economy Program (CSFEP) (www.csfep.org).

We are deeply grateful for the contributions, insights, and dedication of the many organisations and individuals who have supported this journey. Special thanks go to Katie Baldassar, Cecilia Burnfield, Stephanie Burrel, Jaboury Ghazoul, Renée Kerkvliet, Mokena Makeka, Christiana Oragbade, Rachel Pasternack, Mireille Perrin, Hester Robertson, Fabrizio Rossi, Rod Taylor, Ellie Tonks, Robyn van den Heuvel, Devang Vussonji, Syakaa William, Mark Wishnie. We also extend our thanks to all those who contributed to the Program, particularly to the Breakthrough Initiatives of the CSFEP and to the wider community who have shaped this work.

In particular, we would like to acknowledge Jamie Lawrence for his valuable input to this report and the input from the Nature Conservancy and Galina Churkina into this publication as independent scientific advisors.

George McLoughlin, Tena Petrovic, Daniel Zimmer, and Simeon Max, led the gathering, synthesis, and finalisation of the knowledge and lessons learned.

How to cite this paper:
McLoughlin G., Petrovic T., Zimmer D., Max S., 2025. *Re-connecting forest-to-wood value chains: A Framework for Action*. Climate-KIC. 101p.

Introduction

Forests and Wood in a Context of Climate Change

Forests and wood play a critical role in the planet and our economies: water cycle and quality, air cooling, biomass production, and other resources are some of the critical amenities they provide (Seymour et al., 2022). However, forests have constantly been threatened by humanity's demographic growth, which has increased pressure on their resources, resulting in degradation and deforestation for settlements and food production.

These tensions remain acute today, and they are exacerbated by climate change. Forests are the product and a key actor of the combined cycles of carbon dioxide and oxygen: they play an essential role in regulating these gases in the atmosphere. They are the major component of the continental carbon sink, which absorbs roughly a quarter of our anthropogenic emissions. This role, around 6 Gt of CO_2 (Global Carbon Project, 2022; Harris, 2021) of net removals annually, is mainly influenced by deforestation, afforestation, wood harvests and the effects of climate change on tree health and natural disturbances. In many regions of the world (EEA, 2024; Gatti et al., 2021), the net removal capacity of the forests is declining due to increasing temperatures and natural disturbances, with forest wildfires playing a critical role (Burton et al., 2024; Byrne et al., 2024).

Siloed approaches to forests and wood value chains is another critical issue. There are trade-offs and synergies between them, but treating them separately does not help.

From a carbon perspective, several authors have demonstrated the importance of taking a holistic approach to forests and wood to maximise their roles in relation to climate, biodiversity, and the economy (Bellassen and Luyssaert, 2014; Nabuurs et al., 2015; Hetemäki et al., 2022). From a climate perspective, the carbon sink and sequestration function of the forest, the carbon storage of carbon in wood and the substitution effects of products with high fossil-carbon footprints with wood are interrelated and could work in synergy (Churkina and Organschi, 2022).

Beyond this carbon logic, the wood economy creates value from the forests; capturing part of this value is critical to convince local communities to manage their forests sustainably and protect all the amenities they provide. The flow and distribution of value generated by the forest and its associated value chains need to be distributed equitably to ensure that both are managed regeneratively. This means that the disconnected actors need to better understand the roles and functions of the parts of the system in which they are not involved. They also need to understand how they depend on each other and how the benefits they generate can be useful to the other.

Achieving such a holistic approach requires a systemic transformation process.

The different functions of forests and their associated value chains need to be examined together, and it is essential to understand how each can be improved in interaction with the others.
This paper is the product of more than four years of activity by Climate KIC working with the Climate Smart Forest Economy Program (CSFEP, see www.csfep.org). This Program aimed to test how synergetic approaches could be established across value chain actors in several regions and contexts. Some of its important learnings generated the methodological approach presented.

> Forests are the product and a key actor of the combined cycles of carbon dioxide and oxygen (...) [responsible for] **6Gt of CO_2 of net removals annually**

Purpose and Audience

This paper presents the Framework for Action which intends to support actors seeking to enhance collaboration across the entire forest-to-wood system. By doing so, it aims to foster a future in which forests and their associated wood products, unmatched in their capacity to sequester carbon and deliver ecosystem services on our continents, play a central role in regenerating landscapes, communities, and economies.

The Framework serves as a practical and strategic tool, offering pathways for diverse stakeholders to build meaningful relationships, bridge silos, and co-create a forest-to-wood value chain that is adaptable, inclusive, and integrated. More than a technical guide, this document also aims to build a shared understanding of the forest system's interconnected ecological, social, and economic functions.

Specifically, the Framework for Action is designed to help users:

Understand how their forest-to-wood system functions today—ecologically, economically, and institutionally

Identify opportunities for regenerative change across land management, material use, and local value creation.

Design and align actions that reinforce each other and deliver multiple benefits

Deliver practical results that hold more carbon, produce longer-lived products, and restore forest functions.

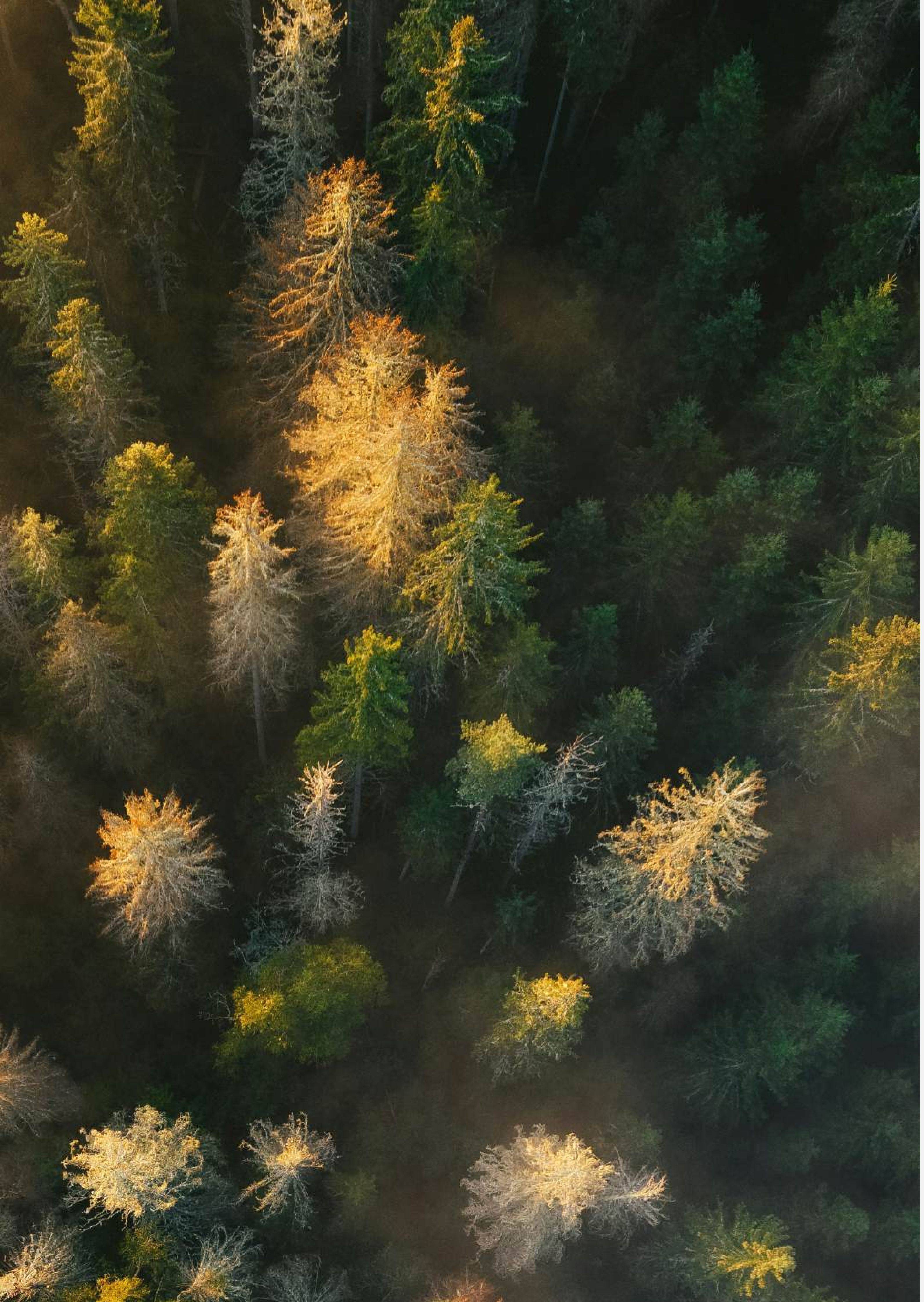
Build adaptive capacity and shared direction across the many actors involved.

Ultimately, the goal is to cultivate a mindset oriented towards regenerative action and support collaborative efforts that can transform fragmented value chains into living systems capable of delivering climate solutions while enhancing the vitality of people, places, and the planet. The expected audience is organisations and practitioners caring about the roles of forests and the way they can be at the same time protected and sustainably managed to adapt to the anthropic pressures (lack of adaptation to climate change, deforestation and degradation) and willing to make the best of the bio-based products they generate for the economy and the welfare of the local communities. In particular, they are motivated to reach across boundaries—sectoral, disciplinary, institutional—to co-create solutions with other value chain actors appropriate to their local context.

This paper does not prescribe what to do but intends to organise a transformative journey. It offers practical guidance for forming a group, starting the conversation, and building momentum towards action.

The following chapters contain a first chapter explaining the need to remove the silos between forests and wood and what this entails. It frames the rationale for a systems-level transformation of forest-to-wood value chains. It explores the underlying challenges and opportunities within current forest and wood systems. A second chapter presents the Framework for action. The third chapter presents nine steps for the Framework implementation and is complemented by concrete case studies and a specific section on the Safeguard's approach developed by CSFEP to provide guidance about unexpected side-effects of the action implemented. The fourth chapter provides additional substance and rationale about the holistic approach and additional details on the relationship between this approach and the Framework for Action. A fifth chapter opens new perspectives on regenerative forest and wood approaches. References and a glossary are provided at the end of the document.

> The goal is to cultivate a **mindset** oriented towards regenerative action, and to support **collaborative efforts** that can transform fragmented value chains into living systems



Chapter 1

Removing Silos

1.1 The Challenge: A Fragmented Forest–Wood System

TThe critical challenge we face is a deep misalignment: forests and the wood they produce are treated as separate domains—conceptually, institutionally, and economically. This disconnection undermines our ability to manage forest and wood value chains as a whole in ways that maximise their benefits for climate, biodiversity, water, and economic and social welfare.

Today, forests are often viewed in seemingly binary terms: either as conservation areas to be shielded from human use or as timber plantations destined for periodic clear-felling. Meanwhile, wood is typically regarded as a uniform and anonymous commodity, detached from the landscapes from which it is sourced and the ecological implications of its harvest.

This divide is reflected in policy frameworks and public attitudes. Within governments, responsibility for forests and timber is frequently divided between separate ministries or departments, each operating in isolation. Among the public, there is often a strong desire to protect forests — yet, paradoxically, wood products are broadly seen as sustainable, with little scrutiny given to how they are sourced or produced. The result is a fragmented system in which neither forests nor wood are stewarded with a complete understanding of their interconnected roles.

This misalignment is critical to resolve, given the fundamental importance of forests to the Earth's climate system. Wood harvesting, however, remains the subject of intense debate. Some argue that sustainably harvested wood, particularly when used in long-lived products such as buildings or furniture, can provide significant carbon storage benefits while substituting for emissions-intensive materials (Krug et al., 2012; Mishra et al., 2022). Others contend that harvesting reduces carbon stocks and can jeopardise the forest sink function (Peng et al., 2023) as well as the forests' health and, thus, other functions. The scientific evidence presents a complex picture, with different conclusions depending on the context, scale, and timeframe considered. Several studies also explain the need to conjunctively manage forests and ensure the wood is appropriately used to store carbon to maximise the benefits (Bellassem and Luyssaert, 2014; Pasternack et al., 2022). Without pleading for such a combination, Daigneault et al. (2022) demonstrate, using economic models and investigating more than 80 IPCC climate and socio-economic scenarios, that in a vast majority of cases, the forest carbon stocks and the use of wood will both increase in the coming decades.

At the heart of the debate lies a core tension: how can we reconcile the immediate reduction in carbon stored in the forest through harvesting with the potential long-term benefits of carbon storage in wood products? And how do we navigate this in a way that fosters the diversity of forest ecosystems, management practices, and societal values?

There is no universal solution. Forests are inherently place-based, shaped by local climates, species, histories, and cultural relationships. Similarly, wood value chains differ widely—some prioritise durable goods, while others are dominated by short-lived uses such as fuel or pulp. We can only unlock their full potential to support economic and ecological resilience and social wellbeing by bridging the divide between forest management and wood utilisation. Only if local communities and forest owners are convinced of the economic value and amenities brought by the forests will they be inclined to manage them sustainably.

1.2 A Holistic Approach

Whilst trade-offs between certain forest management practices and wood production may exist, significant synergies are often overlooked when these elements are treated in isolation. To better understand and enhance these interconnections, we base our Framework on a holistic approach starting from the impacts of forests and wood on the carbon cycle:

- The carbon **sink** and sequestration function of the forest.
- The **storage** of carbon within wood products, particularly in long-lasting ones
- The **substitution** effects of replacing carbon-intensive materials such as cement or steel with bio-based alternatives such as timber.

Such a holistic approach has been advocated by many authors (see, for instance, Hetemäki, 2022; Nabuurs et al., 2015 and 2017; Pasternack, 2022; Cooper and MacFarlane, 2023) willing to maximise conjunctively the benefits of forests and wood for the climate. These three functions, often referred to as the 3S functions, have the advantage of being closely related to the forest-associated value chains: grow and harvest trees relate to the sink and sequestration functions, transform the harvested biomass into a variety of commodities that store the embedded carbon for various durations, utilise these commodities in final products (buildings, furniture...) which can replace products with higher carbon footprints. The recycling and end-of-life of these products and their impacts on the fate of the embedded carbon need to be added to complete the picture (see Chapter 4 for detailed analysis).

The 3S climate functions offer crucial insights, but their assessment requires clarifying the spatial and temporal boundaries of the systems to which they are applied. For instance, in managed forests, it is critical to define what « the forest » is, i.e. what is the forested area that can be considered representative of a certain harvested wood? To assess the substitution function in a building, it is essential to know the current construction practices or the origin of the materials usually utilised to compare the carbon footprints. Each value chain actor has only a partial view of the entire system and can only influence part of it. However, understanding the entire system is critical: an architect should, for instance, know the type of forest management of the wood they use. Reciprocally, a forester should understand what architects need for their buildings. Of course, one of the inherent challenges in all this is the length of time it takes for wood to grow, but this additional complexity is not a reason to avoid reasoning about these interactions. Ultimately, with a better understanding of the critical parts of the system, all actors can interact better to attempt to maximise the benefits of their actions collectively.

Because these 3S climate functions follow the life cycle of forests and wood, they also offer an interesting Framework to support a broader **regenerative forest economy**—an approach that not only optimises carbon outcomes but also fosters long-term ecological health, economic resilience, and social equity. A regenerative forest economy thus rests on the principle that **value chains must restore, not deplete; empower, not exclude**. In this vision, the value generated by forests and wood must circulate back to the local production system, enriching both ecosystems and communities over time (See Regenerative Principles in Chapter 5 for more details). This wealth creation generated by the forest is essential for the local communities and foresters to value and care for their forests.

Without it, it will not be possible to adequately address the global challenges of deforestation and forest climate adaptation.

Beyond the carbon logic, forests and woodlands contribute to a broader set of public goods and ecosystem services, such as water regulation, soil health, and cultural heritage (Seymour et al., 2022). The wood economy, too, must shift from extractive patterns to **circular, place-based systems**, prioritising material reduction, reuse, and cascading use before resorting to the harvesting of virgin timber (See Regenerative Principles in Chapter 5).

A regenerative outlook also means recognising forests as **self-organising ecosystems**—with remarkable adaptive capacities when supported by appropriate conditions. Forestry practices must nurture these natural processes: increasing biodiversity, enhancing soil carbon, fostering climate resilience, and restoring degraded areas through thoughtful interventions (See 3S Functions in Chapter 4.1 for more details).

Crucially, **equity and justice** must underpin the entire system. Fair value distribution is not just a moral imperative but a prerequisite for sustainable outcomes. Those who maintain and care for forests—especially Indigenous Peoples and Local Communities—must be adequately recognised and rewarded. Embedding **safeguards**, as promoted by the Climate Smart Forest Economy Program (CSFEP), is essential to ensure interventions support ecosystems and people alike (See Safeguards in Chapter 3).

Ultimately, realising a regenerative forest–wood value-chain system requires **intentional transformation**. This involves integrating ecological and economic functions, fostering relationships across sectors and scales, and designing interventions for co-benefits rather than compromise. When aligned with regenerative principles, forests and their products can do more than sequester carbon—they can restore landscapes, revitalise communities, and regenerate hope.

Enlarging the view is also essential to keep in mind the broader system in which forest and wood value chains operate (Figure 1). Action started on the left side to reduce the footprint of energy production and consumption. After the Paris Agreement (2015), the focus moved to the natural carbon sinks, recognising that carbon neutrality could not be reached without maintaining a strong continental carbon sink to compensate for the unavoidable GHG emissions. Reducing embodied emissions and the footprint of materials (the central part of Figure 1) remains in its infancy but is gaining traction, particularly with the

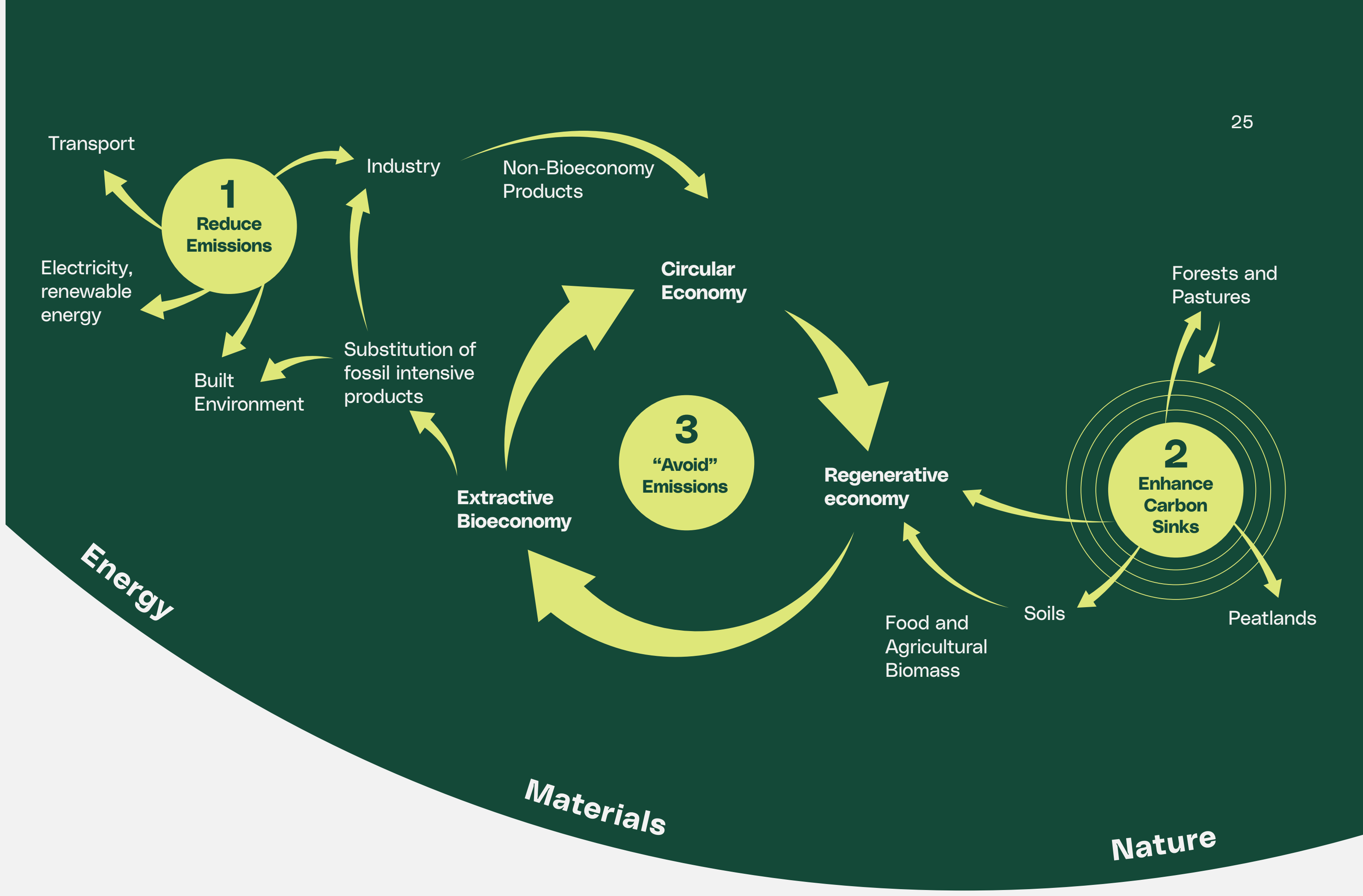


Figure 1. The expanded climate neutrality system in which the forest-to-wood value chains operate.

emergence of the circular economy. This third central area ties emission reduction from energy and carbon sinks together. This is where products from the enhanced carbon sink can be used as materials for industrial purposes, such as wood fibre insulation, substituting fossil fuel-based plastic insulation, for example. This is where actions taken under regenerative paradigms help enhance the sink and improve indirect emissions, such as through local sourcing, low environmental toxicity/pollution and community efforts.

This is also the section where non-bioeconomy products like steel and concrete are circulated and reused before end-of-life disposal under circular economy principles.

Using and reusing biomaterials such as wood will play an essential role in the transition to net zero. They need to be in the centre of a bioeconomy that will remain extractive but needs to become more and more circular and regenerative.

Chapter 2

A Proposed Framework for Action

2.1. The Aim of the Framework

Across the forest-to-wood value chain, there is a growing recognition that the systems we have built are no longer serving us in the ways we need them to. What is missing, for many, is a way to begin: to move from fragmentation to coherence, reactivity to resilience, extraction to regeneration.

The proposed Framework for Action aims to support that shift. It is not a technical manual or a vision document. It is a practical Framework for people and organisations interested to engage with others in new ways of working — whether managing a woodland, operating a mill, designing low-carbon buildings or cities, drafting policy, or shaping community futures. It starts from what is already working in the existing landscape, supply chain, and governance context, helping users understand what is in motion, where the leverage points are, and how actions can be coordinated to serve both people and forest ecosystems over time.

By adopting and applying the Framework for Action, stakeholders across the forest-to-wood value chain can derive a whole suite of tangible benefits.

The Framework first equips them with a shared, evidence-based picture of how their system operates today—ecologically, economically and institutionally—so dialogue begins on solid common ground. It then steers participants to identify clear opportunities for regenerative change, from forest management and material selection to local value creation, and to weave those opportunities into mutually reinforcing sequences rather than isolated projects. Because the Framework insists on measurable results, plans translate into outcomes that sequester more carbon in forests and long-lived wood products, curb emissions in other sectors and restore a wide range of forest functions. Crucially, its emphasis on collaboration, iterative learning and adaptive governance enables diverse partners to build resilience, adjust to emerging challenges and maintain a shared strategic direction as circumstances evolve.

Rather than promoting isolated improvements, the Framework invites a shift in mindset and practice towards connected, locally grounded, and systemically informed solutions. It supports those working with forests in making strategic, meaningful progress consensus. It enables change to begin and to continue with care and rigour.

Systems are inherently complex. The complexity of the forest-to-wood system stems from the need to integrate horizontally across landscapes and territories and vertically across value chains. Dependence on policies and the impacts of climate change introduce further uncertainty. The Framework does not describe a linear path, and it is not the same everywhere. But the method offered here supports movement with clarity and purpose—even when the terrain is uncertain.

2.2. An Overview of the Framework

The following explains how the Framework provides guidelines for the actors of the forest-to-wood value chain to help them contribute to maximising the climate, environmental, economic, and social benefits across the whole value chain and lifecycle. If you are interested only in the implementation approaches, please go straight to Chapter 3. If you want to explore the background, please go to Chapter 4.

In general, all functions of managed forests and their associated wood value chains can be improved, with a limited number of trade-offs. For example, it is possible to increase simultaneously the forest's sink function (and the total carbon it can store) and the wood harvest rate (see Chapter 4), remembering that a forest is not a single stand but an ensemble of stands encompassing the trees and the soil they are rooted in.

Similarly, it is possible and necessary to increase the proportion of harvested wood transformed into long-lived products, which will, in many cases, also increase the avoided emissions from other sectors (the substitution function).

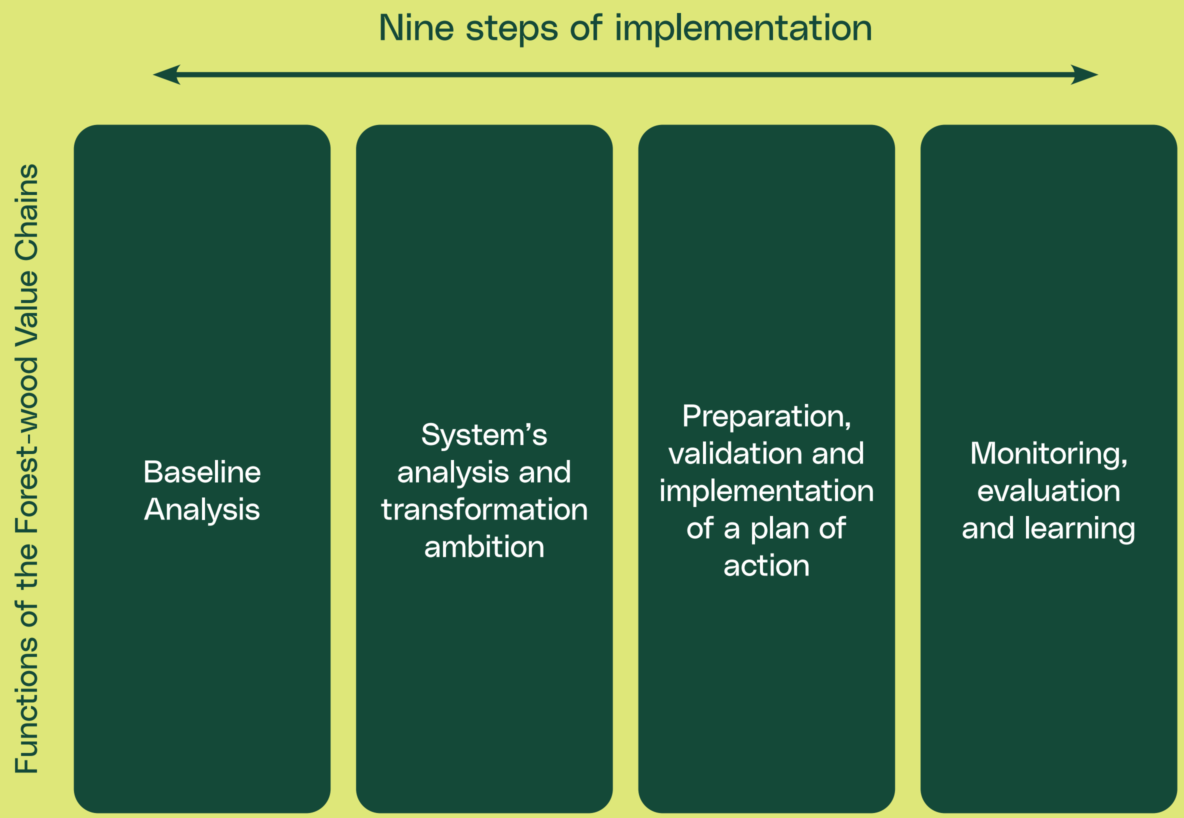
From a systemic perspective, it is important to remember that what is at stake is first a balancing loop between carbon sequestration in forests and long-lived carbon storage in wood products. If the wood carbon extracted from the forest is greater than the atmospheric carbon removal of the entire forest, carbon de-capitalisation occurs, i.e., the forest does not play its role as a carbon sink anymore. Once carbon is extracted from the forest, a reinforcing loop occurs between carbon storage in long-lived wood products and the avoided emissions due to the substitution of fossil carbon-intensive products. This reinforcing loop is amplified in the case of circular economy practices.

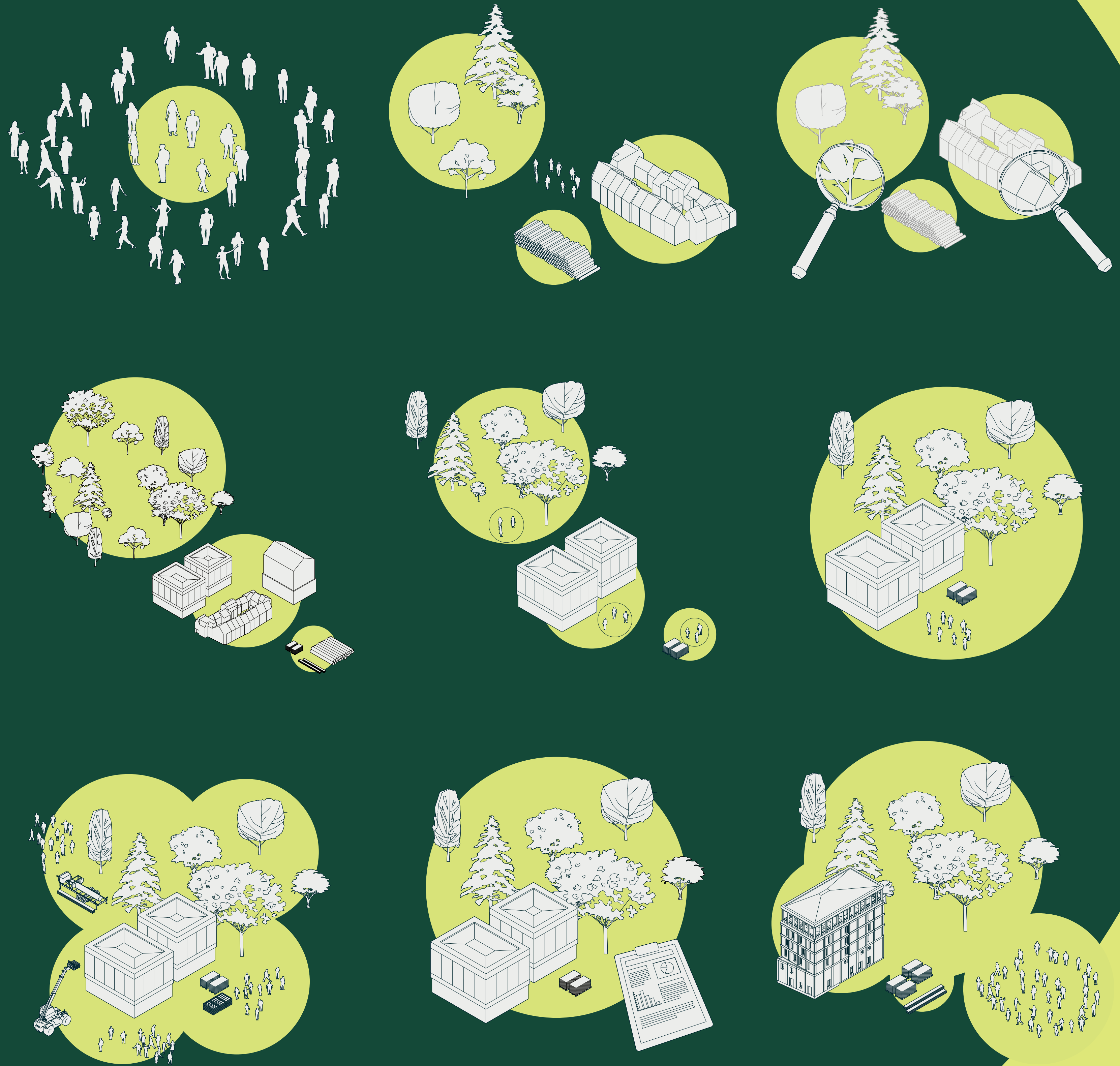
To improve and correct the impacts of the forest-wood value chains, a precise and quantitative assessment of their different functions is not necessary. What is critical is a systemic solutions mindset, such that all actors have a good understanding of several relations and of some orders of magnitude. What is also crucial to remember is that the value obtained by the different wood products can be increased by cascading and circular value chains (e.g. by using by-products to create first panels and then insulation products). The greater the value generated, the better for forest managers or local communities, who can value their forests better and more easily implement sustainable management practices. This is the essence of a climate-smart forest economy, which is more than a simple climate-smart forestry (see discussions in Pasternack et al., 2022; Nabuurs et al., 2015).

Beyond the forest and wood functions, the Framework describes several steps (see Chapter 3) that help practitioners design a systemic portfolio of actions, i.e., a set of interrelated actions that address the leverage points of the forest-to-wood system.

The Framework avoids an idealistic perspective. Instead, it starts from the system's actual situation (the baseline) and attempts to look at possible ways to improve it, considering and mobilising potential solutions already under development.

Framework for Action Overview





Chapter 3

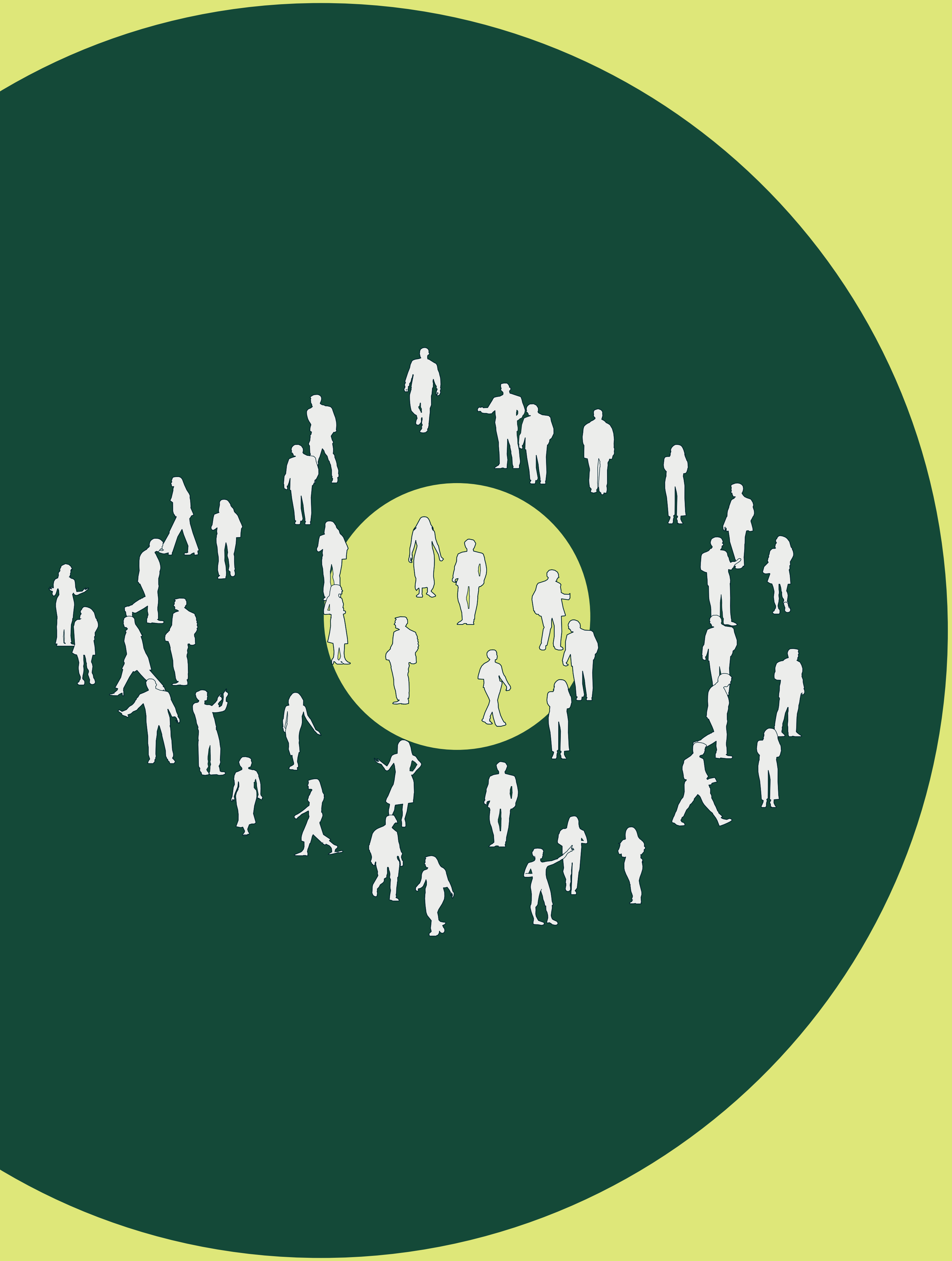
Implementing the Framework

3.1 Overview

The guidance below presents a sequence of activities aimed at implementing the **Framework for Action**. The Framework is structured around **nine core steps**, each addressing a key element of transformation—from understanding the forest's current condition and its value flows to designing and implementing change to consolidation, reflection, and readiness for what comes next.

Each stage is accompanied by a **Practitioner's Guidance** section, offering example-based tools and advice for carrying out the work on the ground, making regeneration not just a vision but a working reality. To achieve this, economic viability must be treated as a cross-cutting concern—ensuring that regeneration efforts are not only ecologically and socially meaningful and just but also financially sustainable and scalable across contexts.

Presented as a sequence, but it is, in reality, iterative

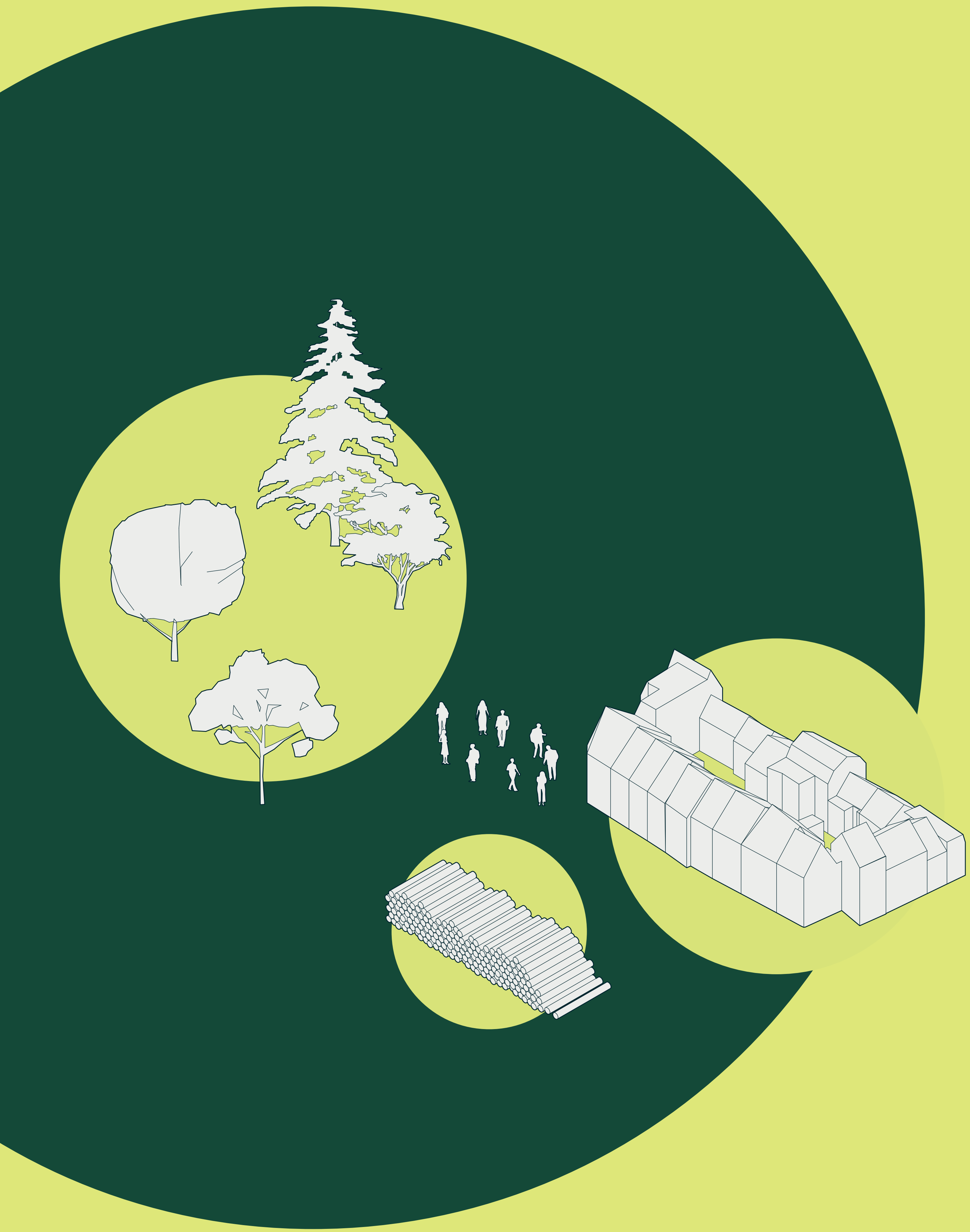


Stage 1
Gather Motivated Stakeholders

Creating regenerative forest-to-wood value chains requires forming a trustworthy coalition of actors representing the different parts of these value chains. This stage establishes a shared foundation around the economic, ecological and climate logic of the work ahead. All actors are interdependent and contribute in different ways to value creation. Understanding collectively how the value is created is important, but it is also critical to understand which share of the value returns to the forest for its regeneration. The sequential logic of the 3S functions—protecting the sink, embedding carbon in products, and enabling substitution—offers common ground for collaboration across different interests and helps frame the gathering not simply as economic coordination but as the beginning of a regenerative relationship between human systems and forest ecosystems.

Practitioner's Guidance

Map stakeholders and their relationships	Identify all those who influence, manage, or are impacted by the flow of wood — from forest to product, from landscape to building. Include voices from land management, industry, design, policy, and community. Recognise both formal roles and informal influence.
Introduce regenerative principles and carbon logic	Use the initial meetings to frame the big picture: this is not just about economic development, but about rethinking how forests serve climate and social wellbeing. Emphasise that forests act as carbon sinks, that products can store carbon, that good design can substitute for emissions-heavy materials, and that circular systems reduce waste and extraction.
Set up the basic architecture of collaboration	Agree on a short purpose statement, but also communication norms, shared tools, and how early decisions will be made.



Stage 2
Establish the Forest-to-Wood Value Chains Baseline

This stage captures the material and carbon flows across the forest-to-wood value chains as well as the economic and environmental services they provide. The goal is to create a shared understanding of the current situation and identify areas needing improvement. Baseline setting is described in more detail under Chapter 4: The Logic of the Framework.

Beyond mapping flows and functions, the roles forests and associated value chains play in the local economy and the community's current welfare need to be assessed. The way this role is evolving is also critical. Does the evolution of the climate threaten the forest's carbon sink? The types of forests, their management, the intensity and methods of wood extraction, and the possible regenerative approaches should all be assessed. Similarly, the different value chains of the extracted wood and their ultimate use and actual substitution effects need careful examination from a carbon perspective but also from a cost-benefit perspective. This is to ensure that outcomes align with economic realities on the ground and lead to improvements to local economies not deteriorations.

Practitioner's Guidance

Collect cross-system data	Gather available information on forest stock and growth, harvesting rates, processing outputs, product use, waste, carbon performance, economic data and policy context. Look at both quantitative (e.g. tonnes, hectares, CO_2e) and qualitative (e.g. lived experience, social outcomes) data.
Map flows of carbon and material	Chart how wood and carbon move from forests to final use — where they are stored, where emitted, and where value is added or lost. Highlight which products have long-term carbon storage potential, which substitute for more damaging alternatives, and where circularity is missing.
Clarify ecological pressures and constraints	Analyse forest health and capacity to act as a stable or growing carbon sink- especially given future climate change related uncertainties. Identify risks to that function — such as overharvesting, pests, or natural disasters.

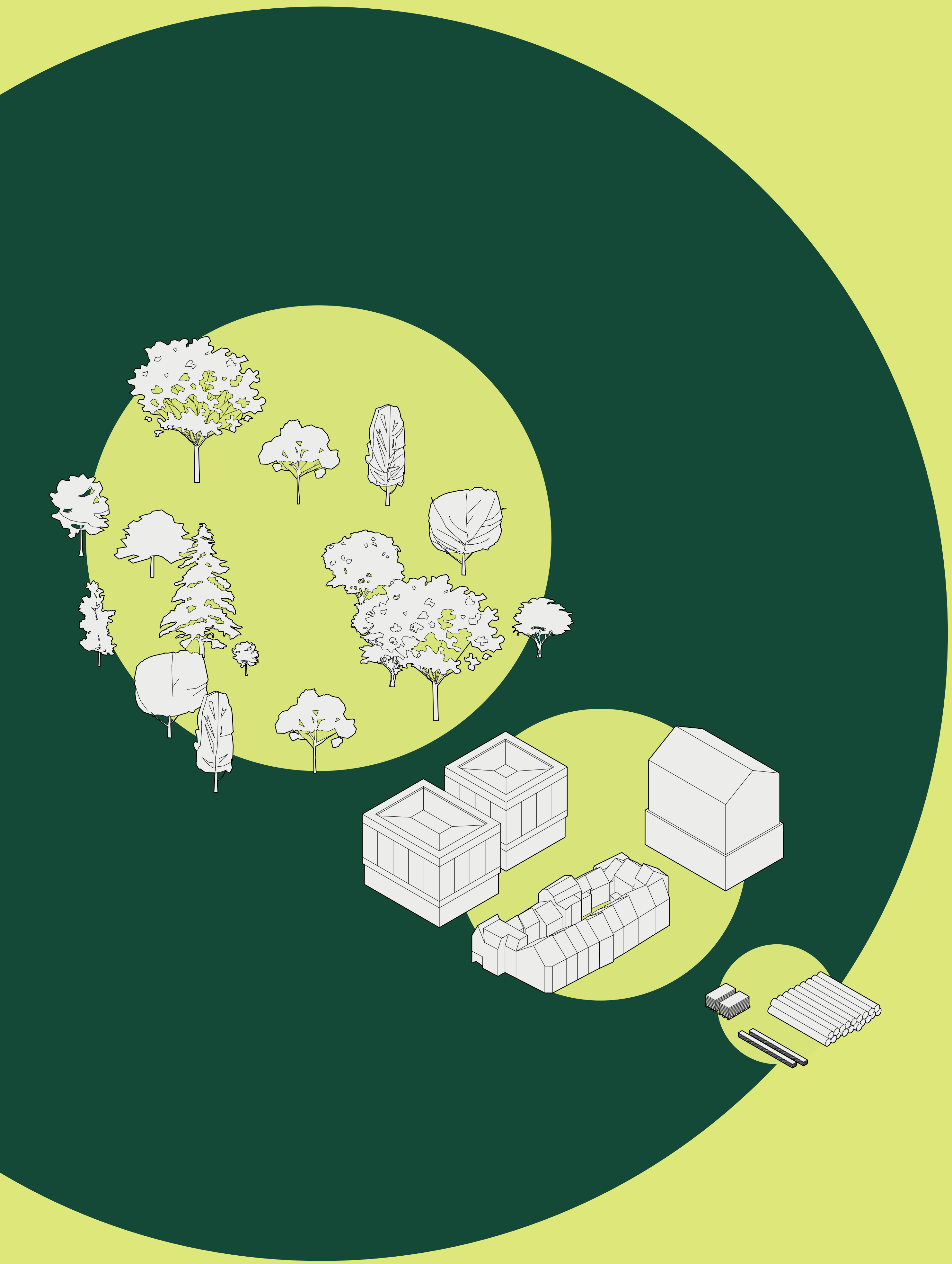
Stage 3
Analyse the System's Transformation and Set Goals

With a baseline in place, the next step is to understand why the system performs as it does — and to set initial goals for what is expected to change. These goals will likely evolve as the actors improve their common understanding. This stage should reveal leverage points and barriers, allowing the group to target the practices, policies, business models or assumptions that need redesign along the various value chains, prioritised by their potential for change.

It is critical to identify and analyse the various feedback loops within the value chain that prevent the evolution of the value chain toward the expected goals. This step starts with a review of the barriers and explaining the loops that explain these barriers (see Case Study Chapter 3: Implementing a transition).

Practitioner's Guidance

Explore root causes and system patterns	Are forests declining in carbon capacity? Is wood being underused or wasted? Are designers unable to access suitable products? Is enough money flowing back to sustainable forest management?
Use systems maps to visualise interconnections	Draw simple feedback loops or flow maps to show how decisions in one part of the system affect others — e.g. short harvest rotations reducing both biodiversity and product quality.
Set goals across the 3S + circularity frame	Agree a focused set of targets such as: • Increase forest carbon sequestration and structural diversity (sink) • Grow the proportion of wood used in long-lived, high-value applications (storage) • Replace high-emission materials in construction and energy (substitution) • Reduce waste and increase reuse or cascading use (circularity) • Increase the funding of sustainable forest management activities Ensure goals are ambitious, measurable, and system-wide — not just incremental improvements.



Stage 4
Identify and Evaluate Solutions

This stage generates possible actions and interventions to shift the system toward expected goals. An important step is to examine what solutions exist already in the region or are under development. These should be added to a system's map, which was previously developed to identify and prioritise the areas for further action.

Practitioner's Guidance

Generate interventions across the value chains	Invite ideas from forest to final use. These might include: continuous cover forest management, engineered timber investment, design training for timber substitution, reuse standards, or low-carbon public procurement.
Assess solutions towards the set goals	Conduct an assessment of technical and social feasibility, as well as an economic assessment and develop robust business models for each solution. • Will it increase the carbon sink or reduce forest pressure? • Will it extend the life and value of carbon in products? • Will it substitute for high-emission materials or practices? • Does it reduce waste and increase circular use? • Will funding for sustainable forest management increase?
Refine a mixed portfolio	Select a blend of short-term wins and deeper structural shifts.

Stage 5
Identify Challenge Owners and Structure Governance

Implementation requires clarity. Each solution must have a defined lead (challenge owner), and the group must maintain oversight without centralising control. This stage requires shared responsibility, role clarity, and adaptive governance. Generally, this stage can only be successful if seed funding can be attained as a catalyst for the transformation.

Practitioner's Guidance

Assign delivery leads	For each action, identify the person or organisation best placed to take it forward. Base this on mandate, capability, and willingness. Confirm the lead's role, responsibilities, and reporting expectations.
Design light governance	Establish a coordinating structure — a core team, steering group, or alliance — to advance individual solutions and also to hold the whole portfolio together.

Stage 6
Develop Portfolio of Actions

From a set of identified solutions, the project needs to be shaped into a logical and unified action plan, thus shifting it from planning to delivery. The action plan connects the solutions by identifying their interdependencies and shapes them into a sequential series. The portfolio needs to ensure that the prerequisites of concrete actions (policies, regulations, certification of new wood products or buildings...) are in place to facilitate the implementation of concrete actions (investing in new products and value chains, improving forest management, producing timber-framed buildings, recycling better wood-based products...). Training may also be needed before embarking on new activities. Intended and unintended feedback loops need to be considered. Changing the rules in the construction sector can, for instance, impact its employment rate. Pragmatism needs to prevail at this stage: the concrete place-based reality will always be more complex than expected. The rules of engagement must be flexible and adaptive, and the sequence must be iterative.

Practitioner's Guidance

Translate actions into delivery plans	Each action should have: clear tasks, delivery steps, a timeline, assigned team, budget estimate, and expected outcomes.
Align the whole system	Visualise dependencies and overlaps between various project streams. Make sure forest outputs match processing capacity, which in turn supports substitution demand in construction or energy.
Secure necessary resources	Map existing funding and capacity. Identify shortfalls and plan how to close them — through fundraising, partnerships, or phased implementation.
Set portfolio-level milestones	Define a small number of high-level checkpoints that indicate whether the system is moving in the right direction (e.g. first hectares under new management, first buildings using local timber, first reuse guidelines adopted).

Stage 7
Implement the Portfolio of Actions

Now is the time to initiate actions within the portfolio. Ensure enabling conditions are in place. Implementation of the portfolio requires lining up donors and investors willing to scale existing initiatives or support new ones. Policymakers and local authorities are, in general, also essential to mobilise because of their critical catalysing role. While initial actions are being implemented, the remaining actions in the portfolio need to be progressively addressed.

Practitioner's Guidance

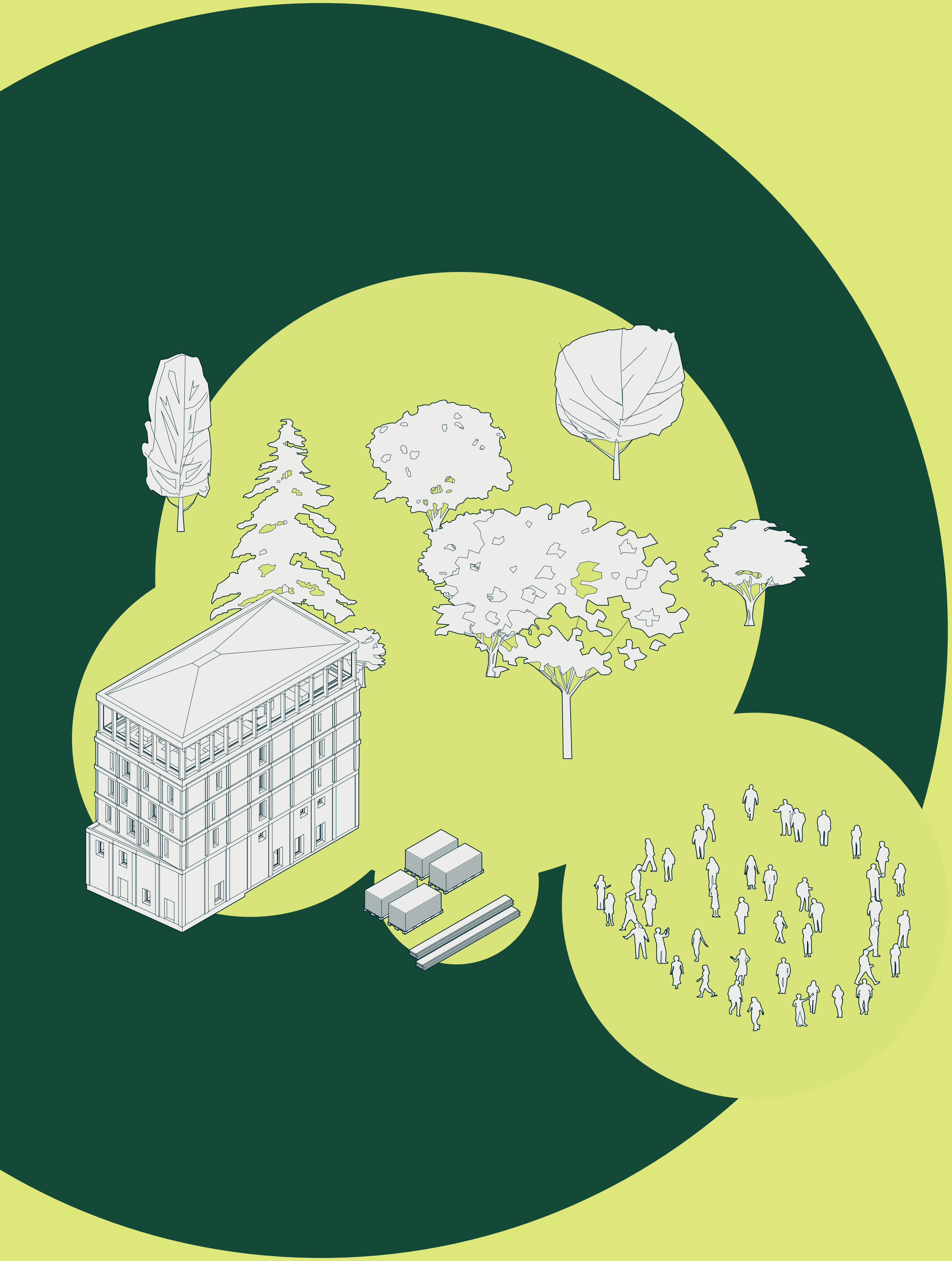
Support delivery teams actively	To enable smooth implementation, provide troubleshooting support, coaching, or peer learning opportunities. Be ready to adjust roles or sequences if conditions change.
Ensure continued system integration	Engage donors, investors, policymakers, and local authorities to secure the necessary funding, policy support, and institutional backing to scale existing initiatives or launch new ones, ensuring cohesive and sustained implementation across the portfolio.
Monitor progress and share stories	Track indicators, but also capture milestones and moments of change — a new building completed, a forest practice adopted, a process redesigned. Share successes and failures to build momentum within the group, but also public facing.

Stage 8
Monitor, Evaluate, and Learn (MEL)

Monitoring is not just about accountability — it is about continuous learning, legitimacy, and course correction. A system this complex will never go exactly to plan. The goal is to learn by observing how the system reacts to the implemented actions. Going back to the baseline, assessing how the different 3S functions have changed and are still changing is critical. Understanding whether these changes improve the socio-economic and environmental impacts of forests and associated value chains and their possible negative consequences (particularly on other economic systems) is also needed. A set of indicators is needed to track progress regularly. Keeping track of climate change impacts on forests and the probable need to adapt them to these impacts and protect existing carbon stocks in these forests will also be critical at this stage.

Practitioner's Guidance

Track carbon and material flows	Use the original baseline and goals to measure: • Change in forest carbon sequestration • Volume and quality of long-life timber products • Substitution of concrete, steel, or fossil fuel • Waste reduction and circular practices adopted
Conduct regular sensemaking cycles	Hold regular reviews to interpret data, update plans, and revise assumptions. Involve the full group where possible. Use visual formats to aid understanding.
Adjust actions and strategy	Be bold about stopping what doesn't work and scaling what does. Document the rationale for changes and update the implementation plan.



Stage 9
Consolidate, Adapt and Iterate

This stage is not the end but the beginning of a new cycle. It consolidates progress, identifies areas for adaptation and possible correction, and prepares the ground for further improvements. It is time for stock-taking: What are the characteristics of the new system? Does the new baseline reflect a deeper alignment with carbon stewardship and regeneration? What has shifted in the stakeholders' collective identity—are they now more forest-centred, more future-facing, and more intergenerationally set up? What might be protected, deepened, or released before the next cycle begins?

Practitioner's Guidance

Assess performance against starting point	Return to the baseline and evaluate changes across sink, storage, substitution, and circularity. Quantify improvements and surface unexpected outcomes on carbon, but also other indicators such as market depth and breadth.
Document and communicate outcomes	Create a simple but powerful final report. Include data, maps, images, and testimonials. Share it widely with partners, funders, and the public.
Re-establish the baseline	Use new data to set a refreshed starting point. If a second cycle is planned, this becomes the new foundation
Celebrate and hand over where needed	Mark the end of the cycle with gratitude and recognition. Ensure continuity by confirming who carries the work forward — and under what conditions.

Supportive Actions

While the Framework for Action moves through defined stages, some actions cut across the entire process. These are not standalone phases but ongoing efforts that support and strengthen regenerative practices throughout. They help embed a long-term mindset and ensure the transition is practical and enduring.

Workforce Development and Skills
Regenerative systems require new ways of working. Throughout the process, investing in skills and training ensures that stakeholders are equipped to lead change. This might include hands-on learning in forest management, wood processing, or low-carbon design. These efforts build local capacity and create a skilled workforce ready to advance regenerative practices.

Finance and Investment
Lasting change depends on financial models that value long-term ecological and social returns. Developing blended funding approaches — combining public, private, and community sources — helps unlock action across the system. Carbon certification and the sale of carbon credits, or the financial recognition of other ecosystem services, can also offer new income streams that reward high-quality, high-integrity forest management. The aim is to ensure capital flows support continuity, fairness, and outcomes centred on forest health.

Communication and Storytelling
Clear, consistent communication builds trust and keeps people engaged. Alongside updates and data, storytelling brings the work to life — sharing successes and challenges in relatable ways. Whether through local media, events, or creative formats, communication helps maintain momentum and invites wider participation.

Feedback and Adaptation
Transitions rarely follow a straight path. Building in feedback loops — like check-ins, pilot reviews, or simple monitoring tools — allows the system to adapt as it learns. These mechanisms help spot issues early, support course correction, and encourage a culture of responsiveness and continuous improvement.

Safeguards: A Toolkit for Responsible Forest Innovation

What Are Safeguards, and Why Do They Matter?

Safeguards are more than just checklists or regulations—they are **protective strategies** that help ensure regenerative projects deliver maximum climate, social, and environmental benefits **without causing unintended harm**. Think of them as a compass and lifeboat on a voyage through uncertain waters: they keep us on course and prepared for challenges (Clay and Cooper, 2022).

These Safeguards focus on **three key impact areas**:

1. **Ecosystem Health and Function**, to maintain or improve biodiversity, soil, water and landscape resilience.
2. **Society and Economy**, to protect rights, livelihoods and cultural values while distributing benefit equitably.
3. **Climate**, to deliver genuine mitigation and adaptation gains across the 3S functions.

The Toolkit: A Practical Guide for Risk and Opportunity

The **Safeguards Toolkit** is a structured, user-friendly system designed for Implementation Leads (**Challenge Owners)** and **Independent Assessors** to evaluate projects using a shared Framework.

Here is how it works:

1. **Self-Assessment**: The Challenge Owner begins by completing a checklist that evaluates potential risks and benefits across the three themes.
2. **Independent Assessment**: An external assessor completes the same checklist, using field observations to validate and compare against the self-assessment.
3. **Compare and Calibrate**: The two assessments are compared to uncover discrepancies, blind spots, or overlooked risks.
4. **Risk Scoring**: Each issue is rated based on the likelihood and severity of impact—from **low-risk** to **high-risk**, or identified as a **co-benefit**.
5. **Recommendations**: The process leads to actionable suggestions to improve the intervention and align it with climate-smart principles.

It's a **feedback loop for sustainability**, designed to assess and manage risk and foster continuous improvement.

The Safeguards Toolkit empowers its users to:

- Identify and mitigate risks early
- Maximise positive impacts across ecosystems, communities, and the climate.
- Build trust with stakeholders and funders through transparency.
- Guide long-term sustainability for forest-to-wood value chain projects.

The complete templates, rating guides and assessor protocols are available at csfep.org/safeguards.

User Journeys

All actors do not have the same view and understanding of the forest-to-wood value chains. They also have different capacities to act in their transformation. The table below tentatively explains how common stakeholders in the forest-to-wood value chains can get involved in each of the nine stages of the Framework. This table also helps to represent how the actions of each stakeholder have an impact on other stakeholders. Thus, their activities represent systemic and holistic solutions.

	Foresters and Land Managers	Industry (Sawmills, Wood Processors)	Architects, Builders, Designers	Policymakers and Officials	Community Representatives and Civil Society	Facilitation/ Coordination Team	Data Analysts and Technical Experts
Stage 1 – Gather motivated stakeholders	Any stakeholder can begin this process						
Stage 2 – Establish the forest-to-wood value chains baseline	Identify forest conditions and capacity to enhance carbon sink and other ecosystem services functions. Begin dialogue on future timber outputs for storage and substitution. Provide data on carbon stocks, tree growth, and threats to sink other ecosystem services functions. Identify areas for increased sequestration.	Describe current processing flows and inefficiencies. Identify potential to improve long-term carbon storage in products and reduce waste. Quantify current outputs, waste, and product lifespans. Map flows into long- vs short-lived uses.	Link building demand to carbon substitution potential. Highlight interest in local, long-lived timber products to store carbon. Include strong focus on wood reuse as part of circularity. Assess which timber types and formats meet carbon substitution and storage needs. Identify design gaps linked to local supply of virgin and reused timber.	Outline policies affecting land use, harvesting, and construction. Begin aligning policy support for 3S-aligned outcomes. Summarise current policy impact on 3S. Identify misalignments and opportunities to incentivise business model changes..	Capture community perceptions on forest value. Introduce 3S concepts as community benefits (climate, jobs, materials). Map social context around forest use and wood products. Include community impacts of carbon and material flows.	Facilitate shared understanding of the 3S framework and regenerative principles across actors. Introduce it as a framework for joined-up climate and resource action. Compile baseline showing current system performance against sink, storage, and substitution potentials.	Lead baseline creation by compiling and digitising data from across the system. Visualise forest, processing, construction, and community flows to clarify current 3S performance and enable future tracking.
Stage 3 – Analyse the system's transformation and set goals	Analyse forest threats and potential to enhance sink and other ecosystem services. Identify practices and funding sources that support longer growth and resilience.	Identify losses in carbon storage across value chain. Explore upgrades to increase product durability and use of residues.	Set design and material goals for carbon storage and substitution. Align with forest-based and city-based supply and standards.	Shape policy and funding goals that encourage high-carbon storage and material substitution using local supplies. Link forest support to downstream use.	Ensure local community benefits are integrated into 3S outcomes e.g. jobs in the production of long-life products, or in climate resilience.	Align analysis around 3S leverage points. Help prioritise system interventions with most climate, social and economic benefits.	Identify trends and leverage points in the baseline. Use models and visuals to show where changes in sink, storage, substitution, or circularity could have the most impact. Support goal-setting with clear, data-driven insights.

	Foresters and Land Managers	Industry (Sawmills, Wood Processors)	Architects, Builders, Designers	Policymakers and Officials	Community Representatives and Civil Society	Facilitation/ Coordination Team	Data Analysts and Technical Experts
Stage 4 – Develop and Evaluate Solutions	Propose silvicultural changes to increase sink and wider ecosystem services (e.g. continuous cover, longer rotations). Highlight funding shortfalls and opportunities to improve this.	Design product and process upgrades that reduce emissions and increase storage (e.g. engineered wood).	Develop building designs that use more circular and responsibly sourced wood, last longer, and substitute for concrete/ steel.	Draft policy and business models to support carbon sink, storage, and substitution (e.g. subsidies for durable wood use, harvesting rules).	Propose outreach or equity initiatives linked to 3S benefits e.g. heating substitution, job access.	Facilitate scoring of solutions by 3S impact. Integrate across actors and timelines.	Assess proposed actions using data. Model impacts on sink, storage, and substitution, and support decisions with clear comparisons.
Stage 5 – Identify challenge owners and structure governance	Work together to assign roles appropriately based on knowledge, skills and value to the forest-to-wood value chain					Support all actors with governance and role clarity for 3S delivery.	
Stage 6 – Develop portfolio of actions	Sequence forestry activities to support sink without disrupting outflow timing for storage.	Align facility upgrades with availability of feedstock and downstream substitution demand.	Plan construction timelines around wood availability and design-for-circularity criteria.	Coordinate timing of incentives and regulatory shifts to catalyse carbon sink, storage, and substitution delivery.	Ensure local community initiatives sync with material and forest timelines.	Build unified delivery timeline for 3S outcomes across projects.	
Stage 7 – Implement the Portfolio of Actions	Lead forest ecosystem and sink-enhancing practices. Coordinate with value chain to plan timber flows for carbon storage. Deliver forest management for carbon gain. Initiate timber outputs aligned with substitution/ storage needs.	Deliver upgrades in processing to lock in more carbon. Reduce emissions and waste. Begin manufacturing with focus on efficient carbon lock-in. Track emissions reduction.	Construct demonstration buildings using locally sourced (forest or city), durable timber. Optimise carbon storage and substitution.	Implement policies tied to 3S outcomes (e.g. low-carbon procurement, forestry incentives). Roll out reforms and incentives in step with implementation needs of other actors.	Lead community 3S projects (wood stoves, training). Monitor benefits. Host wood literacy events or retrofit drives that reinforce substitution behaviours.	Track delivery progress, troubleshoot misalignment across the 3S flow.	
Stage 8 – Monitor, evaluate, and learn (MEL)	Measure changes in forest sink. Report on growth, resilience, and sequestration.	Track product mix, lifespans, and material efficiency. Assess improvement in carbon storage.	Evaluate use of timber in construction and substitution impact. Adjust practices.	Monitor policy effects on 3S indicators. Update to close performance gaps.	Capture public experience of changes in heating, materials, or forest access. Feed into evaluation.	Convene review sessions focused on 3S learning. Help adapt strategy.	Compile cross-system data on 3S performance. Support continuous improvement.
Stage 9 – Consolidate, adapt and iterate	Compare forest sink health to baseline. Reflect on changes in growth and carbon balance.	Summarise industrial gains in carbon storage and emissions reduction.	Showcase completed buildings/products and quantify stored carbon, avoided emissions.	Document institutional support for 3S framework. Recommend continuation or expansion.	Reflect on experience of 3S benefits on comfort, access, employment at local level.	Wrap project with clear evidence of 3S improvements. Support transition to new cycle.	Produce final synthesis of 3S performance trends and future modelling.

Case study
Glasgow City Region Breakthrough Initiative

Introduction

From 2021 to 2023, Climate KIC, in collaboration with the Climate Smart Forest Economy Program (CSFEP), worked with several partners in Scotland on transforming the forestry sector to accelerate the net-zero road map of the country. The steps explained hereafter are foundational to our Framework for Action. They correspond to Stages 1-6 of the Framework for Action. The initial steps were developed at the scale of Scotland, but the development of a portfolio of transformative actions (Stages 5 and 6) was implemented with the Glasgow City Region, where motivated challenge-owners were identified.

Analysing the System's Barriers to the Forest-wood System's Transformation

Scotland's ambitious net-zero roadmap (Scottish Government, 2018) relies on maintaining the important sink function of its forests and the harvested wood. To support this ambition, a Deep Demonstration project started in 2020 to « transform landscapes from carbon sources to carbon sinks ». The collaboration began with Scotland's Land Commission, which intended to identify the critical barriers to the transformations required to meet the ambitious objectives of the roadmap.

Meetings organised with stakeholders resulted in system maps, one of which related to the forest and wood value chains (Figure 2). A system map aims to exhibit the feedback loops that prevent the system's transformation. Each feedback loop helps identify areas for potential action.

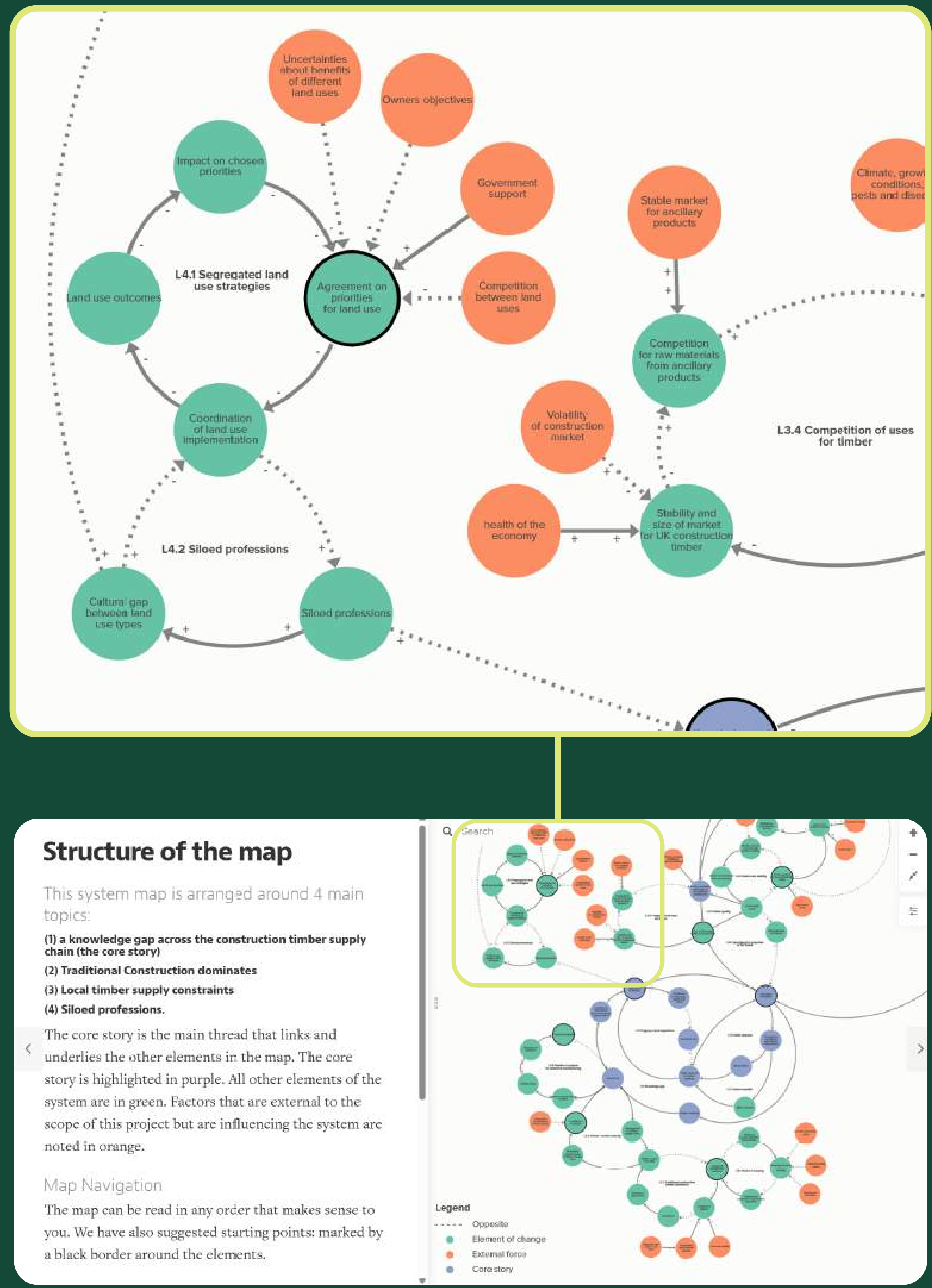


Figure 2. An extract of the system's map prepared with stakeholders (Ghazoul and Toteva, 2021). Each node and each loop is described in the full map available at: https://centre-for-sustainable-forests-and-landscapes.kumu.io/wood-in-construction-system-map

Mapping Concrete Barriers and Innovative Solutions on a Simplified System's Map

The main barriers are then translated into a usable map structured along the key objectives of the transformation: improving forest management and ensuring sustainable harvests, structuring new innovative value chains to store carbon in wood, maximising substitution and recycling the carbon.

This map, close to a value chain map, exhibits the main areas where obstacles were identified and where the action is expected to happen (Figure 3). Existing activities, projects, start-ups, and innovations are added to this map in order (i) to locate actors to mobilise for the next phase and (ii) to see where significant gaps still exist.

The actionable system's map follows the Framework for Action logic. All transformation challenges identified in the previous step are mapped along the forest value chain, and existing initiatives already in place to tackle them are added to the map. This approach facilitates identifying areas where action is needed.

Identifying a Relevant « Challenge Owner »

A relevant « challenge owner » is needed to implement the transformation. A challenge owner is an institution that is legitimate to convene actors and is willing to own the transformation challenge. Experience has shown that a challenge owner is critical for the success of the programme. In this case, the Glasgow City Region i.e. one of the important regions of Scotland, stepped up and indicated their interest to take the programme forward.

Ideally this step should be initiated before or at the beginning of the programme.

Figure 3. The system's analysis translated into actionable areas for the transformation of the forest-to-wood value chains (simplified view). In yellow, the critical forest and wood functions. In grey, the main barriers and areas to transform, as identified with the first system's map. With yellow outlines, a series of existing initiatives that already address these challenges.

Preparing a Portfolio of Actions

All previous results were utilised to identify intervention points with actors of the Glasgow City Region and prepare the Portfolio of Actions aligned with the region's strategy (Glasgow City Council, 2020) (Figure 4).

The Portfolio of Actions ensured coverage of the entire value chain but could not, in the first phase, address all critical challenges identified. The real implementable portfolio of action relies on a coalition of stakeholders motivated and willing to take action.

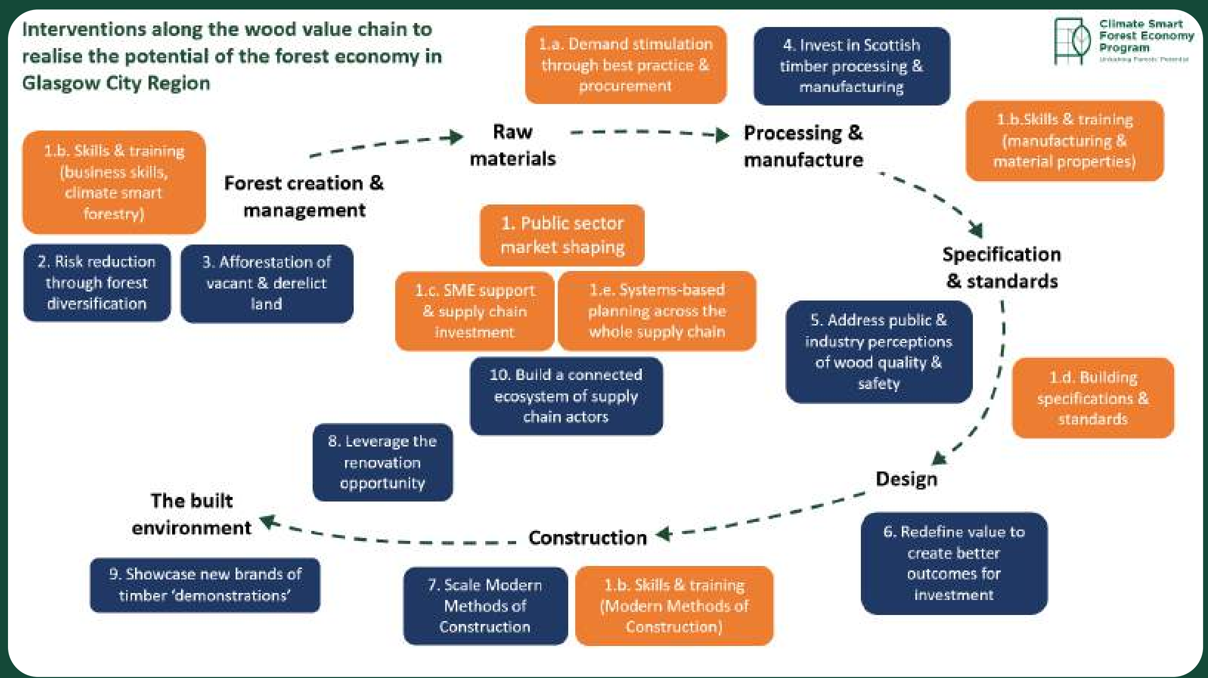


Figure 4. The actionable system's map follows the Framework for Action logic. All transformation challenges identified in the previous step are mapped along the forest value chain. Blue - Targeted actions enabling value chain change. Orange - public sector's market-shaping interventions. This approach facilitates identifying areas where action is needed.

Stress-testing and Evaluating Portfolio Actions

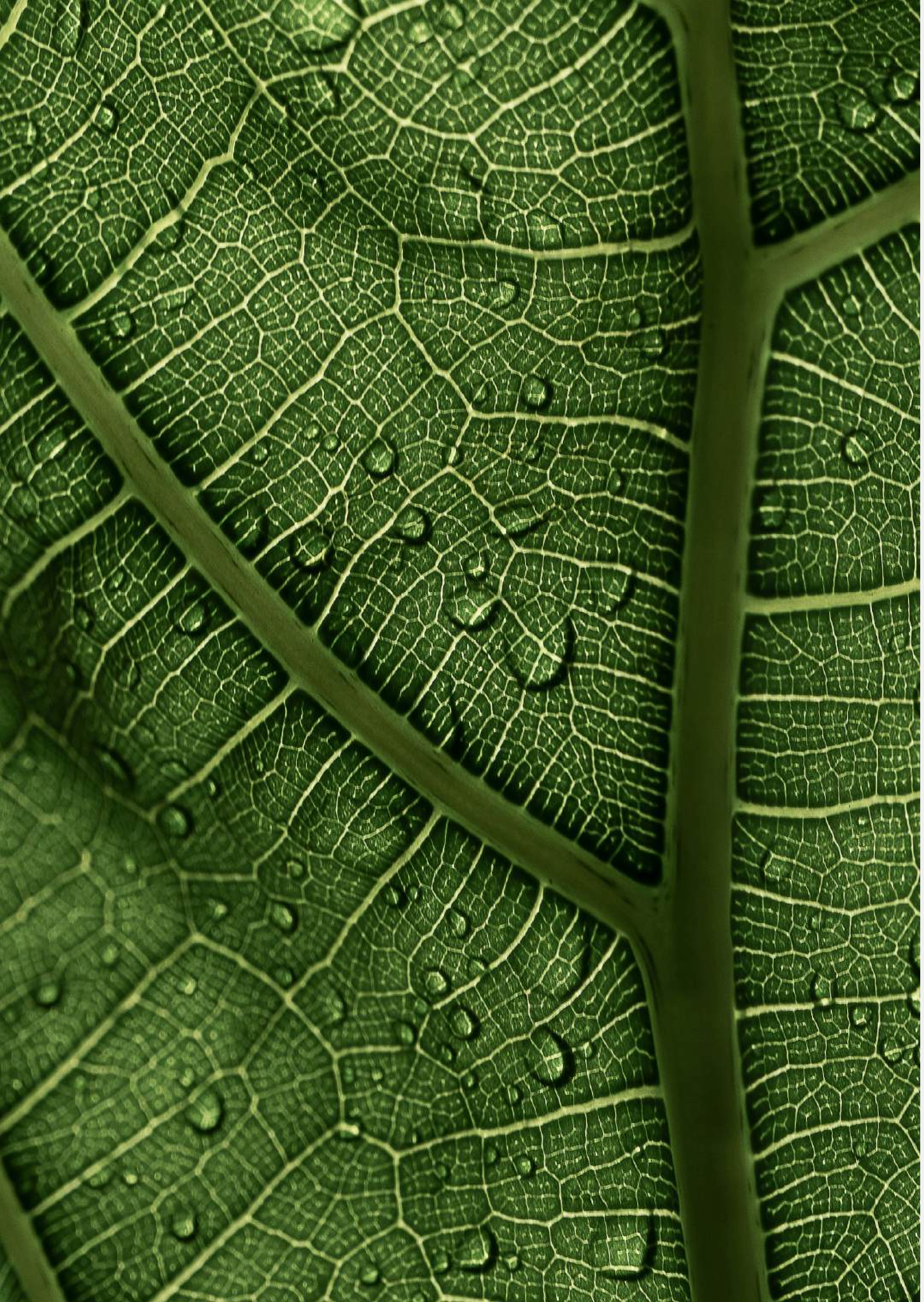
Before implementation, an economic study was commissioned to analyse the costs and anticipated benefits of the proposed actions. This had two practical consequences. It demonstrated first that specific business models were needed for the various solutions to be implemented in order to maximise their possible benefits. Second, it highlighted policymakers' sensitivity to the transformation's consequences.
In particular, the likely impacts of the programme on the existing construction sector in Scotland proved to be particularly sensitive. Transformations come with winners and losers, and anticipating their cascading consequences is essential.

Implementing the Portfolio of Actions

The stakeholders' next step is to prepare detailed implementation plans, which must be complemented by investment plans. The public authority plays a critical role in gaining funders' confidence and providing funds for its responsibilities (e.g., putting in place rules and regulations). Once the detailed plans have been prepared, roundtables with funders and investors are also needed.

Experience shows that this implementation phase is not straightforward but iterative. An initial set of actions needs to be taken to pave the way for a broader movement.

Acknowledgements
This work has benefited from the support and involvement of the University of Edinburgh, the Scottish Land Commission, the Glasgow City Region, and numerous Scottish stakeholders. The project was funded by EIT and CSFEP.



Chapter 4

The Logic of the Framework

For readers interested in going deeper into the knowledge on which the Framework for Action is based, this Chapter offers explanations of what the 3S functions of the forest-to-wood value chains entail from a carbon perspective.

A more detailed explanation of how these 3S functions can be used in the various stages is also provided in Chapter 3.

The 3S Functions
Sink, Storage and Substitution

4.1.1. Forest Carbon Sink

The forest's **carbon sink** is its capacity to remove CO_2 from the atmosphere. It results from two critical mechanisms: the **gross carbon sink** of the forest ecosystem and the losses due to wood harvest.

Gross Carbon Sink

The **gross carbon sink** or **net carbon removal** of a forest is the annual balance between the CO_2 absorbed by the forest (also called the NPP or net primary production that represents the net carbon gain of vegetation during a year; see Luyssaert et al, 2010) and the CO_2 released from the natural decay of all dead organic matter, including that stored in the soil. In other words, it is the balance between CO_2 uptake through photosynthesis by all forest plants and micro-organisms' degradation (mineralisation) of organic matter. In general (IPCC, 2006), five classes (carbon pools) of organic matter are distinguished in forests:

- **Above-ground living biomass** – e.g. trunks, branches, living tree foliage and plants.
- **Below-ground living biomass** – roots and other living organic matter in the soil.
- **Litter** – fallen leaves, needles, and small twigs on the forest floor.
- **Deadwood** – logs, branches, and other woody debris in various stages of decomposition.
- **Soil organic matter** – organic carbon stored in the soil.

Each class has its own dynamics, influenced by factors such as temperature, humidity, soil type, and forest management practices. The gross carbon sink can be assessed using classical "emission factors" (in IPCC terminology) expressed in **$tCO_2e/ha/yr$** (tonnes of CO_2 equivalent per hectare per year). For most forests, these values typically range between **4 and 8 $tCO_2e/ha/yr$.**

RECONNECTING FOREST-TO-WOOD VALUE CHAINS

Wood Harvest

The second mechanism affecting the forest carbon sink is the **harvest of wood** from the forest. Harvesting usually occurs on only a small portion of the forest area each year, but it represents a removal of accumulated carbon over time. For example, in a clear-cut system where trees are harvested on a 50-year cycle, roughly **2% of the forest area** is harvested annually (since 1/50 ≈ 2%). Despite this small fraction of land being cut, the amount of carbon removed from that area is vast, reflecting the **accumulated 50 years of growth.** For instance, if the gross sink is on average **5 $tCO_2e/ha/yr$**, over 50 years, approximately **250 tCO_2e/ha** will have accumulated in the living biomass. Harvesting the trees on one hectare at that point releases an amount of carbon roughly equivalent to the annual gross carbon uptake of **50 hectares** of similar forest.

This explains the sensitivity of the global carbon balance of forests to the wood harvest (see Table 1, p66). The global harvested carbon from managed forests (6Gt CO_2e/year) nearly equals The gross carbon sink (or net removals) of these forests (-6.6 Gt CO_2e/year). If the forests are a global sink, it is mainly due to (i) a positive balance between afforestation and deforestation -the latter declining regularly- (- 2.8 Gt CO_2e/year- and (b) the gross (and net) carbon sink of the unmanaged forests (-2.4 Gt CO_2e/year). Adding the -0.2 $GtCO_2$/year of harvested wood products (HWP) yields a net contribution of the forests of -5.9 Gt CO_2e/year to the global carbon balance. We return to the small amount of carbon sequestered in wood products below.

Net Carbon Sink

The net carbon sink of a local forest is the difference between the gross carbon sink and the carbon lost through harvesting (also named Net Biome Production, IPCC 2006). On a per-hectare basis, the net sink can vary widely. It can be close to 0 in the case of an intensive plantation system where harvesting removes an amount of carbon equivalent to the annual growth of the rest of the forest (this neglects the fact that some carbon may slowly still accumulate in soils). On the other end of the spectrum, the net sink can approach the full gross carbon sink if no wood is harvested at all. However, in that latter scenario, the high uptake rate will not remain indefinite – the annual growth (and CO_2 absorption) will start to decline once the forest matures and trees reach their maximum size.

The harvest pressure – i.e. the proportion of wood extracted relative to the annual gross sink (or net carbon removal) – plays a critical role. Harvesting at or below the level of the annual gross sink can maintain a positive net sink, whereas harvesting more than the annual net removals **decapitalises** the forest's carbon stock. In the latter case, the net carbon sink becomes negative (the forest is releasing more carbon than it absorbs) and the forest becomes essentially a **carbon source** rather than a sink.

In Europe, wood harvest pressures are high in the Nordic countries and in some regions (southwest of France, for instance) where they reach values between 75 and 100%, sometimes even higher than 100% (Nabuurs et al., 2015). They decrease from North to South, being more around 50-75% in the middle countries of Europe and less than 50% in the Mediterranean countries. This decrease from the North to the South explains why Mediterranean countries have large net carbon sinks in their LULUCF reports.

Improving the Sink Function of the Forest

Due to voluntary carbon certification, several forestry practices have been assessed to validate their capacity to increase the carbon stocks in the forests compared to a baseline of existing practices. A comprehensive review of these practices is provided by Haya et al (2023) and a simplified yet very practical description of these practices is available in Nabuurs et al (2017).

What is important to stress is the following:

- The total carbon stock of trees in a forest tends to increase when the density of trees decreases (Luyssaert et al., 2008), which is related to the fact that larger-diameter trunks have the potential to accumulate more carbon (Stephenson et al., 2014).

- For this reason, continuous cover approaches (as opposed to clear-cut practices) provide interesting potential when thinning practices help transform the forest from coppice to mature forest. These practices also offer the possibility of maintaining sufficient biodiversity to progressively adapt the forest to a changing climate.

The overall potential to increase the net sink function is substantive. It could, for instance, double the net sink of the forests in Europe, according to Nabuurs et al. (2017).

Emissions/removals ($GtCO_2$/yr)	**Average 2012-2021**
Land Use Change (LUC)	
Deforestation	+6.7
Afforestation, reforestation, regrowth	-9.5
Forests	
Net removals from managed forests	-6.6
Net removals from unmanaged forests	-2.4
Wood	
Wood harvests	+6.0
Harvested wood products	-0.2
Overall balance	**-5.9**

Table 1. Contributions of forests, deforestation and wood harvests to the continental carbon sink. Compilation of data from Global Carbon Project, 2022; Harris et al., 2021; Luyssaert et al., 2008; Nabuurs et al., 2023. Negative (-) is removals and positive (+) are emissions.

The **net carbon sink** of a local forest is the **difference** between the gross carbon sink and the carbon lost through harvesting.

4.1.2. Carbon Storage in Wood Products

Most of the harvested wood carbon returns to the atmosphere globally in the year following the harvest.

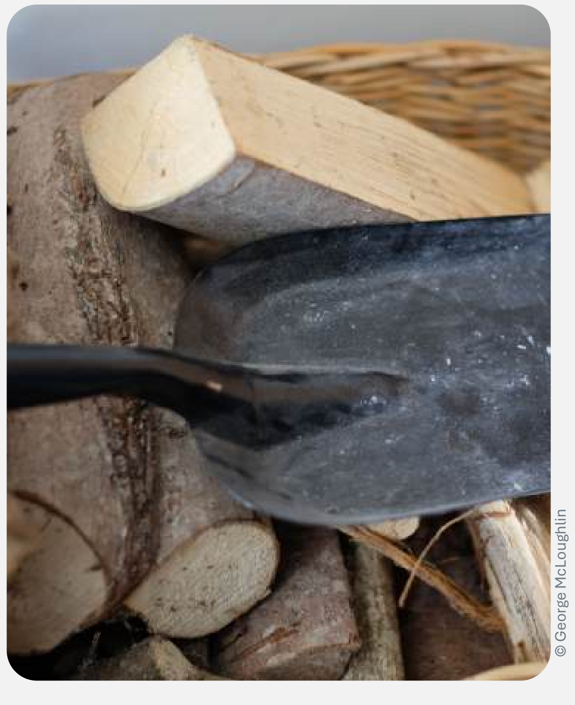
Using harvested wood for long-lived products can extend the storage of that carbon outside the forest. Transferring the carbon stock from trees into wood products (like construction timber or furniture) would keep it locked away for many years. In reality, however, only a small proportion of the harvested wood ends up in long-lived products. Several factors limit the effectiveness of this **wood product's carbon storage function**:

1. **Residues left in the forest:** After harvesting, a significant portion of the tree (often on the order of 30% of the biomass and higher in hardwood species than in softwood) is left behind. This includes small-diameter branches, leaves, bark, and other residual wood that remains in the forest to decompose. This portion of the biomass does not become a wood product; its carbon will quickly return to the atmosphere through decay.

2. **Wood used for energy:** A significant fraction of the wood extracted from the forest is used for energy (heating or cooking) rather than for durable goods. For example, in a country like France (Valade et al., 2017), about **32%** of the harvested wood goes into lumber value chains (sawn wood for construction, etc.), **18%** are used for wood panels or other industrial wood products, and the remaining **50%** are used as fuel for heating purposes. Burning wood for energy means that carbon is released back into the atmosphere on a short timescale, so this portion does not contribute to long-term carbon storage.

3. **Losses in processing and short product lifespan:** Even the wood that initially enters product value chains does not all remain stored in products over the long term. There are losses during processing (sawmill waste, etc.), and many wood products have relatively short lifespans. After a **second transformation** (further processing and the end-use life of products), the distribution of the original harvested wood in the French example mentioned above shifts to roughly **8%** remaining in lumber products, **12%** in wood panels/industrial products, and about **80%** effectively used as energy or otherwise returned to the environment. In other words, only around **20%** of the extracted wood ends up storing carbon for many years.

Similar orders of magnitude for these fractions are observed elsewhere. It is also important to note that if we consider the entire tree biomass present in the forest at the time of harvest (including the portion left as residues), the overall percentage of the forest's carbon transferred to long-lived wood products is even smaller. Using a modelling approach, Bellassen and Luyssaert (2014) found that in the EU, only 18 $MtCO_2e$/yr out of a total harvest of 337 $MtCO_2$/yr (i.e. 5.4%) can be considered as stored for a long duration. EEA values of LULUCF country reports (EEA, 2024) provide values of wood contribution to carbon storage ranging between 10 and 15%, similar to JRC (Cazzaniga et al., 2022). These values can logically be significantly higher when considering plantations of softwood utilised for timber production and can reach 40% (see notes on p96 for an example from Metsa Group)



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RECONNECTING FOREST-TO-WOOD VALUE CHAINS

Improving Carbon Storage in Long-lived Wood Products

Increasing the efficiency of wood transformation to obtain more long-lived products is simultaneously a requirement and a **huge opportunity for the forestry sector** to improve its impacts. Several possibilities exist for this.

The first one is to reduce the demand for biofuel. Traditional heating or cooking systems are poorly efficient, often two to three times less efficient than improved modern systems (see Energy Saving Trust, 2019). They can easily use twice the amount of wood of the latter, which offers many possibilities to either transform more wood into long-lived products or reduce the harvest pressure, increasing the net forest carbon sink.

A second one, which can be stimulated by the first one, is to transform more harvested wood into long-lived products. Le Pierres et al. (2022) explained that a lot of wood by-products or wood discarded due to small diameter of insufficient quality could be used to produce engineered products such as wood panels or furniture. Wood panels, particularly if used in the building sector (e.g. for insulation, floors, walls...), offer many opportunities to store carbon for long periods.

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Such products have a significant market potential (see Le Pierres et al, 2022) and create more value for the industry and the harvested wood.

In this category, the production of biochar needs to be mentioned. Biochar is produced from various types of biomass (green waste, small twigs or pieces of wood...) by pyrolysis, a process that generates energy and a specific type of charcoal that has interesting properties in agriculture: it can store water and fertilisers, and it also improves the digestion of ruminants. Biochar is also a very stable form of carbon that can remain in soils for more than 100 years. Biochar markets are emerging on all continents, and they also offer new possibilities to valorise wood that has not yet been extracted from the forest during harvest.

The emerging circular economy offers a third one. Reusing and recycling wood products has several consequences that must be assessed precisely. Few studies exist on the real impact of the circular economy for wood. However, a recent paper (Foster et al., 2023) evaluated the potential for the recycling of medium-density wood panels and demonstrated that, as compared to a business-as-usual scenario, the impact is (i) an increase in the sawmill emissions, more carbon storage in wood products and lower “wood panel production” emissions, which resulted overall in a reduction of 35% of the Scope 1-3 emissions.

To this, the prolonged life duration of the carbon and the additional substitution effects of the recycled products need to be added. See image below of wood from the former Berlin Tegel Airport repurposed into furniture at Urban Tech Republic in Berlin TXL (https://urbantechrepublic.de/en/).

Overall, increasing the amount and duration of carbon stored in wood products through circular approaches offers ample opportunities to benefit the environment (climate, biodiversity, and other forest amenities) and the economy (new value chains, potential increase in the value generated by wood products).


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4.1.3. Substitution Function of Wood Products

The substitution function of wood – sometimes referred to as *Scope 4 emissions* – represents the GHG emissions avoided when wood is used instead of more carbon-intensive materials or fuels. It quantifies the emissions saved by substituting wood for alternative products with higher fossil carbon footprints. This substitution benefit occurs, for example, when wood is used in construction in place of cement or steel; when wood-based materials replace plastic (e.g. in packaging); or when wood is burnt for heating or cooking instead of fossil fuels like coal, oil, or natural gas.

The magnitude of the substitution effect is the **difference in carbon footprints** between the wood-based option and the option it replaces. For instance, building a house with timber frames can avoid some of the emissions that would have arisen from using concrete and steel. However, this difference is not the wood product’s intrinsic or fixed value. It is context-dependent and likely to **decrease over time** as alternative materials and industries reduce their carbon footprints. In other words, as all manufactured products and energy sources improve their processes to contribute to carbon neutrality goals, the comparative advantage (in terms of carbon savings) of using wood and the substitution function will diminish.

The context dependency of substitution is essential: the local production systems and Scope 1-3 emissions need to be precisely assessed to determine whether substitution is taking place and to compute precisely the substitution function. For instance, if an important proportion of the buildings in a region or country are already constructed with wood, adding more wooden buildings will not have an important substitution effect. What exactly is substituted, and several assumptions related to the computation need to be examined (Howard et al., 2021). Substitution has been assessed in terms of substitution coefficients in scientific literature. A substitution coefficient is the ratio of the reduction of GHG emissions (in C or CO_2 mass units) by the amount of carbon utilised (actually the difference of carbon between the compared products), also expressed in C or CO_2 mass units. It is, therefore, non-dimensional. A substitution coefficient of 1 means that one unit of wood carbon utilised avoids one unit of carbon emissions. The benefit would be doubled if the wood carbon utilised is stored in a long-lived product (e.g., a building).

Substitution coefficients may vary greatly depending on the substituted product (plastic, cement, steel, fossil fuel) and the context of production and utilisation. They also tend to decrease over time since all materials tend to reduce their footprints. Some orders of magnitude have been extracted from a meta-analysis by the European Forestry Institute (Table 2). As can be noticed, most coefficients for materials (steel, chemicals, cement...) are in the range of 1-2. Other coefficients available for fossil fuels range between 0.3 and 0.6. The benefits are lower because, in that case, the carbon of the biofuel is also an emission.

Improving the Substitution Function of the Wood

The substitution function depends on the local context. Hence, when replacing a local method with a new one based on wood, the business-as-usual scenario needs to be precisely assessed and compared to the alternative scenario with the material traditionally used (ideally by Life Cycle Analysis). The difference in GHG emissions provides the avoided emissions. By default, an order of magnitude could be obtained using substitution coefficients, but taking a low value would be recommended.

There is no blueprint to increase the substitution function, but all emissions of the wood products need to be reduced by avoiding, in particular, the GHG emissions due to transport.

In general, storage and substitution functions are positively correlated and even amplified in the cases of (i) circular approaches (more recycling means increased storage time) and (ii) biofuels (more efficient heating and cooking systems reduce wood consumption and have a better substitution coefficient). Therefore, this positive feedback loop needs to be amplified in most cases.

Product Categories	Average Substitution Effect (kgC avoided / kgC in wood product)
Structural construction (e.g. building, wood frames, beams...)	1.3 (0.59-3.47)
Non structural construction (window, door, ceiling and floor cover...)	1.6 (0.59-3.47)
Wood Textiles	2.8
Other products (chemicals, furniture, packaging)	1-1.5
Biofuels vs fossil fuels	0.37-0.64

Table 2. Orders of magnitude of substitution coefficients from a literature meta-analysis of the European Forestry Institute (Leskinen et al., 2018), completed by magnitude ranges for construction wood by Sathre & O'Connor (2010), for biofuel by Olivier et al. (2014) and Roux et al. (2017).

The Framework Matrix

4.2.1. Overview

The overview of the Framework presented in Chapter 2 can be refined to explain its overall logic (Figure 5). The nine steps are simplified (the last steps are not represented, for instance) to facilitate practitioners' understanding.

The Rows of the Framework Matrix

The rows of the matrix (see Figure 5) are grouped along the three climate functions of wood and forests, which can also be seen as steps in the value chains: (i) the carbon sink function entails the forest management and the harvest practices, the storage of carbon in long-lived products is primarily the result of the entire transformation and valorisation of the wood, amplified as much as possible by circular economy approaches, (iii) the substitution role of the wood-based products which essentially depends on the wood products' utilisation. These categories remain useful when combined with other climate issues such as biodiversity, water, and socio-economic impacts.

The Columns of the Framework Matrix: Baseline, System's Analysis and Improvements

The columns are divided into two main sections: "baseline" and "transformation," separated by the system's analysis (see Figure 5). The "baseline" section focuses on analysing the current roles of forests and wood value chains. The system's analysis analyses its current functioning and the main barriers and levers of its transformation. The "transformation" section focuses on improvements to the baseline resulting from the previous steps.

The different actors may not see or experience the entire system at play. However, they are invited to understand the broad picture and how their activities may influence and possibly improve the other parts of the system.

Nine steps of implementation

Functions of the forests and value chains

	Baseline		Improvements / Transformation		
	Carbon and other ecosystem services	**Socio-economic roles of forests and wood**	**Technical and innovative solutions**	**Economics and business models**	**Transformative actions**
Forest management and sink	Net carbon sink, biodiversity, other ecosystem services	Forestry: economic returns to forest owners, jobs	Improved forest management and afforestation practices	Carbon and biodiversity payments, subsidies, impact assessments	Definition and implementation of a portfolio of policies, procurement rules, capacity building, standards and certificiation, carbon credits, just transition mechanisms, investment facilitation, guarantee mechanisms, innovative technologies.
Long term carbon storage in wood products	Material flows, wood-carbon storage in long-lived products	Wood transformation: number and types of actors, jobs, added value	Increased material flows toward long lived products, including from non-conventional wood	Increased competencies in harvest and wood transformation	
End of life / circularity	Avoided waste, reusing and recycling of wood-based products, implications for storage and substitution	Wood based product circulation and recycling: jobs, cost-benefits, added value	Enlarged circular use of wood-based products	Public role through procurement, just transition	
Substitution of fossil-based products	Fossil-carbon substitution through wood-based products	Wood utilisation: sectors, jobs, added value	Increased efficiency of heating systems with high substitution coefficients	Socio-economic consequences of substitution: jobs, new businesses	

Systems analysis

Figure 5. Overall logic of the framework for action. The rows represent critical functions of forests-to-wood value chains. The columns are a simplified sequence of the implementation stages presented in Chapter 3.

4.2.2. Baseline Assessment

The baseline assessment provides essential insights into the current roles of forests and wood value chains in relation to people, the environment, and the economy. It helps identify areas for possible improvements.

The system considered needs to be defined for each function. For instance, the representative forest, its area, the management of its different stands, the material flows of the harvested wood products, the duration of carbon sequestration in the different materials, and the total stock of wood in a city all have specific features and boundary conditions.

The baseline assessment provides a reference point offering a comprehensive understanding of forest management practices, wood transformation and volume flows, and wood product utilisation. The assessment of this local context will be specific to each user: a forester, an architect, a wood transformer, or a policy maker does not see the same parts of the system and has different needs and opportunities to transform.

The assessment has two complementary aspects:

First, the environmental parameters provide valuable forest-level information on carbon, biodiversity, and other ecosystem services such as water or atmosphere cooling. Wood use also provides services such as reducing the embodied carbon of buildings or avoiding GHG emissions in other sectors (energy, construction). The environmental threats related to deforestation, natural disturbances (e.g. wildfires), the declining adaptation of the trees to the changing climate or the increasing heat island effect are essential parts of the assessment (Churkina, in review). Regarding other environmental roles, the Safeguard approach developed for CSFEP by Michigan State University provides a practical toolkit based on a three-step approach:

1. A self-assessment of the environmental risks encountered in the forest and its associated value chains,
2. Further guidance based on a guidance document helping the users improve their risk assessment, and
3. A series of checklists aiming to help align local priorities.

Another assessment component is understanding the material flows associated with the different wood products. Traceability and transparency of wood supply chains are essential for downstream users. But often, forest-level information is lost at the mill, where many different loggers drop logs off at a log yard. They are all mixed and not segregated, making it hard to differentiate the log quality. Despite this difficulty, it is critical to develop at least an order of magnitude of the different carbon functions of the wood and their associated forests.

The **second** component is an assessment of the socio-economic roles of forests and their associated value chains. What are the forests' cultural or inspirational roles? How important are non-wood value chains? How many jobs are created? What value is generated, and how is the added value distributed along the supply chain?

From the baseline assessment, a series of indicators and areas where improvements are needed or could be achieved need to be identified. At this stage, a group of stakeholders needs to be in place to agree on the general directions for the improvements and review the initiatives that have already been launched.

4.2.3. Systems Analysis

Systems have essential characteristics: they have their own internal logic and tend to maintain themselves through a number of interrelated feedback loops. Value chains and territorial systems are, in addition, auto-adaptive systems of systems that evolve in complex ways that are almost impossible to predict. Describing and understanding them is, therefore, difficult. Nevertheless, it is important to develop a minimum understanding of what the system's transformation entails, what the critical barriers, feedback loops and leverage points that may have an impact on the success of a transformation in order to select areas where actions should be implemented (see case study GCR).

Working with systems in the forest-to-wood value chains means taking stock of the interrelations between their different functions. The 3S functions exhibit many interrelations (Figure 6) that need to be explored to understand the reasons for the baseline situation and where the barriers and levers are to increase the overall impacts. Similar analysis should be carried out for other functions (e.g., socio-economic) and for the stakeholders.

Once this is achieved, the challenge owners have been identified, and the governance of the process has been agreed upon, the implementation phase can be initiated (Chapter 3).

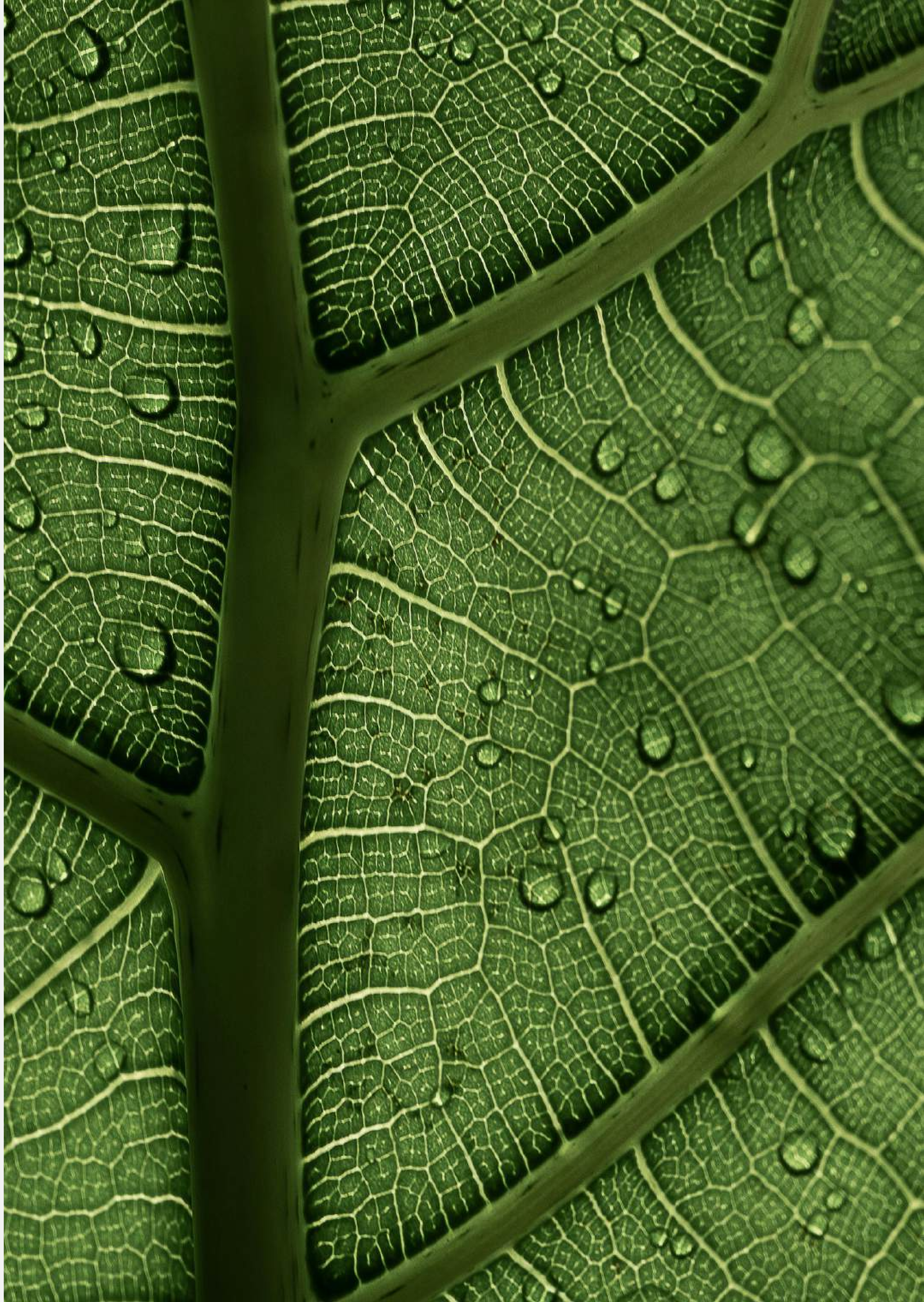
Figure 6. A simplified view of the interconnections between forest-to-wood value chain functions. Yellow outlined boxes and circle are overarching strategic goals, yellow boxes are key strategic actions, and grey boxes are supportive implementation steps.

4.2.4. Defining and Implementing Improvements

The transformation has three important components. The first are technical and innovative solutions, followed by economic and business models, and the last is the portfolio of transformative actions.

To guide and assess the transformation process, a combination of monitoring, evaluation, and learning (MEL) tools is required. These tools include indicators (quantitative or proxies) combined with KPIs tracking the transformation's progress. Target values for these indicators need to be defined at the beginning of the process, and sensemaking sessions with stakeholders need to be organised to learn from and guide the transformation.

Technical and Innovative Solutions	Transforming forest-to-wood value chains starts with the identification of technical and innovative solutions for all functions (i.e. rows of the matrix) to improve the baseline. All functions can be improved and generate value. Several solutions are already under development e.g. to use smaller-diameter trees or utilise wood in building structures. Many are probably available in the region where the transformation is to be implemented.
Economics and business models	The cost/benefit ratio of the different solutions needs to be assessed and compared with alternative scenarios. A particular case is that of substitution which requires assessing counterfactual scenarios to compare carbon footprints. In many cases, a business model will be needed to implement new innovative solutions. It is also critical to assess the cascading socio-economic consequences of the various solutions: a just transition approach is needed that anticipates their possible detrimental socio-economic effects.
Portfolio of actions	Once all previous analysis has been conducted, a portfolio of actions can be designed that ideally starts acting upon areas identified as leverage points in the system. Quite often, it is critical to ensure policies and regulations will not prevent the deployment of solutions. Training and capacity building should also not be neglected.



Chapter 5

Towards a Regenerative Forest and Wood Industry

Sustainable vs. Regenerative Approaches

Over the past forty years, a new ontological principle has emerged that challenges how humans relate to nature and structure their societies: regeneration. **Regeneration** arose in response to the deep nature-culture divide that has shaped knowledge, economics, and industrial development since the 17th century. This divide fostered the exploitation of nature as a limitless resource, blinding humanity to the long-term harm inflicted on ecosystems and, ultimately, human well-being.

Regenerative approaches start from a fundamental shift in mindset: recognising that separating humans from nature is at the root of many current crises. Indigenous groups living outside this division offer alternative models where human activity nurtures, rather than extracts from, natural systems.

Reintegrating human systems with natural processes is critical to redesigning how we manage and relate to our shared ecological resources.

While **sustainability** has historically focused on minimising human harm and maintaining ecosystems in a steady state, **regeneration** goes further. Sustainability often assumes that ecosystems will remain in balance if human impacts are minimised. However, nature is not static—ecosystems evolve, adapt, and thrive through dynamic change. Regenerative approaches embrace this reality, seeking to sustain and actively participate in and amplify life's capacity for renewal, abundance, and evolution.

A regenerative approach is thus not only about reducing negative impacts; it is about generating positive impacts based on principles that living systems have evolved over millions of years:

- **Recognising** that ecosystems are self-organising, dynamic, and create richness through symbiotic relationships.
- **Guiding** human activities by harnessing these characteristics to foster prosperity, resilience, and evolution.
- **Designing** interventions that mimic and reinforce nature's regenerative processes rather than seeking to impose artificial equilibrium or control.

Learning from Nature: Two Illustrative Systems

Natural ecosystems offer powerful examples of regenerative processes.

- Coral reefs result from the symbiotic association of algae with corals. Some of them initially used resources from ancient volcanoes but continued to thrive after these emerged volcanoes sank again into the ocean. The symbiotic relationship between corals and algae builds on the combination of photosynthesis that generates organic molecules and mineral absorption by the corals. It progressively creates an extraordinary biodiversity. According to the EPA (2023), 25% of all marine life, including 4000 fish species, depend on coral reefs at some point in their life cycle. This is facilitated by continuously recycling the nutrients within the coral reef, which continuously accumulates resources. Coral reefs are also self-organised systems that have often survived severe sea-level changes.
- The tropical Amazon rainforest develops on relatively poor soils called laterites, which result from the intense leaching of most nutrients in humid tropical regions. Nevertheless, some of the most biodiverse ecosystems have emerged from these poor soils. These ecosystems are enormous webs of interdependent species that share resources and ensure that the nutrients are continuously recycled across the multiple species of the forest. It has been shown (Gaillardet, 2023) that the tiny amount of nutrient losses drained by the Amazon River network is mostly compensated by wind deposits of mineral species from the Sahara region.

Both ecosystems illustrate key regenerative mechanisms:

- **Symbiosis and interdependence** among species
- **Continuous recycling** of resources to maintain productivity

Human economic systems, including the forest and wood sectors, must be redesigned around these principles to truly thrive over the long term.

A **Regenerative Forest Economy** envisions industries and regions where economic activity does not merely reduce harm but **actively contributes** to the health, resilience, and vitality of forests and the communities that depend on them

Principles for a Regenerative Forest Economy

Introduction

Building on the understanding that regeneration means working with, rather than against, the dynamic principles of living systems, we propose a set of principles based on existing literature that are tailored explicitly to the forest-to-wood value chain.

A **Regenerative Forest Economy** envisions industries and regions where economic activity does not merely reduce harm but actively contributes to the health, resilience, and vitality of forests and the communities that depend on them (Capital Institute, 2024).

In this model, forests are seen as evolving living systems. Their management—and the industries that rely on them—are designed to enhance the ability of these systems to regenerate themselves over time, socially, ecologically, and economically. Value extraction is no longer a one-way process but is continuously reinvested into strengthening the forest's capacity to thrive (Larsen et al., 2022; Soil Association, 2024).

Principles

The following principles lay the foundation for transitioning from extractive and linear models toward a truly regenerative forest economy:

Taking a holistic and systemic approach
Acknowledge the interconnectedness of forest landscapes, wood products, ecosystem values, and socio-economic realities. It focuses on "seeing" the whole forest and wood system as one. The value extracted from the forest must be returned in ever greater volumes through integrated loops (Soil Association, 2024; Capital Institute, 2024).

Prioritising material avoidance and circular use
Virgin harvesting from forests must come last, only after all options to use reused or recycled wood have been exhausted. Through careful design:

1. The **avoidance of material use** comes first,
2. The **reuse of existing materials** in their original form (wood or otherwise) comes second,
3. The **recycling of materials** through cascading uses comes third, and
4. **Virgin sourcing** from forests is a last resort, in line with circular economy principles (Ellen MacArthur Foundation, 2024).

Maximising carbon storage throughout the forest-product lifecycle
Increase carbon sequestration in forest soils, dead biomass, and living trees while simultaneously expanding carbon storage in long-lived harvested wood products. This approach is amplified by circular design strategies that ensure wood products are reused multiple times before recycling or disposal, and by substituting fossil-fuel-dependent materials such as steel and concrete (Built by Nature, 2024; WorldGBC, 2023).

Promoting improved forest management practices
Support forest management practices that deliver optimal outcomes for climate, nature, and people, regardless of management style (active or non-intervention), forest origin (planted or regenerated), or designated purpose. This holistic approach contrasts with traditional short-rotation forestry models, which often prioritise biomass output through intensive management and monocultures (Di Sacco et al., 2021; FAO, 2023; Larsen et al., 2022).

Emphasising restoration, resilience, and adaptability
Ensure that forests can continue to provide essential benefits over the long term. This requires realistic assessments of climate risks and biodiversity pressures, alongside adaptive management strategies that bolster forest resilience (Di Sacco et al. 2021).

Acknowledging and managing trade-offs
Recognise the inevitable trade-offs between timber production and the wider ecosystem services forests provide. Integrate these considerations to ensure forests contribute meaningfully to climate goals, biodiversity, and human well-being (Clay and Cooper, 2022).

Focusing on place-based approaches
There is no "one-size-fits-all" model for a regenerative forest economy. Successful strategies must be rooted in deeply understanding local ecological, cultural, and socio-economic conditions and respecting each landscape's unique characteristics, as Regenesis proposed (Mang and Haggard, 2016).

Empowering local communities and supporting strong livelihoods
A Regenerative Forest Economy must strengthen the capacities of local communities, provide meaningful livelihoods, and foster social contracts that link economic prosperity directly to the health and regeneration of forest ecosystems (Soil Association, 2024).

Aligning for Impact: Mapping Forest-Wood Principles

As demand for wood-based materials increases—from buildings to packaging and paper—there is a need to ground this transition in shared principles that uphold environmental integrity and social value. Wood-based materials help reduce emissions and link forests, industries, and communities through a value chain that supports long-term climate resilience. To guide this, we highlight three frameworks for improving forest-to-wood value chains:

Principles for Responsible Timber Construction (Built by Nature, 2024)

Global Policy Principles for a Sustainable Built Environment (World Green Building Council, 2023)

Regenesis Group's regenerative development philosophy (Mang and Haggard, 2016)

Though Built by Nature and WorldGBC focus on the built environment, their principles extend further. Ideas like whole-life carbon thinking, circularity, regeneration, and equity also apply to sectors such as furniture, packaging, and paper. Aligning around these fosters coherence, enabling wider collaboration and greater impact.

Each framework provides a distinct lens. Built by Nature stresses responsible sourcing, carbon accountability, and circularity. WorldGBC offers a systems-level approach covering emissions, equity, health, and biodiversity. Regenesis promotes a regenerative mindset rooted in place, living systems, and the evolution of human and ecological potential.

The comparative mapping draws these perspectives together, showing both alignment and distinction. Several themes support the forest-to-wood value chain's role in climate resilience:

- Carbon accountability and storage are core across frameworks
- Circular design improves material efficiency, eases forest pressure, and supports carbon goals
- Collaboration and capacity-building drive systems change, especially in Regenesis's long-term regenerative focus.
- Place-based thinking and ecosystem restoration stress local context and stewardship.

By recognising these foundations, forest-to-wood actors can align and shape a regenerative future that enhances life.

Theme	Built by Nature	WorldGBC	Regenesis Group
Carbon/ Climate	Account for Whole Life Carbon Emissions and Maximise Carbon Storage Potential of Wood	Eliminate operational and embodied carbon across a material/product lifecycle	-
Water	-	Conserve and protect water resources	-
Resilience	-	Enhance climate resilience and promote adaptation	-
Biodiversity	-	Regenerate ecosystems and restore biodiversity	-
Circularity/ Materials	Maximise Carbon Storage Potential of Wood and Extend the Life of Existing Buildings	Drive waste out of the construction value chain	-
Health, Equity & Access	-	Develop healthy, resilient buildings and cities and Ensure access to safe, sustainable homes for all	-
Place-based	-	-	Work from and tell the Story of Place
Living Systems Alignment Beyond Sustainability	Align Human Activities with Natural Systems	Promote holistic, transformative change	Align with Living Systems and move Beyond Sustainability
Collaboration	Promote a Timber Building Bioeconomy	Support equal access and public consultation	Foster Collaborative Relationships
Capacity Building	Promote a Timber Building Bioeconomy	Develop healthy, resilient buildings and cities	Evolve Capacity, Not Just Outcomes

Principles for Responsible Timber Construction

Built by Nature's Principles for Responsible Timber Construction provide a framework to ensure sustainable and responsible practices in timber building.

1. **Extend the Life of Existing Buildings:** Prioritize repurposing, renovating, or extending current structures using timber and other low-carbon materials over demolition.
2. **Account for Whole Life Carbon:** Emissions Design and construct timber buildings to minimize life cycle impacts, optimize operational efficiency, and reduce embodied carbon emissions, with transparent differentiation between biogenic and fossil carbon.
3. **Ensure Sustainable Forest Management:** Source wood-based materials from forests managed to maintain and enhance economic, social, and environmental values for present and future generations.
4. **Maximize Carbon Storage Potential of Wood:** Use wood efficiently, prioritize its application in durable products, and promote circularity through design for disassembly to facilitate reuse and extend material lifespan.
5. **Promote a Timber Building Bioeconomy:** Provide education and training across the value chain on responsible timber use, and support innovation and research to enable a thriving timber construction economy and culture.

Global Policy Principles for a Sustainable Built Environment

WorldGBC's Global Policy Principles for a Sustainable Built Environment provide a systems-level framework to drive climate resilience, equity, and ecological restoration across the building and construction sectors.

1. **Carbon:** Prioritise renovation of existing buildings and eliminate operational and embodied carbon emissions throughout the building lifecycle.
2. **Water:** Protect water resources by ensuring equitable access to clean water and sanitation, while enhancing efficiency and reuse.
3. **Resilience:** Enhance communities' capacity to adapt to shocks and stresses through climate-resilient planning and infrastructure.
4. **Biodiversity:** Restore and protect ecosystems by avoiding development on ecologically sensitive land and using nature-based solutions.
5. **Circularity:** Reduce waste and resource consumption by designing for reuse, recovery, and minimal use of primary materials.
6. **Health:** Promote public health through better building design—prioritising indoor air quality, safe materials, and healthy environments.
7. **Equity and Access:** Guarantee all citizens access to safe, affordable, and sustainable housing, with a focus on inclusivity and human rights.

Principles of Regenerative Development

The Regenesis Group's Principles of Regenerative Development offer a living-systems approach, focusing on working from place, aligning human activities with nature, and evolving the capacity of communities and ecosystems to thrive over time.

1. **Work from Place:** Understand and respond to the unique ecological, cultural, and historical character of each place to reveal its deeper potential.
2. **Align with Living Systems:** Design and build in harmony with natural processes, enabling human and ecological systems to thrive together.
3. **Tell the Story of Place:** Use storytelling to deepen connection, inspire stewardship, and guide meaningful development rooted in local identity.
4. **Foster Collaborative Relationships:** Engage diverse stakeholders to co-create solutions that strengthen community and ecological resilience.
5. **Evolve Capacity, Not Just Outcomes:** Focus on building the ongoing ability of people, communities, and systems to regenerate themselves over time.
6. **Move Beyond Sustainability:** Shift from minimizing harm to actively creating conditions for life to flourish—socially, environmentally, and spiritually.

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Glossary

A

Afforestation
The establishment of forests on land that was not previously forested, enhancing carbon sinks and ecosystem resilience.

B

Bioeconomy
An economic model centred on renewable biological resources—such as forests—for producing food, energy, materials, and services sustainably.

C

Carbon Accounting
The process of measuring, tracking, and reporting carbon emissions and removals within a defined boundary, often used in climate policy and offset schemes.

Carbon Sequestration
The long-term capture and storage of atmospheric CO_2 in biomass (e.g., trees), soils, or durable timber products.

Carbon Sink
The capacity of a forest to absorb more CO_2 than it emits, primarily through photosynthesis and soil carbon storage.

Cascading Use (of Wood)
A strategy in which wood is used first in the highest-value and longest-lived applications (e.g., construction), followed by reuse, recycling, and finally energy recovery.

Circular Economy (Forestry)
A resource-efficient system prioritising the reuse, recycling, and cascading of wood before extracting virgin materials.

Climate-Smart Forestry (CSF)
Forest management practices that maintain or enhance carbon sinks while increasing forest resilience to climate change.

Climate-Smart Forest Economy (CSFE)
An economy based on sustainable forest use, aimed at delivering climate benefits, supporting local economies, and safeguarding ecosystems.

Commons
Community-governed natural resources managed collectively, often based on traditional or customary rules, ensuring equitable and long-term stewardship.

D

Decarbonisation
The process of reducing or eliminating carbon emissions across sectors such as energy, transport, and construction, often through renewable energy and low-carbon materials.

Decomposition
The biological breakdown of dead organic material, releasing carbon dioxide as part of the natural carbon cycle.

E

Ecosystem Health
An ecosystem's ability to maintain its functions—such as biodiversity, carbon storage, and nutrient cycling—under changing conditions.

Emission Factors (EFs)
Standard values (e.g., tonnes CO_2 per hectare per year) used to estimate emissions or sequestration based on land use and forest type.

F

Forest Archetypes
Typologies of forest use, including: Plantations: Intensively harvested and often monocultural.

- Unmanaged Forests: Left to natural processes, important for biodiversity and long-term carbon storage.
- Managed Forests: Sustainably used to produce wood while maintaining ecological benefits.

G

Gross Carbon Sink
The total annual amount of carbon dioxide absorbed by a forest before accounting for emissions from harvesting, fires, or decay.

H

Harvest Pressure
The proportion of a forest's annual growth that is harvested. Pressures above 100% suggest carbon depletion and unsustainable use.

I

Improved Forest Management (IFM)
Enhanced forestry practices designed to increase carbon storage, biodiversity, and resilience compared to business-as-usual scenarios.

K

Key Performance Indicator (KPI)
A quantifiable measure used to evaluate the success of a project or strategy in achieving defined environmental, economic, or social goals.

L

Landscapes as Regenerative Commons
An integrated approach that treats landscapes as co-managed ecosystems, governed locally and designed to regenerate over time.

Life Cycle Assessment (LCA)
A methodology to assess environmental impacts throughout a product's entire life cycle—from raw material extraction to end-of-life disposal.

LULUCF
"Land Use, Land Use Change, and Forestry": a category used in climate policy for emissions/removals from land-based activities.

M

Monitoring, Evaluation and Learning (MEL)
A structured, iterative process for tracking progress, reflecting on results, and adjusting strategies for greater impact and resilience.

N

Net Carbon Sink
The carbon sequestered by a forest after subtracting emissions from harvesting, fire, and decomposition. A positive value supports climate mitigation. Also named Net Biome Production by IPCC.

P

Place-Based Approach
A method that tailors strategies to local ecological, cultural, and socio-economic conditions to ensure appropriate, effective outcomes.

R

Regenerative
Describes approaches that go beyond sustainability by actively enhancing ecosystems, community wellbeing, and long-term resource capacity.
Regenerative Forest Economy (RFE)
An economic system where forest-based industries enhance carbon stocks, community resilience, and environmental integrity.

Resilience
The capacity of forests or communities to adapt to and recover from external pressures, such as pests, fire, or climate change.

S

Safeguards (CSFE)
Preventative and adaptive measures to ensure forest-related actions deliver climate, social, and ecological benefits without unintended harm.

Scope 1, 2, 3 Emissions
Greenhouse gas emission categories:

- Scope 1: Direct emissions from owned/controlled sources.
- Scope 2: Indirect emissions from purchased electricity, heat, or steam.
- Scope 3: All other indirect emissions (e.g., supply chain, end-use).

Symbiosis
A mutual, interdependent relationship in nature (e.g., between trees and fungi), fundamental to regenerative ecosystems.

Climate KIC

Reconnecting Forest-to-Wood Value Chains
A Framework for Action

May 2025