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Mass timber: wood buildings as a climate solution

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INTRODUCTION

Mass timber is a category of engineered wood products designed for structural applications. The development of mass timber technology in recent decades has paved the way for constructing low-rise, mid-rise, and industrial buildings with wood. Whereas traditional building materials like concrete and steel emit CO2 when produced, trees used to make mass timber products naturally absorb and store carbon as they grow. Increasing the amount of wood used in buildings, as a substitute for these more carbon intensive materials, has the potential to significantly reduce emissions from the building sector, which currently accounts for about 40% of global greenhouse gas emissions annually.[1] In addition to climate benefits, in some markets, mass timber construction also has economic advantages over traditional approaches. Altogether, conditions are primed for growth in mass timber markets and potential disruption in the construction sector.

Although mass timber currently accounts for a relatively small share of global wood consumption, it represents one of the fastest growing markets for timber. Globally, mass timber consumption is expected to more than double by 2027 and increase by more than five times over that same period in North America.[2] By one estimate, mass timber is expected to account for USD 1.4 billion of the USD 14 trillion global construction industry in 2025,[3] though its market share could rise far beyond that.

Growing demand for wood-based construction will affect both mass timber's market share as well as timberland, wood products, and real estate markets, though not all markets or regions will be impacted equally.

For timberland investors, growing demand for mass timber products and wood buildings has the potential to increase demand for timber, the carbon value of sustainably managed timberland, and the role of the forest products sector in combating climate change. Here we provide an overview of mass timber markets and examine the potential climate benefits of wood-based construction. We begin with an introduction to mass timber products used in building construction. Next, we provide an overview of mass timber production and consumption, with a focus on North America and the E.U. Finally, we conclude with a discussion of what growing markets for mass timber mean for timberland investors.

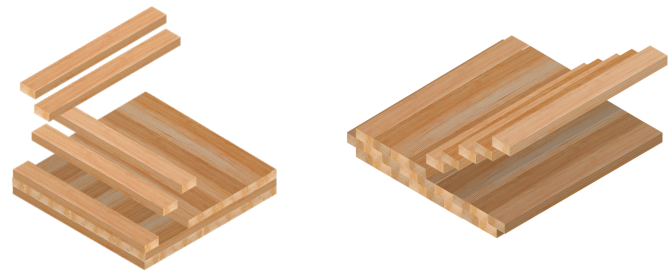
WHAT IS MASS TIMBER?

Mass timber building systems are characterized by the use of large, solid wood panels for wall, floor and roof construction. Cross-laminated timber (CLT) is the dominant mass timber panel product, though other panel products include dowel-laminated timber (DLT), nail-laminated timber (NLT), and laminated veneer lumber (LVL). In addition to use of large wood panels, the construction of mass timber buildings often feature glulam beams. These engineered wood products and systems were developed in Europe several decades ago and today, production methods have advanced and spread to other parts of the world.

COMMONLY USED INDUSTRY TERMS

CLT	Cross-laminated timber
DLT	Dowel-laminated timber
GWP	Global warming potential
LCA	Life-cycle analysis
LVL	Laminated veneer lumber
MPP	Mass plywood panel
NLT	Nail-laminated timber

Figure 1: Cross-laminated and glue-laminated timber



Sources: Think Wood

A brief description of the two most widely used products, CLT and glulam, follows below.

Cross-laminated timber is an engineered multi-layer panel wood product, made by laminating several layers of boards perpendicular to each other. Alternate layers of boards are placed crosswise to each other and bonded together with durable, moisture-resistant adhesives. CLT's exceptional strength and stiffness as well as two-way span capabilities are similar to a reinforced concrete slab (USDA Forest Service, 2022). In a building, CLT is used for surfaces like floors, ceilings, roofs and walls.

Glulam is an engineered wood beam made of glue laminated boards (or lamstock). Layers of boards are bonded together with durable, moisture-resistant adhesives, and the grain of the laminations is parallel with the length of the beam. One of the key advantages of glulam is that it can be manufactured in large sizes and curved shapes that can meet both architectural and structural design requirements. In a building, glulam is used for the loadbearing frame like rafters, beams, or columns.

Production

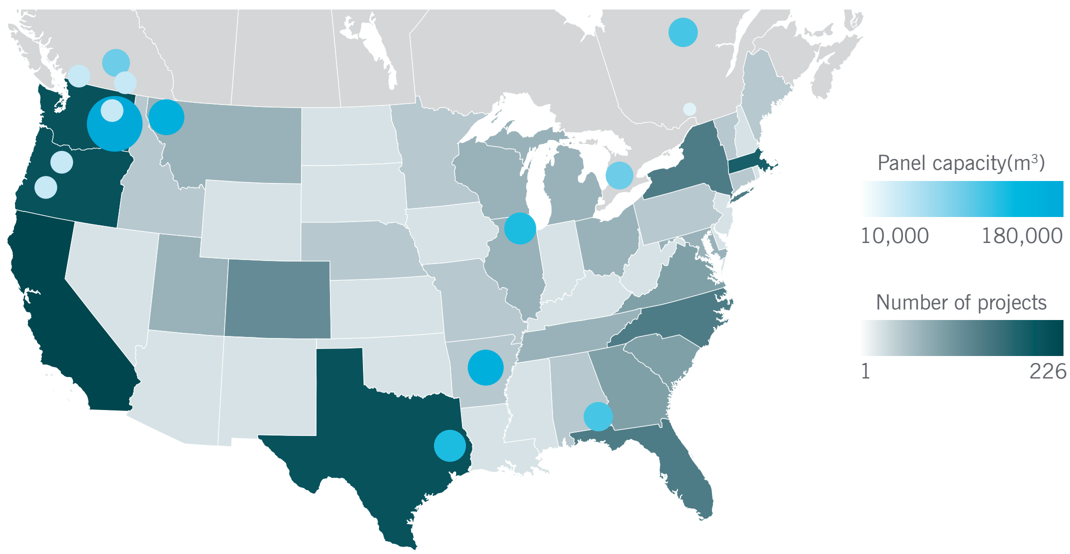
CLT technology was developed in Austria in the early 1990s and the first mass timber buildings were built between 1993 and 1995 in Switzerland and Germany. Europe remains the primary producer (and consumer) of CLT globally, with about 3.15 million m3 of CLT capacity. Holding to its roots, global mass timber production is concentrated in Austria and Germany. Major European producers include binderholz (Austria and Germany), Stora Enso (Austria, Sweden and

Czech Republic), KLH (Austria), and Hasslacher (Austria and Germany), with product mixes that include both CLT and glulam and production for local markets as well as exports to North America.

CLT has been in use in North America construction since 2010. The first few structures in the U.S. were built with CLT and glulam imported from Austria. Since 2013, several companies have established mass timber manufacturing plants in the U.S. and Canada. North American mass timber panel capacity for construction is rapidly growing and now totals about 800,000 m3 across 14 producers.[4] Major regional producers include Mercer (Washington), Structurelam (British Columbia and Arkansas), Nordic (Quebec), Smartlam (Montana and Alabama), and Element5 (Ontario), among others. As mass timber consumption grows, operating rates among existing producers are expected to increase along with new capacity coming online.

In addition to domestic production, North America imports meaningful volumes of mass timber from the E.U. In 2021, the U.S. imported about 32,000 m3 of CLT and 10,000 m3 of glulam from the E.U. (FEA, 2022). Binderholz is the single largest European exporter and world's largest producer of CLT with a capacity of over 315,000 m3. Reflecting expected growth in North American mass timber markets, Binderholz recently purchased two sawmills in the U.S. South (Florida and North Carolina), stating their intention to add mass timber to the product mix at the two sites, which could significantly boost North American production capacity.

Figure 2: North America mass timber panel capacity by facility and number of projects by U.S. state

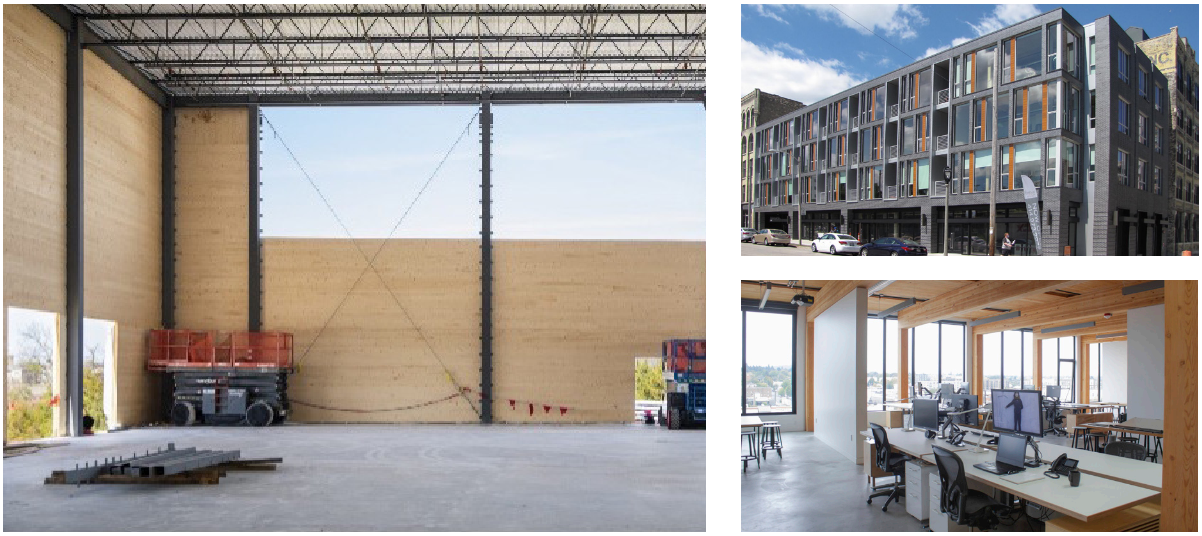


Sources: FEA; Woodworks. Notes: production capacity includes CLT, DLT and MPP. Number of projects includes completed and in design mass timber buildings in the U.S. as of September 2022. In addition to the 738 total projects in the U.S. included above, there are 484 projects completed and in design in Canada.

End-use markets

Global demand for mass timber is increasing rapidly in large part from a growing focus on reducing building sector emissions. However, these new materials and technology are impacting some building sectors more than others. In North America, to date, the vast majority of mass timber projects have been multifamily and office, with a smaller but growing number of projects in the industrial sector. Multifamily housing and office buildings are well-suited to mass timber systems because of the potential for standardization and modular construction. In North America, FEA reports that over 70% of mass timber panel consumption by building occupancy are in multifamily and office buildings (average 2020 to 2Q 2022)[4]. In the industrial sector, mass timber systems are also well-suited to tilt-up construction methods, with CLT panels used in place of concrete panels.

Figure 3: Mass timber multifamily, office, and industrial buildings



Sources: Thinkwood; Timberlab; WoodWorks. Notes: Industrial warehouse at Southfield Park 35 Warehouse in Dallas, TX (left) Photo credit: Southfield Park 35 Warehouse / PDMS Group / Timberlab / photo Erika Brown Edwards; multifamily at Timber Lofts in Milwaukee, WI (upper right), Photo credit: Timber Lofts / Engberg Anderson Architects / Photo ADX Creative and Engberg Anderson Architects; District Office, Portland, OR (lower right) Photo credit: Hacker Architecture and Interior Design, Portland, OR

In the U.S., there are currently 804 mass timber buildings in design, more than double the number of projects in design the previous year.[4] Geographically, mass timber construction has been concentrated on the coasts, though the number of projects in Texas, Colorado and Illinois is rising quickly. WoodWorks data show that mass timber projects in Washington, Oregon, California, Texas, and Massachusetts represent over half of all completed or started projects in the U.S. since 2013.[5]

Building codes in some U.S. jurisdictions have supported a more favorable environment for mass timber. Specifically, the 2021 and/or 2024 editions of the International Building Code (IBC) increased the maximum height for mass timber structures to 18 stories and allow for greater exposure of mass timber ceilings and beams. At present, 19 states, including California, Colorado, Connecticut, Virginia, and Washington, along with eight major cities in Texas, including Dallas, Fort Worth, and Austin, have adopted codes in whole or in part.

WHAT IS DRIVING DEMAND FOR MASS TIMBER?

Although mass timber currently accounts for a small share of global wood consumption, it is one of the fastest growing markets for timber. Additionally, embodied carbon from building construction activities and materials is largely unaccounted for in the real estate sector carbon accounting and company targets. As embodied carbon impacts and targets come into focus for the real estate community the demand for mass timber buildings is expected to drive CLT consumption up by over 40% annually in North America and by about 15% in the E.U. through 2027.[4] There are three areas that are driving demand for mass timber:

1. Potential to reduce building sector emissions — embodied carbon — from the substitution of wood for higher-emissions concrete and steel materials
2. Real estate industry alignment around the measurement and management of embodied carbon
3. Cost and efficiency advantages over traditional building systems

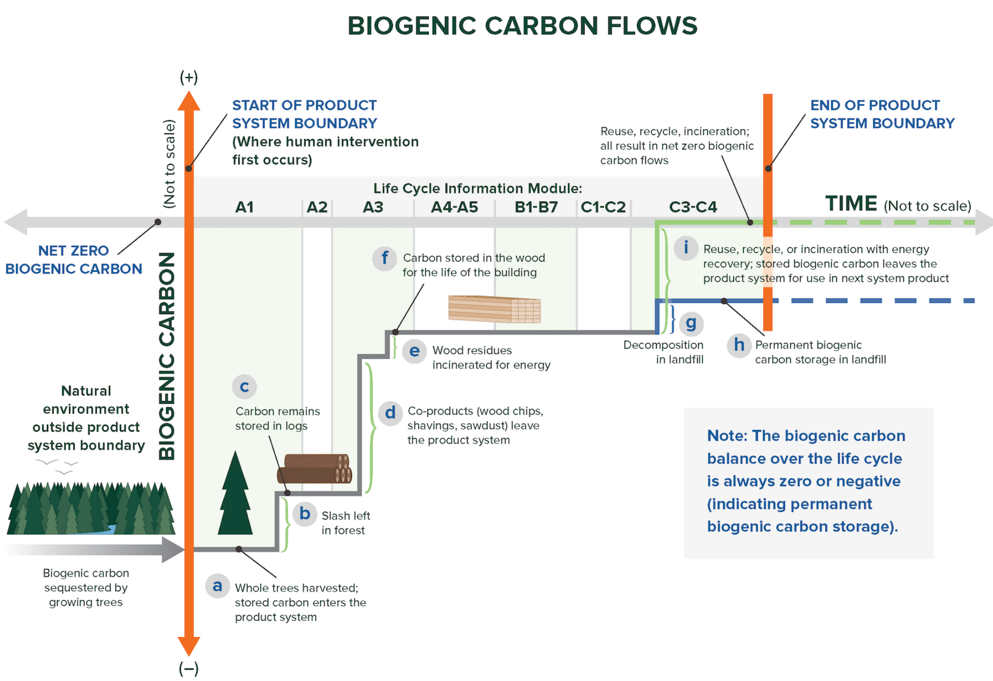
Embodied carbon and its measurement

Governments, corporates and investors are working to reduce emissions across their operations, supply chains, and the global economy. The building sector accounts for 40% of global emissions, though to date, most focus has been on reducing operating emissions because of its greater relative share of total emissions (27%) compared to building materials and construction (13%).[6] However, as emissions reductions targets become increasingly stringent and as buildings become more energy efficient, embodied carbon assumes greater relative importance. As a result, there is increasing focus on a building's embodied carbon. **Embodied carbon** includes all the GHG emissions associated with construction activity and building materials — those that arise from extraction, transportation, manufacture, and installation as well as end-of-life emissions associated with those materials.

How is embodied carbon in a building measured? The quantification of embodied carbon in a building is part of a life-cycle analysis (LCA). To demonstrate the potential climate benefits from building with wood, an LCA quantifies and compares embodied carbon in two or more functionally equivalent buildings — one made of mass timber and the other made of steel and concrete. The embodied carbon calculation outputs a global warming potential (GWP) metric for each building type — expressed in terms of CO2e for the building in total and kgCO2e/m2. The GWP for each building type is calculated using estimates of GHG emissions based on best available science and best practices. This side-by-side comparison quantifies the potential emissions reductions from building with mass timber.

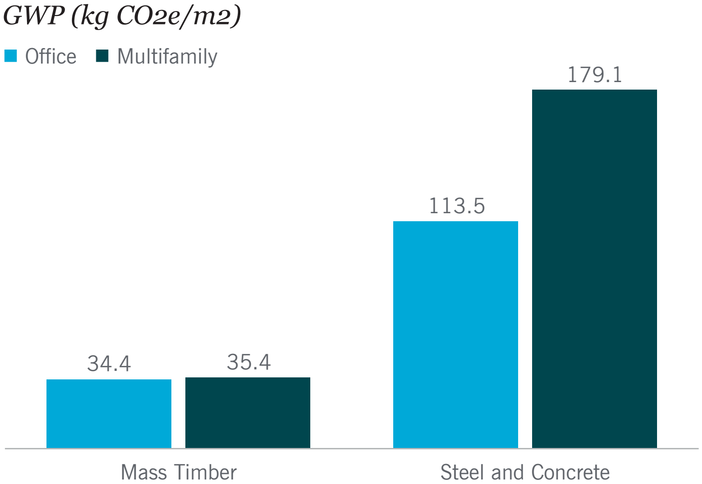
A key result from LCAs is that as wood material volume increases, GWP decreases due to both avoided emissions linked to concrete and steel and greater carbon storage in the wood itself — the biogenic carbon. Biogenic carbon is the carbon that is sequestered by trees, through photosynthesis as they grow, and that continues to be stored in wood products. Figure 4 shows the flow of biogenic carbon from the forest, through harvesting, processing and finally end-of-life. The vertical distance between net zero biogenic carbon and end of product system boundary, represents the net negative, permanent carbon storage from building with wood.

Figure 4: Biogenic carbon flows



Source: WoodWorks. How to include biogenic carbon in an LCA. Note: Biogenic carbon flows follow ISO 21930 and life cycle stages above are consistent with European Construction Materials and Building standards calculation methods (EN-15978) and include product phase (A1-A3), construction (A4-A5), use (B1-B7), and end-of-life (C1-C4).

Figure 5: Global warming potential of mass timber vs. concrete and steel building systems



Source: WoodWorks, 2022. Note: For the office building, all GWP estimates consider only the structure above the podium and the steel and concrete GWP is an average.

The precise reduction in GWP that comes from building with wood instead of more carbon intensive materials will depend on the LCA tool used and building-specific parameters. The three primary tools for LCA — Tally, Athena, and OneClick — each include a unique set of end-of-life assumptions about materials. Review of two completed LCAs revealed that in an office and multifamily building, the reduction in GWP ranged from 70% to 80% for mass timber systems compared to equivalent concrete and steel buildings (Figure 5).

REAL ESTATE MARKET ALIGNMENT ON EMBODIED CARBON

The Commercial Real Estate (CRE) industry has historically focused on measuring, managing, and reducing operational carbon, but a growing consensus is building around the need to tackle embodied emissions as the building stock expands to accommodate the world's growing population and advancements in economic growth and quality of life in the developing world. The World Green Building Council[7] issued a bold new vision in its 2019 report, "Bringing Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon", that calls for:

- By 2030, all new buildings, infrastructure and renovations will have at least 40% less embodied carbon with significant upfront carbon reduction.
- By 2050, new buildings, infrastructure and renovations will have net zero embodied carbon.

Achieving this vision is becoming more plausible as real estate property owners and developers now have tools and resources to support expanding to include embodied carbon. Additionally, green building certifications, which have set the standard for best in class as it relates to sustainability, have adopted the use of LCAs and embodied carbon measurement. Some net zero certifications like ILFI Zero Carbon set targets for 30% reduction over traditional building construction.

Figure 6: Green building certification standards

Certification Standard	Embodied Carbon Target	Geographic Scope
LEED	5-20% reduction over baseline building (2 – 4 pts)[8]	Global
BREEAM International	Assessment only (up to 9 points)[9]	Global
BREEAM UK	Improvements against the self-declared baseline value	UK
ILFI Zero Carbon	10% reduction, compared to equivalent baseline scenario[10]	Global

As institutional investors and asset managers adopt net zero strategies that consider embodied carbon, the need to quantify and strive to reduce carbon emissions in the construction materials will increase. The U.K. Better Building Partnership Climate Commitment, which currently has 37 signatories with investments in over 11,000 properties, incorporates both direct and indirect investments, operational and embodied carbon, and Scope 1, 2 and 3 emissions.[11] As clients increasingly seek opportunities to invest in climate solutions, real estate owners that can harness carbon savings in value-add and development investments are looking to strategies like mass timber.

Building sector constraints

In addition to the intrinsic climate benefits of wood-based construction, constraints in the building sector are making mass timber systems an increasingly attractive alternative to traditional steel and concrete systems. In the U.S., a persistent scarcity of skilled labor is impacting all building sectors and with about 41% of the current U.S. construction workforce expected to retire by 2031, these challenges are likely to intensify (FEA, 2022).

The shortage of skilled workers in construction has contributed to challenges in meeting both building timelines and budgeted costs. Wood-based modular construction, which involves producing standardized sections of a building off-site then assembling on-site, has the potential to accelerate project timelines and reduce costs. Research suggests that modular construction can improve time to completion by up to 50% and produce up to a 20% cost savings.[12] These purely economic advantages make mass timber cost competitive with concrete and steel systems, especially in high labor cost markets.

WHAT DOES THIS MEAN FOR INVESTORS?

Expanding markets for mass timber construction in multifamily and office mid-rise and high-rise, as well as industrial building sectors has the potential to materially increase demand for timber. More broadly, the opportunity for timberland investors reflects the increasing significance of climate, carbon and sustainability as value drivers in timberland markets. Timberland portfolios with certified sustainable forest management practices, rigorous ESG frameworks and favorable logistics relative to mass timber manufacturing and end-use building markets will be well positioned to benefit from these growing markets.

Figure 7 compares market development in the U.S. and the E.U., highlighting key differences in the two markets. Mass timber market development in the U.S. has been accelerated by over three decades of European experience. Major European producers like Binderholz, KLH and Hasslacher, are not only exporting CLT and glulam products but also exporting their engineering and design experience to penetrate U.S. construction markets. Evaluating more advanced European producers and integrated systems can provide insight into the potential development of the industry in the U.S.

In Europe, sawmill and mass timber production are highly integrated. In many cases, production includes both CLT and glulam as well as incorporating value-add manufacturing for modular building applications. In the U.S., a high degree of disintegration exists across the value chain — for example, a wood building in California may incorporate CLT from Oregon, glulam from Europe, and modular manufacturing and assembly in Texas. However, the European model suggests that there may be efficiency gains from consolidation. In addition to reducing costs, reducing logistics and transportation will reduce GWP as well. As a result, the timberland location relative to manufacturing and end-use markets will determine actual climate benefits.

Figure 7: Comparison of mass timber market development in North America and the E.U.

	NORTH AMERICA	EUROPEAN UNION
First mass timber building	2010	1993
Mass timber production	• Developing, with reliance on E.U. expertise and imports • Mix of integrated and disintegrated manufacturing	• Highly advanced • Integrated sawmill and mass timber manufacturing • Concentrated in Germany and Austria
Market development	• Fastest growing end-use markets globally • Together, Washington, Oregon, California, Texas and Massachusetts account for about 52% of completed or started projects	• Largest producer and consumer of mass timber globally • Together, Germany, Austria, Italy, Switzerland, Finland, and the U.K. account for about 80% of total consumption
Production and consumption	• Rapid growth in production and consumption • CLT consumption about 200,000 m3 in 2022 expected to increase 250%+ by 2027	• Steady growth in production and consumption • CLT consumption about 1,700,000 m3 in 2022 expected to increase 90% by 2027
Mass timber standard	• Uniform manufacturing standard and model code • Adoption varies by jurisdiction	• No uniform standard • Panel dimensions and structural properties differ by manufacturer

Impacting both the U.S. and E.U., global voluntary carbon credit markets are now expanding to include mass timber. The first methodology for mass timber construction is forthcoming under Verra's Verified Carbon Standard. Currently, carbon credit markets offer mechanisms for valuing carbon stored in the forest. The new mass timber methodology will soon offer a mechanism for verifying carbon stored in wood buildings and generating credits for the global voluntary market. We expect that requirements for certified sustainable timber as part of the supply chain to be part of the new methodology. And this will likely mean third-party forest certification of sustainable forest management practices and could include consideration of forest carbon stock as well.

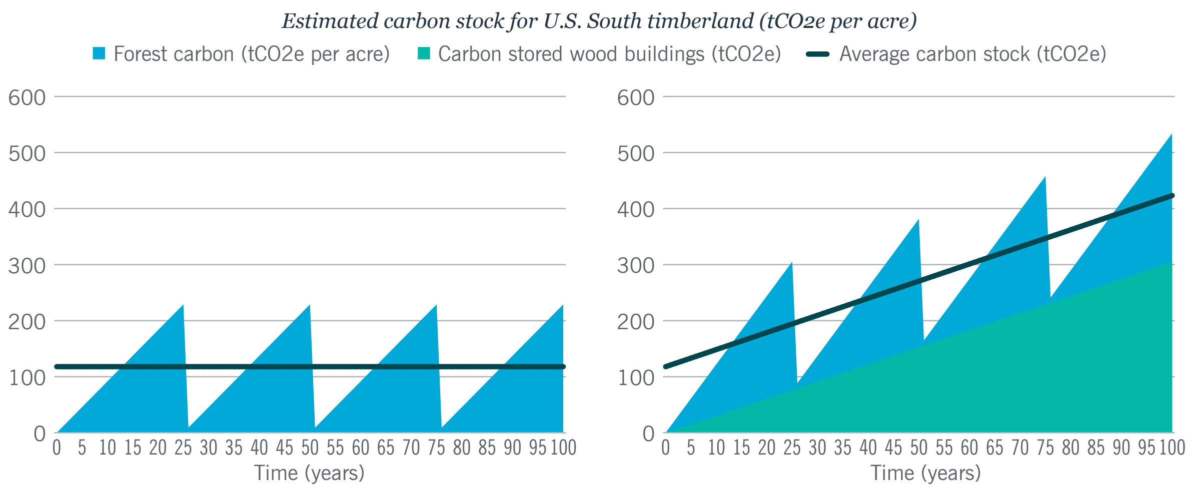
Mass timber leverages sustainably managed forests' ability to sequester carbon to permanently store and grow a pool of carbon in the built environment. Figure 8 (left) shows long-term average carbon stock is constant in a sustainably managed forest, with clearcuts every 25 years. Assuming one-third of the forest carbon is permanently stored in mass timber products, then average carbon storage is no longer constant but increasing over time , also shown in Figure 8 (right). Not shown in the Figure 8 are avoided emissions from the substitution of concrete and steel, which would further increase climate benefits from mass timber construction.

Verified carbon storage in the built environment complements sustainable forest management on the landscape and increases the capacity of trees to provide scalable climate solutions in two ways. First, carbon storage in buildings is essentially permanent. Unlike carbon stored in forests, where there is a risk of reversal from wildfire, illegal logging or insect/pest outbreak, for example, risks to long-term carbon storage in buildings are relatively limited. Second, mass timber made with wood from sustainably managed forests with harvesting and replanting has the potential for sustained timber production and more mass timber for more carbon storage in wood buildings. Through this process, carbon stored in buildings is being transferred from forests to the built environment.

Private timberland investment can help unlock the climate mitigation potential of substituting wood for conventional building materials and for investors with climate or portfolio decarbonization targets, these types of investments may provide added value for their portfolio.

Figure 8: Carbon storage in managed forest and wood buildings

Increasing carbon storage is possible when timber from sustainably managed forests is used in mass timber construction



Source: NNC Research.

For more information, please visit our website, nuveen.com/naturalcapital.

Endnotes

1 Why The Building Sector? – Architecture 2030
2 Forest Economic Advisors. Global Mass Timber Service. September 2022.
3 The Economist Intelligence Unit. Mass Timber: Wood Is Prominent in Construction's Future, Value for Carbon Removal To Be Determined (economist.com)
4 FEA, 2022.
5 See WoodWorks for status of building code allowances for mass timber in the International Building Code (IBC) by jurisdiction.
6 Why the built environment? – Architecture 2030
7 World Green Building Council, September 2019 Bringing embodied carbon upfront
8 LEED BD+C: New Constructionv4.1 - Building Life-Cycle Impact Reduction
9 Mat 01 Life cycle impacts
10 https://living-future.org/zero-carbon/zero-carbon-certification/
11 https://www.betterbuildingspartnership.co.uk/member-climate-change-commitment
12 McKinsey, 2019. Modular construction: From projects to products.

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