The growing role of forest products in climate change mitigation & the need for nationally determined forestry approaches to achieve net zero emissions

Dalberg

17 November 2022

Report available at: www.dalberg.com

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ABBREVIATIONS & ACRONYMS

ACRONYM & ABBREVIATION	DEFINITION
ACT	Assessing Low Carbon Transition
CBD	Convention on Biological Diversity
CLT	Cross Laminated Timber
CO^2	Carbon Dioxide
EFI	European Forest Institute
EIA	Energy Information Administration (U.S.)
EPBD	Energy Performance of Buildings Directive
ESG	Environmental Social Governance
FLEGT	Forest Law Enforcement, Governance and Trade
GHG	Greenhouse gas emissions
IACGB	International Advisory Council on Global Bioeconomy
IIED	International Institute for Environment and Development (IIED)
IRW	Industrial Round Wood
ITTO	The International Tropical Timber Organization
HWPs	Harvested Wood Products
LCA	Life Cycle Analysis
NDI	Nationally Determined Indicators
NDCs	Nationally Determined Contributions
OSB	Oriented Strand Board
PNDF	The National Plan for the Development of Planted Forests (Brazil)
SDGs	Sustainable Development Goals
SFM	Sustainable Forestry Management
SHFs	Smallholder farmers
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Framework Convention on Climate Change
UNFCCC	United Nations Environment Programme
UNFF	United Nations Forum on Forests
VPA	Voluntary Partnership Agreements
WBCSD	World Business Council for Sustainable Development
WEPs	Wood Encouragement Policies
WWF	Worldwide Fund for Nature

GLOSSARY

BIOECONOMY: the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology and innovation, to provide sustainable solutions (information products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy (IACGB, 2020; FAO, 2021)

CASCADING USE: the efficient utilization of resources by using residues and recycled materials for material use to extend total biomass availability within a given system (Vis et al., 2016)

EMBODIED CARBON: carbon emissions stemming from manufacture, installation, upkeep, and deconstruction/demolition of building materials (Gregory Richards, 2022)

FOREST PRODUCTS: refer to either wood products (e.g., wood pulp and timber) or non-wood products (e.g., bioenergy, animal products, food products, etc.,)

FOREST ECOSYSTEM SERVICES: the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber and fiber, regulating services that affect climate, floods, diseases etc., cultural services that provide recreational, aesthetic and spiritual benefits, and supporting services such as soil formation, photosynthesis and nutrient cycling (FAO,2022f)

FOREST POLICY: a set of orientations and principles of actions adopted by public authorities in harmony with national socio-economic and environmental policies in each country to guide future decisions in relation to the management, use and conservation of forest for the benefit of society (FAO, 2020)

HARVESTED WOOD PRODUCTS: wood-based materials harvested from forests, which are used for products such as furniture, plywood, paper, and paper-like products, or for energy (UNECE,2021))

LIFE CYCLE ASSESSMENT: a process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities. (EEA, undated)

NON-WOOD FOREST PRODUCTS: goods derived from forests that are tangible and physical objects of biological origin other than wood (FAO, 2020). Examples include food (e.g., nuts, fruits), food additives (e.g., spices, herbs), and fragrances for perfumes

NATURE-BASED SOLUTIONS: actions to protect, sustainably manage, and restore natural or modified ecosystems and that address societal challenges effectively and adaptively, simultaneously providing benefits for human well-being and biodiversity (FAO, undated)

NATURAL CLIMATE SOLUTIONS: conservation, restoration and improved land management actions that increase carbon storage or avoid greenhouse gas emissions in landscapes and wetlands across the globe (The Nature Conservancy, 2021)

PLANTATIONS: planted forest that is intensively managed and meet all the following criteria at planting and stand maturity: one or two species, even age class, and regular spacing (FAO, 2020)

PULPWOOD: roundwood that will be used for the production of pulp, particleboard, oriented strand board or fiberboard (FAO,2022a)

SUSTAINABLE FOREST MANAGEMENT: a dynamic and evolving concept, [that] is intended to maintain and enhance the economic, social, and environmental value of all types of forests, for the benefit of present and future generations (FAO, 2020)

WOOD FUEL: refers to roundwood that will be used as fuel for purposes such as heating or power production (FAO, 2022a)

EXECUTIVE SUMMARY

More than ever, people are moving to urban areas which have historically made a significant contribution to global greenhouse emissions. Cities already account for more than 80% of global economic output, consume close to two-thirds of the world's energy, and account for more than 70% of global greenhouse gas emissions. Every day our cities grow by around two hundred thousand people. The global urban population is expected to rise by 18% and 52% by 2030 and 2050 respectively, driven by both population growth and the migration from rural to urban areas to seek prosperity, jobs, a better standard of living, access to healthcare, education, and for a longer lifespan (Gresham House, 2020). This is driving an increase in housing, manufacturing, and energy needs.

While this represents one of our greatest challenges in meeting climate targets, it also presents enormous opportunities to transform our existing linear fossil-based economy system towards a new economic paradigm where prosperity takes place within the planetary boundaries and its renewable potential. Notably, cities and communities represent engines of innovation and provide novel sustainable solutions and options to promote resource efficiency which open opportunities to attract new capital and investments (FAO, 2022e).

Forests, trees, and wood and fiber can become the backbone for a circular bioeconomy and sustainable future considering the anticipated increase in population and urbanization. They provide emission reduction benefits through carbon sequestration, storage, and substitution, as recognised by the Intergovernmental Panel on Climate Change: *"in the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit."* (IPCC, 4TH Assessment, 2007).

The forest sector also supports human health, well-being, and urban biodiversity and helps reduce the energy needs for cooling and heating in buildings as well as the urban heat island effect. In construction, wood may increasingly replace high carbon intensive steel and concrete.

The World Business Council for Sustainable Development estimates that wood demand will grow by 8.8% per year to 2030 due to the building and construction sector alone (Moleman, 2020), and greater interest in buildings based on mass timber might further increase that demand. Broad macro trends have shown shifts towards wood and wood fiber usage in meeting increasing housing and energy requirements, especially for renewable material such as fiber packaging over plastics. For instance, in 2020, France enacted a law requiring 50% wood or other bio-sourced material in public buildings from 2022 (The Times, 2020). This trend is expected to continue, and consequently demand for wood and wood fibers is expected to increase further. This demand is estimated to be mainly driven by construction and packaging industries, which are expected to triple and double respectively by 2030 (WBCSD, 2020).

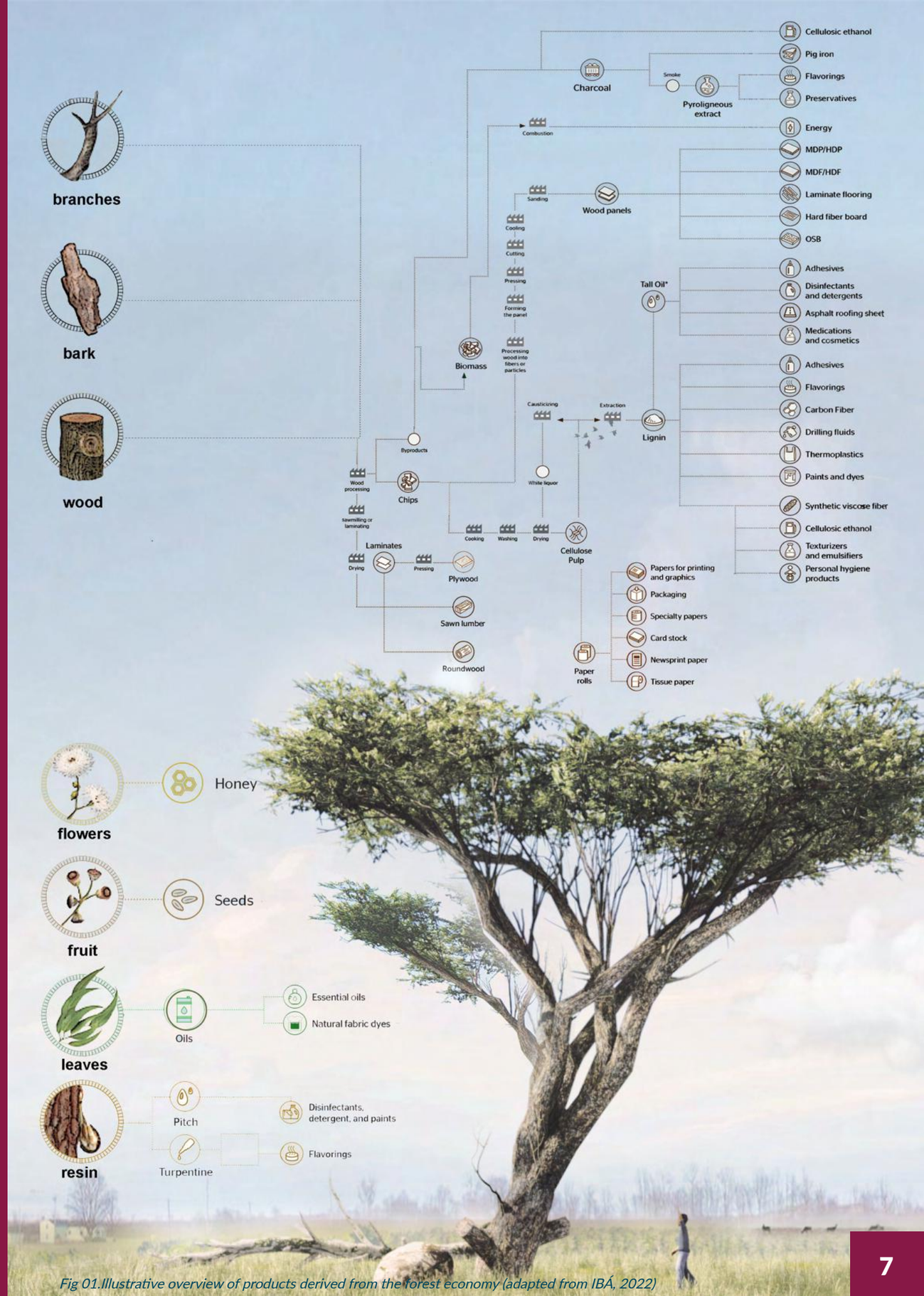


Fig 01.Illustrative overview of products derived from the forest economy (adapted from IBÁ, 2022)

This projected rise in wood and wood fiber demand is set against a constrained supply which must be increased to fully utilize the climate mitigation contribution of wood-based products.

In the short term, there are quick wins around ensuring that forest ecosystems are sustainably managed to optimize their benefits. For instance, there is a need for awareness creation and knowledge sharing around the different types and contributions of various sustainable forest management systems to complement the existing supply of wood.

This could involve sharing good practices on holistic approaches that incorporate sustainable forest management alongside the protection of ancient forests, reforestation of native species and afforestation in some places with sustainable timber plantations or planted forests. Additionally, creating conducive environments for forest actors can unlock market forces that far outweigh the monetary value of non-market agents and further incentivizes sustainable forest management, but also complements the increased efficiency in the sector. Innovative approaches, should also be adopted in monitoring and evaluating current practices to ensure learning from existing approaches are ongoing.

Notably, wood and fiber value chains have experienced severe shocks in the last 36 months, with the COVID-19 pandemic and the Ukraine-Russia conflict as particular and ongoing market stresses. The importance of building resilient value chains for wood and wood fiber to reduce the inherent breakages in “long” value chains is vital. To achieve this, investment in the local supply side and diversification in demand side options will be necessary for continuous optimization in a multi-polar political world that is increasingly vulnerable to human made and climate related shocks.

The assessment also identifies the need for coordinated international efforts aimed at globalizing knowledge around the opportunity with wood products, understanding challenges with meeting demand, and localizing solutions at a national level. To achieve this, governments, private sector players, and other policymakers will need to work together and learn from each other.

Fig 02. Collaboration among stakeholders in within wood product industry include suppliers, consumers and policy makers (Dalberg, 2022).

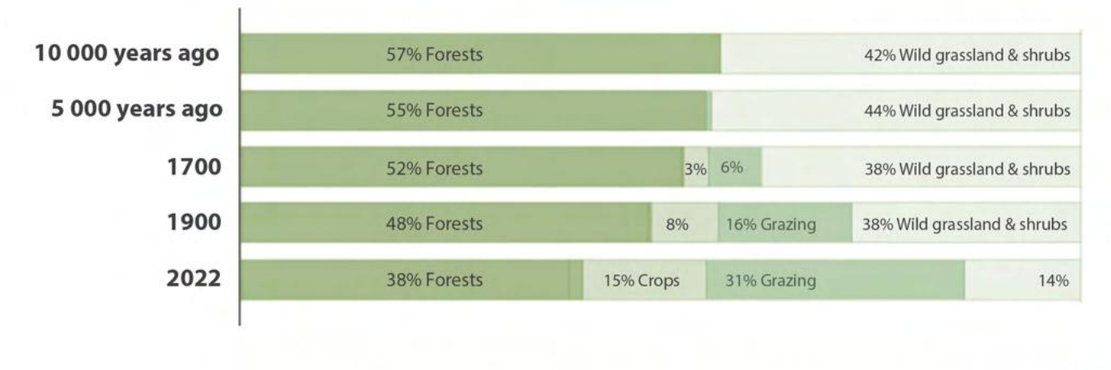


Fig 03. Graph showcases forest and other habitat destruction over time (Dalberg, 2022).

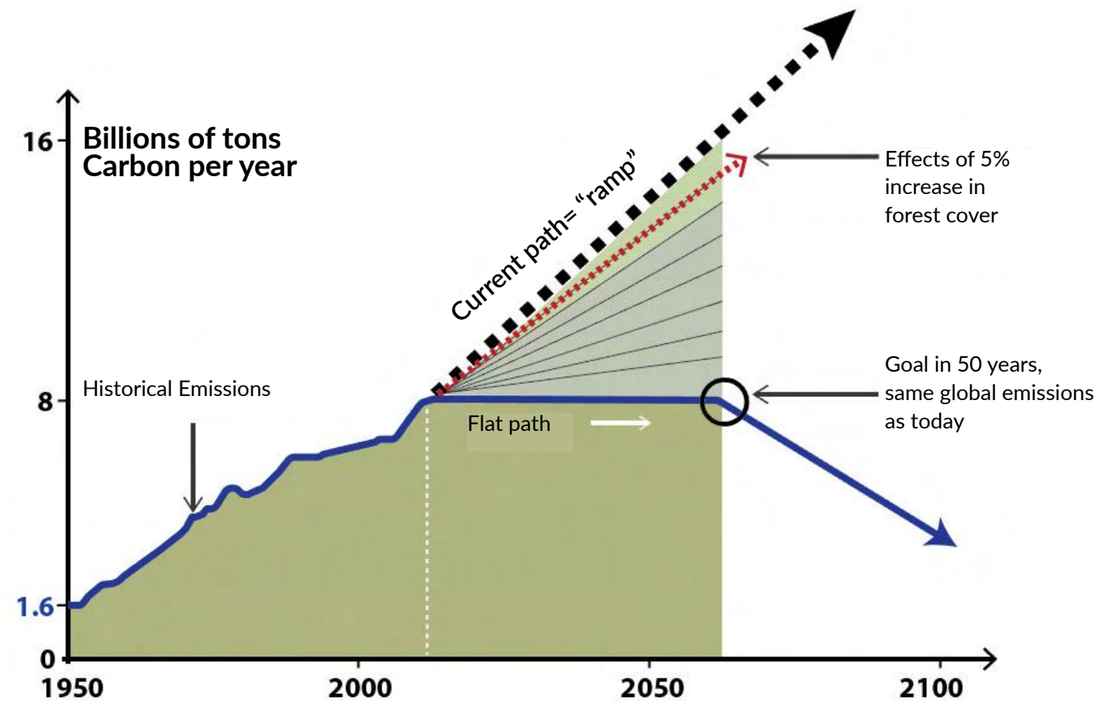
Biodiverse forests can be conservation proposals that are applied on a large scale for all land and waters which have increasingly relied on 30% (i.e., 30% protected by 2030) and 50% targets for protection that involve triage approaches (DellaSalla et al., 2022). There is policy relevance in large-scale target setting as shown by United States President Joe Biden's executive order which directed agencies of the federal government to develop 30x30 targets for all lands and waters in the United States that aim to reverse the negative impacts of biodiversity decline and climate change. (White House, 2022).

The global commitment to not only preserve and conserve forests, in the manner of 30x30, could be well served by a similar ecological initiative to increase forest cover by 5% by 2050. A high-level analysis of total carbon sequestered per hectare was undertaken to determine what a moderate target range for increased forest cover for tangible impact on the Paris agreement. FAO statistics informed the base line data, while the proposed percentage increase in forest cover is based on World Bank data.

The analysis below, based on historical data, highlights 3 potential scenarios of the volume of carbon sequestered when forest cover is increased by 1%, 5% and 10%.

SCENARIO	BASELINE - FAO	CONSERVATIVE – 1% INCREASE IN FOREST COVERAGE	MODERATE – 5% INCREASE IN FOREST COVERAGE	AMBITIOUS – 10% INCREASE IN FOREST COVERAGE
TOTAL FOREST COVERAGE	4.06 billion Ha	101% x 4.06 billion Ha = 4.1006 billion Ha	105% x 4.06 billion Ha = 4.263 billion Ha	110% x 4.06 billion hectares = 4.466 billion Ha
CARBON SEQUESTERED PER HA	163 tons	163 tons	163 tons	163 tons
VOLUME OF CARBON SEQUESTERED PER HA	662	4.1006 billion Ha x 163 tons per ha =668.3978 Gt Increase in carbon sequestered = 668-662 = 6 Gt	4.263 billion Ha x 163 tons per ha =694.869 Gt Increase in carbon sequestered = 695-662= 33 Gt	4.466 billion Ha x 163 tons per ha =727.958 Gt Increase in carbon sequestered = 728 – 662 = 66 Gt

Fig 04. Stabilization Wedge Analysis of the impact of 5% increase in forest coverage on carbon sequestration (Dalberg, 2022).

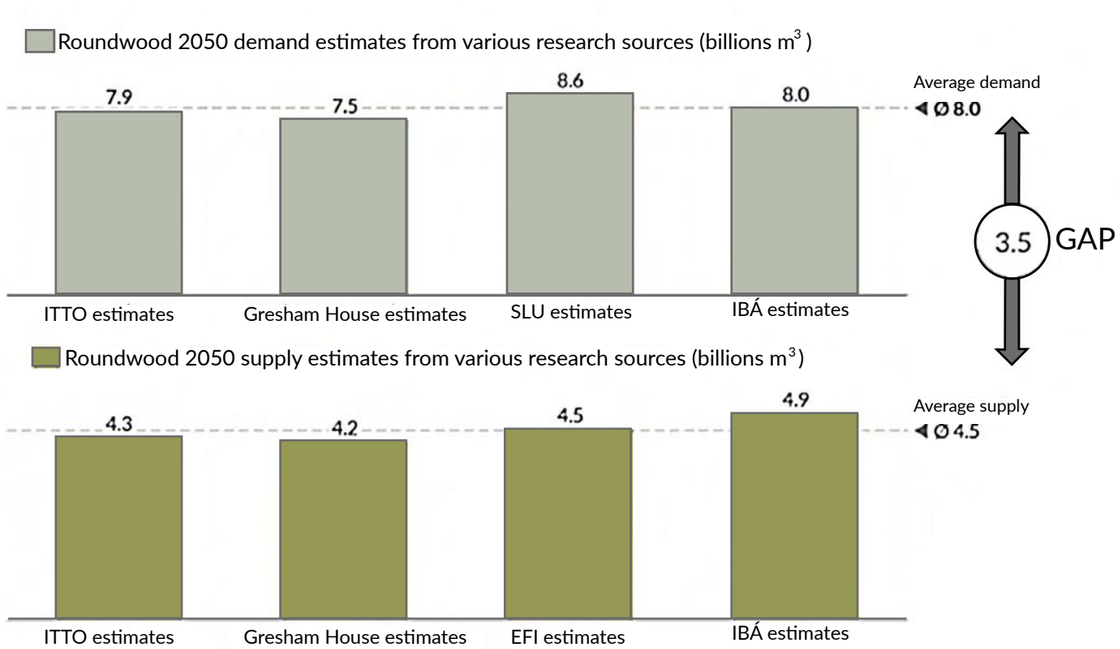


A moderate 5% increase, would comprise of varying contributions by various countries, determined within their ecological and socio-economic constraints, and vary according to their capacity and intersection with ecosystem services, resources, and land use practices and regimes.

These biodiversity and afforestation commitments would give greater life to Nationally Determined Contributions (NDCs) which are at the heart of the Paris Agreement and the achievement of its long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change, and the significant impact of NDCs to new and existing forests could further secure climate smart sustainable wood and wood fiber supply to meet the unavoidable demands of future generations. Every country would exercise their sovereign rights in respect of their contribution.

By 2050, the supply/ demand gap for roundwood alone is estimated to range from 3.1-4.1 billion cubic meters which implies an average of 3.5 billion cubic meters based on multiple supply and demand estimates (SLU,2017; Gresham House, 2020; ITTO, 2021; IBÁ, 2022). This is as a result of increasing demand for wood and wood products and constrained supply. Consequently, the world will need to boost supply to close this projected gap.

Fig 05. 2050 roundwood demand-supply gap (Dalberg, 2022).



To meet this gap, it is projected that, holding naturally regenerated forest production stable, an additional minimum 33 million ha of highly productive plantation forest would need to be established to supply basic industrial roundwood demand (FAO, 2022d). Other studies considering the full range of products from forests such as lumber and packaging, project that the area of planted forests for timber production is likely to increase by 20-40 million ha by 2050 (Korhonen et al., 2021).

Various technological innovations in farming and animal husbandry, and forest management suggest that land uses may be further optimized whilst increasing biodiversity, supporting green livelihoods and increased food security. The 2021 United Nations Food Systems Summit and related initiatives has shown that transformation of global agrifood systems has started (FAO,2022f) and likely to catalyse global recovery from the short-term crisis resulting from the pandemic and the longer and deeper emergency due to potential "planetary health" crisis (FAO, 2022).

The recent report, "The State of the World's Forests 2022," by FAO is instructive, providing three interrelated forest activities for economic and environmental recovery (FAO,2022):

a. Halting deforestation and maintaining forests- This could avoid 3.6 +/- 2 gigatons of carbon dioxide equivalent (GtCO2e) emissions per year between 2020 and 2050. This about 14 percent of what is needed up to 2030 to keep planetary warming below 1.5 °C, whilst safeguarding over half of the Earth's biodiversity (FAO,2022f).

b. Restoring degraded lands and expanding agroforestry – This restoration would benefit 1.5 billion ha of degraded land and increased tree cover could boost the productivity of agriculture on another 1 billion ha. The restoration of degraded land through afforestation and reforestation is a cost-effective way to take 0.9–1.5 GtCO2e per year out of the atmosphere between 2020 and 2050 (FAO,2022f).

c. Sustainably using forests and building green value chains- This would help meet the future demand for materials as the global consumption of all natural resources is expected to more than double from 92 billion tons 2017 to 190 billion tons in 2060 – and be the foundation of sustainable economies (FAO,2022f).

These pathways are mutually reinforcing, and when synergies are maximized, the pathways can provide some of the highest returns in the form of climate and environmental benefits while also enhancing local sustainable development potential, adaptive capacity, and resilience (FAO, 2022).

A 5% increase in biodiversity-rich and climate-smart global forest cover, would bode well for the Paris Agreement, increase the likelihood for greater biodiversity, support land degradation neutrality and help unlock the potential of green livelihoods which will increasingly rely of sustainable forest economies and products. Framing this as biodiversity pledge or commitment would be a tangible benefit for climate and biodiversity.

Sustainable forestry operations, and therefore policies which will enhance those operations, vary across the globe in efficacy. The suggestion therefore is that, as is the case in climate change negotiations, it is sensible to strive for a shared global understanding and agreement of the need to grow sustainable production and supply of wood-based products but seek nationally determined approaches towards said goal.

Fig 06. Sustainable forestry practice across the globe (Dalberg, 2022).

INTRODUCTION

Purpose of this report

This report seeks to understand the future supply and demand patterns of the full range of wood and fibre products derived from trees and forests to pose promising considerations for policy and decision makers. There is an opportunity to create policies that help to promote a sustainable forest product market and are suited to different national contexts while working cohesively across regions and the globe. There are also opportunities for knowledge sharing to ensure that future supply can meet demand, while reaping the benefits of forestry and forestry products for climate mitigation goals.

Throughout this report, the reader should engage with content on the role of forestry and forest products in climate mitigation, and broadly in support of sustainable forest management. Not all forest economy development leads however to desirable long-term outcomes. For example, while forests and the use of forest products play a crucial role in realizing climate mitigation ambitions, developing the forest sector also presents deforestation risks if not aptly managed. Additionally, developing other forest-sector adjacent carbon markets may hinder the supply of wood products and carbon only plantings can remove productive land from food and fibre opportunity. Thus, the need for sustainable forest management cannot be overstated

Finally, this report aims to make a case for country-specific approaches to sustainable forest economies, all anchored on shared principles. Having established the shared importance of forests and forest products to the climate mitigation and adaptation agenda, the research pulls examples of efforts that vary by country (and at times locality) but which all work towards the shared goal of building sustainable forest economies.

Scope and methodology

The scope of this report focuses on:

I. Showcasing the importance of wood and fibre based products (timber, paper and packaging and others) in global climate change mitigation ambitions to move to carbon-neutral societies

II. Analysing the impact of climate change mitigation policies, commitments, and other macro trends (e.g., increased population, urbanization, carbon offset markets) on wood products demand, and comparison of this demand to supply

III. Illustrating the gap, if any, that will exist in sustainable supply to meet demand by 2050

IV. Outlining a high-level view of potential interventions by policymakers and other decision-makers to curb a possible supply-demand gap in 2050

Insights presented in this report are from extensive desktop research. Illustrative demand and supply estimates of wood products by 2050 are from comparing the results of various publications that either incorporate an illustrative business-as-usual scenario demand-supply gap assessment or seek to pursue more exact estimates.

BACKGROUND

Forests, forest products and climate mitigation

The resounding global commitment to limit warming to 1.5 degrees requires a larger arsenal of climate mitigation pathways, central among them Nature Based Solutions (NBS) which are estimated to contribute to about a third of the 2030 emissions reductions targets (UNDP, 2019). NBS are conservation, restoration, and improved land management actions that increase carbon storage or avoid greenhouse gas emissions in forests, grasslands and agricultural land, and wetlands across the globe (The Nature Conservancy, 2021). If implemented across all ecosystems, they can deliver emission reductions and removals of at least 5 GtCO2e per year, with a maximum estimate of 11.7 GtCO2e per year. By 2050, this rises to at least 10 GtCO2e per year, with a maximum estimate of 18 GtCO2e per year. (UNEP, 2021)

The SDGs and multiple climate mitigation agreements also recognize the contribution of nature-based solutions to sustainable development. SDGs 6, 12, and 15[1] place sustainable use of natural resources, including forests as a key tenet of the development goals (UN, 2015). If implemented well they can support more productive and resilient communities with social, economic, and environmental returns. Climate mitigation and adaptation pathways related to forests are recognized under the Paris Agreement, the United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD), and other multilateral agreements. The SDGs and climate mitigation agreements are included in approximately 77%[2] of the Nationally Determined Contributions (NDCs). In addition to their inclusion in Nationally Determined Contributions, the SDGs and climate mitigation agreements induce international initiatives such as the Green Great Wall Initiative (GGW) which has the potential to provide environmental and socio-economic benefits.

The GGW initiative is an African-led movement that seeks to restore 100 million hectares of currently degraded land, sequester 250 million tons of carbon, and generate 10 million green jobs by 2030 (UNCCD, undated). This initiative has the potential to create potentially valuable tree crop value chains that through commercially viable restoration, that leads to ecological, and social-economic benefits within the Sahel (World Economic Forum, 2022). These benefits may include food security, financial opportunities for women as well as soil quality improvement, supporting biodiversity and carbon sequestration (World Economic Forum, 2022). The GGW offers these downstream benefits while being an economically viable initiative for investors, offering an average return of $1.2 for every dollar invested, with returns peaking at $4.4 (Isonio, 2021).
The private sector is also following suit with multiple actors recognizing this and accelerating private investments in forests. seeks to plant 200 million trees by 2030 (1t.org, 2021).

[1] SDG 6: Ensure availability and sustainable management of water and sanitation for all; SDG12: Ensure sustainable consumption and production patterns, SDG 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt reverse land degradation, and halt biodiversity loss

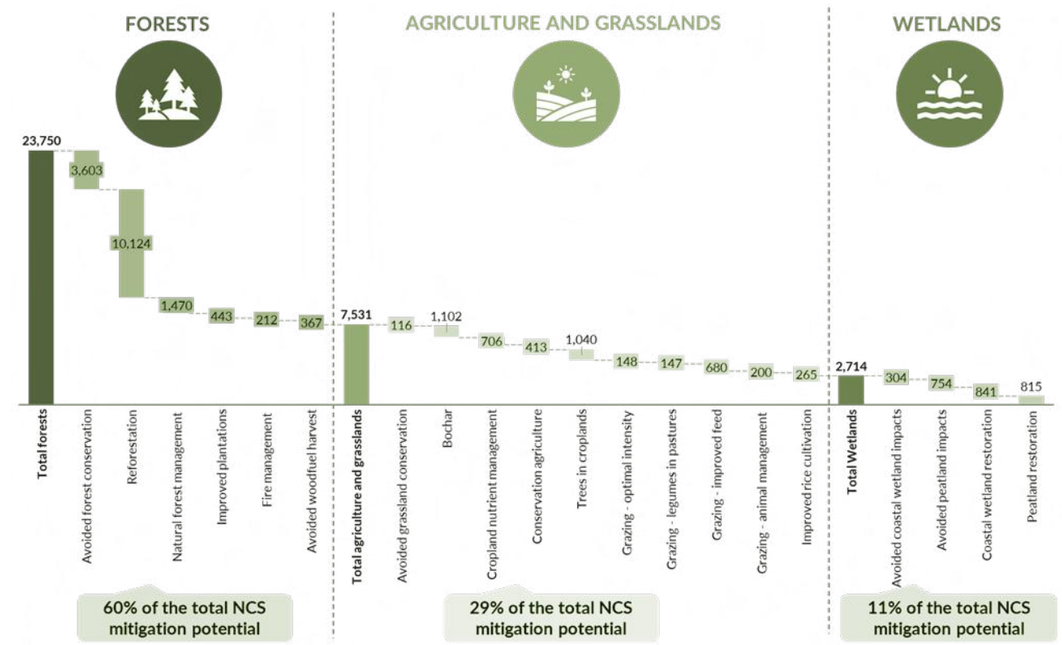
As of September 2022, 37 private companies, ranging from Amazon to AstraZeneca, have for example signed the “1t.org pledge” which offers companies the opportunity to make transparent and accountable their pledge towards conserving, restoring and growing trees and forests over the coming decade, and requires corporates to commit to ecological and social responsibility across their planning, implementation and monitoring activities and report annually (1t.org, 2022). Notable projects under this pledge include American Tower Corporation’s Million Trees initiative (1t.org, 2018), which seeks to plant one million trees across the United States of America and Nestle’s Global Reforestation program which seeks to plant 200 million trees by 2030 (1t.org, 2021).

The Komaza Smallholder Forestry Vehicle in Kenya is an example of another private sector investment in sustainable forestry. Under this vehicle, farmers provide land and labor, and the company provides technical assistance, presenting a viable option as farmers can invest in their own plantations without getting into debt and can convert their labour into assets (trees). 6,000 farmers have planted 2 million trees in about 4,000 ha under the scheme (FAO,2022f).

Beyond their economic benefits, forests have the highest contribution to climate mitigation ambitions compared to other natural pathways. Natural and planted forests occupy less than 30% of the earth’s surface but represent a $372 billion global market and provide over 60 million direct and indirect jobs (IBÁ, 2022). Planted forests take up 7% of global forest area but already provide over 50% of wood for industrial uses. (IBÁ, 2022). Renewable forest products from lumber to packaging to bioproducts possess vast potential to contribute towards the carbon-neutral transition of societies and build inclusive, resilient, and sustainable economies (FAO, 2022f).

Approximately 60% of the contribution to emission reductions from NBS is estimated to come from solutions related to forests, with about 29% stemming from solutions in grasslands and croplands, and 11% from solutions in wetlands[3]. Underlying these pathways is understanding that a sustainable forestry future includes a combination of protection of ancient forests , the careful management of native forests (for both reversing effects of centuries of human-induced deforestation and ensuring sustainably sourced supply) and an increase in the area of sustainably managed planted forests and timber plantations (to provide new sources of sustainable supply as consumption increases) (Climate Endowment, 2021).

Fig 07. Climate change mitigation potential of various natural pathways in million tons of CO2e per year (Griscom et al., 2017)

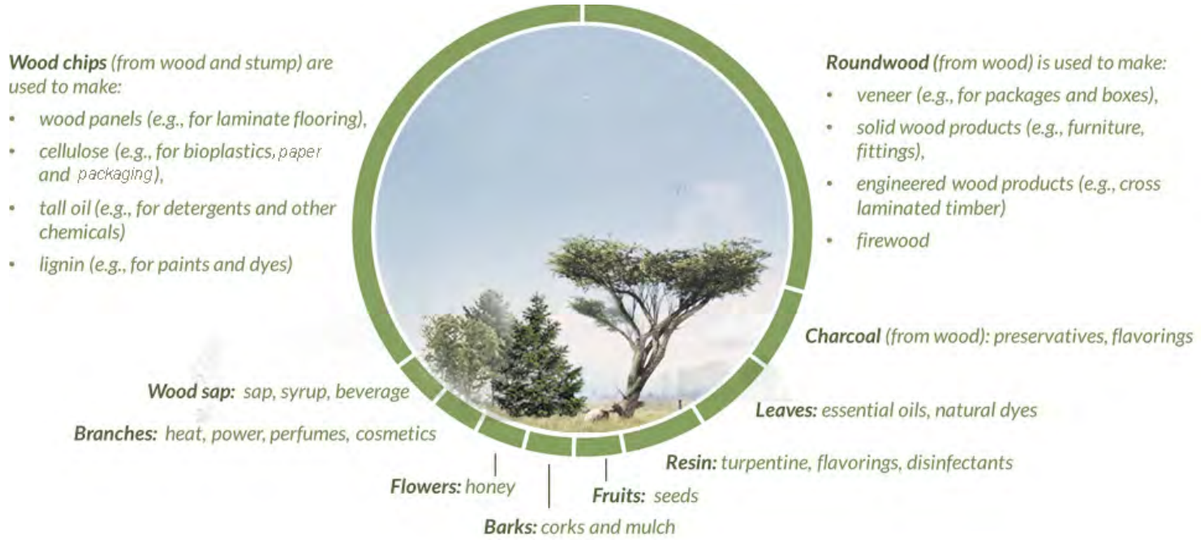


[3] Dalberg 2022 analysis of PNAS, Natural climate solutions 2017 data on climate mitigation potential of the 20 natural pathways

Forest products and services

In this report, 'forest products' refer to either wood (e.g., wood pulp timber, packaging) or non-wood (e.g., bioenergy, animal products, food products, etc.,). Forests offer a range of public and environmental goods beyond tradable products, including a sense of place, biodiversity richness, the regulation of the water cycle, protection against natural hazards, and offers opportunities for recreation, and spiritual and cultural amenity (Vussonji et al., 2022). Whilst these are vital and inalienable aspects of the broader value of forests, they are not covered in this report.

Fig 08. Illustrative overview of products derived from the forest economy (adapted from IBÁ, 2022)



The carbon cycle across various forest products

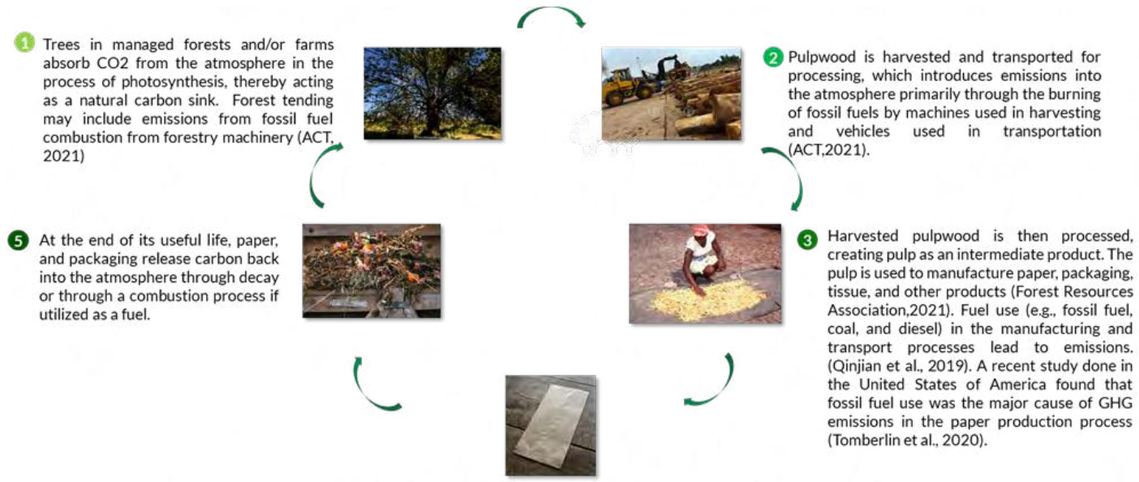
The total carbon contribution of forests and forest products to climate mitigation ambitions can be illustrated through the carbon cycle across various forest product categories below[4].

a) Paper and packaging

The paper and packaging industry represents a combination of both, paper and paperboard as well as packaging materials. Paper and paperboard includes the sum of graphic papers; packaging materials and paperboard, excluding manufactured paper products such as boxes, cartons, books, and magazines etc. (FAO,2022).

The packaging materials represent paper or paperboard that is mainly used for wrapping and packaging purposes (FAO,2022). The circulation of carbon in the paper and packaging value chain is through the following stages:

Fig 9. Carbon cycle for paper and packaging (adapted from ACT, 2021)

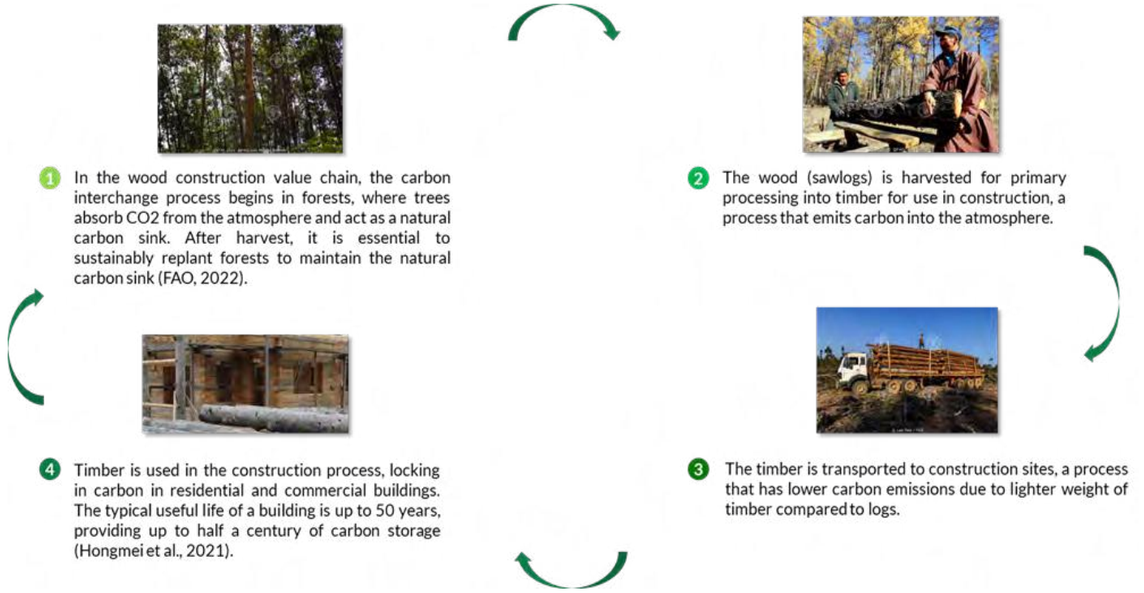


[4] Kindly note that the list does not consider use hierarchy and quality of wood

b) Mass timber

Mass timber can be defined as multiple solid wood panels nailed or glued together, which provide exceptional strength and stability (FAO and UNECE, 2021). Mass timber provides carbon storage and carbon substitution benefits, as shown in the carbon cycle described below:

Fig 10. Carbon cycle for mass timber (IIED, 2022)



c) Wood fuel

Wood fuel refers to roundwood that will be used as fuel for purposes such as heating or power production (FAO, 2022). It includes wood harvested from main stems, branches, and other parts of the trees for fuel purposes, charcoal, wood pellets and other agglomerates, as well as wood chips to be used for fuel that are made directly (FAO,2022).

Fig 11. Carbon cycle for wood fuel adapted from (Schulze et al., 2022)

1. The wood fuel carbon cycle begins in forests and other wooded areas, where trees absorb CO2 from the atmosphere and act as a natural carbon sink.

2. The wood is then processed into biofuels such as charcoal, which results in carbon emissions.

3. Biofuels are either used or sold to both rural and urban players, leading to carbon emissions during transportation.

4. Unlike fossil fuels, the burning of wood fuel releases emissions into the short-term carbon cycle which can be sequestered through the addition of new trees (IEA Bioenergy, 2018). If forests are sustainably managed, the emissions released through the burning of wood fuel may be absorbed by the new trees. However, this is highly dependent on regional and contextual considerations across the world.

d) Timber manufactured products

Timber-manufactured products, also known as secondary wood products, are defined as wood products and furniture, including products resulting from the further transformation of sawn wood and other wood-based materials (FAO, 2022a).

Fig 12. Carbon cycle for timber manufactured products (Dalberg,2022) loosely adapted from (IIED,2022)

1. The carbon interchange process begins in forests farms, where trees absorb CO2 from the atmosphere acting as a natural carbon sink.

2. Wood is harvested and transported, a process that introduces emissions into the atmosphere through the burning of fossil fuels by machines used in harvesting and transportation.

3. The harvested wood undergoes primary processing into timber. Secondary processing converts timber into wood products such as plywood, panels, furniture, etc. Emissions are introduced into the ecosystem during both manufacturing processes, except for processes that utilize renewable energy sources. The wood products may be finished products or inputs for other manufacturing processes.

4. The manufactured wood products continue to store carbon over their useful life either through their use in buildings or as furniture and fixtures (Hongmei et al. , 2021). The accumulated carbon is not released into the atmosphere until disposal. In wood products such as furniture, carbon is sequestered for approximately 30 years (Janowiak et al. ,2017).

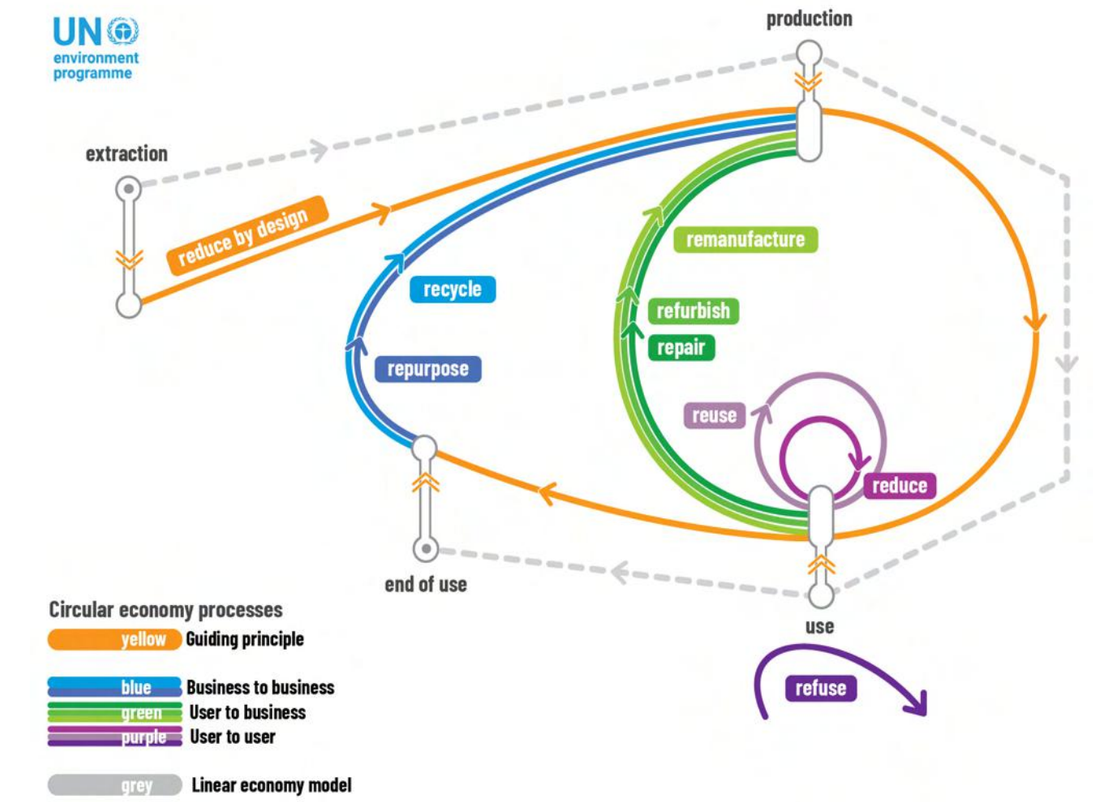
5. Once disposed, carbon from wood products may find its way back into the atmosphere either through decay or through burning to produce energy. At this point, the sequestered carbon is released back into the atmosphere.

Forest products can strengthen carbon cycles when utilized in circular, bio-based economic models (FAO and UNECE, 2021). This entails responsible and cyclical utilization of wood and wood products and the minimization of waste and pollution along the forest products value chain. Notably, the forest sector applies many tenets of circularity (UNECE, 2022).

Wood products lower the carbon footprint of buildings and wood cellulose and its derivatives present viable substitutes for non-renewable materials. Additionally, lumber salvage and paper recycling are common practices in the sector (UNECE, 2022). Consequently, forests products can take up a central role in the circular economy through the provision of a renewable source of raw materials. A unified approach that can tap into the full potential of the forest sector can transform it into a key pillar of the circular economy (UNECE,2022).

Furniture and pulp, paper, and cellulose value chains are examples of forest product value chains that can effectively employ a circular economy, if practices to reduce loss are employed (FAO and UNECE,2021). Wooden pallets are examples of wooden products that are used in circular ways, beginning primarily by being used to transport goods safely, and can be repurposed several times for reuse in the packaging industry (Wood for Good, 2021). These pallets are also repurposed into desks, bars, coffee tables etc., and finally are recycled into chipboard, extending the life of the timber further (Wood for Good, 2021).

Fig 13. The circular economy process (UNECE, 2022)



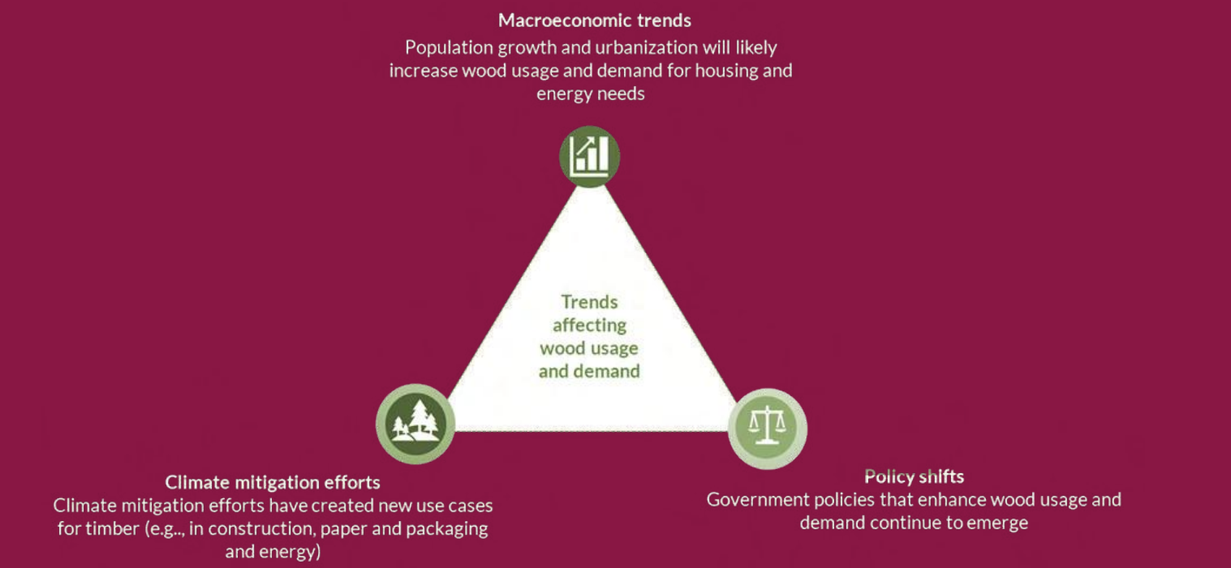
Forest products also provide cascading benefits. Wood in its raw form cannot be transformed or renewed in the same way as materials such as metals in closed production loops. Consequently, wood circularity should be seen as a process of the cascading use of transformed wood products (FAO and UNECE, 2021). Cascaded wood use is more environmentally friendly offering the potential to save up to 35% of fresh wood resources (Taskhiri et al., 2019). However, an abundance of wood resources may make cascaded use less attractive since the use of fresh resources is more economically feasible than setting up an entire recycling system (WWF,2016). While some wood fibers are lost in the process of recycling or reuse, cascading wood use lengthens the carbon storage period by keeping wood in products for longer and delaying biogenic carbon emission (Navare et al., 2022).

WOOD PRODUCTS DEMAND & SUPPLY

Understanding current and future wood demand

Timber manufactured products
A blend of macro-economic trends, concerted climate-mitigation efforts, and policy shifts promise to substantially change wood use and demand over time.

Fig 14. Illustrative overview of the triad of issues driving wood usage and demand (Dalberg, 2022)



- These shifts, which are expected to influence future wood demand, are primarily driven by increasing population and urbanization. With forecasts of a 53% increase in the urban population, urbanization will result in demand for new homes (Gresham House, 2020).

    - Population growth pressure is likely to drive up wood usage and demand for affordable housing. As the global urban population increases relative to available housing, affordable housing will become a key concern for most governments. In India, Zindia is utilizing eco-friendly CLT housing to replace the current urban slums (Zindia Forestry, undated). Employing an innovative timber system, HA-HA Design and Development in the Netherlands will develop four social housing projects for the Ridderkerk community, increasing the number of affordable units by 13% (ArchDaily,2022). To address the ballooning costs associated with housing shortages on the back of increased population and urbanization, prefabricated construction modules, made largely of wood, have recently emerged allowing for cheaper alternatives to the traditional means of construction (Evergreen Holdings, 2022).

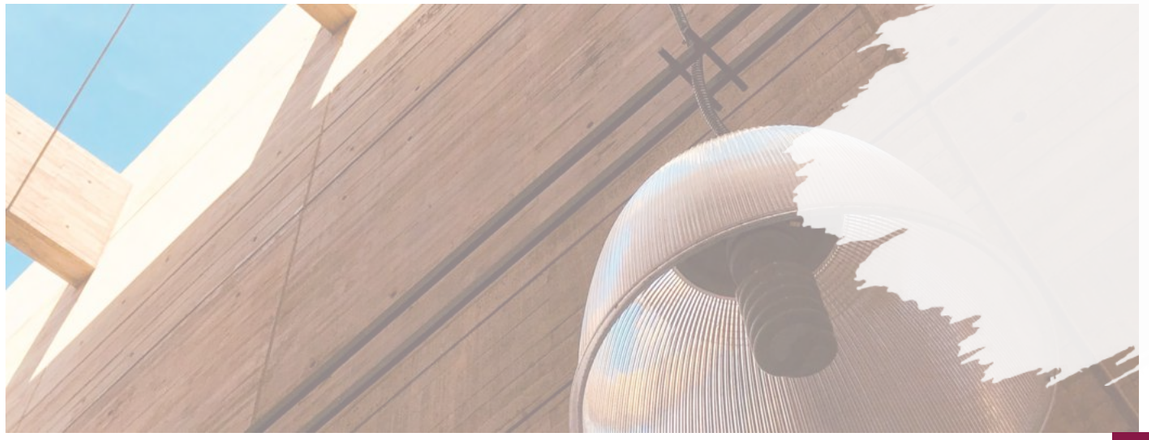
    - Growing populations and urbanization are likely to heighten energy demand. As populations continue to grow, the demand for energy increases. Global energy use is expected to increase nearly 50% from 2020 to 2050 due to economic growth and population growth in non-OECD areas, particularly Asia (EIA,2021). Notably, renewable energy consumption is expected to more than double accounting for 27% of global energy consumption by 2050 (EIA,2021). These renewable energy sources are projected to overtake fossil fuels as the primary source for electricity generation (EIA,2021). Population growth is likely to be highest in the African context at roughly 2.7% each year. Consequently, the population is expected to double by 2050 (The Economist, 2020). Wood energy accounts for more about 27% of the total primary energy supply on the continent (UN,2017). As the population continues to grow on the continent, the demand for wood energy is likely to increase, and timber demand will follow suit.

- Emerging timber and fiber uses in line with climate change mitigation efforts/commitments. Such uses include mass timber buildings that are becoming commonplace, the dramatic and now almost universal pivot away from single-use plastic in favor of fiber-based packaging, the use of renewable energy sources in place of fossil fuels, and the use of fibers in manufacturing of textiles, chemicals, among others.

    - Mass timber buildings: Mass timber construction and associated novel wood-frame multistorey construction have recently gained popularity due to their multiple benefits, primarily the potential to combat climate change (World Economic Forum, 2021). Mass timber buildings have been said to be stronger, more visually beautiful, and have positive impacts on the physical, mental, and emotional health of occupants (FAO,2022f).
      In their study "Wood as a Restorative Material in Healthcare Environments," Augustin and Fell (2015) explored the connection between wood and psychophysiology. Their results show that there is a significant reduction in stress levels, with tangible reduction in blood pressure and lowered heart rates. Wood has been by used architects in design of public stature and calmness, from libraries to law courts due to its psychosocial and aesthetic properties (Augustin and Fell, 2015). This is in addition to helping to reduce GHG emissions from the construction sector, which is responsible for roughly 40% of energy- and process-related GHG emissions in 2018 (WBCSD,2020).

      The growing interest led to significant growth in demand for engineered wood products, particularly cross-laminated timber (CLT). CLT represents wood layered at right angles to one another and glued to result in structural panels that possess strength, dimensional stability, and rigidity (Shafayet and Ingrid, 2020). It also allows for a 40% reduction in carbon footprint when used in lieu of conventional construction materials (Younis and Dodoo, 2022). Notable investments are being made in this shift towards low-carbon construction.

      The USD 400 million Gabon Special Economic Zone, created in 2010 as a joint venture between the government of Gabon, Olam International, and African Finance Corporation seeks to act as a platform for wood-processing facilities in Africa, as part of the government's priority of sustainable construction (FAO,2022f). The Gabon Sovereign Wealth Tower is poised to be Gabon's first cross-laminated timber building with the potential to remove 1.5 million kg of carbon dioxide (FAO,2022f). Although most cross-laminated timber projects are in developed countries, wood construction is poised to gain momentum in other parts of the world. In South Africa, the Nelson Mandela University has established a CLT Engagement Unit with the goal of advancing the adoption of CLT in South Africa, including a joint R10.8 million construction of a CLT building on campus in partnership with Innovhousing (Nelson Mandela University, 2020).



- Paper, tissue and packaging: According to FAO, demand for forest-based biomass in the packaging sector is expected to double by 2030 ((WBCSD, 2020). This will be driven by the demand for wood fiber base packaging in place of plastics, and the growth of e-commerce which will also result in increased packaging demand. The substitution of plastics with wood-based fiber has resulted from increased awareness of their negative environmental impact. A 2020 study showed a growing concern over single-use plastic waste and changing customer attitudes, with 53% of surveyed consumers actively looking for recycling information on packages and 47% of surveyed consumers indicating that they will not buy products in packaging that is harmful to the environment (Trivium Packaging, 2020).

  Private sector actors have started responding to these shifting consumer preferences – companies such as L'Oréal are launching innovations around paper-based cosmetic tubes and Nestle making commitments to make 100% of packaging recyclable by 2025. Unilever has committed to a "Less plastic. Better Plastic. No Plastic" mantra to reduce the overall impact of plastic on the environment. Under the "No Plastic" dimension, the company has replaced plastic packaging with paper alternatives in some of their brands in select regions around the world (Unilever, 2021). The increased awareness about the negative environmental impact of plastic packaging waste has led to a public outcry that has catalyzed regulatory responses with countries issuing directives or bans on plastic. For instance, in 2017, Kenya banned the use of single-use plastic bags and has recently taken a step further by banning single-use plastic in protected natural areas (UNEP,2020). Such trends are expected to continue, and thus wood fiber-based packaging alternatives will likely keep growing in the coming years.

- Manufactured products: Wood is being utilized across a broad range of manufactured products as it allows for carbon and cost benefits. Examples include the use of fiber in new generation tissue products, textiles, use in chemicals, other nanocellulose uses, etc.,

  - The textile industry faces increasing pressure to improve sustainability across value chains and product cycles (FAO, 2022c). Textiles currently cause 10% of GHG emissions during raw material production, processing of fibers and apparel. manufacturing (European Parliament, 2020; Ellen MacArthur Foundation, 2017) Wood fibers are replacing oil-based synthetic fibers such as polyester which currently dominates the value chain. Wood fibers are a worthwhile alternative owing to their similar characteristics to other fiber types, and better environmental impact (FAO,2022c). Wood-based fibers are forecasted to make up 30% of the total fiber demand of the textile sector by 2040, as they partially replace polyester and cotton (FAO and UNECE, 2021).
  - Resin and its derivatives - from wood - are used to manufacture chemicals whose products have a lower carbon footprint than fossil-based equivalents (FAO, 2022c). For example, crude tall oil from pine pulping is used to manufacture detergents, adhesives, etc., with benefits such as lower carbon footprint and renewability (Kraton, undated).
  - Nanocellulose is used widely, ranging from biomedical products to batteries (Trache et al., 2020). The cellulose fibers which are sourced from trees and plants, offer a green, renewable, and sustainable material to produce other high-value products with low environmental impact (Trache et al., 2020).
  - Lignin can replace petroleum derivatives to produce thermoplastic. This form of 'renewable plastic' is 10 times more resistant than the product commonly used in the market – ABS (Acrylonitrile, Butadine, and Styrene) (IBÁ, 2022).
  - Biodegradable plastics are lighter and more resistant than conventional polymers. They can be used by the automotive industry in injection-molded polypropylene parts (IBÁ, 2022).

- Wood fuel: In the global shift to renewables, wood energy is an optional substitute for fossil fuel energy sources by virtue of being a renewable and potentially carbon neutral. Its sustainable production and efficient use have been considered to have the potential to contribute to climate mitigation ambitions and sustainable goals. However, this potential is not evenly distributed at the global scale, and regional and contextual considerations may mitigate against wood for fuel as a preferred green livelihood solution. The science on the climate positive impact of wood fuels remains an ongoing body of ethical and technical research.

- On-the-ground policies around the use of wood products within respective value chains will also influence timber prevalence across varying use categories. These policies vary in scope, across countries and regions, but all have impact on current and future use of wood products. They include:

Fig 15. Illustrative global policies encouraging wood use in the built environment in Europe, Asia, and the Pacific (Dalberg, 2022)

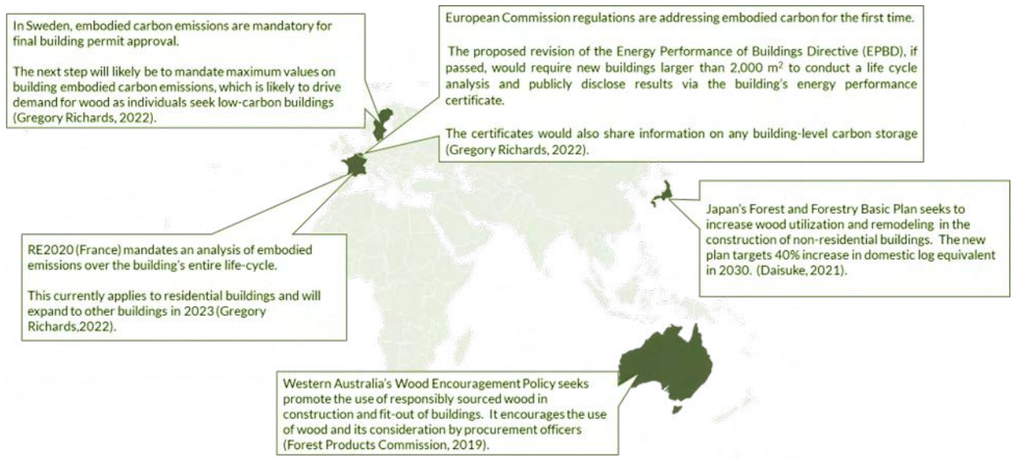
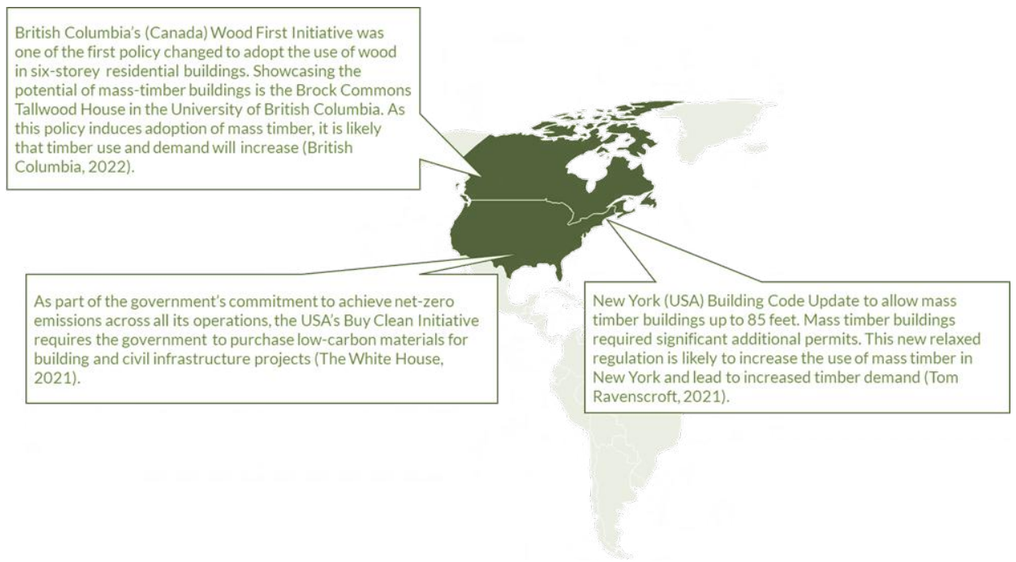


Fig 16. Illustrative global policies encouraging wood use in the built environment in North America (Dalberg, 2022)



Future wood demand estimates

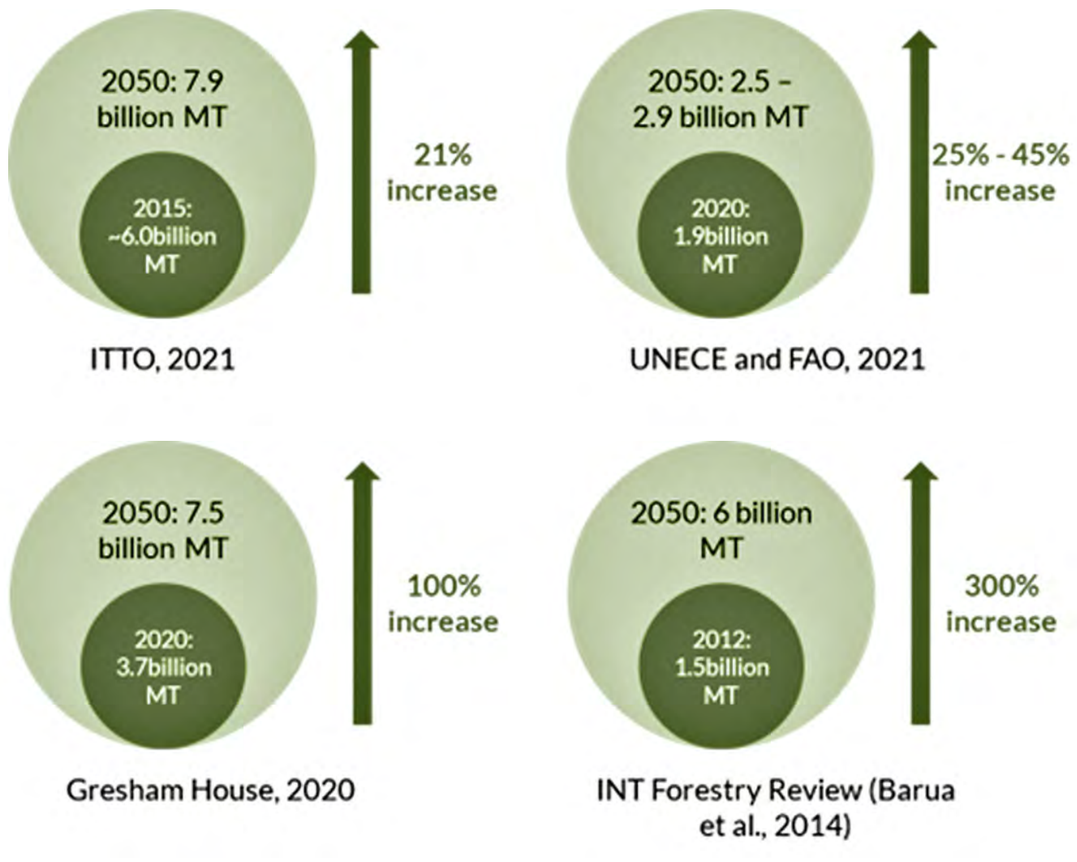
Increased urbanization will lead to a future increase in housing, life products such as tissues, paper and packaging, manufacturing, and energy needs, which in turn drive future wood demand. The global urban population is forecast to rise by 18% by 2030 and 52% by 2050 driven by both population growth and the move from rural to urban areas to seek prosperity; a job, a better standard of living, better access to healthcare, education, and a longer lifespan (Gresham House, 2020).

Construction is already the main driver of timber demand, with about 60% of timber consumption coming directly from the construction industry, so any increases in the use of timber in construction will significantly impact timber demand. This has been seen in the past, for example, in China, which has experienced a 96% increase in urban dwellers over the past 20 years, timber consumption also increased by 96%, driven by the increase in construction and rising incomes per capita (Gresham House, 2020). Similar trends have been observed in other countries which have developed over the past 20 years.

The case is similar for energy consumption which is expected to increase with urbanization. Global policy-driven uptake of wood pellet consumption is expected to increase wood pellet demand, which is likely to double by 2025, from 2020, representing a CAGR of circa 9% (Gresham House, 2020).

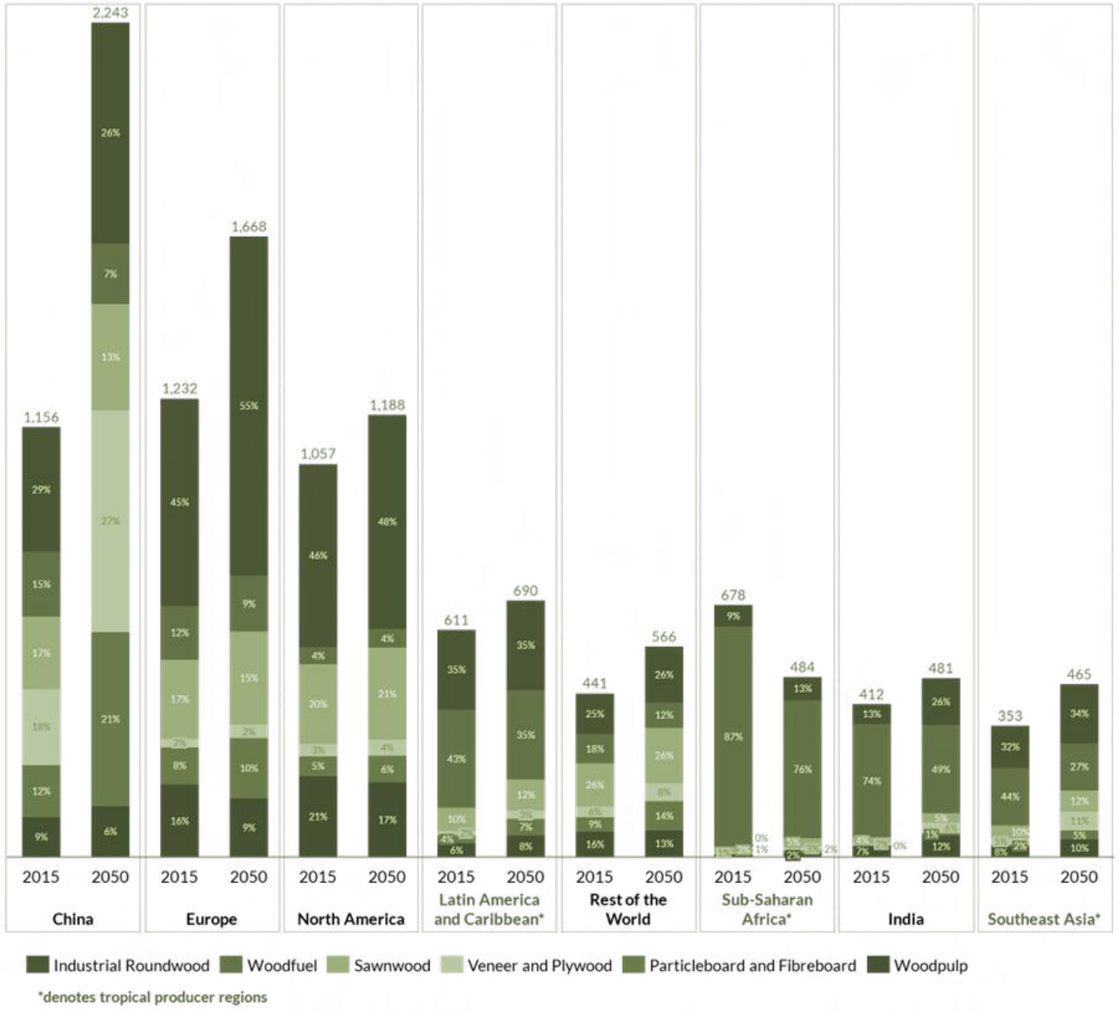
Turning to roundwood alone, multiple reports provide varying estimates of 2050 wood demand, with all sources indicating an expected increase in demand. Methodologies and scope of the various estimates vary and below are the high-level estimates sampled from various reports:

Fig 17. 2050 projected industrial roundwood demand estimates (Dalberg, 2022)



The highest demand is predicted to come from China and India; most of the global demand will be for industrial roundwood, followed by woodfuel (ITTO, 2021). This is in line with anticipated increase in construction, especially mass timber building and use of wood fuel as a main energy source for many households in emerging economies and increased shift to renewables in developed economies.

Fig 18.Regional analysis of ITTO's forecasted 2050 wood demand (ITTO,2021)



Understanding factors and approaches influencing wood supply

Several key factors influence the steady availability of timber supply, including: (i) the prevalence of sustainable harvesting and forest management activities, (ii) the impact of carbon market incentives on forest product markets, and (iii) the breadth and depth of supply-side policies. Any constraints in these areas therefore draw back the ability of current and future timber supply to match growing timber demand.

Sustainable harvesting and forest management

Sustainable harvesting and forest management across the world look different due to the geosocial nuances in the respective national and regional ecosystems. Sustainable forest management (SFM) is concerned with the maintenance and enhancement of the economic, social, and environmental values of all types of forests, for the benefit of present and future generations (FAO, 2020). The SFM approaches used globally fall under the passive to active (intensive) spectrum. Passive approaches involve little to no management intervention, allowing natural processes and natural disturbance regimes to develop.

The intention is to allow internal dynamics to continue undisturbed (Bernes et al., 2015). These approaches put ecological and social goals at the forefront (Duncker et al., 2012). In passive approaches, the economic outturn is important, but most occur in the context of ecological goals (Duncker et al., 2012). Active approaches involve more direct management usually with intensive machine operation, direct planting and seeding for regeneration and, in some cases, short rotation of trees. Active approaches employ a greater focus on timber production and economic output (Duncker et al., 2012). In between active and passive approaches of forest management, objective forestry has been incorporated. The concept states that various management approaches can be combined in a way that satisfies diverse needs better than zoning, which satisfies individual objectives in areas that are separated (Duncker et al., 2012).

Benefits have been found in both passive and active forest management approaches. There is a widely accepted view that active forest management leads to the enhancement of carbon uptake because the rate of carbon uptake declines as forests mature and unmanaged forests have higher risks of carbon losses through fire, insects, or disease infestations (UNFF, 2019). Notably, these studies have been done within the contexts of different regions and forest types and as such, results are likely to vary on the most appropriate forest management approach.

In forested areas where protection of endangered plant and animal species is the objective, passive forest management approaches are relevant as they emphasize ecological and social goals over economic ones and ensure limited human disturbance of already endangered species. Conversely, in planted or plantation forests where an economic goal is at the centre, active management approaches are more appropriate as they enhance productivity and wood quality hence improving economic outcomes and generating greater sustainable supply.

The application of the different management approaches varies across the world's forests and planted forests or timber plantations. Examples of these applications include:

Image credit: Commonwealth of Australia, 2018

The "A Billion Trees for Jobs and Growth" initiative in Australia seeks to increase the coverage of high production planted forests to meet a large wood supply deficit. In a bid to meet the ever-increasing demand for wood, the Australian government seeks to plant a billion trees in the form of plantation timber forests to provide the market with wood supply and close the current and future deficit. This implies an active management approach with the goal of boosting the forestry sector as a key tenet (Commonwealth of Australia, 2018).

Image credit: KFPL website

Kolombangara Forest Products Limited (KFPL) in the Solomon Islands has both timber plantations and a protected natural forest. Given the commercial nature of the company, the plantation section appears to employ an active management approach as trees are grown for timber production purposes with an economic goal in mind. Notably, this plantation is FSC certified indicating a sustainably managed forest (Kolombangara Forest Products Limited, 2021).

Image credit: SAFCOL website

Mondi, an integrated paper, and packaging company in South Africa utilizes active management through intensively managed planted timber plantations. Once awarded the government privatization tender to lease and manage Safcol commercial timber, Mondi appointed a representative team with the park authority to create a new eco-boundary area. Mondi retained enough productive area suitable for intensively managed forestry and the rest of the land was returned to the park resulting in a thriving planted timber plantation and park (Kanowski and Murray, 2008).

Image credit: CGTN

Saihanba Mechanical Forest Farm in China employs active forest management. In a bid to restore bare land through large-scale afforestation, the Ministry of Forestry established the Saihanba Mechanical Forest Farm in 1962. The forest has been actively managed historically with techniques such as thinning, targeted cutting, and block clear-cutting being used to optimize the structure and the quality of the forests (World Economic Forum, 2022).

Image credit: Northern TOSIA Brochure

Inshriach Forest in Northern Scotland applies both active and passive forest management (Pizzirani et. Al, 2011): About 3% of Inshriach, and 0.5% of UK forestry is permanently retained for biodiversity and recreational purposes, implying passive management (Pizzirani et. Al, 2011). 43% of Inshriach and 71% of UK Forestry utilize intensive even-aged forestry with the optimization of production timber being a key objective. Thus, a substantial portion of the forest is actively managed (Pizzirani et. al, 2011).

Image credit: IBÀ website

Klabin's forests in Brazil utilize active and passive management techniques through mosaic planting (Klabin, 2022). Mosaic planting involves interspersing commercial plantations with natural forests with the aim of forming ecological corridors. These corridors act as important sources of food and shelter for fauna and flora (IBÀ,2022). Klabin mixes planted forests of different ages with preserved native forests, helping protect natural resources, improve the production potential of forests and preserves biodiversity through ecological corridors (Klabin, 2022).

Carbon Markets

As forestry and forest related activities remain a key tool to offset carbon emissions, the state and development of carbon markets will be central to the supply of timber and fiber based products in the near to long-term. Timber and agricultural landowners generate most carbon offsets by deferring or modifying the harvest of trees or the disturbance of soil to sequester more carbon (Ferguson et al., 2021). Forest owners typically get paid to preserve, replant, or delay the development of their land, with companies purchasing credits to represent the avoided emissions that compensate for the company's pollution (Boyd, 2022).

Other important activities are afforestation and reforestation, characterized by the anthropic establishment of new forests in areas that previously did not contain forests. By removing or "sequestering" CO2 from the atmosphere, based on photosynthesis, forests can create and maintain carbon stocks in terrestrial ecosystems, which results in the reduction of the GHG concentration in the atmosphere. (Marques, 2019)

In 2021, the value of carbon credits traded on the voluntary market exceeded US$2 billion, more than four times the value in 2020 ($520 million), indicating a growing carbon market (Ecosystem Marketplace,2022). As private companies take on net-zero goals, the demand for offsets is only likely to grow, and with it, carbon credit markets (Ferguson et al., 2021). Since this increased demand is likely to induce the preservation and possible afforestation or reforestation of trees, the timber supply base will likely increase as well.

However, because the nature of the carbon offset is to maintain and preserve forests and timber plantations, and often does not take into account the additional carbon stored in harvested wood products, these additional trees risk not becoming a harvestable supply base if carbon credits are in force. Additionally, forests grown for this purpose are not likely to produce significant quantities of timber, but will take up primary planting resources, and thus could reduce land for agriculture and timber production (Gresham House, 2020).

Supply-side policy instruments and regulations

Supply influencing policies and practices remain minimal with limited international and intra-regional complementarity. Regulation and policy in the forest sector is diverse, attempting to address several issues ranging from legality of timber products to sustainability. While necessary, some regulations may inadvertently lead to constraints on forest sector growth. Notably, criticism has been given as to the effectiveness of regulation as unsustainable harvesting, illegal logging and corruption continue to defy regulation and lead to degradation and deforestation (Smyle et al., 2016).

At an international level, tools such as FLEGT, REDD+ and NDCs have attempted to encourage cohesive efforts towards establishing sustainable forest economies.

FLEGT

Forest Law Enforcement, Governance, and Trade (FLEGT) is a measure by the European Commission to combat illegal logging and associated trade (FAO,2016). FLEGT aims to reduce illegal logging through by promoting legal timber production, improved governance and sustainable forest management (FAO,2016). A key tool in the FLEGT Action Plan is voluntary partnership agreements (VPAs) which include bilateral commitments from both parties to halt trade in illegal timber (European Commission, undated). A VPA partner country must implement a timber legality assurance system (TLAS), built around a practical definition of legality and agreed on through participatory processes by key parties (European Commission, undated). These agreements seek to assist timber exporting countries to stop the illegal logging of forests through improved regulation and governance of the forestry sector (WWF,2022). VPA partnerships also have the economic benefit of allowing countries to unlock new markets for their timber in the European Union (WWF,2022). To operationalize FLEGT strong political commitment is required as well as addressing underlying forest governance issues (Thuy et al., 2021). This may hamper or slow the effective implementation of these VPAs.

REDD+

REDD+ aims to encourage developing countries to contribute to climate change by (i) reducing greenhouse gas emissions by slowing, halting, and reversing forest loss and degradation; and (ii) increasing the removal of greenhouse gas emissions from the atmosphere of the earth through conservation, management, and expansion of forests (FAO, undated). The scheme offers to countries, upon development and implementation of natural strategies and results-based demonstration activities (FAO, undated). Since 2008, USD 2.4 billion has been approved for activities that are dedicated to REDD+ (Watson and Schalatek, 2020). For example, USD 2 million will be invested to improve the sustainable management and governance of Myanmar's mangrove forests across six districts. (UN-REDD Programme, 2022).

While there have potential carbon and non-carbon benefits of REDD+, the initiative may have a number of key shortcomings. Issues surrounding measurement of the acceptable limits of deforestation that necessitate payments are arising as critics suggest that the limits are quite low and based on 10-year averages where deforestation was at an all-time high in some instances. This has been said to give room to countries to continue with deforestation while claiming results-based payments from the various REDD+ related funds (World Rainforest Movement, 2019).

REDD+ incentives have also been criticized for not being as competitive as the commercial returns from forest use (e.g., logging) (Cannon, 2019). They could signal for depriortization of customary indigenous rights as investors seek out forest land for interest income. It has also been noted that REDD+ could inadvertently signal for deprioritization of customary indigenous rights as investors seek out forest land for interest income. (Cannon, 2019). Consequently, these issues may affect the effective implementation of REDD+ and the achievement of goals under the framework. Nevertheless, REDD+ strategies have the potential of protecting the current forest stock through halting of deforestation while also promoting the sustainable management of forests and sustainable trade of forests products. If effectively implemented, REDD+ could increase wood supply by improving forest governance and sustainable forest management.

NATIONALLY DETERMINED CONTRIBUTIONS

Forest sector solutions in line with NDCs are helping to hold the global temperature increase to below 2.0°C or 1.5°C through a large-scale reduction of greenhouse gas (GHG) emissions and removal of carbon from the atmosphere. Forest-specific measures contributing to NDCs have included conservation, restoration, and improved forest management. NDCs could have several benefits for the forest sector such as informing an increase in forest coverage, afforestation, forest stock volume, and reducing the deforestation rate (Sato et al, 2019).

However, challenges facing the implementation of the NDCs could affect the progress of rebuilding the forest sector. Governance challenges, as is often seen in implementation of cross-sectoral plans, could hinder implementation of NDCs. Additionally, NDCs tend to have a high degree of political backing at the highest level of government as opposed to end beneficiaries who drive the implementation. A recent study on budgeting for NDC action concluded that one of the most important barriers to implementation is a lack of capacity in ministerial budget planning and reporting (Bird, 2017). Financial mobilization and accountability for implementation also pose a challenge to NDCs. Clarity of what financing plans should look like as well as how to account for climate actions is still being sought after. In light of this, countries have established an enhanced transparency framework (ETF) that countries will be required to report transparently on actions taken and progress in climate change mitigation, adaptation measures, and support provided or received starting in 2024.

FOREST MANAGEMENT PLANS

A typical policy instrument used in the forest sector are Forest Management Plans (FMP). Historically, FMP's have been complex, costly, hard to develop, implement, monitor, and enforce. They also have not made consideration for local context and knowledge in promoting sustainability making participation and execution by forest communities difficult (Smyle et al., 2016). This implies unrealistic institutional capacities and budgets as well as burdensome compliance and transaction costs. Failure of local sensitivity leads to conflict as the regulations are perceived as unjust and illegitimate (Smyle et al., 2016). Consequently, the implication is that these regulations may hamper the achievement of sustainable growth initiatives due to the implicit and explicit costs associated with the policies.

The existence of policies and practices that influence wood supply across the globe remain limited and generally differ due to national and regional contexts. Whilst a great many policies have a heavy focus on increasing wood usage there are few obvious policies to drive corresponding increases in sustainable supply. Examples are:

Fig 19 Examples of supply side policies in Africa (Dalberg, 2022)

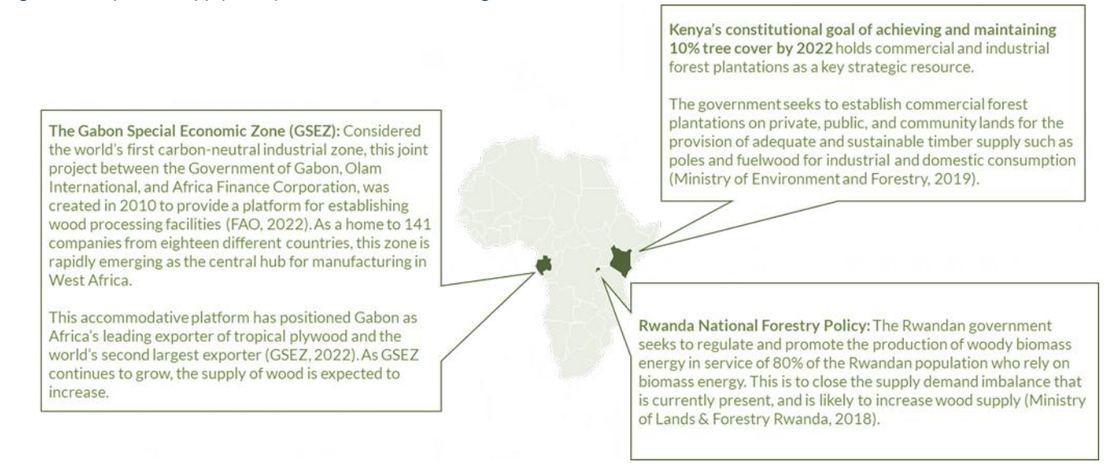


Fig 20. Examples of supply side policies in the Americas (Dalberg, 2022)

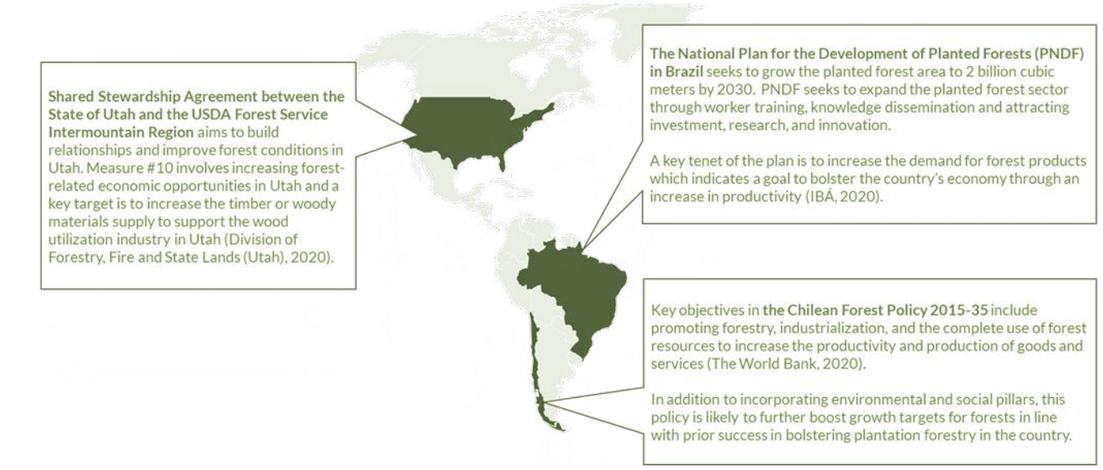
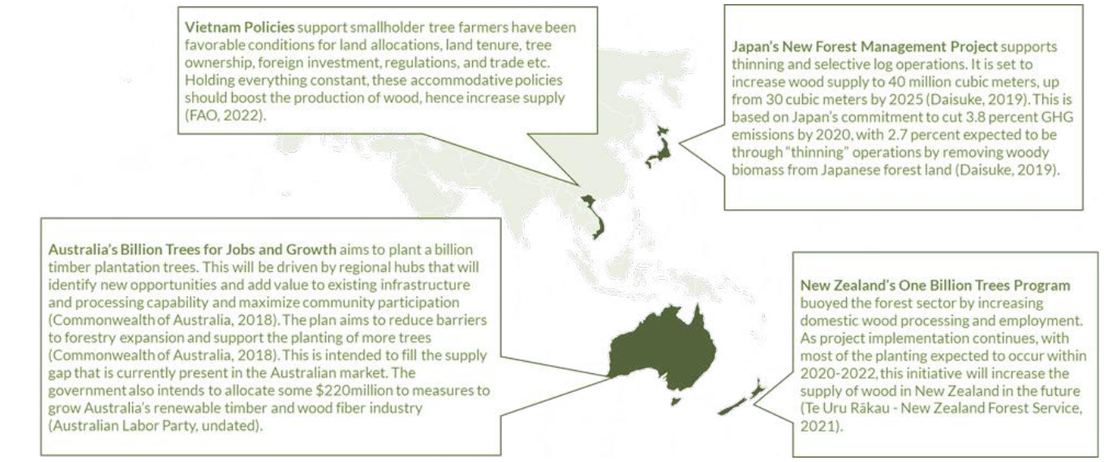


Fig 21. Examples of supply side policies in Asia and the Pacific (Dalberg, 2022)

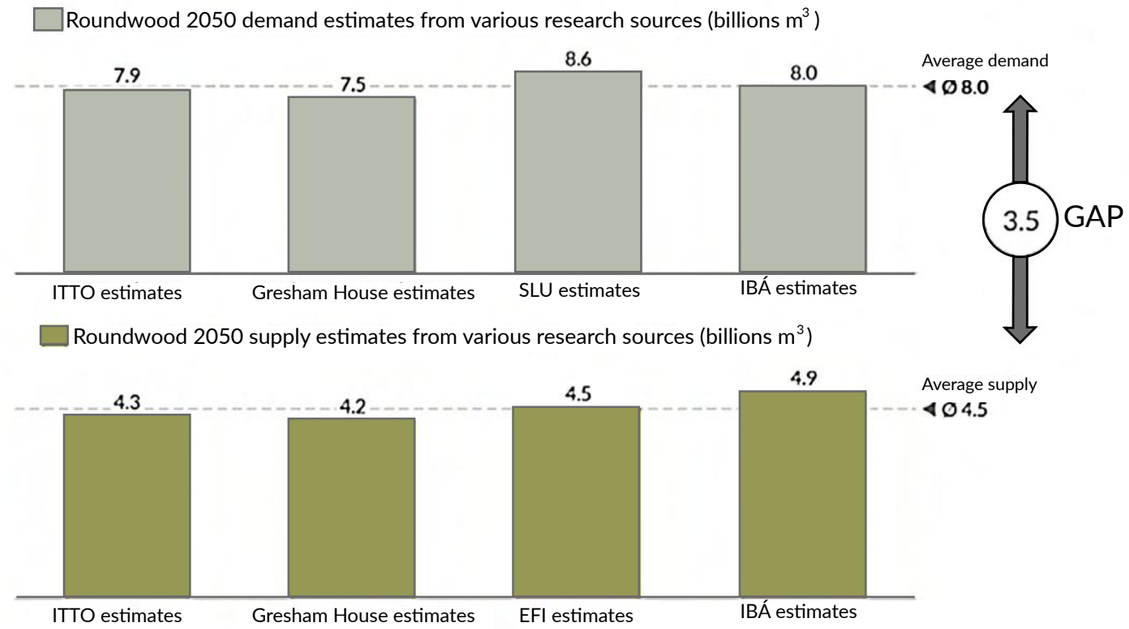


The policies that influence supply of timber have varied objectives, from energy security, timber supply security, employment creation, and emissions reductions. While they may lack complementarity, they reflect a degree of specificity by region which may allow for achievement of targeted objectives which are relevant to specific regions.

The timber supply-demand gap in a business-as-usual scenario

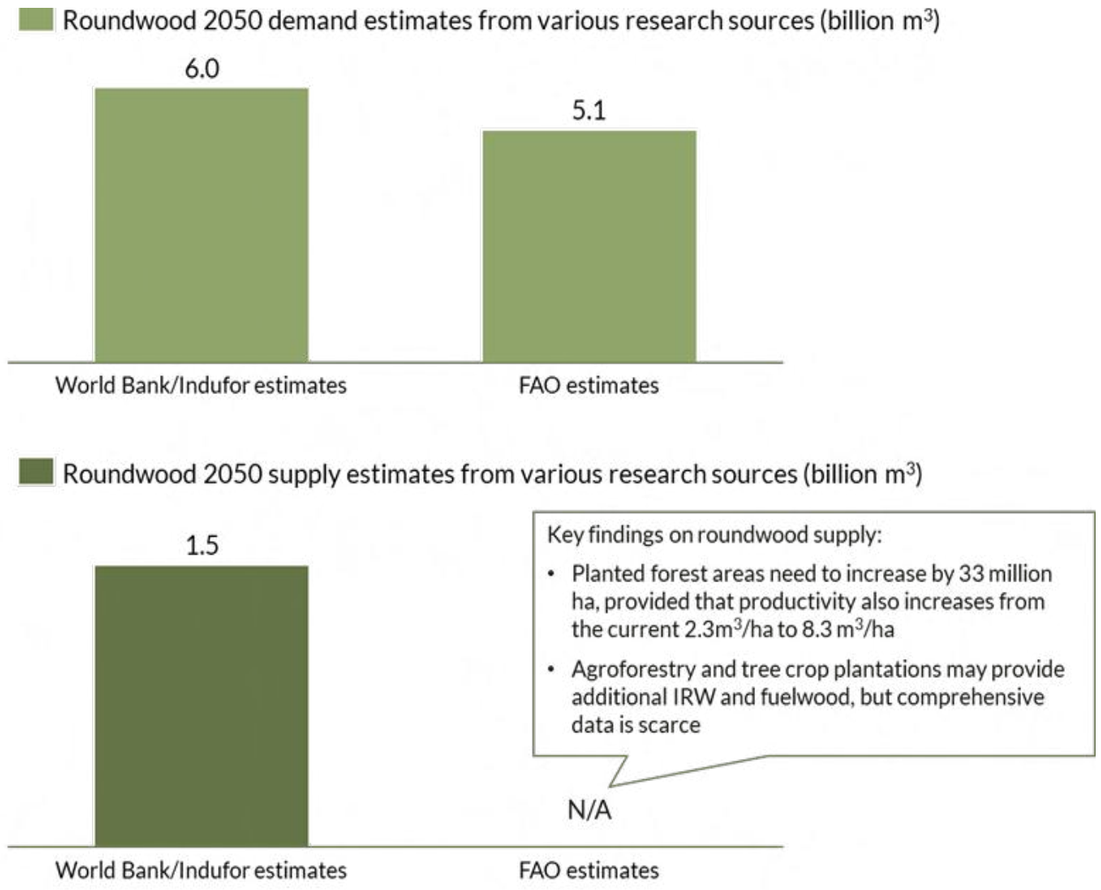
Without proper policy and market interventions, the supply-demand of timber fiber gaps could be ~ 3.5 billion m³ on average in a business-as-usual scenario as illustrated in the figure below. There are publications that either incorporate an illustrative demand-supply gap assessment, or seek to pursue more exact estimates, however, this report is based on the forecasted roundwood production and consumption by 2050 from multiple reports, as shown below.

Fig 22. 2050 roundwood demand-supply gap (Dalberg, 2022)



FAO's estimations, for example, present projected IRW demand by 2050 (~ 6 billion m3), but do not identify a global IRW supply gap to meet basic outlook needs in 2050. FAO's supply calculations focus on the required forest expansion area (33 million ha of highly productive, planted forests) and productivity improvements in planted forests from the current 2.7 m3/ha to 8.3 m3/ha. On the other hand, World Bank/ Indufor figures (shown below) estimate the volumes of timber required (World Bank,2016). These figures are lower than the average shared above because they offer a partial view. Calculations focus on industrial roundwood demand only, and not expected pulpwood for packaging and other bioproducts nor wood fuel demand and supply by 2050.

Fig 23. Additional estimations on roundwood supply-demand gap (Dalberg, 2022)



Being a combination of estimates, considerations around smallholder farmer contribution and processing efficiency are worth bringing to the fore. Given scarce documentation on smallholder farmers' contribution to timber supply, there arises the possibility that existing supply estimates may be higher than assumed. Similarly, as technology advances over time, it is expected that timber processing will yield more and higher quality output per m3 of input. Thus, producers and processors will play a central role in expanding supply to meet growing timber demand.

Without policies to increase sustainable supply, the supply-demand gap may mean future wood shortages, undermining climate aspirations, increasing pressure on forests and promoting unsustainable sourcing. Given the economic and non-economic constraints on supply, the business-as-usual scenario may lead to a supply-demand gap which creates a shortage of wood in some markets. This shortage may lead to an increase in timber prices over the medium to long-term (Gresham House, 2020) incentivizing more unsustainable forest outcomes in parts of the world with more problematic governance and policing.

This may result in the growth of the illegal timber trade which already represents 15 to 30 percent of the timber taken at an estimated annual value of US$50 billion to $150 billion in 2018 (Wallen, 2018). As the overall market value of wood continues to rise, the entry of more players into the illegal timber trade may occur as individuals seek to cash-in. The consequent effect is pressure on already existing forests as well as non-environmentally friendly supply entering the global market for wood. Notably, given the possible rise in the prices of timber, the shift back to less-climate friendly solutions such as plastic in packaging, concrete and steel may be a consequence of this gap.

RECOMMENDATIONS: A CALL TO ACTION

Addressing the supply gap: by using 'nationally determined approaches' as a proposed way forward

Looking ahead, countries could carry forward principles from the NDCs to guide their own efforts towards building sustainable forest economies. Nationally Determined Contributions (NDCs) serve as country-specific climate action plans to cut emissions and adapt to climate impacts in line with the Paris Agreement to limit global warming to below 1.5 degrees. As a result, NDCs account for countries' varied demands, such as the urgent need for emissions reductions, as well as pressing issues such as industrialization for economic development. This delicate balance of shared global goals and individual, country-specific commitments could inspire a new way to build and sustain forest economies across the world. As it stands, countries have varying priorities and endowments when it comes to their forest resources.

For example, Gabon's forestry sector is strongly intertwined with the country's economic activity. Gabonese forests cover over 85% of the national territory and provide the second largest number of jobs in the country after public services (AfDB, 2021).The government recognizes that timber in particular plays a critical role in the industrialization of the economy (ANRC, 2021). By contrast, Brazil has the added priority of protecting biological diversity as a custodian of 15% - 20% of the world's biological diversity (UNEP, 2019). Beyond supporting its thriving forest based economic activities, forest policies also have to factor in ecological goals. These examples demonstrate how individual country priorities, resources and implementation capabilities ought to be at the heart of building sustainable forest economies.

This could mean employing different country-specific approaches to apply shared principles on sustainable forest management across the world. For instance, Gabon set up special economic zones to boost wood processing and production as part of the government's priority of sustainable construction (FAO,2022f). Meanwhile, in Sweden, replanting of harvested areas is carried out in a scientific manner, including provision of significant deadwood, which produces the effect of a natural regeneration.

In pursuit of tailored solutions, nationally determined approaches would therefore aim to provide a blend of overall **cohesion**, individual **flexibility**, and shared **accountability**.

Potential national levers to foster sustainable forest economies

The projected gap, with minimal supply-side intervention, is an urgent call for nationally supported policies from forest sector actors that can in turn foster sustainable forest economies.

Markets forces alone are inadequate to address the supply-demand gap; policies will be needed to enable these markets forces to fulfil forecast demand. Policies can divert financial flows towards investment in key pathways for forest economies: conservation, restoration, and sustainable use (FAO, 2022f). Demand-side policies such as Wood Encouragement Policies (WEPs) are increasingly driving the uptake of timber products in building construction. WEPs aim to support local forest industries, sustainable economic development, and climate change mitigation objectives (FAO, 2022f). Supply-side policies such as special economic zones to boost wood processing and production (as seen in Gabon) can encourage wood supply if sustainably managed and implemented.

In more established forestry markets, including sustainability criteria in tendering processes nudges actors towards sustainable forestry practices (Karsenty, 2021) For example, in Sarawak, the Malaysian Timber Certification Scheme will become compulsory by 2022. Policies surrounding promotion of investments in natural and planted forests are necessary to close the gap given estimates of US $40 billion per annum to meet 2050 industrial roundwood demand and mass timber investments of about US $0.6 billion-2.5 billion per annum (FAO,2022d). Public investments could help raise scalable private investments to stimulate sustainable growth (FAO,2022d). Blends of both demand-side and supply-side policies, as REDD+ and other results-based payment schemes could support developing countries' efforts towards creating sustainable forest economies. All in all, policy can and will play a key role in catalyzing market building in the forest sector.

In the short-term, there are quick wins around reframing our collective perception of forest ecosystems. For instance, there is a need for a more nuanced understanding of large-scale planted forests and forestry plantations and the different types of plantations necessary to complement the forestry supply of wood fiber. If sustainably managed, timber plantations can protect people, planet and provide more fiber. Planted forests take up 7% of global forest area but already provide over 50% of wood for industrial uses. (IBÁ, 2022). Planted forests and timber plantations have been found to reduce pressure on natural forests and woodlands near charcoal demand centers (FAO,2022f). Such intensively managed areas for production (e.g., for wood biomass, wood for building material, etc.) present carbon mitigation strategies (Lindner and Karjalainen, 2007). This holds especially true in short rotations where substitution with younger trees results in a net carbon emission mitigation effect after each cycle (F. Bravo et al, 2015).

Sustainable planted forests and timber plantations directly increase carbon stock in marginal lands and produce a sustainable source of wood. They also indirectly protect carbon stocks in ancient forests by providing an alternative to fiber source . Planted forests and timber plantations that do not lead to the replacement of natural habitats can help recover degraded land and lead to natural ecosystem regeneration. A complementary benefit from timber plantations is the creation of green jobs, with some scenarios suggesting that 25 million jobs would be created in Africa alone through additional forest plantations and processing to meet increasing wood demand (FAO, 2022f).

From an economic point of view, the supply-demand imbalance may result in timber price increases over the medium to long-term, which implies that planted forests and timber plantations may provide a greater economic return (Gresham House, 2020). Moreover, investing in forests promotes business resilience through reducing supply, demand, regulatory, and capital risks and business profitability and growth, through expansion into new markets (World Economic Forum, 2021). Additionally, improved customer trust, talent attraction and retention, and relationships are likely to be additional benefits of investing in forests that occur due to value-based leadership (World Economic Forum, 2021).

Creating conducive environments for forest actors unlocks market forces that far outweigh the monetary value of non-market agents and further incentivizes sustainable forest management. At a national level, China's ecological approach to poverty alleviation showcases significant success in forest management and income creation. China's economic development policy planning found that poverty-stricken areas were doubly affected by ecological fragility. By adopting an ecological approach to poverty alleviation, China implemented over ten programs between 2012 and 2020 ranging from forest restoration and protection, to support for the forest industry, green jobs creation, and ecotourism. The programs mobilized over UDS 8.86 billion annually, and increased incomes for over 14 million people per year. (FAO, 2022f)

At a granular level, recognizing the customary rights of communities has been shown to increase income earning opportunities while enhancing sustainable forest management. Devolving public land rights enables smallholders, local communities, and indigenous people to sustainably harvest forest resources and generate income from providing ecosystem services, REDD+, and carbon credits. This impact can be enhanced further through affordable and credible certification, finance mechanisms, and access to markets.

The assessment uncovers the need for coordinated international efforts as supply-demand gaps in certain geographies have real implications on forest ecosystems in other regions given current cross-border trade. There is a wealth of experiential knowledge across countries, organizations, and communities. These can be harnessed to develop feasible strategies contextualized to local needs and priorities. Global platforms (e.g., UNFCCC COPs) convene key national and regional actors to set and steward the world-wide forest ecosystem agenda in pursuit of the Paris Climate Agreement and the Sustainable Development Goals. Private sector platforms (e.g., Forest Business Network) facilitate dialogue around market-led successes, challenges, and concerns. Community platforms (e.g., regional networks, municipalities, forest producer groups) harness the first-hand knowledge of those who know the areas and resources best. At a policy level, ever-changing challenges arise from the increasingly diverse and complex wood uses and forest products. Co-operation among agencies and actors can help to create a stable long-term environment that minimizes uncertainty and incentivizes sustainable growth. (Hetemäki et al. 2017, Wolfslehner et al. 2018).

Further, there are opportunities to adopt complementary policies across national and regional ecosystems given the demonstrated differences in respective countries' ecosystems. Policies should aim to address all three forest pathways for sustainable growth. For example, unilateral policies focused exclusively on conservation will effectively protect forest resources and carbon stocks but may ultimately stifle the supply of wood as a climate friendly resource in the long run.

For a more holistic approach, supporting policies around use (to manage wood harvesting and processing) and restoration (to ensure steady supply of wood and fibre) are critical to enhancing the forest ecosystem.

There are many growth targets for forestry/reforestation in the world, accompanied by a surge of good will as many countries increasingly work towards growing their national tree coverage. This presents ample opportunity to focus on growing trees that produce climate-friendly materials. As a long-term aspiration, the global community could more strongly entrench timber and fiber related targets in their nationally determined approaches for climate goals. Setting out clear timber and fiber related metrics as part of mitigation ambition and targets will build upon countries' commitments to climate change. Furthermore, it provides serious ways to distil action from countries' widespread recognition of the potency of forests in climate mitigation and adaptation. Crucially, contextual nuances should remain at the heart of climate commitments. As countries reflect on the way forward, it will be paramount to align nationally determined approaches to each countries' unique contexts, ecological priorities, and needs.

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- Zindia Forestry. Affordable Housing Project India, https://zindiaforestry.com/affordable-housing-project/

This report was supported by:

INTERNATIONAL COUNCIL OF FOREST & PAPER ASSOCIATIONS

and

Scottish Forestry Coilltearachd na h-Alba

FPAC.ca APFC.ca

Swedish Forest Industries

Confor Promoting forestry and wood

Australian Forest Products Association

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SUPPORTED BY

Osato Noah, Devang Vussonji, Geraldine Worship, Iminza Mbwaya, Mugambi Wahomean, Divine Mutonia, Carren Mwanzia, Linnie Kamanda and the whole Dalberg team.

ACKNOWLEDGEMENTS

This work is a Dalberg foresight synthesis of inputs and data from FAO, ACSFI, and various other sources. Please reach out to Mokena.makeka@dalberg.com for the extended report.