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Technical Documentation for

Advancing Social Impact Using Mass Timber in Industrial Building Types

US Forest Service 2022 Wood Innovations Grant

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SUSTAINABLE FORESTRY INITIATIVE

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About This Report

Ecotone Analytics conducted this impact analysis and projected the social benefits of mass timber construction using responsibly sourced wood. This analysis was conducted as a part of a 2022 Wood Innovations Grant led by the Sustainable Forestry Initiative (SFI). This project helps to increase demand for mass timber in three key ways by: 1) tapping into the industrial building sector currently not leveraging wood, 2) quantifying the social benefits of building with wood procured from responsibly managed forests, and 3) telling the story of how building with wood procured from responsibly managed forests contribute to social and environmental benefits.

About Ecotone Analytics

Ecotone Analytics is an impact analysis and impact strategy organization that does benefit-cost analysis for clients' social and environmental impacts. Combining evidence-based research analysis and monetization of impact outcomes, Ecotone projects impacts and identifies the key stakeholder groups to whom those benefits accrue.

Disclaimer

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Introduction

This document details a social impact analysis of mass timber construction utilizing responsibly sourced wood. It serves as one part of the project: Advancing Social Impact Using Mass Timber in Industrial Building Types, funded by a 2022 Wood Innovations Grant and managed by the Sustainable Forestry Initiative. The project as a whole seeks to positively influence the industrial sector to build with mass timber. This is needed because to date few industrial buildings have utilized mass timber, instead continuing to rely on more traditional concrete and steel construction materials.

Why was this social impact analysis needed in particular? The otherwise intangible social benefits of mass timber and wood procured from responsibly managed forests have historically been unaccounted for as there is no commonly accepted way to quantify their impact in fore-casted financials.

This project offers a solution by delivering a social impact valuation toolkit that provides a more tangible ROI to investors. Topics explored included economic effects on local communities, jobs across the value chain, wildfire awareness/education, sustainable forestry, climate change, strengthening and elevating Indigenous rights, healthy buildings and biophilia.

As a part of this grant, the owner of A1X Automation plans to construct a mass timber light industrial building in St. Paul, MN. This was to be analyzed for its social impacts as a case study. The design and development of this building is ongoing however and as a result, a social impact analysis of this specific building was not feasible at this time. However, numerous characteristics of the building including its approximate size, potential amount of wood vs. concrete used (when compared to a concrete tilt-up), and the number of future workers in the building are known. As a result, the analysis moved forward with these features to generate quantified impact estimates applicable to a hypothetical light industrial mass timber building.

The analysis focused on conducting a systematic review of evidence on the benefits of mass timber and sustainable forestry and based on that evidence, qualitatively mapping the expected benefits as well as developing estimates of the monetized social and environmental value of those benefits. Several benefits were valued including, for example, the value of the ecosystem services provided by a well-managed forest and the improved employee well-being from working in a facility with biophilic design features (e.g. exposed wood surfaces).

The outputs of this analysis are intended to provide a case study for the broader architecture/engineering/construction (AEC) community for use in educating clients on the social impacts of building with wood procured from responsibly managed forests in the U.S.

Finally, this analysis identifies quantifiable metrics for municipalities, communities and project owners to better understand the broader social (and economic) impacts of building with mass timber procured from responsibly managed forests, therefore increasing demand and expanding markets.

Analysis Scoping

The scope of this analysis was developed collaboratively with the SFI team to ensure alignment and a shared understanding of objectives. Through a series of in-depth meetings, both teams worked together to define the goals, priorities, and structure for the impact projections. This collaborative process was instrumental in ensuring that the analysis would address the most significant aspects of a light industrial mass timber building using responsibly sourced wood.

The final scope of analysis differed slightly from the originally proposed analysis due to data availability. To summarize, the scope of work included:

1. Comparing the social, environmental, and economic effects of a light industrial building that was built with mass timber using responsibly sourced wood in comparison to the same building built using concrete tilt-up.
2. Analyzing impacts for hypothetical a building that reflects known variables of A1X Automation's planned building.
    a. Why a hypothetical building? Many specifics of the planned A1X mass timber building are unknown at the time of this analysis but there is still research and experts' knowledge that can be capitalized on to understand and pool information around potential social and economic impacts of mass timber.
3. Projecting monetized benefits rather than a Social Return on Investment (SROI) ratio
    a. Why only monetized benefits for this project? The bids received for the A1X mass timber building were higher than what many in the industry think is appropriate. This means the "I" of the SROI is inflated. When the investment is larger than what it could/should be, the SROI ratio will be lower than it could/should be. It would not be a useful exercise to estimate an SROI that is not using an appropriate estimate for the investment amount - otherwise there is risk of negatively skewing audience members' perception of the value of mass timber.
    b. Definition comparison:
        i. Monetized Benefits project the impacts of mass timber using responsibly sourced wood. It does not consider the investment amount needed to use that mass timber.
        ii. SROI compares the monetized benefits to the investment needed to generate those benefits.
4. Developing a social impact valuation toolkit
    a. A Key Performance Indicator Framework was developed which details recommended indicators at each stage of the value chain for the industry to track with each mass timber project to build the evidence base for the social and economic value of mass timber.
    b. Details on the monetized benefits projected in this analysis are also shared and are adaptable to other mass timber buildings.
5. Journey Map Visualization
    a. A visualization was developed to showcase a selection of the monetized and non-monetized benefits estimated at each stage of the value chain - from responsibility managed forest to completed building.

Stakeholders

The initial step in developing the analysis involved identifying stakeholders, determining the extent to which they are direct or indirect beneficiaries, and, in some cases, assessing any unintended negative impacts they might experience as a result of the program model. Table 1 outlines the key stakeholders involved.

This stakeholder identification provides a qualitative understanding of how different groups may be affected by, or contribute to, the execution of a light industrial mass timber building. As shown in Table 1, a wide range of stakeholders may engage with the mass timber value chain in various capacities.

Table 1. Key Stakeholders

Wood Sourcing	Mass Timber Processing and Manufacturing	Other Public and Private Players	Construction	End Use
• Communities near and around the forestlands • Loggers and trained harvesting professionals • Project Learning Tree (PLT) teachers and recipients of the training and curriculum • General public • Land owners/ managers • Forest standards such as SFI	• Transportation companies and employees • Processing and manufacturing companies and employees • Forest standards such as SFI	• Governments (e.g. building code development) • Tools and equipment suppliers • Building supply companies (insulation, flooring, siding, windows, plumbing, electrical, etc.) • Furnishing companies • Academia	• Building owner • Architects • Engineers • Developer • Construction contractors and subcontractors • Local government/ municipality • Financier(s) • Insurer(s) • Local community • Green building standards such as LEED • Forest standards such as SFI	• Building owner • Property manager • Tenants • Residents/ Workers • Visitors • Local community

Logic Model

The next step involved developing the logic model to identify the planned inputs, activities, and outputs of a building with mass timber rather than a concrete tilt-up. The logic model then traces the outcomes resulting from these activities, distinguishing them into short-term outcomes, intermediate outcomes, and long-term outcomes, including those who may experience those outcomes. Short-term and intermediate outcomes refer to those directly achieved through the program's activities, while long-term outcomes represent broader, indirect results that stem from the cumulative effect of these earlier outcomes. Finally, the model identifies the impacts directly attributed to building with mass timber using responsibly sourced wood. This logic model serves as a foundational map for the analysis, with intermediate and long-term outcomes forming the basis for monetization.

It is important to note that while the goal is to monetize all pathways identified in the logic model, some pathways are supported by stronger evidence bases than others, and in some cases, the available data is not sufficient to pursue monetization with a reasonable causal understanding. The following sections of this report will provide a detailed discussion of the pathways that were successfully monetized.

Logic Model Key

1. How to Read It

Reads from left to right, with each column collectively influencing the column to its right and being influenced by the column on its left.

2. Relationship Between Columns

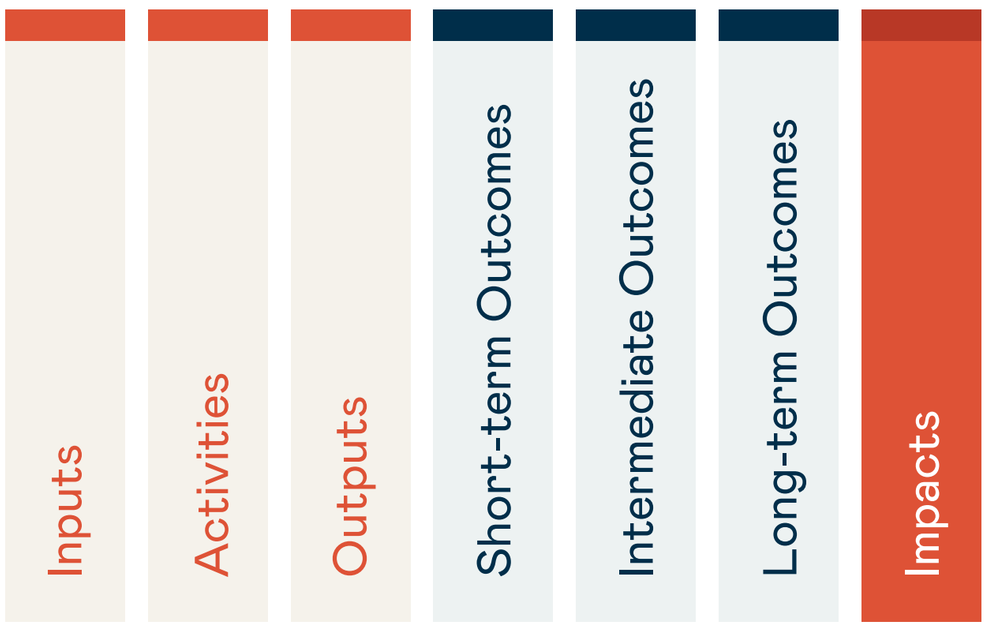
Individual lines do not necessarily link directly to those immediately on their left or right, although these specific causal chains will be established in our next steps.

3. Purpose

Connects 'Inputs', those resources required to begin, with the projected final 'Impact' resulting and attributed to mass timber construction with SFI standards.

4. In Comparison to What

Outcomes and Impact described in the logic model are assumed to be in comparison to not using mass timber construction with SFI standards.



The logic model is a powerful internal tool designed to provide users with a clear understanding of the overarching vision of mass timber's social value proposition and the pathways through which it will be realized. It serves not only as a guide for internal alignment but also as an effective tool for engaging external stakeholders, demonstrating how they contribute to and benefit from the vision. Other key use cases of the logic model include:

1. The full logic model can be used internally to foster alignment among staff by creating a shared understanding of goals. It also acts as a valuable resource for external engagement, allowing mass timber advocates to communicate how stakeholders fit into and contribute to the realization of the vision.

2. The logic model provides an opportunity to examine barriers that may arise between short-term, intermediate, and long-term outcomes. These barriers represent risks to achieving the intended impact and highlight areas where strategic adjustments may be needed.

Inputs	Activities Unique to Mass Timber Building in St. Paul	Outputs	Short-term Outcomes	Intermediate Outcomes	Long-term Outcomes	Impact
• A1X Automation building owner • Stakeholder engagement and design/architecture firm LHB • St. Paul Port Authority • City of St. Paul, Ramsey County, State of Minnesota • Contractors • Engineer • SFI • Forest owners • Mass timber manufacturer • Local workforce to each stage of value chain	• Forest and lumber management • SFI sustainable forestry support • Public agency approval activities • Design and architecture • Manufacturing wood products • Construction of industrial building	• sq ft of mass timber building • # jobs at each step of value chain including end use phase • # of acres of forest supplying the timber	**Building Owners, Operators, and Workers** • Possible increased construction costs for sustainability • Increased diversity of jobs in the value chain (including more physically accessible jobs)	• Potential increased rents to building owner • Lowered stress for workers in the building	• Improved physical and mental health of those working in the completed building	• Improved environmental, social, physical, and mental well-being for stakeholders affected
			Forestry and Construction Industry Players Including Employees • Increased awareness of the benefits of mass timber and sustainable forestry • Reduced on site construction needed	• Increased demand for mass timber construction with sustainably sourced wood • Increased speed of completing building	• Improved ease of implementation of mass timber construction • Reduced disruption to local community	
			Local Communities • Increased engagement with and knowledge of nature • Improved management of forest land	• Increased use of deliberate and respectful forest-focused collaboration • Increase in forested land • Improved water quality and quantity • Reduced wildfire risk	• Increased income and wealth to local communities and indigenous peoples • Increased habitat and biodiversity protected • Avoided health risks of water eutrophication and air pollution • Increased climate resilience	
			Society • Increased carbon capture and reduced carbon emissions	• Avoided GHG emissions	• Increased climate change mitigation	

Projected Outcomes

A monetized outcome is when a monetary value is placed on the change generated by an intervention.

Social and environmental impacts, the changes from building with mass timber rather than concrete and steel, are often unlikely to appear on a financial statement but are still generating value. These impacts are always occurring with everything we do and we know implicitly they have value but there is uncertainty around just how valuable they may be. Monetization puts these often hard to understand impacts into readily understandable units ($), while also allowing for adding multiple impacts together and comparing impacts to each other.

Monetization forces the analyst to ask 'so what?' - why does this activity, this output, this short-term outcome matter? Not all social and environmental impacts can be readily monetized but it allows us to paint a partial picture of monetized value of otherwise often uncertain impact values.

Estimating and monetizing the impacts of mass timber using responsibly sourced wood required a rigorous, multi-step process. This process relied on evidence from existing literature (see the bibliography in Appendix A for a full list of resources utilized, and the outcome estimation rate cards in Appendix B for how each resource was incorporated into each impact estimation).

In total, over 50 resources were reviewed for this analysis. However, not all of them provided figures that were directly incorporated into the impact estimations. This is in large part due to Ecotone's evidence review process to determine what figures are appropriate for use. The resources reviewed include an extensive body of literature on meta-analyses, systematic reviews, and case studies that provide broader insights into the social, economic, and health impacts of mass timber and sustainable forestry, with particular attention given to causal studies that assess the extent a given intervention leads to measurable changes. This category of resources is central to Ecotone's literature review, as the reliability of an impact estimation hinges on the strength of the causal relationship between using mass timber and the intended social and environmental benefits.

To assess the strength of causal studies, Ecotone employs a framework consisting of seven levels of evidence for causality, ranking the methodologies used to estimate causal relationships (refer to the bibliography in Appendix A for details on this ranking). The strongest studies utilize randomized controlled trials (RCTs), akin to those used in drug trials, or meta-analyses of RCTs. These methods rely on a randomized experimental design to isolate causal relationships and precisely measure their magnitude. Studies with weaker levels of evidence may lack randomization but attempt to control for various confounding factors to identify potential causal links.

Whenever possible, Ecotone prioritizes studies with higher levels of causal evidence when making impact estimations, as they provide the most robust and reliable basis for analysis. However, studies with lower levels of evidence can still play a valuable role. They offer insights into areas where causality is suggestive, provide context for what has been studied, and, in some cases, highlight conflicting or refuting evidence. This balanced approach ensures a comprehensive understanding of the evidence base while maintaining rigor in estimating impacts.

To estimate the effect of a program or policy on outcomes of interest, Ecotone's approach integrates insights from two key bodies of research. The first involves reviewing effect sizes from evaluation studies that measure causal effects on a selected set of outcomes. While these evaluations provide valuable evidence, they often do not encompass all potentially relevant outcomes. To address this gap, additional evidence is examined to identify causal linkages between the primary outcomes evaluated and other outcomes logically or empirically connected to them (WSIPP, 2023). By combining the best and most recent evidence from these two research domains, Ecotone aims to estimate benefit and cost values comprehensively.

As an example, if an evaluation demonstrates that exposure to natural wood surfaces improves students' test scores and another study quantifies the effect of improved test scores on graduation rates, Ecotone can estimate the program's benefits by logically inferring that it also impacts graduation rates. This process of building causal linkages is repeated for every monetized outcome, as program evaluations rarely measure all the long-term outcomes that are relevant for benefit analyses such as this.

When reviewing resources for non-causal statements, Ecotone employs additional criteria to assess the reliability and reputability of the source. These criteria include the credentials of the authors, whether the resource underwent a peer-review process, the credibility of the publishing institution or funders, acknowledgment of differing results in other studies, and the date of publication. If a resource is outdated or exhibits clear bias, such as sharing figures that lack objectivity, Ecotone seeks alternative sources to ensure the integrity and accuracy of the analysis.

To monetize the impacts of mass timber using responsibly sourced wood, methods aligned with cost-benefit analysis best practices were employed. The monetization process relied on a combination of market price and benefits transfer methods. This approach allows Ecotone to assign dollar values to impacts using either the market price directly associated with those impacts (e.g., healthcare expenditures) and/or the values estimated in other studies when those studies closely align with two project types.

The monetization estimation generally follows the structure of:

> # of units * effect of mass timber on a given variable * the cost/value of that variable.

When benefits are realized over multiple years, a discount rate is applied to future benefits. This adjustment ensures that future benefits are expressed in the same dollar terms as the costs, enabling a consistent comparison. Without discounting, comparing a dollar in 2035 to a dollar in 2025 would be misleading, as the value of money decreases over time. By applying a discount rate, the benefit estimates provide a clearer and more accurate representation of the impacts in present value terms.

Ecotone's analyses adopt a conservative approach to ensure that impacts are not overstated. During the monetization process, trumping rules—recognized best practices in benefit-cost analysis (as outlined by WSIPP, 2023)—are utilized. These rules dictate that when multiple outcome pathways lead to the same type of outcome for the same individual (e.g., increased earnings from higher educational attainment and increased earnings from improved health), only the largest pathway or the pathway with the strongest causal evidence is included in the SROI calculation. This prevents double counting of benefits and ensures that the analysis accurately reflects the impact without overestimating the gains.

Core Assumptions of Monetized Outcome Projections

While the previously described process is followed, developing specific estimates relies on a series of assumptions. The core assumptions are detailed here and outcome-specific assumptions are included in Appendix B.

Counterfactual:

- Mass timber using certified sustainable wood compared to a concrete tilt up building of the same size and function.

Value chain characteristics:

- No geographic specificity to any steps of the value chain including no location of the forest assumed other than being in U.S./Canada.
- Trees are approximately 30 years old when harvested. There was a range of timelines for softwood trees that would be used in mass timber products, with ~25 years tending to be the low end and 30-35 years often referenced in the southeast (Brasher, 2021). In the north, these figures could be 40+ years and there is advocacy for extending harvest timelines throughout the country which could in some cases double the lifespan of the tree before being harvested. Since we aren't assuming where in the US the forest is that's supplying the wood we're using, we want to be conservative in terms of how many years of forest benefits we are accounting for.

Building characteristics:

- Based on A1X Automation building estimate: At least 23 workers in the completed building with at least one of those workers being considered a very high performer (i.e. max productivity).
- Based on A1X Automation building estimate: Approximately 26,000 sq ft final structure.
- A1X workers have average rates of job retention for the engineering and manufacturing industry.

Duration of impact:

- Impact duration varies by the type of impact – ranging from either one time benefits to benefits that last as long as the building is in good operating order. We assume that from the completion of the building, the building will generate benefits for 30 years before potentially large investments are required to continue to generate positive impacts.
- Multi-year benefits are discounted to present value using a 3% discount rate. This puts future benefits into 2024 dollars, allowing for apples to apples comparison between the investment made and benefits generated from the investment.

Additional Clarification

This analysis is a projection, it is not a measurement of impact realized. The values included in this analysis are based on existing evidence, but their valuation is projected. The actual benefits generated from specific mass timber buildings may vary by the specific contexts of their respective value chains, the characteristics of the people working in the completed structure, how the building is used, etc.

Table 2 shows the outcomes that were monetized in this analysis. The largest single benefit that was monetized was the ecosystem service benefits provided by the forest that supplied the wood used in the structure. It amounts to about 40% of the total projected benefits. The next largest benefit is the improved employee well-being from working in an environment with biophilic design - particularly exposed natural wood surfaces. Several other benefits are estimated across the various stages of the value chain. When viewed at the value chain level, the building use phase has the largest monetized benefit. This is largely due to the greater availability of evidence regarding the benefits of a work environment with biophilic design.

Appendix B includes the outcome estimation rate cards - the description of how each benefit was monetized on an annual basis. This serves as a key component of the social impact valuation toolkit and is paired with the recommended indicators to track, included in the next section of this document.

Table 2. Monetized Outcomes

Monetized Outcomes by Stage of Value Chain	Projected Benefit (in present value)	Time Frame
SFI Certified Forest Management		
Increased forest cover supporting improved air quality and water quality	$849,352	30 years
Construction		
Reduced Global Warming Potential of mass timber compared to concrete - Literature based estimate	$132,538	Lifecycle benefit
Reduced Global Warming Potential of mass timber compared to concrete - Athena LCA	$107,706	Lifecycle benefit
Noise pollution from construction	$6,075	One time benefit
Increased worker safety from more construction in a facility	$4,100	One time benefit
Building Use		
Reduced energy use for non-industrial machinery - HVAC, hot water, lighting	$30,959	30 years
Reduced employee absenteeism	$54,097	30 years
Value of employee retention	$225,405	30 years
Value of attracting and retaining top talent	$78,402	30 years
Improved employee well-being	$ 732,566	30 years
Total (utilizes higher GWP benefit)	$ 2,113,495	30 years

Life Cycle Assessment (LCA) results from project partner LHB Architects show that embodied carbon is the primary environmental benefit of the proposed mass timber building in comparison to the pre-cast/steel alternative. Other environmentally important variables that were analyzed but showed minimal difference between the two building material types included:

- Air quality - Acidification Potential
- Air quality - HH Particulate
- Air quality - Smog Potential
- Water quality - Eutrophication Potential
- Ozone Depletion Potential
- Energy Efficiency - Total Primary Energy

Comparing the estimated social benefits to the estimated rent premium for mass timber buildings

The hypothetical building that was analyzed in this project will be owned by A1X Automation. This means that the owner will not be able to charge a rent premium to tenants to capitalize on the improved work environment supported by mass timber. However, numerous case studies (WoodWorks, 2022) have shown that mass timber buildings can charge a rent premium to tenants in rental agreements. As a result, in theory, the estimated social benefits being realized in the Building Use stage of Table 2 should be capturing some of the rationale for why a tenant would be interested in paying a rent premium. To test this hypothesis, we estimate the potential rent premium the building could generate over 30 years and we compare that to the social benefits estimated. The result is comparable and weighted in the direction we would expect: $1.5 million in rent premium vs. $1 million in estimated social benefits. The social benefits estimated only include those that were monetized, but we know there are other non-monetized benefits that if accounted for would increase the value from $1M to likely be closer to the estimated $1.5M in rent premium. This suggests that the rent premium is relatively well-priced based on the social benefits expected from the building compared to a concrete tilt-up building of the same size and function.

Table 3. Rent Premiums vs. Estimated Social Benefits

Average Rent Premium over 30 years (in present value, 3% discount rate)	Social Benefits estimated for building users over 30 years (in present value, 3% discount rate)
$1.5M	$1M

Rent premium estimation process:

As stated previously, the rent premium can be considered a proxy for the social value experienced by building occupants. The rent premium in the case of this analysis was estimated at $78,000 per year based on existing data points of various commercial structures showing rents at 5%-25% above market rate (WoodWorks case studies, 2022; WoodWorks, 2019). Assuming a $3 per sq ft per year rent premium as applicable to this light industrial building, and a 26,000 sq ft building, that would equate to $78,000 per year. This is a reasonable estimate of a company's willingness to pay for a better work environment supported by mass timber. Taken over 30 years, that results in $1.5M in present value.

Non-monetized Outcomes

As with any monetized outcome analysis, there are inherent challenges in capturing all potential benefits, often due to limited evidence or the intangible nature of certain outcomes. These unaccounted for impacts are referred to as non-monetized outcomes. It is crucial to recognize that when data limitations prevent the monetization of specific outcomes, significant value may remain unrepresented in the estimates provided. Consequently, the figures in this analysis are intentionally conservative and serve as a baseline onto which additional non-monetized outcomes can be incorporated. The reasons for being unable to monetize certain outcomes include:

1. **Intangible and Non-Monetary Benefits:**
   Many benefits are intangible and non-monetary in nature. These can include things like enhanced community cohesion, increased civic engagement, increased confidence, etc. Assigning a monetary value to such intangible benefits is often subjective and challenging.

2. **Externalities and Spillover Effects:**
   Policies or projects may generate externalities, both positive and negative, that extend beyond what is feasible to account for in the scope of the analysis due to time and budget constraints. Projects may also spur an unintended change in human behavior that leads to previously unforeseen ripple effects that may take years to realize and connect back to the project being analyzed.

3. **Subjectivity in Valuation:**
   The process of assigning monetary values to certain benefits involves a degree of subjectivity. This analysis uses market prices wherever possible to create a defensible valuation, however different stakeholders may have varying perceptions of the value of certain outcomes. For example, cultural and contextual factors can influence the perceived value of a benefit such as increased future earnings.

4. **Uncertainty and Risk:**
   Outcome monetization is conducted under conditions of uncertainty, and certain benefits may be associated with higher levels of uncertainty. Where the amount of uncertainty, even in case of strong evidence, grows to be too significant, it may be misleading to still assign a monetary value to the outcome.

5. **Data Limitations and Measurement Issues:**
   Data limitations are a constant obstacle in outcome monetization analyses that impede the scope and accuracy of benefits valued. In many cases, a topic may simply not have been rigorously studied yet to allow for it to be monetized.

Non-monetized Outcomes by Value Chain Stage

The following lists non-monetized outcomes by value chain. This is not an exhaustive list but it recognizes some of the most significant outcomes to the value proposition of mass timber using responsibly sourced wood.

1. Forest Phase

a. Income to landowners / wealth to Indigenous communities
b. Reduced wildfire risk
c. Educational impact to landowner and communities from community benefits of sustainability managed forests
d. Logger training for quality forest harvesting operations

2. Processing and Manufacturing Phase

a. Any benefits from the manufacturing of engineered wood products compared to concrete/steel (we developed estimates of the negative air and water costs of concrete production but LCA results suggest there is little net benefit of going with mass timber)
b. Revenue to sawmills

3. Construction Phase

a. Reduced impact on neighboring road traffic/congestion from faster construction
b. Reduced impact on local businesses from faster construction
c. Reduced impact on neighborhood aesthetics from faster construction
d. Reduced local air pollution from faster construction

4. End Use/ Operational Phase

a. Physical health of workers in the completed structure
b. Mental health of workers in the completed structure

5. Value Chain Wide

a. Diversity of workforce in the value chain including workforce development programming

In some cases, the non-monetized outcomes listed here may be partially accounted for in other monetized outcomes. For example, when considering social impacts such as the required logger training - that training is another means of supporting the $849k in benefits provided by the forest and ensuring that value is realized. At the same time, the SFI-required training and education likely expand just how well-managed forests are including uncertified forests, but saying for example, $15 in ecosystem services would not have been generated per acre without the logger training would be a stretch. In the future it would be great to understand how the logger's life changed as a result of the training - do they get paid more? Do they engage in more conservation activities? That part of things is where we run into data gaps that make it so we can't monetize the impacts from the logger training, but we can still say things like, for example, 'Based on Van de Wetering et al., (2022), environmental education such as logger training for sustainable forest management will likely lead the logger to take more conservation actions in the future than they otherwise would have'. It's hard to say what the value of those conservation actions might be, but it seems likely they will happen - so there is likely additional positive impact from logger trainings that is not accounted for in this analysis. This is one example of how non-monetized outcomes are not included in the total building benefit of $2.1 million, but they are still an important part of the story.

Key Performance Indicator Framework

An important part of this project was to provide quantifiable metrics for municipalities, communities and project owners to better understand the broader social (and economic) impacts of building with mass timber procured from responsibly managed forests, therefore increasing demand and expanding markets. This is important because effective monitoring and evaluation (M&E) are essential components to the longevity and robustness of any effort, as they provide the data and insights necessary to assess the performance, impact, and overall effectiveness. This is especially true in instances where the activities being undertaken have not been fully studied, as is the case with mass timber.

Ecotone has identified a series of indicators that will serve as useful benchmarks for better understanding a mass timber project's social and economic impact and help provide a greater sense of the ROI of mass timber going forward. Indicators in Table 4 are aligned with a stage of the value chain and outcomes previously identified in the logic model.

Table 4. Recommended Indicators to Build Mass Timber Value Proposition

Stage in Value Chain	Outcomes by Value Chain Stage	Indicator to Track per Building
Forest	Diversity of workforce	% of forest owners, forest managers, loggers, that are not white
	Earnings to workers in the mass timber value chain	Average income per worker
	Environmental education	# of children reached (by demographic); # of adults reached (by demographic)
	Size of workforce	# of FTEs engaged in managing and logging forest (per 100 acres)
	Acres of forest responsibly managed	# of acres harvested to supply the wood needed for the mass timber components
	Volume of wood harvested for building	Board-feet of wood harvest
	Age of forest harvested	Average age of trees harvested
Sawmills/ Processors	Size of workforce	# of FTEs engaged (per million board-feet)
	Earnings to workers in the mass timber value chain	Average income per worker
	Change in board-feet outputted	Board-feet processed per year

Stage in Value Chain	Outcomes by Value Chain Stage	Indicator to Track per Building
Mass Timber Manufacturers	Earnings to workers in the mass timber value chain	Average income per worker
	Size of workforce	# of FTEs engaged in building mass timber products
	Volume of wood used for building	Board-feet of wood in final product
Construction	Worker safety	# and % reduction in on site accidents experienced by contractors
	Earnings to workers in the mass timber value chain	Average income per worker
	Time to complete mass timber structure	# of days
	Size of workforce	# of FTEs engaged in constructing building
	Time to complete concrete/steel structure of the same size	# of days and % change in speed to complete structure
	Reduced noise pollution	# of noise nuisances reported
	Reduced access to nearby businesses	# of businesses impacted by construction

Stage in Value Chain	Outcomes by Value Chain Stage	Indicator to Track per Building
Building Use	Employee productivity	Output (revenue) per worker (on average) measured each year
	Employee absenteeism	# of days missed per worker per year
	Size of workforce	# of FTEs working in the completed structure
	Rental rate (if applicable)	$ per sq ft per year above market rate
	Employee retention rate	% of employees that leave each year
	Operational energy use	KWh used per year
Economy	Greater local economic activity relative to location of build site	% of materials sourced from within 250 miles
	Labor income to local economy	% of spend going towards labor income
	Reduced lifecycle carbon emissions	% change in embodied carbon when compared to concrete/steel building

Outcomes Deserving Future Study

In addition to the recommended indicators to track, there are other outcomes that would be more difficult to track and require a designated analysis. Having this data would significantly improve the ROI understanding of mass timber.

Table 5. Recommended Topics of Future Study to Build Mass Timber Value Proposition

Stage in Value Chain	Outcomes by Value Chain Phase
Forest	Wildfire risk
	Increased sense of respect for Indigenous rights and practices
	Wealth and/or well-being for Indigenous communities
Sawmills/Processors	Increased revenues
Mass Timber Manufacturers	Reduced energy use to generate engineered wood building materials compared to concrete
	Improved air and water quality vs. concrete production
Construction	Change in noise pollution
	Change in air and water pollution
	Reduced access to businesses and housing
	Change in traffic congestion
	Change in aesthetics (e.g. the eye sore of a construction site)
Building Use	Mental health of workers - satisfaction with work environment, reported stress levels
	Physical health of workers - blood pressure, air quality
Economy	Economic growth
	Economic diversification

Across these various topics deserving of future study is the overarching research need of a social lifecycle assessment

Environmental LCAs of mass timber buildings have become relatively commonplace, however social LCAs seem to be few and far between and if they have been conducted they tend to have a very limited scope i.e. look only at the social benefits of the end users of the building, such as biophilia related benefits.

It is recommended that a social LCA be conducted that would cover the full value chain of the mass timber building and include a comparison against a concrete-tilt up (in the case of light industrial building analysis). This would entail reviewing the social and local economic implications at each stage of the value chain, noting changes in labor distribution, labor force size, income levels, demographics, health, safety, etc.

Impact Communication

As with any impact analysis, effective communication of the results is essential to the usefulness of the analysis. The following section details alignment with a major framework - the United Nations' Sustainable Development Goals - as well as identifies key talking points from the analysis that align with specific stakeholder groups: Architects, Engineers, and Contractors; Local and State Governments; and Building Owners.

Communicate the Relevant Sustainable Development Goals

This analysis aligns with several of the United Nations' Sustainable Development Goals (SDGs), highlighting how mass timber construction using responsibly sourced wood can contribute to a more sustainable future. The SDGs are global goals that are readily recognized by governments, policymakers, and potential funders and can serve to quickly highlight the types of impacts that can be generated. Here are the most relevant SDGs:

SDG 3: Good Health and Well-being

The analysis emphasizes the positive impacts of biophilic design, particularly the use of exposed wood surfaces, on employee well-being in mass timber buildings. This connection supports the goal of promoting mental health and well-being.

SDG 8: Decent Work and Economic Growth

The analysis highlights the potential for mass timber construction to:

- Create jobs in forestry, manufacturing, and construction.
- Stimulate economic growth in rural communities.
- Support sustainable forest management practices.

SDG 9: Industry, Innovation and Infrastructure

The analysis positions mass timber as an innovative building material that can contribute to:

- Sustainable infrastructure development.
- The growth of a more sustainable construction industry.

SDG 11: Sustainable Cities and Communities

The analysis demonstrates how mass timber can help create more sustainable cities and communities through:

- Reduced noise pollution during construction.
- The use of responsibly sourced wood, supporting sustainable forest management.
- The creation of buildings that promote employee well-being.

SDG 12: Responsible Consumption and Production

The analysis advocates for the use of mass timber as a renewable and sustainable building material, supporting the shift towards responsible consumption and production patterns.

SDG 13: Climate Action

The analysis emphasizes the reduced global warming potential of mass timber compared to concrete. This finding directly supports the goal of taking urgent action to combat climate change.

SDG 15: Life on Land

The analysis highlights the importance of responsibly managed forests for sourcing the wood used in mass timber construction. This practice aligns with the goal of protecting, restoring, and promoting sustainable use of terrestrial ecosystems.

Key Analysis Talking Points

This in-depth analysis quantifies the social and economic value of constructing a hypothetical light industrial building with mass timber using wood procured from responsibly managed forests in comparison to a comparable building using concrete tilt-up.

Key talking points of the analysis include:

- Significant Social and Economic Benefits: Building with mass timber from responsibly managed forests, rather than concrete, can generate substantial social and economic benefits across the entire value chain, from forestry and manufacturing to building use and community well-being.
- Monetized Benefits Exceed $2 Million: The projected monetized social and economic benefits of the hypothetical light industrial mass timber building are estimated to be over $2.1 million over a 30-year period.
  - The largest benefits stem from:
    - Ecosystem services provided by responsibly managed forests (e.g., improved air and water quality).
    - Improved employee well-being resulting from working in a building with exposed wood surfaces (biophilic design).
  - Other monetized benefits included reduced employee absenteeism, increased employee retention, the value of attracting and retaining top talent, reduced energy use, and various benefits during the construction phase, such as increased worker safety and reduced noise pollution.
  - There continue to be limitations of monetizing all potential benefits. Several non-monetized outcomes, such as reduced wildfire risk, improved mental and physical health of workers, and economic growth, could not be quantified due to data limitations, but if accounted for would add to the already estimated $2.1 million in benefits.
- Key Performance Indicators for Industry: The analysis provides a framework of KPIs that can be used to track and measure the social and economic impact of mass timber projects. This framework offers practical metrics for municipalities, communities, and project owners to demonstrate the value of mass timber and encourage its wider adoption.
- Need for Further Research: There are numerous areas where future research is needed to strengthen the understanding and quantification of mass timber's benefits, including:
  - The long-term impact on wildfire risk
  - Social benefits for Indigenous communities
  - Development of a comprehensive Social Life Cycle Assessment framework

Audience-specific Talking Points

By tailoring the message to different stakeholders, mass timber and sustainable forestry advocates can effectively convey industry successes, its alignment with sustainable development goals, and its commitment to positive social change. By tailoring the communication approach to each stakeholder group, industry advocates can ensure the message is received, understood, and acted upon. Audience-specific talking points not only enhance the clarity and effectiveness of communication but also demonstrate a commitment to transparency, stakeholder engagement, and the responsible management of social impact.

Key Talking Points for Architects, Engineers, and Contractors

When communicating this analysis to architects, engineers, and contractors, focus on the tangible benefits of mass timber construction, when using wood from certified responsibly sources. Below are some talking points that can be emphasized:

- Mass timber offers a compelling value proposition beyond traditional financial metrics. While initial material costs might be higher, the economic, social, and environmental benefits, when monetized, reveal substantial returns.
- The construction process itself offers benefits. Mass timber construction is often faster than traditional methods, leading to benefits like reduced noise pollution and minimized disruption to surrounding businesses and traffic. Emphasize these advantages to clients concerned about the impact of construction on their operations and the surrounding community.
- The environmental benefits are significant. Using certified, responsibly sourced wood in mass timber construction leads to positive impacts on air and water quality due to increased forest cover. The reduced global warming potential of mass timber compared to concrete is another crucial advantage, supported by both literature and LCA results.
- Employee well-being is a major advantage of mass timber buildings. Studies show that working in spaces with biophilic design, particularly exposed wood surfaces, leads to improved employee well-being, resulting in reduced absenteeism and increased retention. These factors translate into tangible financial benefits for building owners, including higher productivity and reduced costs associated with employee turnover.
- Rent premiums are justified. The analysis suggests that the social benefits enjoyed by building occupants, particularly the positive impacts of biophilia, justify the rent premiums often associated with mass timber buildings. This information can be used to reassure clients about the financial viability of mass timber projects and their attractiveness to potential tenants.
- This analysis offers a framework for understanding and communicating the value of mass timber. The report's key performance indicators can be used to track and quantify the social and economic benefits of mass timber projects. This data can strengthen the case for mass timber with clients and provide a robust evidence base for decision-making.

Key Talking Points for Local and State Governments

When communicating this analysis to local and state governments, emphasize the broad societal benefits of mass timber construction and how these benefits align with policy goals. Here are key points to highlight:

Mass timber supports local economies and workforces. Using certified responsibly sourced wood from local forests can boost regional economic activity with the potential to:

- Create jobs in forestry, manufacturing, and construction.
- Increase demand for local timber, supporting sustainable forest management practices.
- Generate tax revenue and stimulate economic growth in rural communities.

Mass timber can advance environmental sustainability. Environmental advantages of using mass timber compared to conventional materials like concrete include:

- Reduced global warming potential. This point aligns with climate action goals and demonstrates the role of mass timber in reducing carbon emissions.

- Improved air and water quality. This is especially relevant for regions with concerns about air pollution or water resource management.
- Sustainable forest management. Certified responsibly sourced wood promotes healthy forests, which act as carbon sinks, protects biodiversity, and enhances ecosystem services.

Mass timber enhances community well-being. Explain how mass timber contributes to healthier and more vibrant communities:

- Biophilic design in buildings. Exposed wood surfaces have a positive effect on employee well-being, leading to increased productivity, reduced stress, and improved health outcomes.
- Safer construction sites. There are reduced accidents and improved worker safety during construction.
- Reduced effect on communities during construction. Faster construction timelines mean reduced effects on neighboring communities including reduced noise and air pollution, traffic congestion, effect on neighboring businesses, etc. This benefit can be particularly relevant in urban areas or near residential neighborhoods.

Mass timber messaging can also be tailored to specific policy initiatives:

- Economic development programs: Position mass timber as a driver of economic growth and job creation.
- Climate action plans: Showcase mass timber as a sustainable building material that helps reduce carbon emissions.
- Forest management policies: Explain how the demand for mass timber supports responsible forestry practices.
- Public procurement: Advocate for policies that encourage or require the use of mass timber in public buildings.

Key Talking Points for Building Owners

When communicating with building owners considering a mass timber building, highlight the financial and social benefits that go beyond traditional metrics, emphasizing how these benefits can translate into a positive return on investment. Here are key talking points:

- **Increased Employee Productivity and Retention:** Studies show that biophilic design, especially exposed wood surfaces, creates a healthier, more stimulating work environment. This can lead to:
  - Reduced absenteeism
  - Increased employee retention
  - Higher productivity levels
  - Attracting and retaining top talent

These benefits translate to cost savings and a more engaged, productive workforce.

- **Potential for Rent Premiums:** The market analysis suggests that tenants are willing to pay higher rents for mass timber buildings. This is likely driven by the perceived benefits of biophilic design and sustainability features. This premium can enhance the financial return on investment.

- **Faster Construction Time:** Mass timber components are often prefabricated off-site, allowing for quicker assembly on-site. This can result in:
  - Reduced construction costs
  - Faster occupancy and revenue generation
  - Reduced disruption to surrounding businesses.

- **Sustainability and Environmental Responsibility:** Mass timber construction aligns with increasing demand for sustainable building practices. Benefits include:
  - Reduced carbon footprint compared to concrete construction
  - Using a renewable resource from responsibly managed forests
  - Contributing to healthy forests, which act as carbon sinks and support biodiversity.
  - Additional publicity opportunities for the building.

These factors can enhance your brand reputation and attract environmentally conscious tenants.

- **Improved Building Aesthetics and Appeal:** Mass timber offers a unique aesthetic that can create a distinctive and attractive building. This can be a valuable asset for:
  - Attracting tenants
  - Increasing property value
  - Creating a positive image for your business.

Appendix A. Levels of Evidence and Bibliography

Ecotone's analysis is based on two types of data: 1) program data provided by the client; and 2) evidence from external literature. After analyzing all the program data, Ecotone undertakes a systematic review of evidence by reviewing external literature that aligns with the program's goals, services, and outcomes, relying on sources with higher levels of evidence of causal impact where possible.

The review process begins with a well-defined question, identifies relevant studies, assesses their quality, and uses a clear methodology to summarize the evidence (see next slide for details). Over 50 resources were reviewed for this analysis. However, not all of them provided figures that were directly incorporated into the monetized outcome estimations. Some resources were incorporated into the non-monetized outcomes evidence, providing support that an outcome is likely to be experienced, but may not be monetizable at this time. The five steps for conducting a review of evidence:

Step 1: Framing questions for a review
The problems that the review addresses are defined with clear, structured, and precise questions before starting the review process. Once these questions are established, any changes to the search should be permitted only if new ways of defining the populations, interventions, outcomes, or study designs emerge.

Step 2: Identifying relevant studies
The search for studies is thorough, utilizing a variety of sources and evidence repositories without restricting by language. The criteria for selecting studies aligns directly with the review questions (Step 1) and are established in advance.

Step 3: Evaluating study quality
Assessing study quality is essential at every stage of Ecotone's review. When formulating questions (Step 1) and setting selection criteria (Step 2), a minimum acceptable level of design is defined based on the particular topic being explored.

Step 4: Summarizing the evidence
Data synthesis involves creating a library of study characteristics, study quality, and effect sizes (as applicable).

Step 5: Interpreting the findings
Based on the appropriateness of the study, findings are reviewed for their level of evidence and the extent the findings can be linked to other studies (or if they run counter to other studies' findings). Potential publication bias and other related biases are examined.

Levels of evidence used
To assess the strength of a causal study, Ecotone uses 7 levels of evidence of causality to rank what approach a study used to estimate causality (see table on next slide). A stronger study uses a form of randomized controlled trials - RCTs - (such as what is used in drug trials) or a meta-analysis of RCTs. These use a randomized experimental approach to isolate a causal relationship and measure the scale of that relationship. Weaker levels of evidence do not use randomization but may still try to control various influencing factors to identify a causal relationship.

Wherever possible, Ecotone relies on studies that have a higher level of evidence of causality when making impact estimations. Other studies however can still be helpful to gain an understanding of what has been studied, where causality is suggestive but uncertain in scale, and if there are studies that find refuting evidence.

When Ecotone is reviewing resources for both causal and non-causal statements, other factors beyond just level of evidence are utilized to determine the reputability of the source. This includes credentials of the authors, whether a peer-review process took place, publishing institution and/ or funders of the analysis, acknowledgment of potentially differing results in other resources, and date of publication. If the resource is several years old or if there is a clear bias in figures shared for example, Ecotone will look for an alternative resource to use.

Levels of Evidence of Causality
1 is Highest, 7 is Lowest

1. Evidence from a systematic review or meta-analysis of all relevant RCTs (randomized controlled trial) or evidence-based clinical practice guidelines based on systematic reviews of RCTs or three or more RCTs of good quality that have similar results.

2. Evidence obtained from at least one well-designed RCT (e.g. large multi-site RCT).

3. Evidence obtained from well-designed controlled trials without randomization (i.e. quasi-experimental).

4. Evidence from well-designed case-control or cohort studies.

5. Evidence from systematic reviews of descriptive and qualitative studies (meta-synthesis).

6. Evidence from a single descriptive or qualitative study.

7. Evidence from the opinion of authorities and/or reports of expert committees.

N/A, Fact - Information provided in the source does not make causal claims. This includes statistics and other facts.

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Appendix B. Outcome Estimation Rate Cards

Each outcome is estimated initially over a given time frame based on what is included in the evidence base. Certain outcomes were estimated 'per year'. These outcomes are then projected over the assumed 30 year lifespan of the forest and/or building (depending on what the outcome refers to) to end up at the values shown in Table 2. Other outcomes are already estimated as 'lifetime' benefits, so there is no need to project them over multiple years.

SFI Certified Forest Management

Outcome: Increased forest cover supporting improved air quality and water quality

Projected Marginal Benefit: **$43,333**

Estimation Calculation: 130,000 * 0.000067 * $5,000

Time Frame: Per Year

Figure 1: 130,000
Type: Board-feet of wood per square foot of building

Notes: To summarize these assumptions, one square foot of a home requires 0.125 board feet of wood. One square foot of a mass timber building requires 5 board feet of wood. With a 26,000 square foot building, that would result in a rough estimate of 130,000 board feet.
Source: Russell, 2022.

Figure 2: 0.000067
Type: Acres per board-foot

Notes: Expect anyhere from 5,000 to 15,000 board-feet per acre (in PA example).
Source: https://extension.psu.edu/forest-finance-8-to-cut-or-not-cut-deciding-when-to-harvest-timber

Figure 3: $5,000
Type: Value per acre of well-managed forest

Notes: FEMA estimates the value of the average acre of forest that is protected from destruction and/or restored to be worth $12,589. This is disaggregated by aesthetic value (1477), air quality (711), climate regulation (199), erosion control (1672), existence value (7531), flood and storm hazard reduction (368), recreation (94), water filtration (435), water supply (103). If we removee the existence value of the average acre of forest to isolate the ecosystem services and directly experienced envirnmental attributes, the reuslting value per acre is about: $5058
Source: FEMA, June 2022. FEMA Ecosystem Service Value Updates.

Construction

Outcome: Reduced Global Warming Potential of mass timber compared to concrete - Literature based estimate

Projected Marginal Benefit: **$132,538**
Estimation Calculation: 2600 * 0.216 * $236

Time Frame: Lifetime

Figure 1: 2600
Type: Size of building

Notes: At 26,000 square feet for the planned A1X building that equates to about 2,600 square meters

Figure 2: 0.216
Type: CO2e emission savings per square meter of mass timber building

Notes: Based on 18 comparisons across four continents, we found that substituting conventional building materials for mass timber reduces construction phase emissions by 69%, an average reduction of 216 kgCO2e/m2 of floor area. Studies included in our analysis were unanimous in showing emissions reductions when building with mass timber compared to conventional materials. Scaling-up low-carbon construction, assuming mass timber is substituted for conventional building materials in half of expected new urban construction, could provide as much as 9% of global emissions reduction needed to meet 2030 targets for keeping global warming below 1.5 °C.

At 26,000 square feet for the planned A1X building (over 2,600 square meters), the resulting average CO2e savings from the construction phase equates to about 561.6 metric tonnes of CO2e avoided.

Source: Himes, A., & Busby, G. (2020). Wood buildings as a climate solution. Developments in the Built Environment, 4, 100030.

Figure 3: $236
Type: Social Cost of Carbon

Notes: International Foundation on Valuing Impacts (IFVI) uses a cost of carbon of $236 / tonne

Source: International Foundation on Valuing Impacts, 2024

Additional Notes:

“Timber is a more sustainable material and the use of 17% of timber in construction as an alternative to brick, aluminium, steel and concrete, can reduce GHG emissions by about 20% [10,11]. Traditional construction materials such as concrete, cement and steel account for higher embodied GHG emissions (39-44%) in Australia, whilst timber contributes only 9.3% [12, 13] of life cycle GHG emissions. Further, Ximenes and Grant [14] reported that use of timber in structural floor systems could reduce GHG emissions by 31-56% compared to that of concrete slabs.”

https://www.sciencedirect.com/science/article/abs/pii/S0378778819336734

Construction

Outcome: Reduced Global Warming Potential of mass timber compared to concrete - Athena LCA

Projected Marginal Benefit: **$107,706**
Estimation Calculation: 456.38 * $236

Time Frame: Lifetime

Figure 1: 456.38
Type: Global Warming Potential difference between mass timber and pre-cast concrete/steel
Notes:

	Timber	Pre-cast Concrete/Steel	Difference
Global Warming Potential (kg)	5,678,032.01	6,134,414.25	(456,382.24)
Global Warming Potential (tonnes)	5,678.03	6,134.41	(456.38)

Source: LCA results from LHB Architects using Athena

Figure 2: $236
Type: Social Cost of Carbon
Notes: International Foundation on Valuing Impacts (IFVI) uses a cost of carbon of $236 / tonne
Source: International Foundation on Valuing Impacts, 2024

Construction

Outcome: Noise pollution from construction

Projected Marginal Benefit: **$6,075**
Estimation Calculation: 25 * $243

Time Frame: One Time Benefit

Figure 1: 25
Type: Number of neighboring households affected

Notes: We assume there are 25 households experiencing the most severe noise pollution from construction.

Source: Ecotone assumption

Figure 2: $243
Type: Cost of several noise pollution from construction

Notes: Weinhold (2013) estimated the cost of severe noise pollution on household happiness to be valued at 172 euros per month in 2011. This equates to 229 euros in 2024 or about $243 USD in 2024.

Since Mass timber structures can be put up 25% faster on average than the concrete/steel alternative, that is likely to translate into at least one month of avoided construction noise.

Source: Weinhold, D. (2012). THE HAPPINESS-REDUCING COSTS OF NOISE POLLUTION*. Journal of Regional Science, 53(2), 292–303. doi:10.1111/jors.12001

Construction

Outcome: Increased worker safety from more construction in a facility

Projected Marginal Benefit: **$4,100**
Estimation Calculation: 10 * $410

Time Frame: Lifetime

Figure 1: 10
Type: Number of workers on site
Notes: Hypothetical: If there are 10 workers on site to construct the mass timber structure, this is half as many as would otherwise have been on site.
Source: Ecotone assumption

Figure 2: $410
Type: Avoided cost of injury on job site
Notes: The average cost per case of fatal or nonfatal injury is $27,000 in construction (Waerher et al., 2007). In 2024 dollars that amounts to about $41,000 per injury on average. In a study of 100 mass timber buildings in the United Kingdom, Waugh Thistleton Architects found a 50 percent to 70 percent reduction in site staff for structural framing. In a factory setting, there is a dramatic reduction of the hazards experienced on a construction site. Worker safety is improved, and the likelihood of accidents decreases by about half. According to research from University of Utah, “By moving to prefabrication, the construction industry and its workers can experience a much safer environment by a factor of 2. Every year, 1 in 100 construction workers gets injured severely enough to need time off work. Estimated $410 in avoided injury costs on average per worker on site
Source: Waerher et al., 2007; Waugh Thistleton Architects; Clark, 2024

Building Use

Outcome: Reduced energy use for non-industrial machinery - HVAC, hot water, lighting

Projected Marginal Benefit: **$1,580**
Estimation Calculation: 585,000 * 0.1 * $0.027

Time Frame: Per Year

Figure 1: 585,000
Type: Energy use

Notes: The Department of Energy pegs that a commercial building consumes an average of 22.5 kilowatt-hours (KWh) per square foot of floor space. At 26,000 sq ft, the A1X Automation building would use approximately 585,000 KWh per year for its basic operations, excluding machinery specific energy use.

Source: https://blog.budderfly.com/building-energy-consumption

Figure 2: 0.1
Type: Energy savings from mass timber

Notes: According to Chen (2012), mass timber buildings have 10% lower operational energy demands compared to a similar concrete building.

Source: https://www.sciencedirect.com/science/article/pii/S2666790820300070

Figure 3: $0.027
Type: Social costs of energy use in the Midwest US

Notes: 2.7 cents per kwh (in 2019 $) is the health cost savings at 3% discount rate from energy efficiency upgrades in the Midwest US

Source: https://www.epa.gov/statelocalenergy/estimating-health-benefits-kilowatt-hour-energy-efficiency-and-renewable-energy

Building Use

Outcome: Reduced employee absenteeism

Projected Marginal Benefit: **$2,760**
Estimation Calculation: 23 * 0.1 * 0.024 * $50,000

Time Frame: Per Year

Figure 1: 23
Type: Number of workers expected in completed building
Notes: 23 workers expected at the new building

Figure 2: 0.1
Type: Reduced absenteeism from biophilia
Notes: The “Economics of Biophilia” states: “The main causes for deficient productivity include absenteeism, loss of focus, negative mood, and poor health. The built environment, though not always the cause of these stressors, when well-designed, can be a reliever of these undesirable symptoms.” It adds, “10% of employee absences can be attributed to architecture with no connection to nature.”
Source: Anderson et al.,. 2020

Figure 3: 0.024
Type: Rate of absenteeism
Notes: The average absenteeism rate for full-time employees in the manufacturing industry is 2.4%.
Source: https://www.teamsense.com/blog/absenteeism-workplace-statistics

Figure 4: $50,000
Type: Average salary
Notes: Conservatively assuming $50,000 salary for production workers at A1X
Source: Ecotone Assumption

Building Use

Outcome: Value of employee retention

Projected Marginal Benefit: **$11,500**
Estimation Calculation: 23 * 0.1 * 0.2 * $25,000

Time Frame: Per Year

Figure 1: 23
Type: Number of workers expected in completed building
Notes: 23 workers expected at the new building

Figure 2: 0.1
Type: Average turnover rate
Notes: According to available data, the average turnover rate for engineers tends to be higher than production workers, with engineers experiencing a turnover rate around 11.5% to 22%, while production workers might see a lower rate depending on the industry, often around 20% or less; however, both roles can have significant turnover depending on the specific company and market conditions

Figure 3: 0.2
Type: Reduced turnover from biophilia
Notes: Anecdotally, Green Office Solutions noted that a tech company in NY saw a 25% decrease in employees leaving after introducing biophilic features. We will conservatively assign a 20% reduction in employee turnover thanks to the mass timber and exposed wood surfaces.
Source: Ryan et al., 2023

Figure 4: $25,000
Type: Cost of losing an employee
Notes: Cost of losing an employee (assume: $33/ hr): $ 1,000 termination $ 9,000 replacement $15,875 lost productivity $25,875 total.
Source: Ryan et al., 2023

Building Use

Outcome: Value of attracting and retaining top talent

Projected Marginal Benefit: **$4,000**
Estimation Calculation: 0.1 * 0.2 * $200,000

Time Frame: Per Year

Figure 1: 0.1
Type: Average turnover rate

Notes: According to available data, the average turnover rate for engineers tends to be higher than production workers, with engineers experiencing a turnover rate around 11.5% to 22%, while production workers might see a lower rate depending on the industry, often around 20% or less; however, both roles can have significant turnover depending on the specific company and market conditions

Figure 2: 0.2
Type: Reduced turnover from biophilia

Notes: Anecdotally, Green Office Solutions noted that a tech company in NY saw a 25% decrease in employees leaving after introducing biophilic features. We will conservatively assign a 20% reduction in employee turnover thanks to the mass timber and exposed wood surfaces.

Source: Ryan et al., 2023

Figure 3: $200,000
Type: Cost of losing high productivity employees

Notes: Superior talent is up to 8x more productive. If we assume 1 of the 23 employees is very productive, the cost of losing that employee is going to be about 8x greater than that of other employees.

Source: https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/attracting-and-retaining-the-right-talent#/

Building Use

Outcome: Improved employee well-being

Projected Marginal Benefit: **$37,375**
Estimation Calculation: 23 * 0.033 * $50,000

Time Frame: Per Year

Figure 1: 23
Type: Number of workers expected in completed building
Notes: 23 workers expected at the new building

Figure 2: 0.033
Type: Improved employee well-being from biophilia
Notes: With studies demonstrating that biophilic design can improve employee health and wellbeing by 13% and productivity by 8% [1], and that timber surfaces provide stress-reducing effects [2], Dunn notes that it is no wonder occupiers are seeking greener offices from investors and landlords. If we assume because workers spend 1/4 of their time at their job, that means the 13% increase in wellbeing is experienced while at work and there is no increase in well-being for the other 3/4 of their time. This is to make the estimate more conservative and not assume wellbeing is boosted throughout all aspects of the person's life - of course though there will be some spillover benefits given a good work experience can mean better mental health outside of work. This is an area deserving future research.
Source: Pollinate Health Report, 2018

Figure 3: $50,000
Type: Value of well-being
Notes: If we assume that the multi-dimensional measure of well-being can be valued similar to QALY, then there is at least $50000 in annual value that is on the line for workers.
Source: Neumann et al, 2014

Appendix C: Glossary

Common Terms in the Ecotone Analysis:

Baseline: The initial set of data collected at the start of a program to establish a reference point for comparison. It represents the conditions, characteristics, or status of participants or communities before any intervention, allowing evaluators to measure changes over time and assess program impact.

Discount Rate: The annual rate of reduction of the value of outcomes accrued in the future, designed to account for uncertainty and the time value of money when calculating a present value.

Effect Size: The change in the likelihood of a cost occurring given the program

Estimated Return: Present value of all monetized outcomes.

External Data: Data not gathered by and/or studies not conducted by the program being analyzed.

External Validity: The extent to which results of a given study are applicable across other contexts.

Evidence Based: An approach to the program's work which is designed based on existing research and applications.

Evidence Informed: An approach to program's work which is designed with the knowledge and influence of existing research.

Impact: The change in outcomes derived exclusively from the given program.

Internal Data: Data gathered by the program itself.

Internal Validity: The extent to which results of a given study are only applicable to the context of that study.

Intermediate Outcome: The change resulting from the short-term outcome.

Levels of Evidence of Causality: Level 1 = greatest level of evidence that there is a causal relationship between the variables, Level 7 = lowest level of evidence that there is a causal relationship between the variables.

Logic Model: The planned methodology for accomplishing the desired change(s).

Long-term Outcome: The change resulting from the intermediate outcome.

Marginal Cost: The effect size * the outcome cost. The average change in cost accrued.

Monetized Outcome: An outcome which has been linked to a cost occurring event, thereby placing a dollar value on the outcome.

Net Present Value (NPV): The aggregation of benefits and costs valued in the present day given an assumed time period and discount (interest) rate

Non-monetized Outcome: The change which is not or could not be linked, due to data quality, to a cost occurring event, thereby keeping the outcome from having a dollar value placed on it.

Outcome: The resulting change occurring from the program's inputs and activities.

Outcome Cost: The total cost of an event occurring.

Output: The product from the inputs and activities of the program (e.g. number of people served).

Present Value (PV): A single annuitized benefit or cost (depending on the outcome) valued in the present day given an assumed time period and discount rate.

Short-term outcome: The initial change generated from the program.

Social Value: the quantification of the relative importance that people place on the changes they experience in their lives.

Trumping Rules: Selecting certain outcomes over others when they are interlinked to avoid double counting.