Cities4Forests

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***Sustainable Wood for Cities*: Background Research and Resources**

BETA DRAFT

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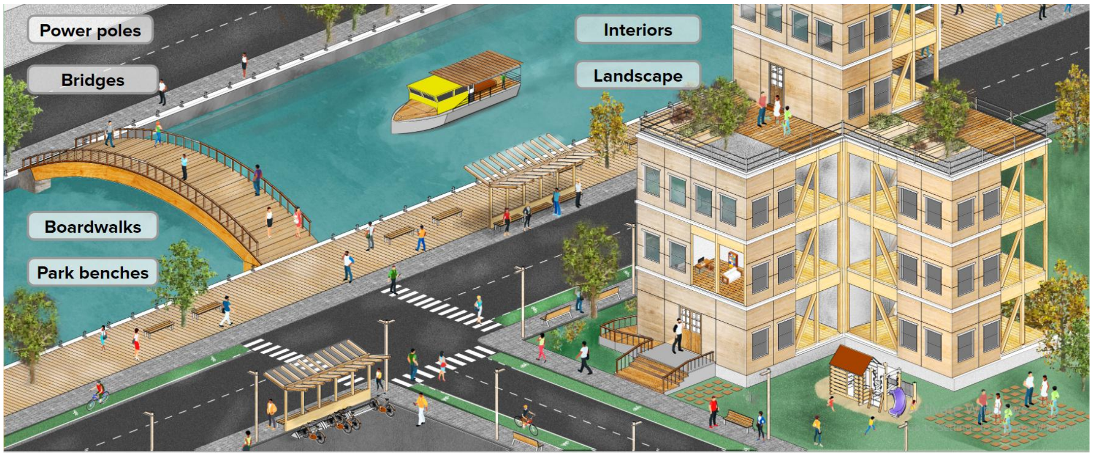
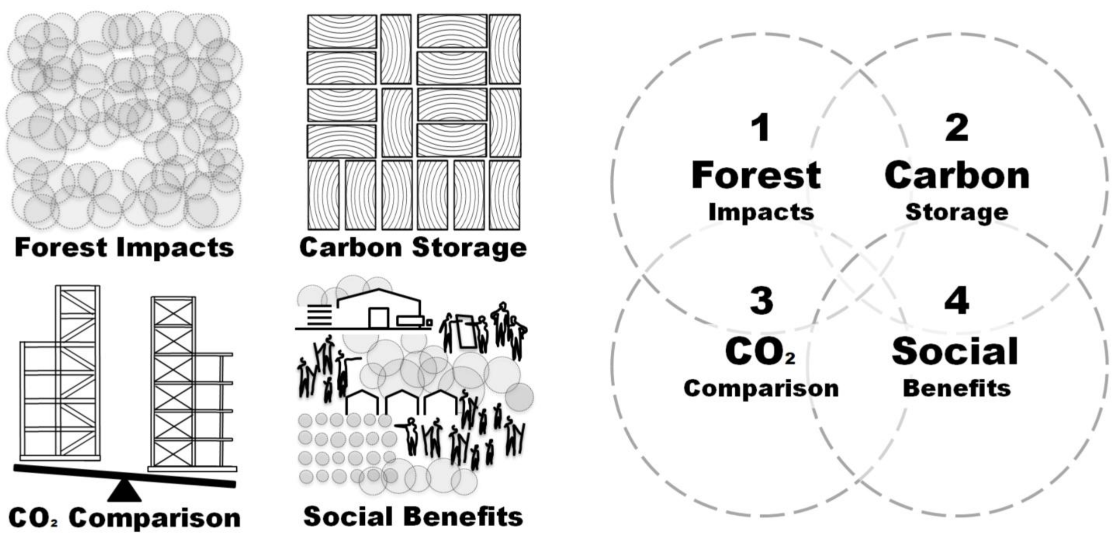
Introduction

"Sustainable wood" is wood that by its use (consumption) provides net benefits to the global climate, and supports long-term sustainability of the forest systems, and social systems, that supply the wood. Sustainable Wood Pathways are approaches to sourcing sustainable wood, each offering a different way to get to the destination. They can be followed independently, in parallel, or in combination and may be used as a qualitative framework for aiding in decision-making processes. Traceability and transparency are key to all of these pathways, as if the wood received is not actually coming on the pathway from the intended source the sustainability benefits will be lost.





The four pillars of sustainable wood.

How can wood products protect the environment and mitigate climate change? These four interdependent impact systems are vital to understanding the sustainability potentials and pitfalls of wood.

1. Wood that helps conserve forests, mitigate or reverse degradation and deforestation.
2. Wood that reflects and supports sustainable economies, businesses and communities
3. Wood that has embodied carbon benefits after all systems components are considered.
4. Wood that replaces more carbon-intensive materials on a life cycle basis (LCA).

Table 1: Summary of Pathway Sustainability Benefits

Pathway	Forest Impacts	Social Sustainability	Carbon Storage	CO_2 Comparison
1. Forest Certification	Support of Sustainable Forest Management principles	Added value of certified wood could lead to improved livelihoods, income & equity, in forest and along supply chain	Protects forest existing carbon pool	May avoid emissions associated with conventional forestry practices
2. Social Forestry	Can decrease deforestation and forest degradation, biodiversity conservation, preserve forest health	Successful community enterprises can lead to improved food security and standard of living, job training and education, potential increases in equity; protection of cultural practices	Carbon stored in protected forests	May avoid emissions from deforestation
3. Species & Grade Selection	Reduces pressure for forest clearing, protects biodiversity	Creating markets in communities with lesser-known species or unique wood properties	Conserves forest, and diverse forests can sequester more carbon	May avoid emissions from waste wood (slash) burning
4. Strategic Geography	Supports actions against forest degradation, illegal logging; promotion of SFM	Can support rights of forest communities, good governance; “Jurisdictional Approach” offers multiple benefits	Some VPAs centered on carbon sequestration, protect carbon pool	Allows targeting of high high-conservation-value forest areas to deal with or avoid; Jurisdictional approach can reduce comparative carbon footprint.
5. Local & Urban Wood	Incentivizes optimal use of wood from inner & nearby forests	Can promote local opportunities for new enterprise	Diverting local wood waste improves carbon storage	Avoided emissions from transport & waste
6. Reuse and Long Life	Reduced need for fresh-cut wood means reduced forest harvesting	Promotes local business and employment opportunities, Green jobs in upcycling	Ensures carbon is stored in secondary uses	Longer wood material life means longer avoided emissions from wood decomposition
7. High Efficiency Production	Higher efficiency means less forest needed for a given unit of wood-product used	Potential for new technology to add production value + skills, to remote communities	Can Incentivise long-term carbon storage in LLP	Reduced wood waste means lower carbon footprint
8. Net Carbon Accounting / LCA	Incentivizes low-carbon forestry; Drives innovation	May incorporate health impacts of materials into sustainability metrics	Incentivises long-term carbon storage in LLP	Permits comparison over entire material life cycle, from forest through to building

Pathway Verification

Any sustainable wood framework depends on verifying the interconnected criteria of the sustainability "pathway". Depending on the pathway, this may include: precise source location, forest management plan, adherence to local regulations, means of harvest, final production methods, etc. Without verification the efforts of diligently and creatively sourcing will not guarantee the sustainability benefits. But verification is not always clear cut or simple to achieve. There are different degrees and approaches to verification depending on the pathway in question.

To address these challenges and encourage incremental progress, we have organized a matrix of verification types and methods that aim to 1) demystify the verification process, 2) show how diverse Pathways lend themselves to different types and levels of verification, and 3) aid in user capacity-building and "systems development" through better knowledge and tools.

In this matrix users will find three types of verification: 1st party (seller performs internal evaluation), 2nd party (buyer evaluates seller), and 3rd party (independent party evaluates seller). Within each of these types, verification may be determined via personal contact, official documents, or technological tracing. There is some overlap between these types and methods. They are designed to serve as building blocks for project-specific verification strategies and empower cities and other users to understand the options and benefits with respect to their specific needs.

Table 2: **Sustainable Wood for Cities Verification Matrix**

Verification Types, Methods and Examples (applied to Pathways and Strategies)			
Type > ***Method***	**1st Party (Seller Verification)** producer/supplier performs an internal evaluation based upon city specifications and provides reports on progress/adherence.	**2nd Party (Buyer Verification)** the buyer (i.e. city) verifies that a supplier and/or the products of that supplier conform to a certain standard	**3rd Party (Auxiliary Verification)** an independent party verifies that a supplier and/or its products conform to a certain standard
Personal contact or relationship Based on mutual goals and trust, long standing relationships, and experience. Credibility, transparency, accessibility, and organizational permanence are key factors.	● E.g., an urban wood salvaging company with longstanding community ties has developed a personal relationship with city departments and is tapped to lead a city wood salvaging project in a local park.	● E.g., a regional wood salvage company offers reclaimed wood to the city; invites officials to visit the mill where flooring is made from barn timbers it claims (Whitney Museum/ Hudson Co.)	This strategy may have limitations without written documentation. ● E.g., an NGO oversees the import of tropical timber from a social forestry conservation enterprise that they have a longstanding association with.

Documents and paperwork Request applicable documentation from suppliers, including certification docs, licensing permits, receipts of sale, forest management plans, etc.	● E.g., a social forestry enterprise completes a self-evaluation of their forest management practices and associated conservation impacts using a checklist/questionnaire created by the buyer	Buyer works with the seller to ensure that the wood meets sustainable procurement criteria. ● E.g., while a certain forest may not be certified by a third party the city be able to prove to qualify as an equivalent to any standards (i.e. FSC or PEFC) required in procurement.	This strategy is most common with 3rd party verification schemes. ● E.g., complete paperwork for FSC certification is required by city from importer of tropical timber from Social Forestry enterprise
Technological tracing An emerging practice, new technologies such as blockchain, DNA fingerprinting, isotope analysis, can increase transparency and help validate origin, species and other supply chain processes.	Depending on the technology the information can be recorded, uploaded and shared by various members of the supply chain, including the "seller" and "buyer". ● E.g., suppliers use DoubleHelix's product verification technology to guarantee supply chain transparency.	● Buyer uses technology (such as Tracy of Sweden) verification technology to guarantee sustainability criteria of purchased wood, for example, origin of wood from social forestry enterprise, jurisdictional legality, or species selection.	● E.g., reclaimed timber contract requires DNA verification performed by 3rd party service for species and isotope testing to ensure lesser-known species or exclude counterfeit timber.

Further resources to assist in Pathway verification:

1. Sustainable Procurement of Forest Products - WRI & wbcsd
    a. See Chapter 2 (Information Accuracy)
2. Biomass Sustainability Verification - Forest2Market
3. Technologies that Help Thwart Illegal Logging by Tracing Wood's Origin - WRI

Sustainable Wood 4 Cities: Detailed Pathways

1. Forest Certification

a. Description

i. There are many different voluntary certification schemes (VCS) for wood and wood products that have emerged in the past thirty years, most notably FSC and PEFC [1]. Generally speaking, a certification board guarantees that the forestry operation adheres to a set of minimum criteria (in addition to local and national regulation) to ensure that the ecological health of the forest is maintained. The specific criteria and strictness of ecological stewardship varies from VCS to VCS, which has been argued to cause confusion amongst buyers. Common to most VCS are:

   a. Approved forest management plans, monitored at regular intervals,

[1] FAO (2020) gives a good overview of the main difference between FSC and PEFC (of which SFI is included) in the following statement: "The FSC and the PEFC have differing approaches. The FSC employs a system for accrediting certifiers, who are responsible for auditing forest operations, assessing compliance with FSC standards (developed at a national or subnational level), and issuing FSC certificates. Forest enterprises and groups of forest management units certified in this way are permitted to use the FSC label on their products. In contrast, the PEFC endorses national certification systems (e.g. the Australian Forestry Standard and the Brazilian Forest Certification Programme), which develop their own certification standards and accredit certifiers. Forest operations certified in this way are permitted to use the PEFC label on their products."

b. Standards governing environmental, economic, and social sustainability of forests (Moore et al. 2012, p. 79) [2]
c. Enforceability and traceability through Chain of Custody (CoC) certification

ii. It is estimated that 10.7% of global forest area is certified (Global Forest Atlas). While options for certified wood and wood products have expanded over the years, the total forestland under certification is still limited and strongly skewed geographically with the Northern hemisphere accounting for 92% of all certified forests.

iii. See the resource section below for more information on differentiating between certification schemes.

b. Forest Impacts

i. Certification generally supports Sustainable Forest Management (SFM) [3], which promotes the ecological, economic, and social sustainability of forests.

ii. FSC requires:
1. The protection of high conservation value forests
2. Larger tree buffers around streams, etc. than some state laws which protects water quality, riparian habitats, and maintains better ecosystem health

iii. There is evidence that certification improves conservation, enhances biodiversity (Gullison, 2003), and results in real changes to foresters' environmental practice (Moore et al. 2012). [4] Certification has led to less deforestation and wildfires in the FSC-certified portions of Mayan Biosphere Reserve (Hughell & Butterfield, 2008). FSC is often endorsed as the preferred certification scheme due to its regulatory considerations of ecological sustainability (Franklin et al. 2018)

iv. Conversely, there is also evidence that certification has had a marginal impact on deforestation overall, due in part to the "stuck at the bottom" problem whereby certification only occurs in countries with a certain level of development (high costs and lack of price premiums may be part of the explanation for why some countries are currently excluded from certification) (Marx & Cuypers, 2010)

v. Countries with high FSC-FM certification tend to have public ownership of forests and the primary function of forests is production of wood or non-forest products → "the potential for FSC certification is limited to the forests that are managed for production purposes" (ibid, p. 422)

vi. Van Kuijk et al (2009), Auld et al. (2008), Clark & Kozar (2011), Sheil et al. (2010), Romero et al. (2013), Burivalova et al. (2016), Blackman et al. (2015)

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[2] "Standards generally govern forest practices such as harvesting, treeplanting, and chemical use; economic, management, and planning systems; stakeholder, community and worker interactions; environmental protection, biodiversity, high conservation value forests, and aesthetics; and laws, regulations, monitoring, and continuous improvement. Independent auditors determine if management meets or exceeds these standards, and if so, the certifying body provides "written assurance" that the management system or products conform to certification standards." (Moore et al., 2012, p. 79)

[3] "The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems." (FAO)

[4] Studies examining effectiveness of certification: (i) certification improved conservation status and enhanced biodiversity (WWF, 2005), (ii) FSC and PEFC in Scandinavia: improved SFM, mainly in environmental protection (Federation of Nordic Forest Owners' Organisations, 2005), (iii) better environmental practices in the US, (iv) landowners with SFI or FSC certification had better biodiversity practices than non-certified (Hagan et al., 2005), (v) "On average, certified operations were required to make changes affecting 15 different forestry issues as a result of the forestry assessment"

c. Social Sustainability

i. Livelihood conditions for those managing FSC-certified forests better than those managing non-certified forests in Kilwa, Tanzania, have higher household income and provide greater income equity in certified villages (Kalonga & Kulindwa, 2017, Kalonga et al., 2015).

d. Carbon Storage

i. Certifications impact on protecting forest carbon pools is thought to be the greater benefit than the actual sequestration associated with certified products; however, those impacts are not included in this estimate (IDH, 2019)

ii. The IDH estimates that certified timber net carbon benefits to the EU is around -456 to -764 Gg CO_2 per year (IDH, 2019).

e. CO_2 Comparison

i. Using Reduced Impact Logging (RIL) techniques, which FSC and PEFC (Kartika et al., 2020) set as a standard, in tropical production forests could reduce carbon emissions by 29-50% of net emissions from tropical deforestation (Sasaki et al. 2016) [5].

f. Barriers & Risks

i. There are many issues with and critiques of these certification standards, such as leakage, lack of oversight in developing countries, weak environmental criteria, and overall opaqueness. As Judge-Lord et al. (2020) shows between FSC and SFI, there are significant differences between certification systems that result in differing benefits.

ii. The risk of document falsification is a significant barrier to the end user, however there are many resources available to address this (Clarke, 2011). Beyond this Carlsen et al. (2012) identify five major factors affecting certification uptake in Ghana: market conditions withholding premiums for certification from producers [6], compliance costs for certification [7], lack of efficacy in state-led governance [8], distrust of certification schemes [9], and lack of general awareness of certification schemes [10].

[5] "Our study suggests that about 28% of the total area of tropical forests (i.e., all the officially designated tropical PdF) can be targeted for RIL+ and RIL+ can produce 287 million m^3 year-1 of sawnwood, reduce emissions of up to 494 Tg C year-1 or 50% of carbon emissions from tropical deforestation, and increase carbon storage of 8.2 Tg C per year-1 in sawnwood, while preventing logging-promoted and enhanced forest fires." (p. 10-11)

[6] A price premium on certified products would be an incentive but it doesn't always materialize, major limitation for uptake. In developing economies: "the ability of firms to organise themselves and act collectively in their certification efforts and the ability of certifying organisations to establish local networks capable in supporting certification efforts at various stages are more important for certification uptake than market conditions. Likewise, Ebeling and Yasué (2009) suggest that government support rather than market conditions can explain the larger area of FSC certified forest in Bolivia as compared to Ecuador." (p. 84)

[7] Compliance costs include direct (preparation and implementation of assessments and audits) and indirect costs (activities bringing managerial and operational practices in line with standards).

[8] Pre-existing regulatory environment has a strong effect on current timber practices and therefore how much change is necessary to adhere to standards, important for indirect costs. "In many developing countries, ambiguous and overlapping legislative frameworks and weak and selective enforcement create large differences between practises and certification requirements, with implications for indirect compliance costs (Durst et al., 2006; Cashore et al., 2006)." (p. 84)

[9] Some forest owners consider certification "outsider interference"; think certification is controlled by environmental NGOs "whose interests counter those of tropical timber products" (in Sub-Saharan Africa); think certification is a way to "exclude them from lucrative markets in Western countries"

[10] General awareness and organizational capacity of certifying institutions is a significant barrier. The more producers know about certification, more positive they are and collective action for uptake increases.

g. Resources

i. For deciding which certification scheme to use:
   a. FAO Sustainable Forest Management (SFM) Toolbox - Forest Certification: see the "In More Depth" section for a comparison of FSC and PEFC
   b. Introduction to Forest Certification Schemes (Struwe & Specht, 2015)
   c. A Comparative Analysis of Five Forest Certification Programs (Grazon et al., 2020)

ii. Certification scheme pages:
   a. Build With FSC
   b. Buy PEFC-certified products
   c. Buy SFI

iii. Finding certified wood:
   a. Woodsearch: searchable database for FSC certified building materials sold near you in the US, Canada, and Mexico
   b. FSC- Find Products page

iv. Buying good wood:
   a. How to buy good wood - short list of suggestions from NRDC, contains list of tropical woods to be particularly careful with
   b. WRI blog - are your wood products really certified?

v. General or miscellaneous resources:
   a. ATIBT Certification Commission study forthcoming with Nepcon
   b. FAO Sustainable Forest Management (SFM) Toolbox
   c. Private Landowners' Guide to Forest Certification in the South
   d. Estimating demand for certification
   e. Effectiveness of FSC-FM at the micro level (Karmann & Smith, 2009)

Box #1: Ecological Forestry Criteria (or Ecological Restoration Forestry)

A forest could be sustainably managed and not certified or vice versa. In either case, it is important to have an understanding of what types of forests and forest management practices produce sustainable wood, especially if specifying in procurement policies. Ecological forestry (or 'ecological restoration forestry') is an approach that restores or maintains ecosystem integrity while continuing to produce wood products. While there are many and varying opinions on best management practices for forestry, these nine criteria[11] for ecological forestry serves as a strong reference for robust management practices that will produce what we deem to be sustainable wood. These criteria and the concept of ecological forestry should be considered in other pathways as well where relevant.

1. **Multi-age**: Ecological forestry utilizes multi- or uneven-aged management regimes.
2. **Native species**: Focuses on native species and genotypes that provide an array of ecological and other values.
3. **Landscape planning**: Stand-level treatments focus on maintenance of ecosystem processes and

[11] These criteria were adapted from 'Ecological Forest Management' by Jerry Franklin, Norman Johnson, and Debora Johnson for this guide by Sustainable Northwest

structures across the landscape context.

4. **Harvest rotation**: Utilizes rotation lengths or periodic partial cutting entries that allow expression of forest complexity.
5. **Retention**: Utilizes variable-retention regeneration harvesting practices.
6. **Complexity**: Emphasizes complexity in thinning and, consequently, on modifying understory and midstory conditions as well as overstory conditions to restore natural condition. Retains defective trees and structures (e.g., snags, logs, cavities, and brooms) and may create additional such features during treatments. Values complexity and heterogeneity. Emphasizes the contribution of thinning to financial return and consequently, on concentrating growing stock on the most efficient growth engines. Eliminates defective trees and structures and does not create more. Values simplicity and homogeneity.
7. **Risk management**: Emphasizes ecosystem diversity and resilience to reduce risks from major ecosystem disruptions. Emphasizes fast-growing species on short rotations to reduce financial risks.
8. **Diverse successional stages:** Seeks to maintain an array of ecosystems conditions (e.g., successional stages) at larger spatial scales, including older trees and forest and early successional ecosystems. Seeks to maintain age variants of single successional stage (young forests) at larger spatial scales; does not include older trees and forest or early successional ecosystems as management goals.
9. **Natural disturbance:** Considers and incorporates impacts of natural disturbances. Attempts to eliminate or avoid potential for natural disturbances.

Non-Ecological-Focused Silviculture for Comparison

- Utilizes even-aged management regimes on high-productivity sites and selection (high-grading) on low-productivity sites.
- Focuses on fast-growing species with desirable financial characteristics, often with tree improvement and genetic engineering.
- Landscape context of stand-level treatments focuses on efficiency of harvest path, road, and logging design.
- Utilizes financially determined rotations on high-productivity sites and opportunistic removals on low-productivity sites.
- Utilizes clear-cut regeneration harvesting practices on high-production sites.

2. Social Forestry

a. Description

i. This pathway focuses on the social and ecological sustainability associated primarily with forest management, wood harvesting, and secondary products from community forestry and related enterprises. [12] This pathway also focuses on the social benefits and sustainability associated with wood products originating from small to medium size enterprise (SME), community forest enterprises (CFE) and related youth programming. Forest communities are best situated to know what's going on in surrounding forests

[12] Community managed forests are defined as "those where multiple use takes place under a variety of tenure, benefit-sharing and governance schemes and that include local, rural, and/or indigenous groups" (Pagdee et al., 2006). While community-managed forests offer higher levels of social sustainability than sustainable forest management models alone, the management of ecological resources is given equal importance in decision making (Dahal & Cao, 2017).

and more likely to be invested in consistent forest health, and therefore investing in CFM/CFEs is often positioned as a leading measure of forest conservation and sustainability (PRFOR, 2019 [13]; Sapkota et al., 2020 [14]). When communities have access and rights to forests, they can receive the economic benefits of those forest resources and have greater incentive to invest in those forests in the long-term (Slee et al. 2004) [15]. Furthermore, they have direct control over an important force for ecosystem and human health, allowing communities greater autonomy and economic sustainability (Dahal & Cao, 2017) [16] provided the CFEs and/or SMEs have equitable governance structures and dynamics (MacQueen, 2006 [17]; Persha, Agrawal, & Chhatre, 2011 [18]).

ii. Finished wood products can vary widely, however common examples include tabletops and other furniture. An important component of this pathway is that it supports social sustainability and economic development in forest communities, either through job training or profit sharing so that such communities are better equipped to take better care of the forests and environments around them (Molnar et a., 2007) [19].

b. Forest Impacts

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[13] "1) A substantial proportion of forest sector SMEs have the potential to grow in a sustainable manner; 2) forest sector SMEs that can grow sustainably create good quality jobs and other multiplier effects, which in turn contribute to shared prosperity; 3) improving the competitiveness of forest sector SMEs augments the incentive to manage the resource base sustainably, establishes mutually beneficial partnerships with forest produce collectors and suppliers, and, increases the demand for sustainably managed forest products and services; and 4) through the creation of greater demand for sustainable forest products and services, these forest sector SMEs can contribute to economy-wide growth." (PRFOR, 2019)

[14] 1) *Accommodating multi-stakeholder needs and interests* to ensure the program avoids conflict and receives support from stakeholders, 2) *adaptive management and learning* to address unforeseen challenges and tap new opportunities utilizing new knowledge and innovations, 3) *capacity development of stakeholders* to ensure the stakeholders can effectively play the roles expected from them, 4) *clear rights and tenure to forest resources* to ensure local communities adequately invest in protection and sustainable management of forest resources, 5) *community forestry enterprises* to ensure the program meets the basic needs of local communities and remains economically attractive to them, 6) *effective participation and governance* to ensure local community, particularly marginalized groups, participate in the decision making, receive fair benefits and the program receives their ownership, and 7) *effective policy and regulatory support* to ensure the program is supported by institutional framework of the state with the authority, responsibility and resources for the implementation.

[15] Values from forestry, Understanding Forestry in Rural Development project, Slee et al., 2004; 1) Forest values, leads to employment and direct outputs; 2) 'Shadow' values - tourism and recreation, housing location, value increases; 3) Non-market values - carbon sequestration, biodiversity, air quality; 4) Social values - historic, cultural, symbolic, social capital building related to entrepreneurship

[16] In reviewing and giving recommendations on improving community management in Nepal, Dahal & Cao (2017) state that "Community forestry is essentially about management of both people and resources, so both institutional and ecological criteria must be considered and given equal weight in any assessment of management outcomes."

[17] Key internal factors that make forest enterprise associations work include: "a strong degree of autonomy; leaders with a track-record of social commitment; gradually evolving sets of procedures that institutionalise the progress made by founding leaders; a focus restricted to a few long-term issues; fair representation and democracy; transparency over costs and benefits; sanctions for free riders or those that break rules and; clear procedures for resolving conflicts" (MacQueen, 2006).

[18] Local community is involved in the rulemaking/policy process for forest governance; evidence that likelihood of more sustainable and positive outcomes on both social and ecological levels increases when there is formal participation by local users (Persha, Agrawal, & Chhatre, 2011).

[19] "Community forestry enterprises (CFEs) generate goods and services that are not created by individual enterprises or private industry. CFEs tend to invest more in the local economy than their private sector equivalents, fostering social cohesion and longer-term equity and making greater social investment. . . CFEs often apply traditional knowledge to their operations, create innovative approaches, and find new ways to increase employment and diversify income strategies." (Molnar et a., 2007)

i. CFM has been shown to promote forest health and decrease deforestation in Mexico (Ellis & Porter-Bolland, 2008), Cambodia (Ota et al., 2020) [20], Nepal (Oldekop et al., 2019) [21], Indonesia (Satinka et al., 2017) [22], and globally (Porter-Bolland et al., 2012).

ii. There is strong evidence that CFM reduces forest degradation but not always deforestation unless deforestation pressures are high (Pelletier et al., 2016). Nearby benefits include better watershed management.

iii. In areas of high biodiversity, CFM can be effective an conservation approach (Kajtewachakul et al., 2004; Molnar et al., 2007) [23].

iv. CFM promotes the long-term economic sustainability of the forest community. Through the promotion of economic diversity, the skills of the forest community related to wood products are broadened making it more economically and socially beneficial to conserve the forest than to clear cut and change the land use.

v. However, the research on community involvement and forest conservation is not absolute. Persha et al. (2011) examined the relationship between biodiversity conservation and forest-based livelihoods in 84 cases and found tradeoffs, joint wins, and joint losses. Contextual factors varied but outcomes were much more likely to be jointly positive when forest users participated in local governance institutions.

c. Social Sustainability

i. CFM contributes to livelihoods but has a limited effect on poverty reduction (Pelletier et al., 2016) in spite of encouragements otherwise on the promise of SME in CFM (Macqueen, 2006) [24]. The distribution of benefits is often not always equitable

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[20] Country-wide analysis of the conservation effect of community forests (CFs), protected areas (PAs), and protected forests (PFs) by comparing deforestation in areas with conservatio approach vs no conservation. CFs significantly decreased deforestation in comparison to other forests, which could potentially be due to strict regulations on the sale of forest products in Cambodia. There is, however, a risk of leakage: "Although there was reduced deforestation within CF areas, other forests surrounding CFs showed significantly higher deforestation. This result implies that forests around the CFs were lost in exchange for conservation of CFs. Thus, CFs may not mitigate deforestation but only change where trees are logged from inside to outside CFs." PAs were more effective than CFs; in other studies, the two have been similar or CFs more effective

[21] CFM has significantly reduced poverty and deforestation across Nepal, and increases likelihood of win-win outcomes. The authors also find that the "estimated reduced deforestation impacts of community forests are lower where baseline poverty levels are high, and greater where community forests are larger and have existed longer. These results indicate that greater benefits may result from longer-term investments and larger areas committed to CFM, but that community forests established in poorer areas may require additional support to minimize tradeoffs between socioeconomic and environmental outcomes."

[22] The community forestry scheme Hutan Desa has overall led to reduction in deforestation. "Our findings add to the emerging consensus showing forest conservation policies that integrate local communities perform better, in general, in zones with higher anthropogenic pressure than in zones with lower pressure (Ferraro et al., 2013, Nolte et al., 2013, Pfaff et al., 2014). A similar pattern was found in the Brazilian Amazon, where a protection scheme that permits some local deforestation on sites with high clearing pressure had more avoided deforestation than from the scheme that bans clearing on sites further from deforestation pressure (Pfaff et al., 2014). However, our findings also suggest that in zones with high anthropogenic pressure, the effect of such policies can be highly heterogeneous across time and space (Blackman, 2015)."

[23] From Molnar et al., 2007: "CFEs are important conservation agents in forests of high biodiversity. In forest-rich areas, CFEs have been positive forces for biodiversity conservation, including CFE investment that leads to significant reductions in forest fires. As they mature, CFEs have tended to diversify looking for ways of making better use of the forest resource, generating greater employment, minimizing their costs relative to returns, and generating income for investment in conservation. Some are also providers of goods and services in the new markets for ecosystem services and the rapidly expanding markets for recreational or eco-tourism."

[24] Macqueen (2006) asserts that forest enterprise associations reduce poverty by: 1) increasing access to basic needs; 2) enhancing security and reducing conflicts; 3) overcoming social isolation and powerlessness; 4) providing decent work; 5) **preventing environmental degradation**; and 6) strengthening cultural identity.

(Mongabay), however long-term establishment and access to markets may serve to abate this concern as Mexico has seen (Bray et al., 2003) [25]

ii. CFM can also address food insecurity in developing countries. Paudel (2008) found households in community-managed forests in Nepal are more likely to find their food consumption adequate.

iii. As with conservation benefits, poverty alleviation connected to forest use and conservation does not have an absolute outcome and is context-dependent but win-win scenarios are possible (Sunderlin et al., 2005). Based on four case studies, Fomete & Vermaat (2001) conclude that key conditions for community forestry to contribute to poverty alleviation include enforced legal protections, community control of planning and organization process, available technical skills, and access to finance.

iv. (Dasgupta, 2017)

d. Carbon Storage

i. Community managed forests act as carbon sinks. Case studies in Nepal (Banskota et al., 2007 [26] ; Thapa-Mehar & Shrestha, 2015) and West Africa (Skutsch & Ba, 2010) [27] have shown that the community management increased the carbon stock of the forests by reducing deforestation/degradation.

e. CO^2 Comparison

i. Estimates have been made of how much carbon could be saved per year from avoided forest degradation by CFM, such as those by Skutsch & Ba (2010). Due to the lack of

[25] Due to widespread reforms in the 1970s, Mexico's community managed forests are "at a scale and level of maturity unmatched anywhere in the world" (Bray et al. 2003). Large number of communities manage forests for commercial production of timber, also finished forest products. On the social benefits, the authors state: "the transition from concession logging to community logging initially meant significant gains in equity. Whereas in the pre-CFE period almost all profits flowed outside the community, in the post-CFE period communities have been able to generate significant new employment within the communities and use profits to invest in the enterprise and to build community assets (such as potable-water networks, schools, clinics, public buildings, and social service safety nets in the form of free medical care and old-age pensions, virtually unheard of in rural Mexico) and fulfill functions left unattended by government (Merino 1997*b*; Alatorre 2000). The successful communities also provide good accountability and a fair distribution of forest benefits, restrict access to the forests, and invest in good forest management (Klooster 2000)" (Bray et al. 2003). On the economic benefits of CFM, "The community of El Balcón on the Pacific Coast north of Acapulco, with 60% of its 25,565 ha in forest uses, has established a successful commercial relationship with U.S.–based Westwood Forest Products. Westwood Forest is currently urging El Balcón to certify their forest operation (a "green seal") as sustainable in order to meet new demands for certified timber products in the United States. The El Balcón CFE also generates around 250 full- and part-time jobs for both members of the community and outsiders and has fixed capital assets of over $4 million, not counting the natural capital of the forest. Further, the social and financial capital generated by El Balcón and other neighboring communities who are also managing their forests has brought relative social peace into a region wracked by political and drug-related violence, some of it associated with illegal logging (D.B.B. & L.M.-P., unpublished data)" (Bray et al. 2003). On the ecological benefits, the authors cite limited data but present some evidence of sustainable management, increasing commitment to biodiversity protection, some communities placed forests in protected areas voluntarily, and reduced impact logging. "Some communities in the Sierra Juárez of Oaxaca consistently log well below the authorized volume in their management plans, in a stated effort to conserve the resource. Further, forest communities have consistently shown a willingness to reduce their volume of extraction when inventories indicate they may be extracting at an unsustainable rate. In earlier periods, the Quintana Roo communities of Noh Bec and Laguna Kaná reduced their logging volume by 29% and 37%, respectively, even though logging is a key source of community income, and instituted permanent sampling plots to better monitor forest dynamics. Neither community showed any interest in liquidating its forest and investing the proceeds in a more profitable economic sector, as a private enterprise would" (Bray et al. 2003).

[26] "The mean carbon sequestration rate for community forests in India and Nepal is close to 2.79 $tCha^{-1}\,yr^{-1}$, or 10.23 $tCO2ha^{-1}yr^{-1}$, under normal management conditions and after local people have extracted forest products to meet their sustenance needs." (Banskota et al., 2007)

[27] Skutsch & Ba, 2010 - Crediting carbon in dry forests: "Preliminary indications are that over the areas of dry forest and savanna woodlands which are under community management, even though there are losses of biomass in some parts, net growth rates of carbon stock are in the range 1.0 to 4 tons/ha/year, which is equivalent to 5 to 15 tons of carbon dioxide."

accurate data with which to create a baseline however these figures are often presented for illustrative purposes alone. This demonstrates that, while it is hard to measure the impact of reduced degradation or deforestation in terms of avoided emissions, if there are reductions without subsequent leakage, then community management of forests could lead to avoided emissions.

ii. For wood products from SMEs there is potential for avoided carbon emissions and lower embodied carbon when there is greater investment in the conservation of forests (WholeForest, 2020). [28]

f. Barriers & Risks

i. Most significant of all are the risks to CFEs when there are unclear or uncertain tenure rights and "adverse policy and regulatory environments" (Molnar et al., 2007) [29], and national or regional governments' general lack of support for CFEs in certain cases such as Nepal (Sapkota et al. 2020) [30]

ii. There is evidence that CFM can intensify existing power dynamics and inequity in the community. Some communities have attempted to counteract this by reinvesting some profits from the forest into the community, for example, in Mexico and cases in India (Mongabay). This reinvestment or some form of equity focus in the management could be an important level to increase the social efficacy of projects.

iii. Risk of leakage if work is contracted out instead of kept local (Slee et al. 2004).

g. Resources

i. Criteria for community forest management (CIFOR, Ghana case study)

ii. ITTO guidelines for Forest Landscape Restoration in the Tropics (2020)

iii. PROFOR: Unlocking the potential of small and medium forest enterprises, programmatic approach

iv. Community-based forest enterprises in tropical forest countries: status and potential (Molnar et al. 2007)

v. Incomes from the Forest: Methods for the development and conservation of forest products for local communities (CIFOR, 1998)

vi. Unlocking barriers to financing sustainable forest-related SMEs: Lessons from Mozambique and Guatemala, IIED [31]

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[28] WholeForest Embodied Carbon rationale: "Whole Forest prevents massive amounts of carbon from entering the atmosphere though long-term rainforest conservation. Based on the square footage of wood you specify into a project, we calculate the amount of carbon able to remain sequestered in the rainforest. When you purchase Whole Forest products, you are actively preventing deforestation and carbon emissions. This can dramatically lower the embodied carbon of your design project." CO2 emissions prevented from entering atmosphere by product: a) flooring: 0.02 tons per square foot and b) countertops, tabletops, bars: .032 tons per square foot. Ex: a 1,500 ft2 floor offsets 135 tons CO2eq (Whole Forest)

[29] "CFE development is constrained by important internal barriers, including: internal social conflicts, mismanagement of resources and income by individuals, lack of organizational and business skills, lack of technical skills, deforestation pressures from agriculturalists in the community, and unwillingness to adapt practices to market demands" (Molnar et al., 2007).

[30] Underlying problems facing community forestry program in Nepal include: 1) distrust to local communities' capacity coupled with willingness among techno-bureaucracy to exercise the power, 2) limited political commitment in furthering CFM program, 3) CFM program being limited within forestry sector boundary despite CFUGs engaging in range of development activities, and 4) poor governance and management capacity of overall state apparatus. (Sapkota et al. 2020)

[31] Recommendations for national governments, international donors, and financing institutions from report:

1) "Create innovative definitions and approaches to collateral and explore ways of guaranteeing credit to help create new mechanisms for granting access to finance for SMEs.

vii. Community-based forest management from Conservation Effectiveness
viii. Facilitating agreements for community-private sector partnerships in forest landscapes in Lao PDR - RECOFTC
ix. The Green Value Tool

3. Species and grade selection

a. Description:

i. This pathway focuses on the ecological benefits to global forests in using lesser-known, lesser-used, or character [32] wood species in the application in question. This is not an uncommon strategy in the public and private sector, as specific types of wood are often and can increasingly be specifically sourced for their physical properties, availability, or environmental impact (WWF, 2013) [33]. The goals of this pathway are to:

1. Reduce pressure on forests high-graded for popular species
2. Encourage species diversification in forest management and products
3. Where appropriate, encourage the responsible use of blighted wood species.

b. Forest Impacts

i. The use of lesser-known species is argued to be an important measure of biodiversity protection, and avoiding overharvesting of popular species and the propagation of monocultural plantation forests. (Barany et al., 2003) [34]

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2) Develop a set of key principles and criteria for identifying appropriate institutions and models for channelling finance through intermediaries with mandates or specific motivations for enabling SME access to finance.
3) Establish agreements with global aggregators with strong partnerships with regional and national aggregators of forest and farm producer organisations to facilitate the effective delivery of climate and development finance to decentralised levels.
4) Design terms and conditions for financing in a collaborative process involving financial institutions, intermediaries and service providers, each of which has a good understanding of the key challenges, risks and incentives that can constrain and enable uptake. Those terms and conditions should consider environmental and social impacts.
5) Invest in national and regional networks of qualified service providers to develop business incubation processes to build the capacity of SMEs and help feed them into higher-value chains.“

[32] The use of the term “character wood” has been important, such as the wood from Sugar Maple that has been tapped and blemished. It is, however, very difficult to use this wood in structural applications due to typical grading systems (character grade or urban grade).

[33] “LKTS can often act as a substitute for more traditionally used species in terms of performance and aesthetics in most applications, but they are generally more cost effective because they are often abundant and overutilized. Many species available have rich, truly beautiful colours and textures, which can provide new design opportunities for many industry sectors. The use of lesser known species can alleviate pressure on the over-exploited timber species, and increase the economic viability of responsible forest management” (WWF, 2013).

[34] “Utilizing LUS to manufacture value-added secondary products such as furniture, doors, and decking can maximize the revenue from natural stock LUS, providing the needed incentive to manage lands for these species and hence maintain forest cover.”
“Through forest products certification, there is further potential to increase Bolivia’s market access for secondary products.”
“Having a large number of commercially viable tree species can help achieve silvicultural sustainability (Gullison 1995) by giving the forest manager effective control over canopy opening, by increasing the likelihood of sufficient regeneration on a site after harvest, by concentrating the utilization of the resources, and by requiring fewer roads (Buschbacher 1990).”
“the availability of technical wood-processing information was one of the two most important factors in promoting the acceptance of LUS by manufacturers (along with long-term resource supply) (Smith 2000).”
“Out of the hundreds of potentially valuable wood species in Bolivia, only a few dozen have been historically used, and only three species are predominant. This dependence on a limited number of species has meant their depletion in natural stocks. This ultimately decreases the value of forest resources and leads to conversion of forestland to other uses. Such conversions are detrimental to industry as well as society at large. Governments and the private sector are recognizing that reliance on key species

ii. Multi-species forestry protects from risks such as disease and climate change while also creating an opportunity to choose lower impact/native species, and enhance diversity (WWF, 2013; Nambiar et al., 2018).

c. Other benefits/social sustainability:

i. Some lesser-known species have valuable properties that would make them good options for replacing over-harvested species or adding to architectural repertoires, such as strength and durability (Brunner et al., 2008) or termite resistance (Wong & Grace, 2014).

d. Carbon Storage

i. Mixed-species plantations sequester more carbon. For example, Liu et al. (2018) tested plots with 3-20 species, finding that for each additional species the total carbon stock increased by 6.4%. If focused on more permanent carbon storage, species that increase carbon in mineralized soil (deeper roots) are better (Jandl et al., 2007)

ii. Species variety can aid in reforestation, carbon sequestration, and climate change adaptation practices. (Ontl et al. 2018) [35]

e. CO^2 Comparison

i. Many sources mention that under-utilized species are often burned when primary species are being harvested (Yeom, 1984; Asamoah et al., 2020). Diverting lesser-known species from fuelwood use displaces the emissions from burning them that would otherwise occur.

f. Barriers & Risks

i. Barany et al. (2003) identify four main barriers to the use of lesser-known species: "a) the inaccessibility of information to the manufacturers; b) the information that exists does not represent species abundant in Bolivia's standing stock; c) species for which information exists are not suitable for the desired end uses; and d) the market for LUS remains weak despite information available to manufacturers [36]. To address many of

eventually leads to the depletion of forest resources as a whole, and therefore it is necessary to widen species utilization to increase value and profit, without expanding the area of harvest."

[35] "Approach 4.2: Restore disturbed sites with a diversity of species that are adapted to future conditions
Many native species are expected to be well adapted to the future range of climatic and site conditions (Prasad et al. 2018). Using management actions that favor such native species in community or forest types can facilitate a shift towards a composition that supports increased forest productivity and enhanced sequestration capacity. Novel mixes of native species that may not have historically occurred in forest or community types may allow for maintaining or enhancing productivity and carbon sequestration as climatic and site conditions change into the future. Unique combinations of native species may lead to altered competitive relationships and result in the conversion to newly defined community types (Davis et al. 2005; Root et al. 2003).
Example adaptation tactics are:
Planting native species on a site to increase overall species richness and provide more options for future management
Favoring or establishing drought- or heat-tolerant species (e.g. pine or oak species) on south-facing slopes, sites with sandy or shallow soils, or narrow ridgetops.
Site preparation to promote the establishment of oak from an adjacent site
Allowing a species native to the region to establish where it was not historically present, if it is likely to do well there under future climate conditions"

[36] Other barriers specific to Bolivia include "barriers to markets for lesser known species in Bolivia: a) lack of working capital for the forest industry; b) lack of skilled and better trained labor; and c) high transportation costs" (Barany et al. 2003)

these concerns, it is recommended that wood property information be made available to manufacturers (ibid) [37].

ii. People are not aware of lesser-known species and therefore the market for them needs to be developed. Furthermore, because lesser-known species are not common in local timber markets, special tools or machines that may be necessary for their processing are not available (Ewudzie et al. 2018)

g. Case Study/examples:

i. Rainforest Alliance, 2015 - Meeting the New Global Demand for Lesser-Known Species: Developing CFE,a case study in the MBR
   1. A CFE in the Mayan Biosphere Reserve, Guatemala teamed up with FORESCOM, which worked first as an intermediary between the CFE and buyers and has become a second-tier business, to gain access to LKS markets.

h. Resources on:

i. Identifying lesser known species:
   a. WWF/GFTN: A Guide to less known tropical timber species - has an extensive list of alternative timber species along with their possible end uses and points of contact.
   b. FSC - Lesser Known Timber Species database: contains a searchable library of timber species and smallholders and communities that sell LKTS.
   c. International Wood Products Association - Lesser Known Species: contains a list of LKS with the most potential in the US market along with technical information on each and an online directory to find a supplier.
   d. Rainforest Alliance, 2015 - Meeting the New Global Demand for Lesser-Known Species: Developing CFE,a case study in the MBR: see Table 2 for a list of lesser-known timber species common to the MBR and notes on their workability
   e. Analysis of the Lesser-Known Timber Species situation and recommendations: contains list of guides/publications with descriptions of them.
   f. Houtdatabase - LKTS

ii. **Restricted, endangered, or overused species to stay away from**:
   a. The Wood Database - Restricted and Endangered Wood Species (Recommended resource)
   b. CITES
      i. Current CITES Listing of Tree Species
   c. IUCN Red List of Threatened Species
   d. 10 Most Endangered Wood Species according to Grace Jeffers

[37] "Overcoming the need for information on LUS utilization requires the transfer of information and marketing of new woods. The first step should be to make available wood property information to manufacturers. This information dissemination should focus on a few suitable species, based on inventory and end use. Even a slight increase in the number of species harvested from a stand could greatly increase the total harvested volume. Second, wood property tests on those species for which there is no information but that are dominant in the forest inventory should be conducted. This may not only provide the forest products industry with suitable woods, but having a wider selection of species suitable for harvest will allow for more silvicultural techniques to optimize forest management options. And finally, promotional efforts are needed in order to help processors and buyers of manufactured products become familiar with these species; without these efforts, markets for LUS will remain limited." (Barany et al. 2003)

e. World Trees Campaign - Red Lists

iii. **General**:

a. The Wood Database's WoodFinder

b. International Wood Products Association - Find a Supplier

iv. Grade - Beetle Kill Wood sellers:

1. Rocky Mountain Forest Products
2. Mountain Heart Woodworks
3. Sustainable Lumber Co.

4. Strategic Geography

a. Description:

i. This pathway focuses on one or many specific geography(ies) in sourcing wood products. Here cities may take advantage of international voluntary partnership agreements (VPA) such as the European Union's FLEGT initiative or other jurisdictional approaches, which assure legality of timber and in some cases minimum environmental standards (EU, 2003) [38]. Legality plays an important part in ensuring sustainability in areas where third-party certification schemes are under-effective and leakage occurs (Brack, 2014). Action taken may also serve to exclude specific countries or jurisdictions, strong justification against non-competition claims in public procurement may be necessary.

b. Forest Impacts

i. This pathway supports countries and regions that are showing a commitment to reducing forest degradation and managing forests sustainably through policies addressing illegal logging and the management of the region's forests. In ensuring legality, the pathway promotes a greater degree of safety in wood harvesting and lowers risk of ecosystem collapse.

ii. Initiatives such as FLEGT have been shown to contribute towards SFM in countries such as Indonesia (Neupane et al. 2019) via " improved harvesting practices, and [a] timber legality assurance system".

iii. While conservation for carbon sequestration and against illegal logging are often suggested to also conserve biodiversity, Nelson et al. (2008) show that policies addressing carbon sequestration do not always lead to species conservation.

iv. In modelling future scenarios of REDD+ implementation, Palomo et al. (2019) found that biodiversity conservation is however much easier to obtain as a co-benefit to carbon sequestration when compared to social equity sought in an equal global distribution of program funds.

[38] "Voluntary Partnership Agreements (VPAs) between the EU and timber-producing countries also promote trade in legal timber products and help to close the EU market to illegal products. A VPA improves forest governance and, ultimately, guarantees that timber and timber products exported to the EU are legal. Each VPA defines 'legal timber' according to the laws and regulations of the timber-producing country. Negotiating the Agreement provides an opportunity for private sector and civil society to get involved in developing national legality standards. Each VPA sets out a strong timber legality assurance system that can verify that a consignment of timber is legal and merits the award of a 'FLEGT licence'. FLEGT-licensed timber will be free to enter the EU market as it will automatically meet the requirements of the EU Timber Regulation. (link)

c. Social Sustainability

i. Initiatives such as FLEGT and REDD+ have led to governance reform, increased government revenues, and strengthened rights of forest peoples in participating countries (EU FLEGT, 2003). REDD+ adding benefits such as "institutional strengthening, reforming policies and frameworks, mobilizing new and additional financial resources and increasing social and ecological resilience" (Neupane et al. 2019).

d. Carbon Storage

i. VPAs such as REDD+ have been specifically developed in the interest of sequestering carbon in tropical forests, however REDD+ is also intended to limit the timber harvested from the jurisdiction receiving financial assistance.

e. CO^2 Comparison

i. Reduced deforestation from jurisdictional approaches have led to avoided emissions from avoided deforestation. Stickler et al. (2018) show that from the 39 sub national jurisdictions studied, the declines in deforestation as a result of policies resulted in 6.8 $GtCO_2eq$ of avoided emissions.

f. Barriers & Risks

i. There are many barriers to the successful implementation of this pathway, and those that depend on international cooperation are often out of reach to municipal governments to influence. Busch & Amarjargal (2020) importantly identify that second-tier governments also play a significant role in reducing deforestation through measures such as VPA, whose authority varies widely between countries [39].

ii. Large-scale, international jurisdictional approaches such as REDD+ have raised significant concern regarding their adverse local impacts in pursuit of reducing emissions associated with tropical deforestation. In response to concerns of illegal logging within REDD+ jurisdictions, some have argued for a better coordination between REDD+ and FLEGT (Tegegne et al. 2018).

g. Resources/organizations

i. Forest Legality Initiative
ii. Sustainable Procurement of Forest Products (Noguerón, 2016)
iii. EU FLEGT Action Plan
iv. CIFOR, EII etc. State of Jurisdictional Sustainability report (Stickler et al., 2018) provides criteria to assess progress to jurisdictional sustainability. [40]
v. Jurisdictional Sustainability: A Primer for Practitioners - Earth Innovation Institute (2017) includes challenges and pathways for action.

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[39] *Broadest authority countries*: India, Brazil, Indonesia, Malaysia, Papua New Guinea, Peru, China, Laos, Mozambique, and Vietnam. *Intermediate authority in*: Democratic Republic of Congo, Ecuador, Mexico, the Philippines, Colombia, Myanmar, Tanzania, Zambia, Mexico, and Republic of Congo. *Least authority in*: Central African Republic, Gabon, Angola, Madagascar, Bolivia, Cambodia, Cameroon, Guyana, Suriname, Thailand, and Venezuela.

[40] Criteria include: integrated low-emission rural development (LED-R) strategy; spatial plan; performance targets; monitoring, reporting, and verification; policies and incentives; multi-stakeholder governments; sustainable agriculture; indigenous peoples and local communities; and LED-R finance.

vi. Chervier et al. (2020) provide key intervention strategies that stakeholders can undertake for a jurisdictional program (link to table) [41].
vii. FLEGT Independent Market Monitor Dashboard & Market Trends
viii. Sustainable Timber Information Exchange (STIX)

5. Local and Urban Wood

a. Description:

i. This pathway focuses on the use of locally-harvested wood and associated products, which is usually defined by a given regional boundary in close proximity to the city or project in question. This is most often invoked to support local and regional businesses and under the assumption that such wood carries less embodied energy, carbon, or other adverse climate effects than imported wood. This includes wood harvested within the urban boundary, taken either from privately or publicly-managed areas (Galvin et al. 2020). [42] The spread of forest diseases, pests, or other general forest health crises lead to vast expanses of forests, urban and rural, that need clearing. This seeks to improve the long-term utilization of these trees instead of them being added to the city wastestream.

b. Forest Impacts

i. This pathway reduces demand on other wood sources from faraway forests by shifting demand to local forests, provided these forests have the capacity to support the shift in demand. Addressing this demand is key to determining whether a city's timbershed can be sustainable in the face of increased urbanization (Nowak & Walton 2005, Anderson & Germain 2009).
ii. Drigo (2009) analyzed the local supply, demand, and sustainable wood production (primarily for wood fuel) of Bangui, Central African Republic, and recommended that government support for the fuelwood industry via managed forests can help reduce deforestation.
iii. When inner and nearby forests are better managed this can benefit urban residents through reduced stormwater runoff, reduced urban heat island effect, decreased wildfire risk, economic growth, and clean drinking water (Mongabay).

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[41] 1) Funding – create a sustainable financing mechanism to cover recurrent costs of collaboration and monitoring in particular.
2) Production of knowledge – create a monitoring and evaluation system and integrated spatial databases and landscape analytics.
3) Promotion of changes in higher-level regulations – national government changes regulations so that laws recognize locally devised rules and removes contradicting regulations.
4) Create a mix of jurisdictional scale interventions
5) Create opportunities for effective interaction – convene stakeholders and recognize these forums and decision bodies and create or strengthen ties with external actors, particularly high-level government agencies, value chain actors, certification bodies, etc

[42] "Fresh cut consists of wood from tree care and maintenance operations and may also include wood from clearing activities related to development and construction. Sources include municipal and private (arborist or utility) operations. Logs and other wood material from these operations may be sent to the landfill, or alternatively, the wood may be put to some use. Using the wood, however, requires that systems for assessing the materials are already in place, so the highest and best use can be considered. . ." (Urban Wood Workbook)

c. **Social Sustainability**
   i. In the interest of keeping wood harvesting close to home and making better, more responsible use of inner and nearby forests, the socioeconomic benefits of are often suggested (The Delta Institute 2014).
   ii. Public is better educated and engaged with inner forests (CT DEEP)
   iii. Supports local economies through job creation and potential artisan businesses

d. **Carbon Storage**
   i. In diverting wood waste from short-lived products to long-lived products in inner and nearby forests, there is greater potential for future carbon storage.
   ii. A deliberate emphasis on increasing forest cover in urban areas can reduce climate impacts (Ontl et al. 2019) and sequester carbon.

e. **CO² Comparison**
   i. Local wood has the potential to reduce embodied emissions in wood products associated with transport and harvesting (CT DEEP). In a recent comparative LCA study, Chen et al. (2018) estimated that transportation accounted for 3% of the production phase emissions (A1-A3) and 8% of the construction phase emissions (A4-A5) of a mass timber building. If avoiding embodied emissions from transport of wood is a concern, local wood should be specified from local forests and mills employing low-energy processing and manufacturing technology.
   ii. Reduces volume of wood disposed of in landfills

f. **Barriers/Risks**
   i. In highly-populated or forest-poor areas, local wood is characterized by inconsistent supply and poor quality (Gordon, n.d.). Local wood is often believed to be more expensive and of lower quality, leading to lack of demand and supply barriers (Nardi-Cyrus et al. 2015). [43]
   ii. Keulemans & Van de Walle (2017)

g. Case Studies/examples:
   i. SW4C's open-sourced Local and Urban Wood Mills and Suppliers list
   ii. *Epilogue Lumber* in Portland
   iii. *SawmillSid* in Toronto
   iv. *Baltimore Wood Project*
   v. *Angel City Lumber* in Los Angeles
   vi. *City Bench* in New Haven
   vii. Twin Cities - Report: Using Industrial Clusters to Build an Urban Wood Utilization Program: A Twin Cities Case Study (Bratkovich & Fernholz, 2010)
      a. Industrial clusters - businesses and organizations form mutually beneficial cooperatives
      b. Wood from the Hood in Minneapolis

h. **Resources/organizations:**

[43] In addition: wood from local sources not available in the quantity and quality of what secondary wood producers want; shortcomings in terms of species, dimensions, and moisture content.

i. Vibrant Cities Lab -
    1. Urban Forestry Toolkit
    2. Urban Wood Use Action Guide
ii. Urban & Community Forestry Program - US Forest Service
iii. The Urban Wood Toolkit - guide for municipal foresters, city managers, and others creating an urban wood use plan
iv. The Urban Wood Workbook: A Framework for the Baltimore Wood Project
v. Successful Approaches to Recycling Urban Wood Waste (Solid Waste Association of North America) - provides case studies covering: lumber products, high-end wood products, salvage, wood chips, compost and mulch, boiler fuel, and cover for landfills.
vi. Wood Utilization Options for Urban Trees Infested by Invasive Species
vii. Urban Forests & Urban Tree Use: Opportunities on Local, State, National and International Scales
viii. Urban Wood Utilization in Connecticut - provides an overview of the uses for urban wood, benefits of utilization, and further resources
ix. Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) methodology
x. Urban Wood User's Resource Guide - Resources to learn about the potential of urban wood and a list of connections in selected states, including urban wood networks, sawmill directories, and more.
xi. Sustainable Northwest Wood - lumberyard in Portland, owned by non-profit, sources only local wood from well-managed forests
xii. Forest Carbon Management Menu - help develop actionable tasks to reduce climate impacts
    1. Approach 1.3: Increase the extent of forest cover within urban areas
xiii. Urban, Salvaged, and Reclaimed Wood (USRW) Certified Wood Standards - Urban Wood Network
    1. The full Standards for Certification and Chain of Custody are coming soon
    2. Currently features 3 appendices, including a sample template for an Urban Tree Recycling Policy
xiv. Urban Wood Economy - consultants and advocacy; supports organizations participating in the urban wood marketplace and its full circle economy
xv. Treecycle America
xvi. Cambium Carbon

6. Reuse & Long Life

a. Description:

i. This pathway focuses on wood that comes from deconstructed buildings or other wood products that can be diverted from the landfill and recycled or "upcycled" instead. [44]

[44] "Deconstruct refers to wood that comes from the removal of existing buildings (often vacant or abandoned structures located in post-industrial cities) and may include flooring, framing, and other wood. Demolition, the standard method of removal, consists of the destruction of a building followed by the disposal of materials in a landfill. Deconstruction is an alternative method that involves the removal of a building in such a way that the materials used in its construction can be recovered. Even though demolition tends to be

The reuse of this wood not only displaces emissions, deforestation, and energy use that would have taken place in the production of virgin materials, thereby helping to reduce pressure on existing forests, but also salvages unique pieces of wood that may come from rare sources. Benefits of reclaimed wood include waste diversion, potential economic growth, and local production (Pitti et al., 2020).

b. **Forest Impacts**
   i. This pathway reduces use intensity on other forests. If less wood is being discarded and/or if more wood can be reused, demand for virgin wood products can be sustained while demand for secondhand wood products increases (Sathre & Gustavsson 2010).

c. **Social sustainability**
   i. Creates local employment
   ii. Reduces waste going to landfill
   iii. Provides higher quality wood with a story since reclaimed wood oftentimes comes from old growth forests or rare species that are no longer harvestable, endangered, or prohibitively expensive
   iv. Benefits of reclaimed wood: landfill diversion, potential economic growth, and local production (Pitti et al., 2020)
   v. Points towards LEED certification (Leblanc, 2020)

d. **Carbon Storage**
   i. The reuse of wood products ensures that carbon sequestered from the original wood source is not released in decomposition or burning, and therefore remains in the product. In countries such as the Netherlands, it has even been shown that carbon sequestered in the wood present in the built environment exceeds that of the country's forests (Müller 2006).
   ii. There are claims that the carbon benefits from avoided landfilling of wood products have been overestimated, as evidenced by Micales & Skog (1996), Ximenes et al. (2015), Morris (2016), and Dwyer et al. (2018).

e. **CO^2 Comparison**
   i. reclaimed wood processing consumes less energy than virgin wood, thus avoiding GHG emissions from manufacturing using new materials. In a life cycle analysis comparing reclaimed building materials to virgin counterparts, Bergman et al. (2010) showed that virgin requires 11 times the energy input of reclaimed materials. Likewise, Ng et al. (2011, 2014) found that a door made from recycled wood (12.8 kg CO2eq) has lower carbon emissions than a door made from virgin wood (16.2 kg CO2eq). Other studies, however, have found equal (or close to) emissions manufacturing energy between virgin and recycled wood products (Hart & Pomponi 2020).

f. **Barriers**
   i. (Ormondroyd et al. 2016)
   ii. Barriers for the industry: "lack of financial resources, lack of storage space, under-performing or insufficient marketing efforts, and lack of consumer awareness, as

quicker, deconstruction creates at least twice as many jobs and can provide health and economic benefits. In Baltimore, deconstruction is done in a way that is cost competitive with demolition, even before accounting for additional positive externalities." (Urban Wood Workbook) well as difficulties associated with raw material sourcing, pricing, and distribution . . . unpredictable urban and reclaimed wood product supplies make it difficult for firms to establish relationships with intermediaries who facilitate large volume sales" (Pitti et al., 2020, p. 5240)

iii. Reclaimed wood often contains metal debris like nails that needs to be removed. This either requires a grading inspector or new technology which can make the wood more expensive than virgin materials or if not properly removed, can be dangerous.
iv. Work is currently being undertaken to assess the feasibility of using secondary wood products in structural applications (Rose & Stegemann, 2019).

g. Resources

i. SW4C's open-sourced Reused Wood Businesses: A Starter List
ii. Reusedwood.org - North America's wood reuse and recycling directory
iii. Urban Wood Network
iv. Wood i-joists - smaller in dimension, potentially recyclable
v. Urban Wood Workbook
vi. Cradle to Cradle Certification
vii. Examples of reclaimed wood companies:
    1. Hudson Company (upcycling)
    2. Tri Lox
    3. Baltimore Wood Project
    4. Details Deconstruction and Brick + Board - Baltimore based deconstruction and salvage companies
    5. Room & Board - line of reclaimed wood products, wood supplied by the Baltimore Urban Wood Project
    6. Viridian Wood - Portland, OR
    7. Good Wood - Portland, OR
    8. Sawkill Lumber Co. - Brooklyn
    9. Elmwood Reclaimed Timber
    10. Timeless Timber - Wisconsin; company that recovers wood logs that sank during the 1800s in the Great Lakes
    11. Reclaimed Flooring Co - Cheshire, UK
    12. English Salvage - Leominster, UK
    13. TerraMai - Oregon
    14. Glasgow Wood Recycling - Glasgow, Scotland

viii. Buying Guide for Reclaimed Wood
ix. Reclaimed Timber: The benefits and challenges
x. The pros and cons of using reclaimed wood
xi. Introduction to Reclaimed Timber: Description, benefits, and sources
xii. Reclaiming Wood Products from Waste Wood

7. High Efficiency Production

a. Description:

i. This pathway focuses on the use of manufactured and long-lived wood products that employ new technologies to use the entire harvested tree more efficiently. Wood waste in the forestry industry is a significant issue, and using it responsibly (i.e. avoiding the burning and/or mass decomposition waste at minimum) can help sustain forests, protect them from fire, and contribute to global climate goals. Examples of this pathway include the use of smaller-dimensioned components in structural wood products and wood fibre insulation. The goals of this pathway are to:

1. Reduce wood waste
2. Use a greater variety of trees
3. Reduce forest impact for product, more range of product. Not just good, straight trees, but all trees.
4. Encourage the reduced use of toxic chemicals in the products' manufacturing process

ii. (Adhikari & Ozarska, 2018)

b. Forest Impacts

i. Through improved harvesting and manufacturing methods, this pathway conserves forests by reducing the number of trees necessary to be cut in future harvests (Eshun et al. 2012, pp. 72). For instance, the use of low-quality logs in small-dimension lumber, wood fiber insulation, and engineered wood products can convert discarded logs into long-life wood products.

c. Other Impacts/social sustainability

i. Adhesive – see dowel-laminated timber (DLT), for instance.

1. Dowel laminated timber: Adhesive free, more sustainable option to EWPs, recyclability retained. (Sotayo et al., 2020 - Review of DLT) Some say lower embodied carbon (Dauksta, 2014)

d. Carbon Storage

i. Carbon that is stored in the wood, approximately one tonne of CO_2 per $1m^3$ of wood.

e. CO^2 Comparison

i. Technology such as solar kilns can drastically reduce the amount of energy required in drying wood products, which usually burns wood waste to produce the necessary heat.

ii. Engineered wood products and reduced emissions (Winchester and Reilly, 2020)

f. Resources:

i. The Envirolam Process

ii. Mass Plywood panels

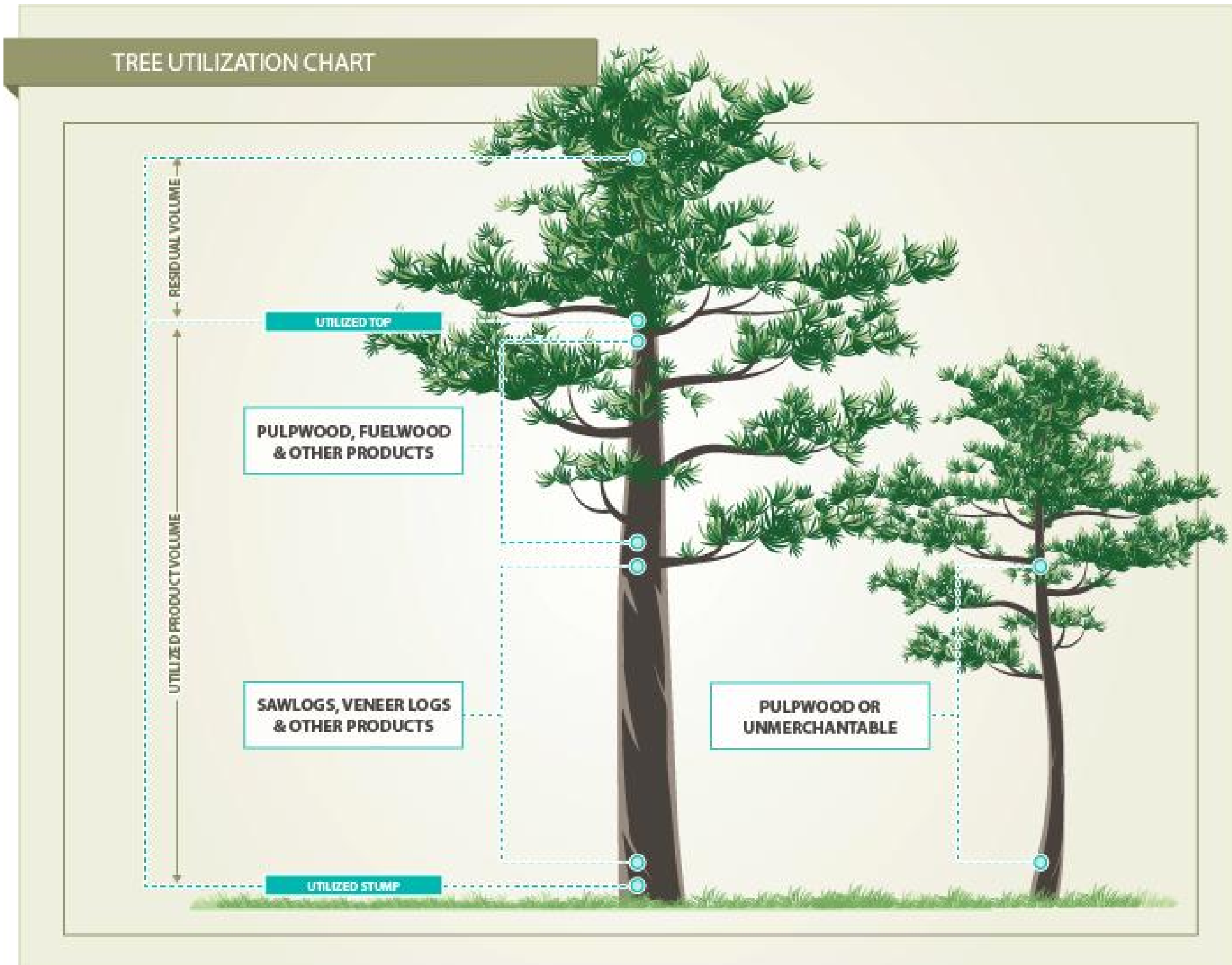
iii. I-Joists

iv. APA Green Verification Reports

v. Swedish Climate declaration when constructing buildings

vi. C40 Clean Construction Declaration

vii. International Living Building Challenge
viii. WholeTrees Structures - build using intact tree trunks



8. Net Carbon Accounting / LCA

a. Description

i. This pathway focuses on the use of wood for decarbonization and climate goals. The complete life-cycle of wood, from the forest to post-consumer uses, determines its real carbon profile. Most existing accounting systems for carbon within wood products fail to consider this and therefore do not differentiate between forest management practices, production processes, end-of-life scenarios and other factors. Acknowledging that wood is not always carbon-neutral Hart & Pomponi (2020), considering and performing carbon accounting that includes each of these factors will produce a more accurate carbon profile and help to reinforce the defining characteristics that lower this profile. Innovative technologies such as solar kilns also have the potential to reduce the amount of carbon embodied in the end product. Furthermore, this pathway aims to discourage the use of harmful chemicals used in the manufacturing and construction processes.

ii. Kalt (2018)

iii. (Kozak et al. 2001)

iv. IPCC and Harvested Wood Products: Guidance on how to estimate HWP carbon contributions, different methods to calculate this and what data is necessary

v.

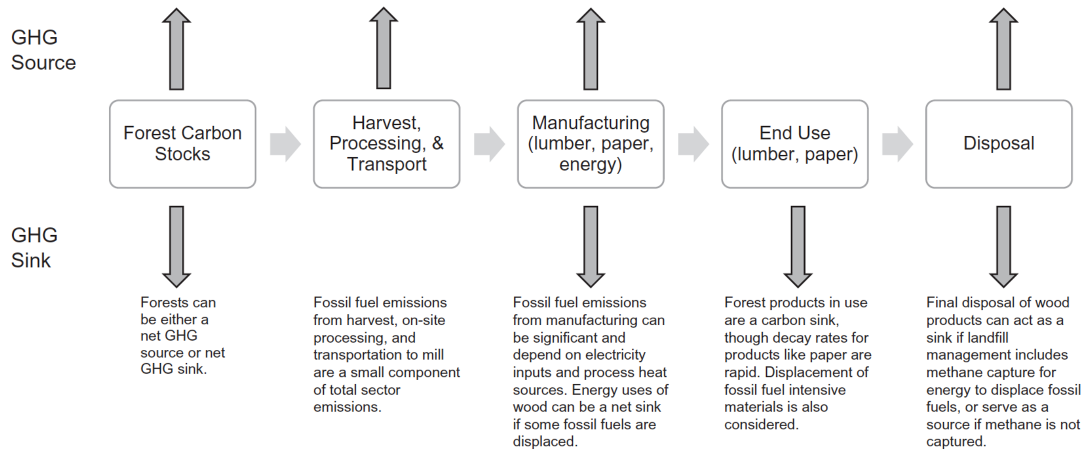


Figure 1 Forest sector Life Cycle Assessment (LCA) boundary and primary GHG source and sink elements used in the study.

1. Figure 1 from Gunn & Buchholz, 2018

b. Forest Impacts

i. Through LCA one is able to identify the carbon footprint in the harvesting of wood products, therefore incentivizing low-carbon wood products.

c. Carbon Storage

i. Carbon is stored within building structures for the long-term

ii. Churkina et al. (2020): If 50% of new buildings were built with mass timber, in 30 years 1-11 Gt of carbon would be stored. Storing carbon in buildings means that the preservation of that building is important to maintain that storage. Carbon storage in buildings should be enhanced by first using reclaimed materials. Large-component pieces from mass timber should be disassembled and reused if the building is demolished, smaller-components can go into secondary/non-structural products.

iii. Johnston & Radeloff (2019): Estimated carbon stored in HWPs. Found that in 2015, global HWPs were a sink of 335 Mt of CO_2 eq and that this could increase to 441 Mt of CO_2eq by 2030 with favorable conditions (these estimates do not include traded timber). While HWPs offset a fair part of industrial process emissions in certain countries, on a global scale this offsets less than 1% of all emissions. The future contribution of HWPs to carbon accounting depends upon socioeconomic pathways and potential economic shocks.

iv. Gunn & Buchholz (2018): Estimates net GHG emissions for carbon pools and emissions sources over 100 and 300 year time horizons for different forest management strategies in Maine
   1. If Baseline harvest rates and practices continued, forest sector remained a carbon sink over 300 years
   2. Harvest intensification (even-aged management, clear-cuts) led to overall increases in emissions
   3. Increasing uneven-aged systems reduced emissions

v. Schlamadinger & Marland (1999) Harvest of forests must be converted efficiently to durable forest products or displace fossil fuel emissions and there be a high re-growth rate for there to be any carbon benefits.

vi. Werner et al., 2010: This study shows different GHG emissions in the short and long-term (100 years) under different forest management scenarios for Switzerland. Short-term effects can differ markedly from the long-term. The Reduced Forest Maintenance scenario (less management, less extracted wood and wood use) in the short term had the most significant CO2 savings due to the sink effect into forests but in the long-term was the worst scenario and led to an increase in emissions because of natural decomposition. In the long-term, the Optimized Increment, Building and Kyoto Optimized scenarios were the best in terms of carbon. To optimize CO2 benefits of forestry/timber sector: utilize the maximum, sustainable increment from forests while considering and conserving biodiversity and soil quality, harvest increment continuously, cascade use, use waste wood with no possible further use for energy generation but do NOT increase use of wood solely for biofuel.

d. CO_2 Comparison

i. LCAs and comparisons to other building materials such as concrete.
   1. Guo et al. (2017): estimated energy consumption in LCA of CLT is 9.9% lower than for reinforced concrete building; carbon emissions for CLT is 13.2% lower than reinforced concrete

ii. Churkina et al., 2020: A primary structure made out of wood contains half of the materials (in tons) of one made from concrete and steel, requiring a smaller foundation and fewer materials in general which translates to energy reductions. Emissions from manufacturing mass timber materials are lower than mineral-based materials

iii. Bribian et al. (2011): LCAs of building materials (pg. 1138)
   1. In general, wood products always have a lower impact compared to other construction materials. Example: “every m3 of laminated wood (not incinerated at the end of its useful life) absorbs 582 kg of CO2, while reinforced concrete emits 458 kg CO2/m3 and steel 12.087 kg CO2/m3”
   2. Improved use of resins: replace urea-formaldehyde and melamine-formaldehyde resins with natural resins, average reduction in CO2 emissions if this is done is 16% for laminated wood and 46% for fibreboard. Furthermore, “obtaining natural resins is a traditional profession that is dying out” and using them “would create jobs and wealth in the rural areas.”

3. "in the right climates and periods, drying cut wood in the open air -humidity levels of up to 20-25%- rather than drying in a furnace would reduce the equivalent CO2 emissions by 11%, simply by increasing the stock of wood to guarantee supply."

iv. Liang et al. (2021): Using the TRACI impact category method, the cradle-to-grave LCA results showed very similar environmental performances and Life Cycle Costing Analysis (LCCA) for the mass timber building relative to conventional concrete building in Northwestern USA with 3153 kg CO2-eq per m2 floor area compared to 3203 CO_2-eq per m2 floor area, respectively.

e. Social sustainability:

i. N/A

f. Barriers/Risks:

i. On risks/limitations of LCAs: defining a baseline in a changing economy is difficult since "the recent past may not be a good predictor of the future" (Gunn & Buchholz, 2018, p. 535)

g. Resources

i. Existing LCA Tools:
   a. Tally
      i. LCA plugin for Revit
   b. Embodied Carbon in Construction Calculator (EC3)
   c. One Click LCA by Bionova
   d. Wood Works review of LCA tools and carbon calculators for construction (2020)
   e. Athena Impact Estimator for Buildings
   f. Gestimat
   g. Purdue LCA Tool for furniture

ii. Environmental Product Declaration (EPD)
   a. EN 15804: standard for how European construction companies should create EPDs (standard revised in 2019)
   b. EPD Verification Scheme - BRE Global
   c. Backing tropical timber products with EPDs: project helping African timber suppliers put products through LCA, generating EPDs and FDESs

iii. Resources on Carbon in Wood Products
   a. FAO's paper on Carbon Storage and Climate Change Mitigation Potential of Harvested Wood Products
   b. Carbon Impacts of Wood Products (recommended resource)
   c. Carbon Sequestration in Wood and Paper Products

iv. Resources on Calculating Carbon
   a. USDA - Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States

v. Wood for Good Life Cycle Database

vi. Carbon Leadership Forum's Wood Carbon Seminars

vii. Modern methods of construction (MMC)

viii. Policies for Embodied Carbon: An International Snapshot (link)

ix. NRCan Low-carbon assets through life cycle assessment initiative

x. www.buildingcarbon12.com
xi. LCA Practice Guide by the Carbon Leadership Forum
xii. Architecture 2030 Carbon Smart Materials Palette
xiii. U.S. EPA's Greenhouse Gas Equivalencies Calculator
xiv. Beacon - Carbon calculating Revit plugin for structural engineers
xv. June 2020 FCWG Learning Exchange Series: Wood Utilization II: Land Use and Global Outlook

Box #2: What about mass timber?

Mass timber is the use of solid or engineered wood components - large beams, columns, arches or slabs - for the primary structure of a building. These structural components are often made up of layers of wood, in processes known as: glue-lamination (glu-lam) and cross-laminated timber (CLT) for large slabs, as well as glue-free "nail lamination" (NLT) and dowel lamination (DLT). The "mass" in mass timber refers to the relative caliber of these components which are designed to be thick enough to slow down burn rates and resist structural failure in the event of a building fire.

Mass timber is often heralded as a potential climate solution due to the amount of atmospheric carbon stored in the wood for the lifespan of the building (and well beyond if the wood can be reused). This use of wood also replaces more carbon-intensive structural materials such as concrete and steel. However, understanding the whole life cycle of the wood used in mass timber buildings, including the forest impacts, is essential if the material is to be considered a climate solution. It is evident that not all wood can be considered "climate positive" (beneficial) when it comes to net carbon storage.

Which Pathways are best suited for mass timber projects?

- #1 - Certification: Consider using certified wood in order to improve the sustainability of mass timber projects. Mass timber buildings require large quantities of uniform wood and not all of the pathways are well-equipped to provide this. Certification may be one of the best-suited methods to acquire the proper amount of wood while still considering the forest management systems used to produce it. See Box #1 on ecological forestry for background on best forest management practices to consider when sourcing wood.
- #5 - Local & Urban Wood: While urban wood would rarely be suitable for mass timber elements, consider sourcing wood from a local forest enterprise nearby the city to decrease transportation emissions, support the local economy, and invest in the sustainable management of the forest within reach of the city.
- #7 - High Efficiency Production: Processes like Enviro-lam can produce structural beams using smaller components so that more of the tree is used and waste is reduced. Each manufacturer should be able to provide wood utilization rates and waste factors for their respective processes.
- #8 - Net Carbon Accounting: Due to the complex, and sometimes controversial, production of mass timber buildings, a comprehensive life cycle analysis of all components, from forest management to chemicals in production to post-life storage, is necessary to ensure the full sustainability story is understood and carbon benefits can be truly accounted for. There are a number of new tools entering the market to assist with this calculation.

What resources are available to cities to learn more about mass timber construction?

- The Wood Institute has short, 1-2hr courses on mass timber code, specification, and construction advancements.
- Naturally Wood resources:
  - Making Embodied Carbon Mainstream
  - Demonstrating the Benefits of Whole-Building Life Cycle Assessment
  - Environmental Building Declaration for Brock Commons Tallwood House
  - A Comparative Cradle-to-Gate LCA of Mid-rise Office Building Construction Alternatives
- Woodworks Innovation Network has many resources and a forum on wood construction topics.
  - Mass Timber Design Manual 2021
  - Mass Timber Building Insurance and related resources
  - Mass Timber Business Case Studies
- ThinkWood's Supporting Tall Mass Timber Buildings in the IBC on changes to the International Building Code (IBC) in 2021 – further detailed on the American Wood Council's website here.
- The American Wood Council has resources on codes & standards.
- Thinkwood's Resource Library.
- Mass Timber Building Science Primer

General Resources:

1. Woodworks Innovation Network
2. AIA Framework for Design Excellence
3. Thinkwood.com's Resource Library
4. The Wood Institute
5. American Wood Council
6. Sustainable Public Procurement tool - Government of the Netherlands
   a. Collects latest SPP criteria for your procurement document