Demystifying Forest Management and Timber Procurement

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The first step to understanding the regenerative potential of mass timber involves assessing the lumber supply chain and forestry best management practices. This paper explores these topics, beginning with an overview of the carbon cycle of wood products and the role designers play in protecting the earth's resources through material selection.

Perkins&Will has a long history of advocating for the use of Forest Stewardship Council (FSC) Certified wood. For many years, our specifications have reflected a commitment to sustainably sourced and produced wood fiber products. The advent of mass timber as a primary structure material available in North America gives us the opportunity to study material sourcing of large-format timber products. As FSC 100% mass timber products are uncommon in North America (1), a deeper dive into material selection is necessary. This guide introduces project teams to strategies that can be used to ascertain the positive or negative impacts of sourcing mass timber for a project so that educated decisions can be made to protect the health of forest ecologies and the environment.

While tracing a project's timber to its source(s) remains challenging, teams can engage in dialogue with stakeholders to improve transparency and specify wood products with assurance that a project's timber comes from responsibly managed forest land. With the right combination of partners, material sourcing care, and design vision, a mass timber project can raise the bar in our portfolios, in the cities in which we work, and in the interconnected ecosystem of our planet.

Kaiser Borsari Hall, Bellingham, WA

Climate Responsibility

The Cycle, System, and Scale of Mass Timber

Craft in mass timber represents an opportunity to engage the cycle, system, and scale of a living material.

Timber production is intrinsically bound to forest ecology. The forest's natural cycle is a closed loop: diverse, evolving, growing, decaying, and perpetually providing our planet with life. Humans' relationship to this ecosystem is ancient. Over time, we have come to understand the forest as a source of life, protection, heat, nourishment, inspiration, and more recently, product and profit.

Today, through a system of harvesting, milling, manufacturing, and distribution, trees are transformed from roundwood into mass timber products. Yet timber is more than a product. It is the only primary structural material approved by the International Building Code that is also derived from a living carbon sequestering resource.

The scale of the building industry's engagement with mass timber as a structural material is set to increase exponentially in the coming years. As this expansion occurs, transparent and responsible forest management and procurement practices will be crucial to utilizing wood as both a product and a part of a regenerative cycle. The design and development community can exhibit leadership by pairing mass timber design with a holistic understanding of this material's physical nature and ecological context.

The first step to engaging timber's regenerative potential is understanding suppliers, the supply chain, and forestry practices. However, the timber supply chain can be complex, so responsible procurement requires time and commitment. Certified timber usually also increases cost, as best management practices and certification require resources to achieve. Project teams must set an expectation in conceptual design that timber products will be derived from responsibly managed sources and follow through with this expectation in specifications and procurement.

The building industry's collective decisions about how timber is procured today will determine whether we utilize this critical ecological resource in a way that leaves trees with a viable forest and humanity with a viable future.

Designing with Disruption

While the preservation of forest land is crucial to a healthy ecology, disruption is an inherent part of the forest cycle. Human engagement with ecology is also characterized by disruption. The impacts we have on our ecosystems are dependent not on *whether* but on *how* we embody our role as disruptors. Disruption is part of life and can instigate new growth, just as it can cause catastrophic failure. When a project team specifies any building material that is extracted from an ecological context, that team has an opportunity to design for a circular pattern of disruption.

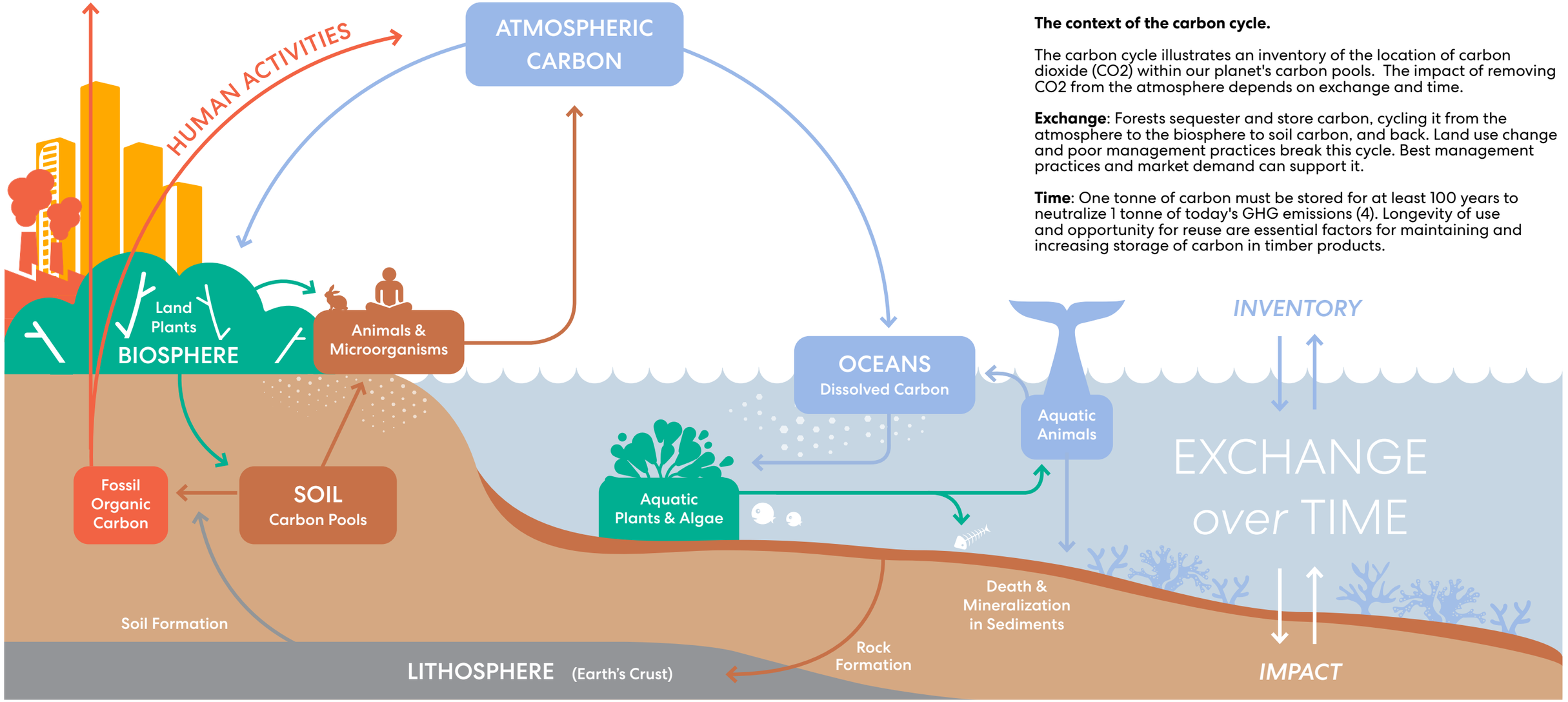
Forests are always fluctuating and are both sources of carbon emissions and sinks for carbon storage. Fire, blight, and extraction are all forces of disruption that result in carbon emissions. However, land-based ecosystems currently sequester and store approximately 30% of global anthropogenic carbon emissions (2). The physical area of forested land in any region is impacted over time by various factors that include:

- Age and distribution of trees
- Management practices
- Environmental factors (fire, blight, drought)
- Land use change (development, mining, livestock, agriculture)

There is potential to sequester and store more carbon through the expansion of forest land. The greatest threat to that potential is a linear pattern of disruption: land use change. Land use change and its associated impacts are the second-largest contributor to global anthropogenic emissions after burning fossil fuels (3). Conversion of forest land to other uses is also the primary driver of deforestation.

Teams that procure legal wood from regions with stable or increasing forest stocks and sound land management regulations (e.g., North America) can support a managed forest cycle where the disruptive act of harvesting trees is coupled with replanting and comprehensive planning for ongoing management. Teams that go further, requiring certified wood and/or more information on source forests, can support best management practices to promote biodiversity, watershed health, resilience, and more. In either case, sustainable timber procurement helps to prevent land-use change by providing suppliers with incentives to manage, maintain, and even increase forest land, fostering the forest's capacity to support life.

Sources of Anthropogenic Emissions Include:
Burning Fossil Fuel, Building Operations,
Cement & Other Manufacturing, Transit
Construction, and Land Use Change.



The context of the carbon cycle.

The carbon cycle illustrates an inventory of the location of carbon dioxide (CO_2) within our planet's carbon pools. The impact of removing CO_2 from the atmosphere depends on exchange and time.

Exchange: Forests sequester and store carbon, cycling it from the atmosphere to the biosphere to soil carbon, and back. Land use change and poor management practices break this cycle. Best management practices and market demand can support it.

Time: One tonne of carbon must be stored for at least 100 years to neutralize 1 tonne of today's GHG emissions (4). Longevity of use and opportunity for reuse are essential factors for maintaining and increasing storage of carbon in timber products.

Can forest land keep up with global demand for materials?

As design with mass timber becomes more common, increased demand for wood products may correlate with a gradual increase in forest land to meet demand. However, this outcome isn't certain. Best management practices and policies will be required to sustain and increase supply of wood (5); it is necessary for project teams to set clear expectations for transparency in mass timber procurement.

The International Organization for Standardization provides one example of guidance to account for wood harvested for products that originates from "sustainably managed forests." Per ISO 21930, a wood product that wishes to claim carbon sequestration and storage benefits (6) must be sourced from either:

1. Certified forests or mills.

Certifications offered by Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), Programme for the Endorsement of Forest Certification (PEFC), Canadian Standards Association (CSA), American Tree Farm System (ATFS), and others can provide teams with a base level of assurance that a project's timber comes from legally harvestable sources with responsible forest management practices (7). Certification supports maintenance and improvement of forested land and is *essential* if a project is considering procuring timber from a region where forest land is decreasing over time. While many efforts are underway to improve the transparency of timber sourcing, at present, certification is the most direct pathway for teams to validate the sustainability of a project's timber.

2. Stable or increasing forest carbon stocks based on reporting.

Data from the United Nations Framework Convention on Climate Change (UNFCCC) National Inventory Reporting shows that in much of Europe and North America, the net carbon flux from forestry is relatively stable (8). However, forest land is shrinking in many regions of the world, and long-term stability is not guaranteed in any region due to increased demand for timber and confounding factors like wildfire and blight. Additionally, regions the size of a large country like Canada or the US are not reliable indicators of localized forest health or biodiversity.

Either certification or a thorough understanding of where a project's timber comes from are the most reliable ways to ensure that management of source forests will support continued carbon sequestration and other ecosystem services.

Best practices for mass timber project teams

Significant points of leverage for forest advocacy through mass timber design include:

1. **Consider salvaged wood and re-use**: Is it possible to use reclaimed lumber or to reuse existing building components before procuring new products? This is the best way to ensure responsible sourcing and reduce a project's carbon footprint.

2. **Promote transparency:** Require certification and/or other verifiable information about the management practices associated with each timber product's wood basket or even source stands. While traceability of wood sources is challenging, emerging efforts will make this more possible over time, and well-intentioned advocacy and dialogue can help.

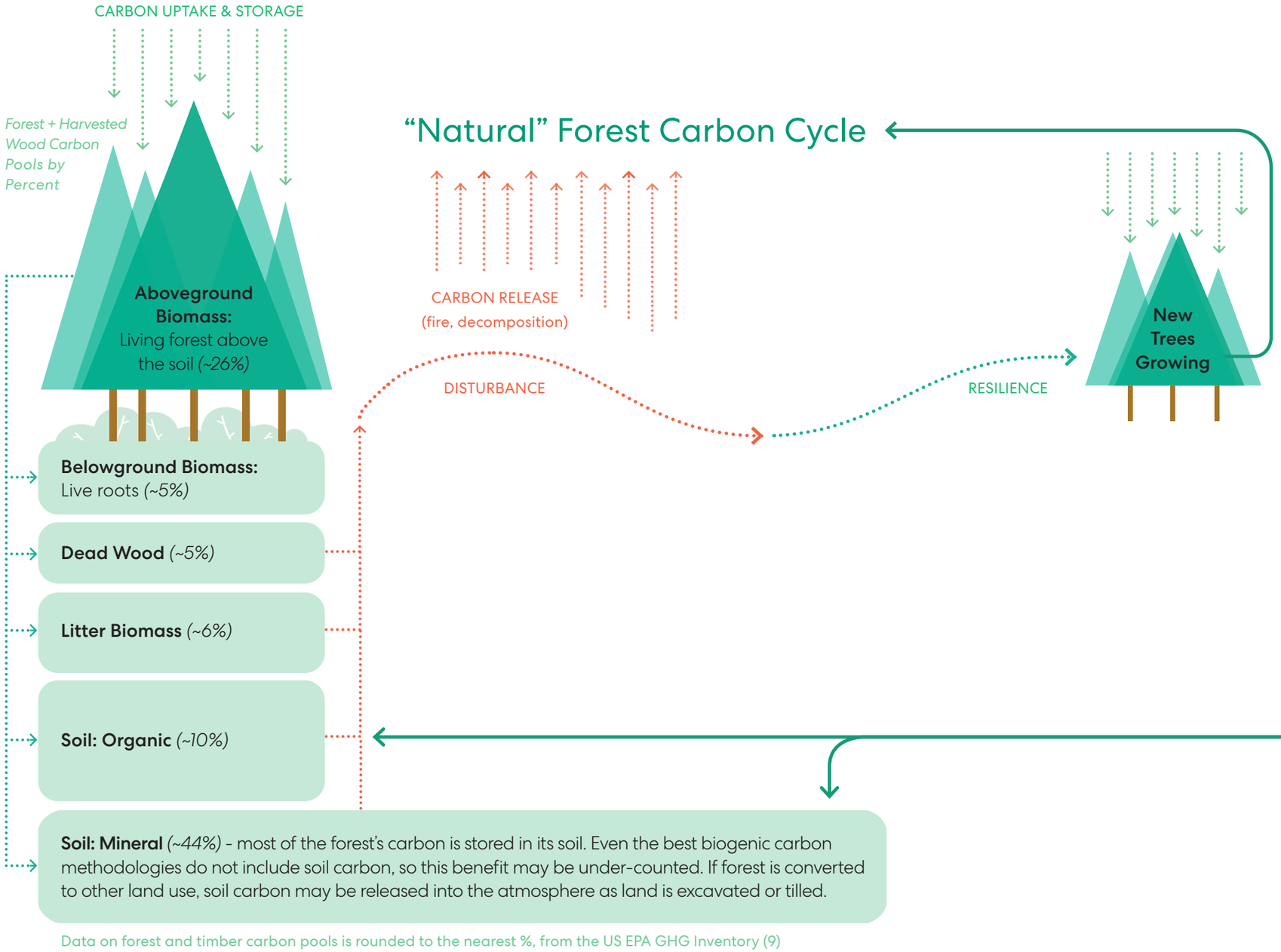
3. **Purchase direct from supplier:** Some "vertical" suppliers fabricate timber from land that they own or control. Investigate options to purchase from a supplier or from a mill that can guarantee wood from a specific sustainable source.

4. **Allocate funds for certified wood**: Incorporate an allowance for certified timber in project budgets.

5. **Design for longevity and circularity**: Maximizing a building's service life and ability to be disassembled and reused in the future are key factors for maximizing the lifespan of carbon storage in timber products, preventing carbon stored in these products from being emitted into the atmosphere.

6. **Design with the material**: Explore options for fiber-optimized design and hybrid members; utilize different species for outer (aesthetic) and core (structural) laminations; specify products such as wood fiber insulation made of chips, residuals, and pulp.

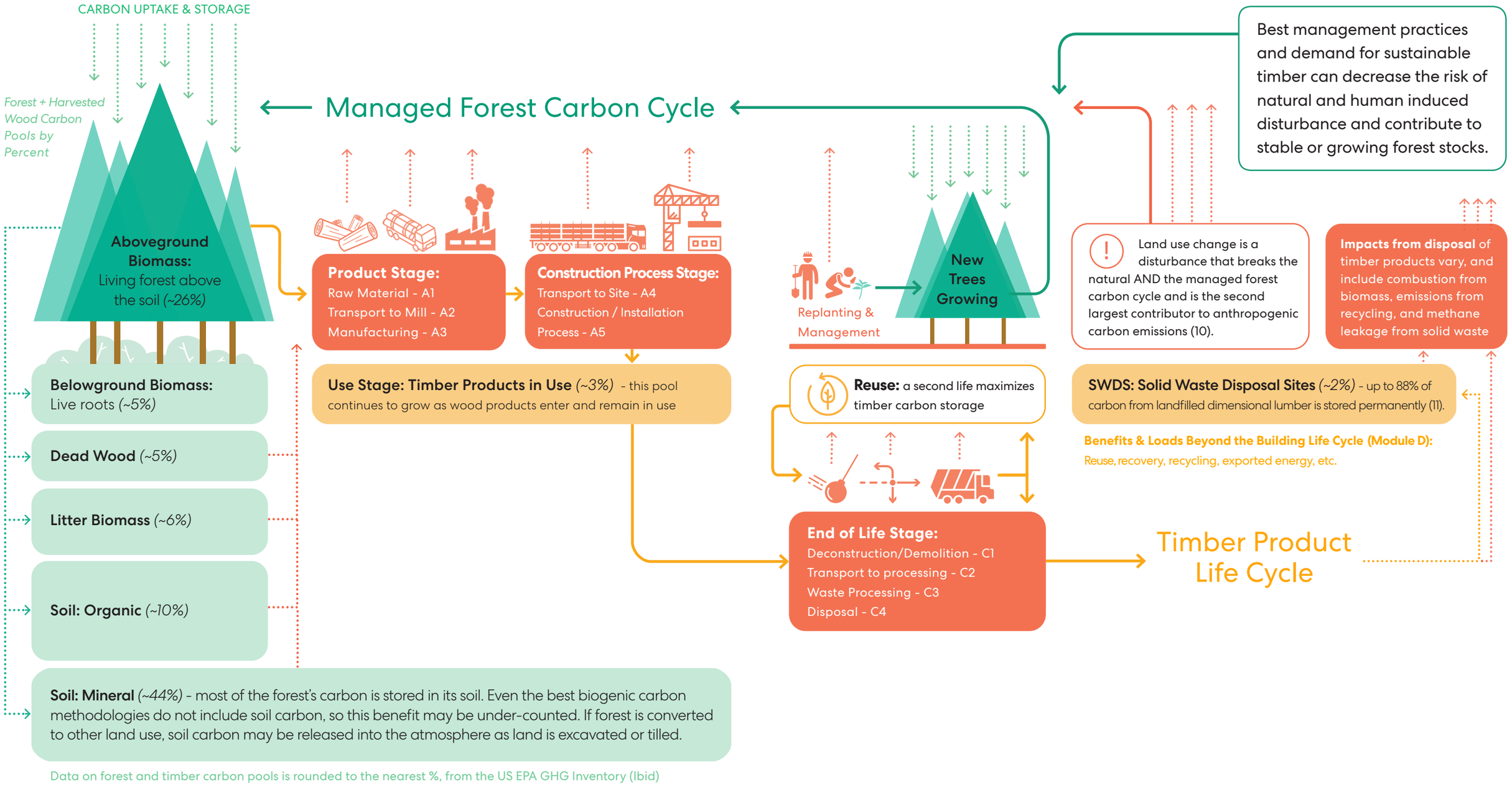
7. **Engage in disruption:** Carbon sequestration is not the only factor to consider in sourcing timber. Using wood from forests that have experienced, or are prone to, fire or blight like beetle-kill can support restoration of a vulnerable ecosystem. Sourcing from drier regions may also incentivize development of mills where infrastructure is lacking.



Data on forest and timber carbon pools is rounded to the nearest %, from the US EPA GHG Inventory (9)

The forest's carbon cycle extends below the surface. Forest soils filter and distribute water, store carbon, recycle organic matter and nutrients, and provide habitat for a myriad of organisms.

Managed Forest Carbon Cycle



Data on forest and timber carbon pools is rounded to the nearest %, from the US EPA GHG Inventory (Ibid)

Wild Thyme Farm, Oakville, WA

Sustainable Sourcing

Forest Management and Responsible Procurement

Sourcing sustainable mass timber can be a challenge. The supply chain is long and has a variety of stakeholder structures. Forestry certifications can be difficult to compare, and the environmental impacts of living systems like forests are challenging to quantify. While industry, forestry, and transparency stakeholders are working toward solutions, designers have a role to play in ensuring that projects use sustainably sourced wood and in promoting change in the industry.

At Perkins&Will, we have advocated for the use of certified wood, highlighting FSC as a gold standard because we trust this promotes a healthy planet. In general, this has served us well. However, this guidance is not the only path to sustainable wood sourcing. FSC 100% mass timber products (where all materials come from FSC certified forests) are uncommon in North America (12). Several suppliers offer FSC Mix, but at varying percentages, and we must consider:

Is the non-FSC fiber coming from responsible sources? If FSC or other certified wood is not available or is not an option for a project team, what are other acceptable paths to sustainable mass timber procurement?

One method to begin answering these questions is to study the region where a project's wood comes from and understand both forest health and land management patterns. At a broad scale, in the United States, 39% of forest land is owned by individuals and families (13). For many small landholders that are managing their own forests, FSC is not a viable option due to cost and extensive reporting requirements (14). Canada faces a different scenario: approximately 94% of Canadian forest lands are owned by public and governmental entities and are governmentally managed (15). Canada manages 37% of the world's certified forest area, and PEFC is the most common certification in Canada and many other parts of the world (16).

While the specifics of forestry certifications vary, at a base level, each certification entity is committed to improving sustainability and supporting biodiversity (17). Adoption of biologically based and carbon-storing building materials like mass timber is a core strategy for the building industry to mitigate contributions to global warming. However, this strategy will be most effective if project teams strive for procurement that contributes to stable or increasing forest stocks, more transparency, and continual improvement of forest management practices.

Sustainable Timber Sourcing Objectives

Procurement of legal wood from regions with stable forest stocks and sound land management regulations provides regional incentive to manage and maintain a working landscape. Beyond this, teams can invest in conversations with stakeholders to understand and support the following Sustainable Timber Sourcing Objectives:

Understand Regional Impacts

Only procure timber from sources that can verify harvest from healthy and stable forest stocks, unless procurement is part of an ecologically restorative forest management operation.

Freshly harvested wood is inefficient to transport because it is round and has high water content, so most mills' "wood baskets" are within a 50-75-mile radius of their source forests (this radius is greater under some circumstances). This region may provide a team with clearer information about which forests a project's wood may come from.

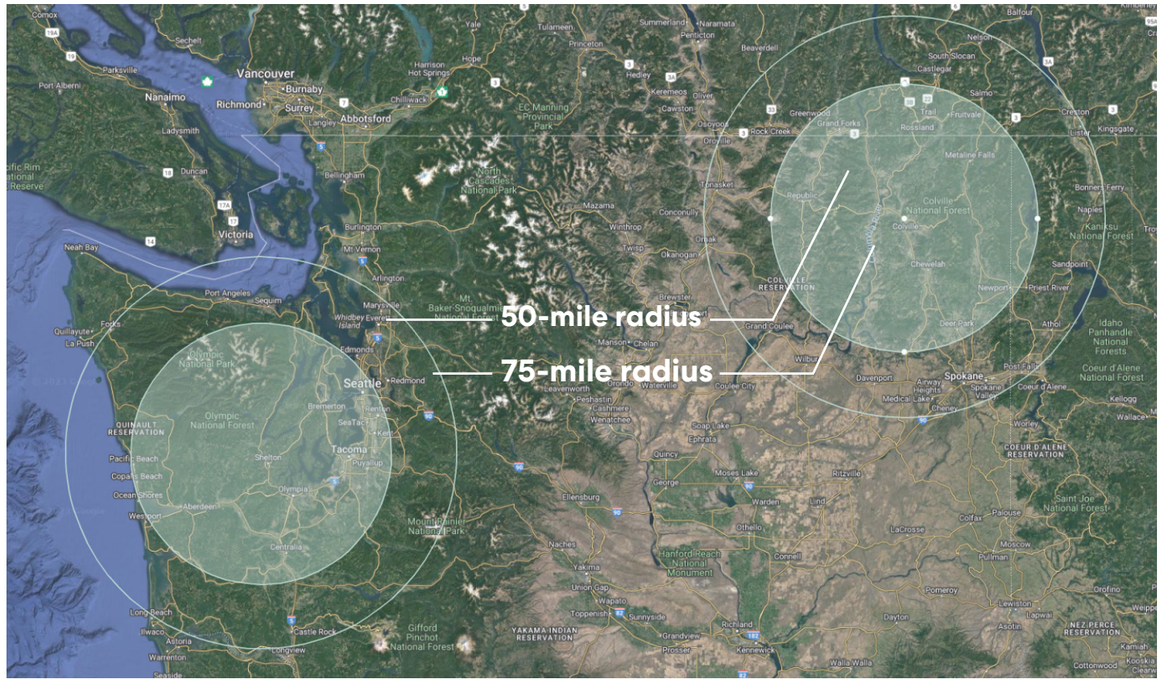
However, once the wood is dried, milled, and fabricated into mass timber, it may be transported across the world to a project site. Whether wood is procured from across the world or across the street, the project team will need to engage in inquiry to ensure that their timber is not contributing to loss or degradation of forests.

Promote Environmental Impact Transparency

In addition to requesting certified timber, teams can request information to help validate, to the highest resolution possible, the source location(s) of a project's timber buyout. At a minimum, a team could ask for the GIS coordinates of a mill, the radius of the wood basket that accounts for 90% by volume of the material that the mill processes, and the year of harvest for the material supplied. While optimal forest management practices may vary greatly within a radius of this size, this information will allow a team to assess the source region and consider whether additional inquiry is needed.

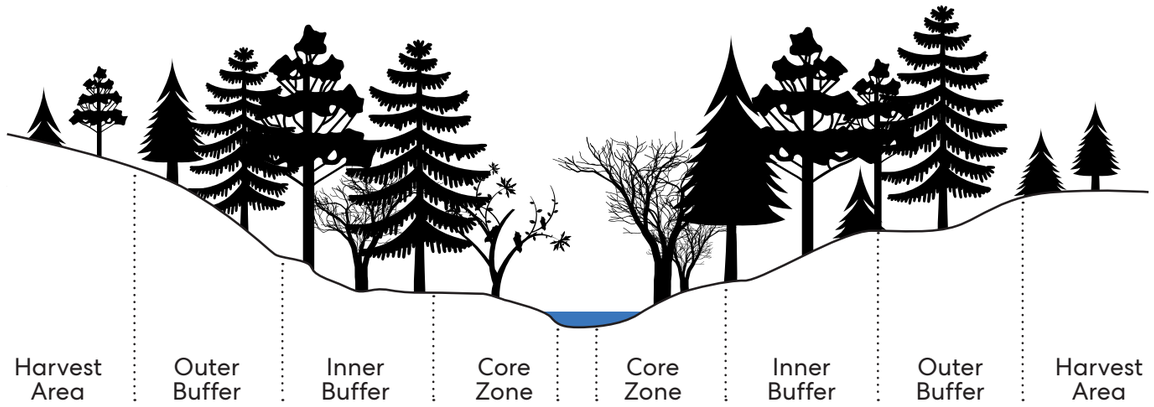
Additional resources to support sustainable procurement are quickly evolving. These include improvements to product-specific Environmental Product Declarations (EPDs) for mass timber and an array of sourcing and traceability tools (18). These resources are emergent and cannot be explored within the scope of this guide.

Potential Wood Baskets for Two Timber Mills



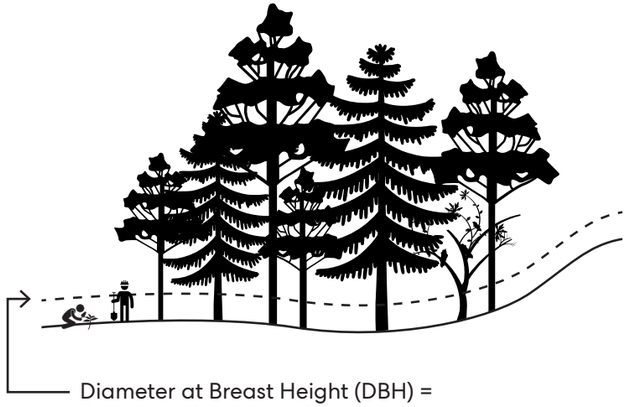
50 & 75 mile radii from each: 1) Sierra Pacific Industries Mill in Shelton, Western WA; 2) Vaagen Brothers Mill in Colville, Eastern WA
For illustration only; does not represent the actual supply area of either mill
Image Source: Google Maps, 2023

Riparian Management Zones

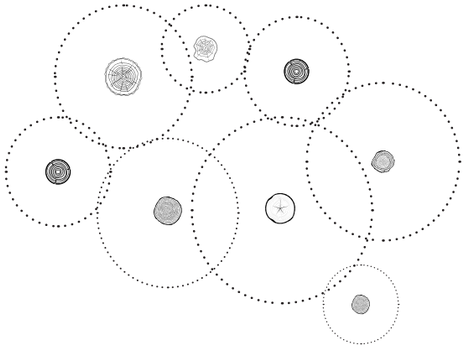


In certified and sustainably managed forests, management activities near the "core zone" of rivers, wetlands, and shorelines are focused on restoration.

Basal Area Measurements



Diameter at Breast Height (DBH) =
Diameter of a tree at 4.5 feet above ground



Basal area of each tree =
Cross-sectional area at breast height

The basal area of a stand of trees (before or after harvest) is measured by the area of all species or stems in a stand at breast height per unit of land area.

Increase Carbon Sequestration and Support Biodiversity

Best management practices optimize each stand's harvest frequency to support ecosystem services and increase residual basal area (the density of "leave trees" that remain standing after harvest), as well as riparian buffers and diversity of species in a forest.

Harvest cycles that are optimized for profit *may* not always align with optimization for carbon sequestration and ecosystem health. Depending on a stand's specific location and species composition, longer harvest cycles *may* lead to increased wood volume, carbon storage, and resilience against fire (19). So long as seedlings have access to sunlight, increased basal area can support age diversity, supporting healthy soils and mycorrhizal networks (20). Riparian buffers and diversity of species support habitat preservation and watershed health, contributing to healthy environments for fish, land-dwelling creatures, birds, and pollinators. Biodiversity of tree species can also help a forest resist blight.

Additional Objectives

Certification standards share additional objectives for sustainable forestry (21), including:

- Preservation of old growth and primary forest (not previously logged)
- Training and continual improvement of forest management practices
- Restriction of Genetically Modified Organisms (GMOs)
- Support for and promotion of Indigenous People's Rights

Other objectives for consideration, which may not be captured by certification, include:

- Forest soil health
- Improve resilience
- Rural community equity
- Conservation and recreational access
- Safety and workers' rights
- Manufactured product impacts on human health (e.g., reduction and elimination of VOCs)
- Waste reduction in the forest through the manufacturing, construction, and installation processes

Washington State Department of Natural Resources Tree Farm: "leave trees" and slash after harvest

Wood Souring Stakeholder Engagement

Many players influence the degree of sustainability embodied in the wood fiber of mass timber products and buildings. The primary stakeholders include:

- Certification Entity (FSC, SFI, PEFC, CSA, ATFS, etc.)
- Landowners and Managers (TIMO, REIT, Family, Tribal, Gov.)
- Lumber Mills
- Mass Timber Panel Manufacturers
- Fabricator Subcontractors
- General Contractor
- Project Client

Landowners and lumber mills have the biggest impact on the availability of sustainable mass timber. Landowners decide how to manage their forest (sustainably or not), and mills determine which landowners they will source timber from. It is worth noting that logging companies are not influential stakeholders because they are agents of mills and landowners, following whatever harvest protocol is required by the mill and landowner.

As forests are owned and managed by many types of entities, including federal, state, tribal, private industry, and private non-industry groups, the goals and objectives of each vary. While forest managers are experts in their complex domain, many owners are motivated to manage their land in response to regulations and market demand. A team may be able to secure timber that meets specific requirements through early planning. However, it is important for teams to advocate for an increased budget to account for management practices that add value to timber products. If discriminating owners increase demand and willingness to pay for higher-resolution traceability and specific management practices, suppliers will respond.

Mills do not sort logs by the stand from which they are harvested. They sort them by species and diameter and stack them into the log deck with all the other truckloads of lumber coming in daily or weekly. In addition, mills do not sort outgoing lumber by the stand from which it is harvested. They sort lumber by species, size, grade, etc. Consequently, when a mass timber manufacturer sources lamstock from various mills, the only way to ascertain the sustainability of the resulting mass timber products is to ensure ALL the wood going in and out of ALL the source mills is from sustainable forests. This is not currently a standard offering from North American suppliers.

Questions for Conversation and Verification

To make an impact on projects, teams need buy-in from clients that meeting the Sustainable Timber Sourcing Objectives to the maximum extent possible is a clear goal. From there, they can work with the general contractor to select a suitable fabricator who works with suitable mills. This can only be done by augmenting specifications and having real-time conversations with fabricators and mills, whose upstream supply, certifications, and Environmental Product Declarations (EPDs) represent opportunities for discussion.

The following list of questions for mills and fabricators will help initiate this conversation. Dialogue promotes transparency and helps the team and client develop confidence in the products procured for the project.

Questions for Mills

1. How do you work with landowners to ensure your wood sourcing promotes equity, biodiversity, water quality, and carbon sequestration?
2. What sustainable forest management certification(s) (if any) does your company use: FSC, other certification, no certification? What social and environmental advantages does your approach offer?
3. What is your maximum stand-to-mill distance for hauling logs?
4. What type of landowners do you work with, by percentage?
5. How do you sort your logs, and how do you sort your lumber? What is your methodology for timber source accounting? For instance, do you tag logs from different stands, and do you tag lumber from different tree stands?
6. Can you provide lumber buyers with GIS information for the tree stand(s) where 90% or more of a buyout comes from as well as the year of harvest? At a *minimum*, can you provide GIS coordinates that define your wood basket and the sourcing year for a buyout?
7. Can you certify that no forest conversion or harvesting from prime forest will be included in the source material (unless this sourcing is tied to an ecologically restorative forest management initiative)?
8. As the industry works to develop product and source-specific EPDs (more specific than industry-average EPDs) for downstream products like glulam and CLT, how do you intend to participate?

Perkins&Will has corresponded with several mills to obtain a sense of the state of the industry. Mills have expressed a range of responses.

Fraserwood Industries, Squamish, BC

Questions for Fabricators

1. How do you work with mills to ensure your wood sourcing promotes equity, biodiversity, water quality, and carbon sequestration?
2. What is your methodology for timber source accounting? For instance, do you require inventory control from your mills?
3. For a specific project, can you provide us with GIS information for the source forests where 90% or more of the lumber used in your products comes from, as well as the year of harvest?
4. Is the lam stock in your products certified? If so, to which standard(s)?
5. Do you have product-specific EPDs that include source-specific data for the timber used in your fabrications (more specific than industry-average EPDs)? If not, are source-specific EPDs forthcoming?

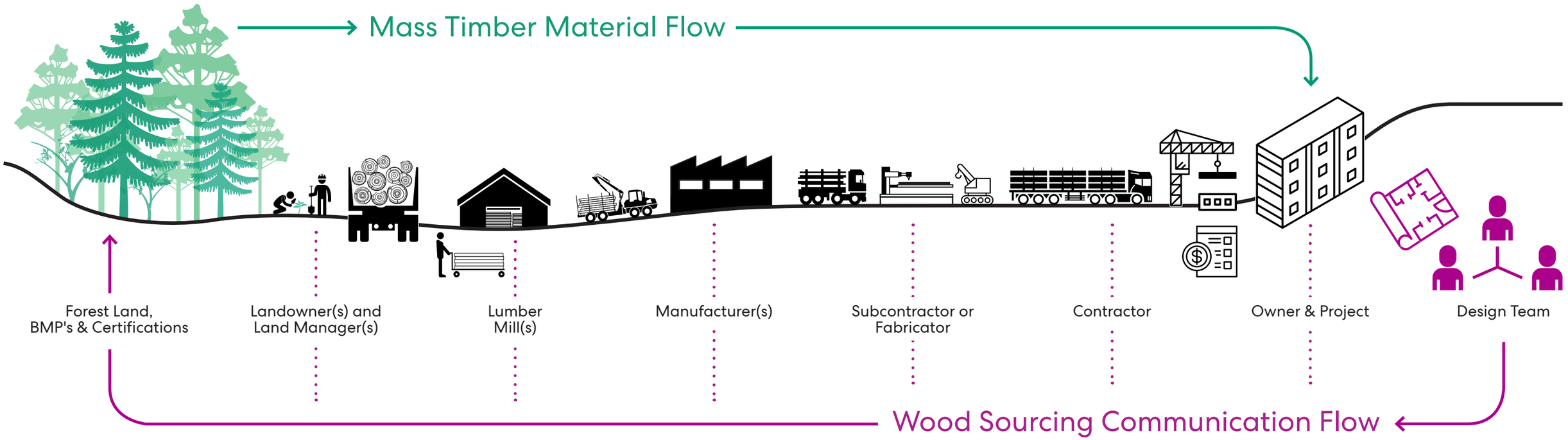
As with mills, fabricators have expressed a range of responses to the above questions. The fabricators who are most aligned with our Sustainable Timber Sourcing Objectives have expressed that they are currently finalizing EPDs, but some still rely on industry average wood impact data (source-specific data is required to understand localized impacts). They are also limited to the mix of wood that suppliers in their region can provide. Very few fabricators can provide stand locations for their products' timber harvests because they source from multiple mills. Mills should be able to provide coordinates of their wood basket; however, even with mills, stand-specific information is less common. This means that only some of the wood in any given mass timber panel meets the objectives of even the most sustainably minded fabricators.

Apart from certification, one path to sourcing transparency is procurement from a “vertical” supplier (i.e., a fabricator or manufacturer who manages their own land and mill) whose land management practices align with our Sustainable Timber Sourcing Objectives. Another path (though rare) is targeting buyout from specific tree stands, leading to complete chain of custody for every fiber. The latter path requires a mill to be aware of and prepared to collaborate to achieve the intention well in advance and to plan for storage and a dedicated run of milling for that specific wood. This is disruptive and costly for the mill, and associated costs are passed on to the project.

If none of these options are available, a team may need to communicate further upstream to learn more about the forestry practices associated with a wood product.

Art Massif Structure de bois, Saint-Aubert, Quebec

Wood Sourcing Stakeholders & Communication



Many steps occur between a forest, its management practices, and finished mass timber project.

Upstream Communication

Many steps occur between a forest, its management practices, and a finished mass timber project. Depending on how many entities are involved across these steps, a design team may need to communicate upstream, at least as far as a lumber mill, to validate sustainable forestry practices for each mass timber product. The questions presented throughout this section provide a starting point for conversation. Ideally, key requirements to validate sustainable sourcing will be translated into specification and bidding documents. (22)

Increasing the demand for sustainable forest management and harvest necessitates a multi-pronged approach through projects that require certified wood, teams that communicate up the supply chain to improve transparency, and industry collaboration to improve standards and regulations, develop source-specific EPDs, and elevate best practices.

BC Passive House, Mount Currie, BC

Normalize Dialogue

As design teams work to popularize the use of mass timber, the industry must simultaneously increase dialogue about sustainable sourcing. Conversation between teams, project owners, and timber suppliers is essential to ensuring sustainable wood sourcing, from early cost estimation through specifications and procurement.

While obtaining certified or other sustainably sourced wood will take time and may add to a project's costs, the gravity of transparency and the importance of keeping forests functioning as forests cannot be overemphasized. Circular forestry practices are in the best interest of project teams, the timber industry, and ecology alike, as they ensure long-standing availability of resources for all.

As a product and a compelling building material, mass timber invites teams to engage in a deep understanding of the forest as a crucial resource and to participate in stewardship to ensure a stable supply chain and ecological health for decades to come.

Resources

In addition to the resources in this guide, the following resources provide useful information about sustainable forestry and timber sourcing.

- Tallwood Design Institute's "Sustainability and Environment" Research (23)
- "Forest Certification Update 2021: The Pace of Change." Dovetail Partners (24)
- "Wood Carbon Seminars," Carbon Leadership Forum (25)
- "Carbon Narratives for Design Planning" series, The Institute for Health in the Built Environments (26)
- The Climate Smart Wood Group (27)
- Work by David Diaz of Ecotrust and partner organizations to assess the carbon and other ecological impacts of forestry management (28)

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Lee Scott, Element5
Arthur Tsai, Canfor
Mitch Warren, Kalesnikoff Mass Timber
Washington State Department of Natural Resources
Herbert Yancey, International Woodland Company

References

1. Everett, Aaron et al. "Climate Smart Wood Procurement Guide". *Climate Smart Wood Group*, 2022, 19. https://www.climatesmartwood.net/wp-content/uploads/2022/11/Climate-Smart-Wood-Procurement-Guidance.pdf.

2. "Land-Based Solutions Offer a Key Opportunity for Climate Mitigation". *UNCCD*, 2023. https://www.unccd.int/news-stories/stories/land-based-solutions-offer-key-opportunity-climate-mitigation.

3. "Global Greenhouse Gas Emissions Data | US EPA". *US EPA*, 2016. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

4. Compagnon, Thibault. "Reductions or Removals? Why Science — Not Just Market Forces — Must Shape Our Pathway to Net Zero". *Quantis*, 2020. https://quantis.com/why-science-not-market-forces-must-shape-our-pathway-to-net-zero.

5. "Global forest sector outlook 2050: Assessing future demand and sources of timber for a sustainable economy – Background paper for The State of the World's Forests 2022. FAO Forestry Working Paper, No. 31. Rome". *FAO*, 2022. https://doi.org/10.4060/cc2265en.

6. "Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services". *ISO 21930:2017, section 7.2.7.* 2023. (Current, reviewed and confirmed in 2023)

7. Certain factors associated with forest management are not well understood, such as the impacts of logging on soils, ideal time spans between planting and harvest to maximize ecosystem health, and protection of sensitive ecologies like riparian zones. Certification standards are one verified path to address these and other factors.

8. "United Nations FCC International Council on Climate Change, National Inventory Submissions 2023". *Unfccc.Int.*, 2023, https://unfccc.int/ghg-inventories-annex-i-parties/2023.

9. Data on forest and timber carbon pools pulls from the EPA's "Inventory Of U.S. Greenhouse Gas Emissions And Sinks: 1990-2018 | US EPA". *US EPA*, 2020. This data and forest carbon are also well explained in this report: Hoover, Katie, and Anne A. Riddle. "Forest carbon primer." *Congressional Research Service: Washington, DC, USA*, 2020. https://crsreports.congress.gov/product/pdf/R/R46312

10. "Global Greenhouse Gas Emissions Data | US EPA". (n 2)

11. "Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)". *US EPA*, 2019. https://www.epa.gov/sites/default/files/2019-10/documents/warm_v15_management_practices_updated_10-08-2019.pdf.

12. Everett, Aaron et al. "Climate Smart Wood Procurement Guide". (n 1)

13. "Forest Ownership Statistics". *National Association of State Foresters*, 2018, https://www.stateforesters.org/timber-assurance/legality/forest-ownership-statistics.

14. "Carbon Narratives for Design Planning". *Institute For Health in The Built Environment*, 2020, https://buildhealth.uoregon.edu/carbon-narratives-for-design-planning.

15. "Forest Land Ownership". *Natural Resources Canada*, 2020, https://natural-resources.canada.ca/our-natural-resources/forests/sustainable-forest-management/forest-land-ownership/17495.

16. Fernholz, Kathryn, et al. "Forest certification update 2021: the pace of change". *Dovetail Partners*, 2021. https://dovetailinc.org/upload/tmp/1611160123.pdf.

17. Fernholz, Kathryn, et al. "Differences between the Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI) certification standards for forest management". *Dovetail Partners*, 2011. https://www.dovetailinc.org/report_pdfs/2011/dovetailfscsficomparison32811.pdf.

18. As an early example, the American Wood Council recently introduced a wood sourcing tool: "How Can I Tell If Wood Is Sustainably Sourced?" *American Wood Council*, awc.org/wood-sourcing.

19. Diaz, D.D.; Loreno, S.; Ettl, G.J.; Davies, B. "Tradeoffs in Timber, Carbon, and Cash Flow under Alternative Management Systems for Douglas-Fir in the Pacific Northwest". *Forests*, 2018, 9, 447.

20. Jabr, Ferris. "The Social Life Of Forests (Published 2020)". *NY Times*, 2020, https://www.nytimes.com/interactive/2020/12/02/magazine/tree-communication-mycorrhiza.html.

21. Fernholz, Kathryn, et al. "Differences between… certification standards for forest management". (n 5)

22. Climate Smart Wood Group is collaborating to design two model specification approaches; the authors of this paper are contributing as reviewers: "Specification Language." *Climate Smart Group*, 31 Oct. 2023, www.climatesmartwood.net/procure/specification-language.

23. "Sustainability and Environment." *TallWood Design Institute*, tallwoodinstitute.org/sustainability-research/. Frequently updated timber research repository featuring topics like design for disassembly and reuse, carbon studies, and explorations of innovative assembly and manufacturing techniques.

24. Fernholz, Kathryn, et al. "Forest certification update 2021: the pace of change." *Dovetail Partners*, 2021. https://dovetailinc.org/upload/tmp/1611160123.pdf.

25. "Wood Carbon Seminars - Carbon Leadership Forum". *Carbon Leadership Forum*, 2020, https://carbonleadershipforum.org/wood-carbon-seminars.

26. "Carbon Narratives for Design Planning". *Institute for Health In The Built Environment*, 2020, https://buildhealth.uoregon.edu/carbon-narratives-for-design-planning.

27. *Climate Smart Wood Group*, 2023, https://www.climatesmartwood.net. Includes guidance for sustainable wood procurement in North America. The group includes representation from FSC, but as of this publication, does not include representation from other forest certification entities.

28. Diaz, David D., et al. "Tradeoffs in timber, carbon, and cash flow under alternative management systems for Douglas-Fir in the Pacific Northwest." *Forests* 9.8 (2018): 447. Additional forestry-related work from EcoTrust can be found at: https://ecotrust.org