Sierra Institute for Community and Environment

2021

MASS TIMBER AND OTHER INNOVATIVE WOOD PRODUCTS IN CALIFORNIA:

A STUDY OF BARRIERS AND POTENTIAL SOLUTIONS TO GROW THE STATE'S SUSTAINABLE WOOD PRODUCTS SECTOR

FULL 7(f)

MASS TIMBER AND OTHER INNOVATIVE WOOD PRODUCTS IN CALIFORNIA:

A STUDY OF BARRIERS AND POTENTIAL SOLUTIONS TO GROW THE STATE'S SUSTAINABLE WOOD PRODUCTS SECTOR

AUTHORS:

Lauren Redmore, Sierra Institute for Community and Environment
Steve Marshall, Mass Timber Strategy
Jonathan Kusel, Sierra Institute for Community and Environment
Daniel Kunches, Sierra Institute for Community and Environment
Roy Anderson, The BECK Group
Zoe Watson, Sierra Institute for Community and Environment
Addie Wright, Sierra Institute for Community and Environment

ADVISORY COMMITTEE MEMBERS:

Heather Strong, Woodworks
Scott Leavengood, Oregon State University
Tim Robards, CalFire
Daniel L. Sanchez, University of California-Berkeley
Lindsay Hanna, Forterra

GRANT MANAGER:

Katie Harrell, Board of Forestry and Joint Institute for Wood Products Innovation

REPORT DESIGN: **Chris Oldroyd**

THE BECK GROUP

MTS
Mass Timber Strategy

Executive Summary

This report responds to Request for Proposals (RFP) 9CA04945 California Barriers to Mass Timber and Other Innovative Forest Products. In 2019, the California Forest Practice Act was amended through legislation to include Assembly Bill 2518, Innovative Forest Products and Mass Timber. Implementation of AB 2518 called for a report to identify barriers and recommend solutions to develop in-state production of mass timber and other innovative forest products. The RFP also called for identification of mass timber workforce training and job creation consistent with California's climate objectives on forest lands.

This report examines various barriers and solutions to help grow the state's mass timber and other innovative wood products sector. As states across the West, including California grapple with the implications of overstocked forests threatened by catastrophic wildfire, governments and others view mass timber manufacturing as one high value product that can incentivize forest restoration. As of this writing, there are no mass timber manufacturers in the state, though this research revealed that California is already a leader in the design and utilization of mass timber in projects. California has two-thirds more projects in the design and construction phase and completed than the next leading state.

Near-term recommendations

- **Identify a state agency or external body to take responsibility to link and advance mass timber sector activities to ensure that coordinated actions result from investments;**
- **Launch a California wood innovations program and develop long-term funding to tip the scales for both manufacturers and design/construction teams interested in experimentation and innovation in mass timber and wood products manufacturing and utilization; and**
- **Create opportunities for entrepreneurship to grow and act through community-scale wood products manufacturing, including through long-term support to wood product campus investments to advance wood utilization and to revitalize rural communities**

Long-term recommendations

- **Identify and invest in a university body or bodies to carry out research and development in the mass timber and wood utilization sector. Strategic investments can advance research on mass timber that propels the state into a leadership role nationally, for example advancing the understanding of mass timber's role in climate change, psychological and social well-being, and health, among other areas;**
- **Develop and invest in technology and tools to create market opportunities for mass timber and other wood products using materials from fuels reduction projects in high hazard forests used in mass timber construction. These include: harvest and sawmilling technology, chain-of-custody tracing, among others; and**
- **Integrate and incentivize the use of mass timber as a key development strategy to harden wildfire-risk communities in both urban and rural areas, including through overbuilds, retrofits, and new developments.**

Highlights from findings include:

- California's appetite for mass timber is driving growth in the sector nation-wide;
- Growing demand for the technology will be met with increased supply in mass timber panels, meaning more manufacturers will come on board with time. Some will locate in California in order to be close to the market;
- The mass timber sector requires a diverse ecosystem of mass timber-adjacent businesses, including fabrication, hardware and connectors, and design and construction, among others;
- Leveraging extensive federal landownership coupled with long-term supply guarantees across the state's woodbasket can offer opportunities to industrial manufacturers to advance mass timber manufacturing;
- Inadequate sawmilling capacity across the state and the lack of local markets for mill residuals and other low value wood fiber reduce the ability for forestry businesses across teh state to compete nationally and internationally and if not addressed will likely limit in-state production of mass timber;
- Mass timber manufacturing brings opportunities to reinvest in rural areas and the forestry sector, though explicit focus on smaller-scale businesses and improved technologies can ensure wood products manufacturing is supporting forest management objectives for fuels reduction;
- Prefabricated and modular housing developments offer significant time savings and a pathway to close the gap on affordable housing needs in both rural and urban contexts. Government support can incentivize the use of mass timber in these projects by alleviating materials costs and experimentation in the design and build sector;
- Perceived workforce shortages are a product of complex and interconnected challenges facing much of the rural workforce that must be addressed by considering job quality, family supporting wages, mobility within the sector, and general infrastructure development;
- There are many examples of policy levers from around the world that California can draw from to ensure that the mass timber sector is meeting climate change, forest management, and equitable development goals.

Key Recommendations

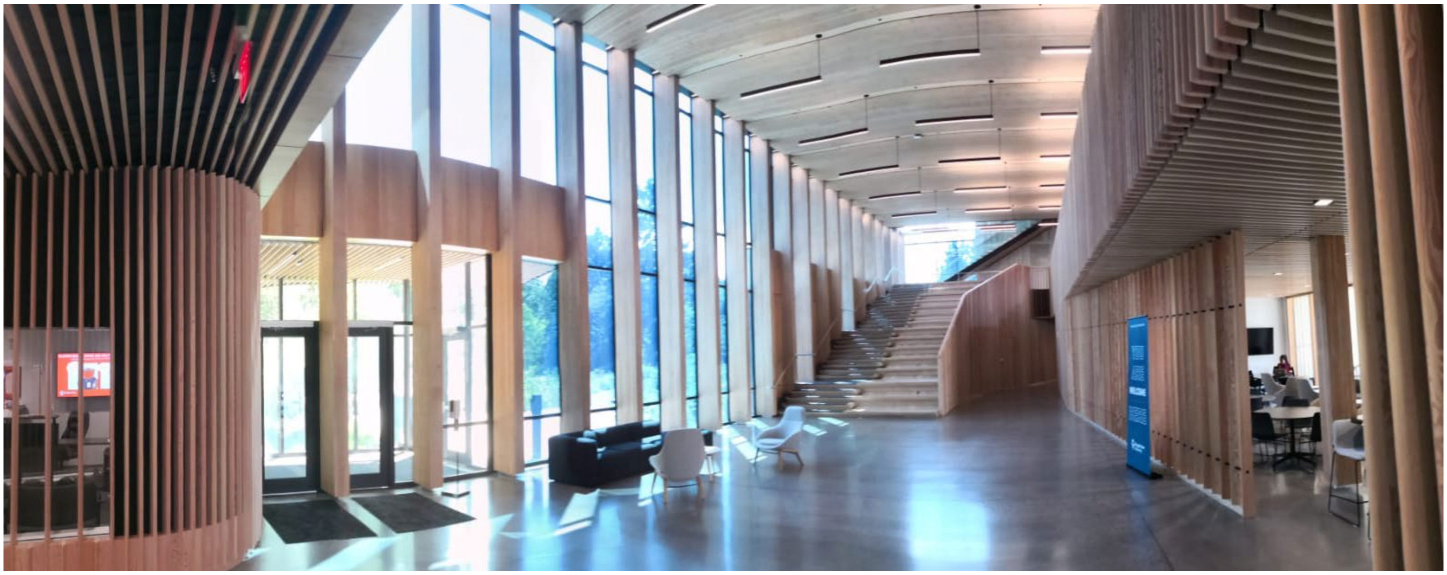
- Recommendations offered in this report are guided by the charge of the state given to Sierra Institute for Community and Environment to recommend actions California can take to grow the sector, with a specific focus on forest restoration, carbon management and climate change, and rural and urban development. Recommendations presented in this Executive Summary are priority actions that can put California on track to being a mass timber leader. Additional recommendations are found at the start of each chapter. Near-term recommendations are achievable in the next three years, while long-term recommendations are made with the intent that steps should be put into action now so that actions can be realized in three or more years.

Table of Contents

Table of Tables:

Table of Figures

INTRODUCTION



Oregon State University Peavy Hall mass timber building

Mass timber is an engineered wood product, usually comprised of layers of wood fixed together with adhesives or mechanical joiners. Frequently referred to by the popular term "cross-laminated timber," or the shorthand "CLT," there are many different types of non-CLT mass timber products made not only by gluing but by mechanically fastening (using dowels or nails, for example) to connect layers of wood together. When layers of wood are joined together, one layer perpendicular to adjoining layers, strength is multiplied, enabling developers to use wood for structural building components, roads, elevator shafts, and more.

Mass timber is also a technology that allows for quicker build time compared to conventional building construction, reduced construction labor costs, reduced waste, and more predictable building products. Wood can store carbon for long periods of time and increasingly, forests and wood products are seen as a part of the climate solution for the building sector that in recent years has contributed significant carbon to the atmosphere. As forest managers, government representatives, and others seek a more climate resilient future, there is growing interest in the mass timber sector from innovators and leaders across the country and in California. Mass timber offers a unique opportunity to capture more economic value from forest health-related projects and can revitalize the forest products industry, with the potential for breathing life into depressed rural economies and changing the nature of the construction sector.

California is in the midst of a dynamic moment for mass timber. Despite the lack of a single mass timber production facility in the state, California is currently leading the pack in new mass timber developments, a trend that is likely to continue as the technology sector seeks more sustainable development and recognition of mass wood capabilities are understood. Increasing demand for the technology and innovation in the build and design community have both been instrumental in growing the mass timber sector, though barriers remain to California-based companies seeking to use the technology. Although mass timber holds promise to bring innovation to the forestry sector to benefit both forest stewardship and rural communities, it remains to be seen whether and how mass timber can help the state meet multiple objectives for rural and urban development, forest management, and carbon neutrality. Guided development and incentives will likely be critical to spur mass wood development that jointly addresses these objectives.

California is experiencing considerable peril and threat to its forests and watersheds. In 2020, the state experienced the worst wildfire year in recorded history, with 2021 shaping up to be even worse. Roughly 10,000

New saplings growing following a stand replacing fire

An overstocked forest post-fire

fires burned over 4.2 million acres in 2020, including the August Complex fire, the first ever "gigafire" that exceeded one million acres.[1] The Dixie Fire of 2021 stopped just shy of close to becoming the second gigafire. A combination of drought and exceptionally dry conditions, climate change and increased temperatures extending the fire season, extermination and removal of indigenous people and their use of cultural burning to reduce fuel loads, the more recent legacy of fire suppression, and decades of reduction in forest management capacity have led to overly dense forests and trees that are more susceptible to disease and insect outbreaks. Through the removal of select small, unhealthy trees and the use of prescribed fire and cultural burning, forest managers can reduce the risk of large wildfires, while also reducing air pollution, sequestering more carbon, and improving water quality and retention.[2]

Mass timber product development and utilization offer a potent opportunity to increase use of timber in the state, including smaller diameter material that is currently limited by technological and economic imperatives, essential for increasing forest health and reducing the risks of catastrophic wildfire. California's early adoption of the 2021 International Building Code, which went into effect in July of 2021, now allows for the development of mass timber buildings up to 18 stories tall, opening up markets across urban centers. Given the numerous mass timber projects in development around the state and the growing scope of those projects, the future of mass timber is, in many ways, found in California.[3]

However, despite California's appetite for mass timber, mass timber is exclusively imported, similar to California's importation of the vast majority of its lumber and engineered wood products. Relying on mass timer production to change forest management is unrealistic, but if users demand mass panels to be 'California grown' or contribute to forest health improvement in California, given the growth trajectory for mass timber in the state, a mass timber industry might will prove to be an important pathway to improved forest resilience. Advancing in-state mass timber manufacturing offers the opportunity to simultaneously address forest health challenges and capture economic development through the manufacturing sector, as well as help California reach its 2045 carbon neutral goal.

1 https://www.fire.ca.gov/incidents/2020/

2 Stephens, S. L., Westerling, A. L., Hurteau, M. D., Peery, M. Z., Schultz, C. A., & Thompson, S. (2020). Fire and climate change: Conserving seasonally dry forests is still possible. Frontiers in Ecology and the Environment, 18(6), 354-360.

3 Carpenter, A., & Knize, S. (2021). California catches up on mass timber. Linkedin post.

This report was developed in response to a call from the Department of Forestry and Fire Protection (RFP 9CA04945) that is based on Assembly Bill 2518 introduced by Assembly Member Aguiar-Curry and adopted in regulation after its passage. In response to the RFP, the purpose of this report is to:

1) Identify barriers to in-state production of mass timber and other innovative forest products, including the raw material for mass timber and smaller trees as part of innovative forest products that can advance effective fuels treatments and resilient forests;

2) Identify barriers to innovative forest product and mass timber workforce training and job creation; and

3) Develop solutions to the barriers above that are consistent with sustainable forestry and the state's climate objectives on forest lands.

The content of this report is informed by an extensive literature review, first-hand experience working in the sector, participation Mass Timber Conferences held in Portland and the virtual 2021 conference, and other regional or state-focused forest product and workforce-development related workshops and seminars. Additionally, this report was informed by interviews with 75 key stakeholders representing a range of experts in the field, from mass timber manufacturers and fabricators, equipment manufacturers, researchers and community college program coordinators, government representatives, contractors and developers, non-profits, among others, conducted from October 2020 through August 2021. These experts were identified based on their experience working on various aspects of mass timber and other wood product manufacturing. Interviews focused on identifying and exploring key constraints and opportunities for the market, workforce development, and the development of other innovative wood product markets. Data from these interviews were used to identify key barriers and potential solutions, and to fill in gaps in knowledge.

Following the introduction, this report is organized into six chapters, each beginning with actionable recommendations identified in the research process and highlights summarizing each chapter's content. The first chapter explores trends in forest products industry in California, and examines how different mass timber models of production and technologies might influence the future market in the state. The second chapter focuses on the advantages and challenges to building with mass timber, including how mass timber can help the state meet goals related to climate change and development. The third chapter examines persistent barriers facing the growth of a mass timber sector. The fourth chapter explores how different types of policy tools have been used by other states and regions to grow a green building sector, and can be used as examples for strategies the state can pursue to target growth of a sustainable forestry and wood products manufacturing sector that meets the needs of today and the goals for the future. The fifth chapter focuses on challenges and opportunities facing the development of a forestry workforce, and the final chapter focuses on innovative wood products that can be manufactured at a community-scale to address goals of rural development, product development, and forest health.

CHAPTER 1

WHAT IS MASS TIMBER AND WHAT OPPORTUNITIES ARE THERE TO GROW THE SECTOR IN CALIFORNIA?

Recommendations

- **The state should identify incentives to support sawmills capable of processing smaller diameter roundwood to ensure there is adequate infrastructure to support sustainable forests, especially facilities scaled to localized wood baskets;**
- **Multiple mass timber technologies and production models are promising for California, and the state should consider incentives that target a diverse mass timber ecosystem, spanning types of mass timber technologies, as well as scale and production models of businesses; and**
- **The state can make less costly investments into lower barrier-to-entry opportunities, especially community-scale mass timber panel manufacturing and secondary manufacturing. The development of lower-cost operations signals that the state has the necessary know-how, and can serve as a recruitment strategy for the attraction and retention of more mass timber operations.**

Highlights

- **California demand for mass timber is two-thirds larger than the next largest state;**
- **Given increasing demand, in part driven by the state's efforts to remove barriers, location of mass timber manufacturing facilities in the state is a very viable near-term goal;**
- **Sawmilling and other residuals infrastructure has consolidated or disappeared from the state in the past thirty years, presenting a challenge to process timber and smaller-diameter material harvested in forest health treatments for its highest value;**
- **Diverse mass timber technologies and operations exist with varying entry costs: larger scale panel manufacturing requires tens of millions of dollars; computer numeric control machinery used for specialized cutting and preparation of mass panels can be launched for roughly two million dollars, and community scale mass timber panel manufacturing has entry costs at roughly half the cost of computer numeric control machinery; and**
- **Mass timber technologies offer important business recruitment and employment opportunities to revitalize and restore rural, forested communities.**

1 The changing nature of California's forest products industry

The forest products industry has been affected by multiple overlapping economic and environmental factors. A prime example of this is 2020, which proved to be an unprecedented year for the forest products industry across the nation. The COVID pandemic initially caused the prices of most building materials (e.g., lumber, plywood, etc.) to fall when society went into lockdown. Most forest products manufacturers responded by curtailing their operations, keeping workers at home to prevent further spread of an unknown virus. However, by late spring of 2020 many homeowners in the U.S. found themselves spending much more time at home, and many decided to use the time to upgrade and improve their homes through rebuilding and remodeling projects. This spurred demand for building products at precisely the time many manufacturers had curtailed operations. When demand began to build, many manufacturers were unable to increase production sufficiently because COVID-related issues prevented them from finding needed labor to operate their plants at higher levels of production.[1]

Stacked poles after debarking and processing

By May of 2021, lumber prices in the U.S. skyrocketed to over $1,500 per thousand board feet before returning closer to long-term historical average prices at roughly $550 per thousand board feet by late August.[2] In the last couple of years there has been a beetle epidemic across Central Europe that killed vast areas of forests and spurred extensive salvage efforts.[3] As a result, log supply exceeded demand and European lumber prices dropped relative to lumber prices in North America.[4] In fact, this price difference led sellers of mass panels in the U.S. to rely on European mass panel imports due not only to European panel manufacturing capability and capacity but because panels were cheaper due to lower-priced European lumber.

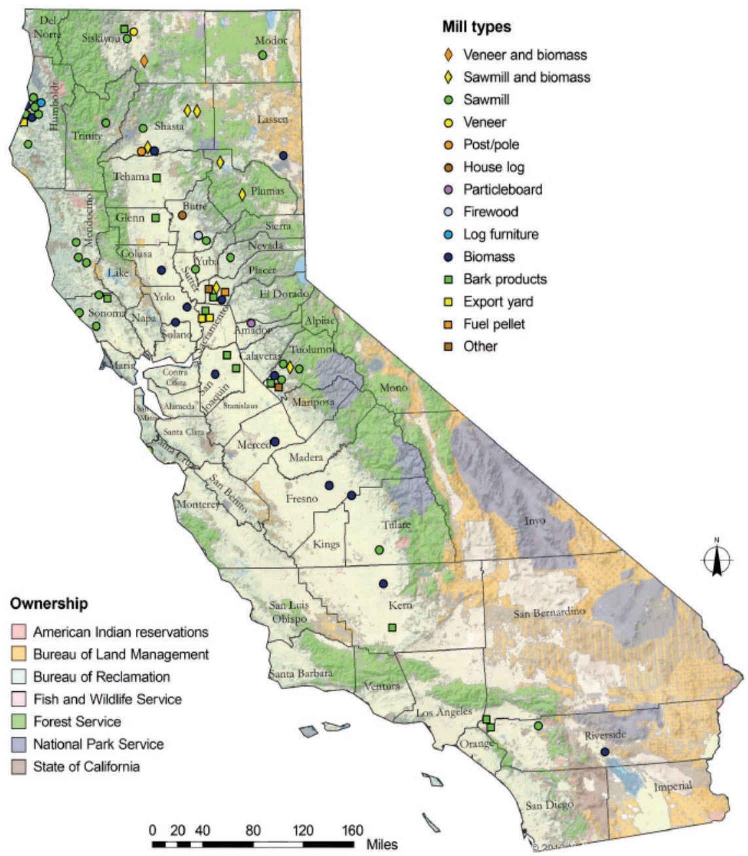
Mass timber is a secondary wood product, meaning that lumber, plywood, or veneer are key raw material for manufacturing mass timber. Sawmilling infrastructure is a critical component for the future of the mass timber sector in the state. As of 2016, there were a total of about 80 primary forest products manufacturers in California (Figure 1). Of this total, roughly 32 were sawmills. These numbers show a period of stabilization following sharp declines in primary processing capabilities in the state from 1968, when over 200 sawmills were processing lumber, through 2006 when 33 sawmills remained active.[5] This decline, due to increased efficiency and upgrades to large, high speed mills, increased centralization and competition for logs, closure of smaller, less efficient mills mostly in rural areas, and environmental restrictions, among other factors, have led to reduced timber processing capacity and challenge the growth of mass timber manufacturing sector in the California. California now faces insufficient sawmill capacity or the workforce needed to improve productivity to supply the potential market.

Forest product manufacturing is most efficient when more of the fiber is used for higher and better values. the sawmilling of lumber results in around 30% wood fiber residuals, while veneer peeling technology results in

1 https://www.nbcnews.com/business/economy/how-lumber-industry-misread-covid-ended-global-shortage-sky-high-n1272542
2 https://tradingeconomics.com/commodity/lumber
3 https://newseu.cgtn.com/news/2020-10-12/The-beetles-infestation-destroying-European-forests-UvOv2YFNXW/index.html
4 https://www.woodbusiness.ca/covid-19-and-beyond-virtual-global-softwood-log-and-lumber-conference-2020-takeaways/
5 Marcille, K. C., Morgan, T. A., McIver, C. P., & Christensen, G. A. (2020). California's forest products industry and timber harvest, 2016. *Gen. Tech. Rep. PNW- GTR-994. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p., 994.*

around 20% wood fiber residuals. There are two veneer mills in the Northern part of the state which is shipped to Southern Oregon and beyond to produce plywood and engineered wood products (e.g., laminated veneer lumber). Of the total timber volume harvested in California about 67% is utilized at sawmills in the state, about 10% is utilized at veneer mills in the state, and 20% is utilized at bioenergy facilities.[6] The balance is either exported or used in other miscellaneous forest products manufacturing operations. Furthermore, a significant amount of wood products used in the state come from out-of-state. California imports about 2/3 of the lumber it uses and nearly all of the panel and board products it uses, mostly from neighboring wood-producing states.[7]

Figure 1. Map of California primary forest products manufacturing facilities[8]



Between 2007 and 2017, California lumber production averaged 1.85 billion board feet per year and exceeded 2 billion board feet in 2007 and 2016 (Table 1). To put this total in a national perspective, softwood lumber production in North America was about 60 billion board feet in 2020. Thus, California accounts for about 3% of all North American lumber production. This is partly due, as mentioned above, to labor shortages, mill closures, along with reduced timber available from federal land as a result of extended planning horizons and timber sale litigation. Lumber produced in the state is generally comprised of a mix of about 25% is Douglas fir, 30% hem-fir (a mix of hemlock and other true firs), 15% redwood, and the balance is a mix of various other softwoods. Only about 50% of the lumber produced in California is kiln-dried with the balance sold green (undried) or air-dried.

---

6 Marcille, K. C., Morgan, T. A., McIver, C. P., & Christensen, G. A. (2020). California's forest products industry and timber harvest, 2016. *Gen. Tech. Rep. PNW-GTR-994. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p., 994.*

7 Samuel Evans, University of California, Berkeley. Personal communication on August 26, 2021.

8 Marcille, K. C., Morgan, T. A., McIver, C. P., & Christensen, G. A. (2020). California's forest products industry and timber harvest, 2016. Gen. Tech. Rep. PNW-GTR-994. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p., 994.

Combined, this data indicate that the current wood products supply chain may be inadequate to ensure that mass timber manufacturing will have the necessary supply to meet demand. This may offer an explanation as to why action to develop mass timber manufacturing in the state seems to be restricted to small businesses looking to add value to forest restoration material, where prospective businesses are certain to readily find a supply of material.

Table 1. California lumber production 2007 to 2017 measured in million board feet (MBF).

Year	California lumber production (MBF)
2007	2,309,000
2008	1,920,000
2009	1,442,000
2010	1,435,000
2011	1,623,000
2012	1,838,000
2013	1,937,000
2014	1,938,000
2015	1,957,000
2016	2,029,000
2017	1,928,000
Average	**1,850,545**

1.2 Mass timber technologies

The global mass timber movement presently underway is largely being driven by the advent of cross-laminated timber (CLT). This technology was developed in Europe in the early 1990s and has become quite established there. Over the last seven years, CLT and other forms of mass timber have gained considerable traction in the U.S. including in California. However, the mass timber sector involves other technologies in addition to CLT. Both the market opportunities and manufacturing considerations for this full suite of products merit review as the state considers the roles it may play in shaping and benefiting from the future mass timber market. This section describes five different mass timber technologies along with two structural timber technologies, including cross-laminated timber (CLT), glue-laminated timber (GLT), nail-laminated timber (NLT), dowel-laminated timber (DLT), mass plywood panels (MPP), and other timber technologies including heavy and structural round timber. Each mass timber technology is explained briefly, with an introduction to the manufacturing sector and general state of production and demand as of this writing in August, 2021. Finally, each technology is examined in terms of implications for the state, especially whether there are unique opportunities or restrictions in terms of demand and supply. For a more complete list of specific technologies and producers, please see https://www.masstimberstrategy.com/key-resources.

1.2.1 Cross-laminated timber (CLT)

CLT (sometimes referred to as XLT) consists of layered lumber boards (usually three, five, or seven) stacked and glued crosswise at 90-degree angles, delivering excellent structural rigidity in both directions (Figure 2). The incredible versatility of CLT has been the basis for the ongoing global mass timber phenomenon. In the U.S. CLT it is commonly used in floor and ceiling applications and to a less so in walls though in Europe the use in walls is quite common. It is currently being used nationwide. While an increasing number of buildings underway are five stories or more, the vast majority of CLT buildings in the U.S. thus far are four stories or less.

Figure 2.Cross-laminated timber layers. Image from the 2021 Mass Timber Design Manual, courtesy of WoodWorks and ThinkWood (info.thinkwood.com/masstimberdesignmanual)

There are currently 13 factories producing architectural grade CLT in North America. Eight of these are in the U.S. and five are in Canada. At least four European CLT manufacturers have exported material to the U.S. At this time CLT used in California has come from Oregon, Washington, Montana, Alabama, British Columbia and Quebec. Most CLT factories are designed to accommodate large-scale production mainly targeting commercial scale real estate development. Research for this project uncovered two very small CLT production operations in the U.S. that operate at a community scale that warranting further discussion that follows below.

Implications for California: There has been considerable interest in establishing CLT production in California. While the demand for CLT in California is rapidly increasing, so far state CLT production has not happened for several reasons. These include access to fiber, competition with existing production capacity and a perception that California is a tough place to establish a manufacturing business. With the anticipated strong demand for CLT in California, however it is reasonable to assume there will be one or more factories proposed within the state within the next five years. To potentially accelerate this process and to target specific benefits, California should consider attracting both large and small CLT production facilities.

Furthermore, there is some concern about which species are appropriate to be used in CLT production. California has four species of tree that meet the minimum of 0.35 specific gravity requirements, as outlined by the American Lumber Standards Committee under PS 20 or the Canadian Lumber Standards Accreditation Board under CSA-0141 (Table 2). Importantly, any given layer in a CLT panel shall be made from lumber of the same: thickness, type, grade, and species or species combination. Adjacent layers in a CLT panel can be made from differing thicknesses, types, grades, and species or species combinations.

Table 2. Tree species that are acceptable (left-hand columns) for use in CLT based on specific specific gravity of common North American softwood species, with commonly harvested California tree species listed in italics.

Acceptable CLT species		Nonacceptable CLT species	
Species	**Specific gravity**	**Species**	**Specific gravity**
Longleaf pine	0.54	Eastern white pine	0.34
Slash pine	0.54	Balsam fir	0.33
Western larch	0.48	Engelmann spruce	0.33
Loblolly pine	0.47	White spruce	0.33
Douglas fir	*0.45*	Subalpine fir	0.31
Western hemlock	0.42	Western red cedar	0.31
Red Pine	0.41		
Jack pine	0.40		
Lodgepole pine	0.38		
Ponderosa pine	*0.38*		
Black spruce	0.38		
Sitka spruce	0.37		
Grand fir	*0.35*		
White fir	*0.37*	Source: Measurement of Roundwood, M.A. Fonseca	

1.2.2 Glue-laminated timber (GLT)

Figure 3. Glulam cross-section. Photo courtesy of ThinkWood (https://www.thinkwood.com/mass-timber/glulam)

GLT, more commonly referred to as glulam, is composed of individual dimensional lumber wood laminations bonded together so that the grain of all laminations runs parallel with the length of the members, which can be customized as straight, curved, arched, and tapered (Figure 3). As one of the oldest and widely used mass timber products, glulam's application is broad and includes virtually all building types. Beyond buildings, it can serve as the primary material for major load-bearing structures such as bridges, canopies, and pavilions. It can be used as columns, straight or curved beams and affixed side-by-side to form panels. It is particularly well suited to long-spanning structures, custom curvilinear shapes and combines well with hybrid assemblies and building systems. While typically used as beams and columns, designers can use glulam in the plank orientation for floor or roof decking. With careful specification and design that considers the flatwise structural properties, deep glulam sections can be placed flatwise as decking, like has been done with Nail-Laminated Timber (NLT).

Glulam has played a bigger role in the growth of the mass timber sector in North America than it has in Europe. In Europe it is quite common for load bearing to be provided by CLT walls whereas in North America many "CLT" buildings have frameworks of glulam columns and beams holding up horizontal panels of CLT that make up the floors and ceilings. In many of these structures fully half of the mass timber value is in the glulam component. So far, there has been glulam production in Oregon, Washington, and British Columbia.

At present nearly three-quarters of the lumber used to manufacture glulam beams is Douglas fir. Thus, at the current time the market expects and prefers Douglas fir glulam timbers. Douglas fir is a species less prevalent in California than other states such as Oregon and Washington (about 25%, or roughly 500 million board feet, of California's lumber production is Douglas fir). Thus, a glulam manufacturer sited in California may at times need to rely on lumber supplied from outside of California which is determined by the scale of the operation and the lumber grade mix produced by the state's sawmills.

Implications for California: Glulam may represent a notable opportunity for California in the near term. While the volume of glulam going into mass timber buildings has been growing at a rapid pace, unlike CLT, there has not been a comparable growth in production capacity. This is in part because there was already widespread glulam production in the U.S. allowing increasing demand to be met with existing facilities. Some current CLT producers have expanded from a starting point of being glulam producers. Some, but not all, new CLT production has included glulam production capacity as well. But it is not uncommon for a single mass timber project to involve CLT from one producer and glulam from another. Given that, it may be possible for glulam production to start-up in CA before potentially much more expensive CLT production is started in the state. While there are strict requirements around stress indices and knot distributions for glulam production as found in ASTM D3737, many species of trees commonly used in glulam are found in California's forests (Table 3).

Table 3. Allowable tree species for use in glulam, by group. Species group and species within each group that are commonly harvested in California are listed in italics.

Species group	Allowable glulam species included in group
Alaska cedar	Alaska cedar
Douglas fir-larch	*Douglas fir*, western larch
Eastern spruce	Black spruce, red spruce, white spruce
Hem-fir	*California red fir,* grand fir, noble fir, Pacific silver fir, western hemlock, *white fir*
Port Orford cedar	Port Orford cedar
Southern yellow pine	Loblolly pine, longleaf pine, shortleaf pine, slash pine
Spruce-pine-fir	Alpine fir, balsam fir, black spruce, Engelmann spruce, jack pine, *lodgepole pine*, Norway pine, Norway spruce, red spruce, Sitka spruce, white spruce
Softwood Species	Alpine fir, balsam fir, black spruce*, Douglas fir,* Douglas fir south, Engelmann spruce, Idaho white pine, *lodgepole pine*, mountain hemlock, Norway pine, Norway spruce, *ponderosa pine,* red spruce, Sitka spruce, *sugar pine,* western larch, western red cedar, white spruce

1.2.3 Nail-laminated timber (NLT)

NLT was a commonly used material 100 years ago where it was incorporated as flooring in multi-story commercial and industrial buildings. Some original NLT buildings are still in use to this day (Figure 4). NLT is made by stacking dimensional lumber boards together on edge and fastening them with nails. Once the individual pieces of dimensional lumber are nailed together the panel becomes a single structural element. Uses for NLT include flooring, decking, roofing, and walls, as well as elevator and stair shafts. Adding plywood or oriented strand board sheathing on one face of the panel provides load-bearing capacity, allowing NLT to be used as a shear wall or structural diaphragm. NLT offers a consistent appearance for decorative or exposed-to-view applications and can include curves and cantilevers.

Figure 4. Nail-laminated timber. Image courtesy of ThinkWood (https://www.thinkwood.com/mass-timber/nlt)

Historically, industrial buildings often used NLT construction to span between solid timber posts and beams to form sturdy solid floors. Many of these buildings are sought after for their historic appeal and continue to serve today as refurbished office and residential spaces. NLT's revival is due in large part to domestic availability. The mass timber product does not require a dedicated manufacturing facility—compared with other building materials like CLT—and it can be fabricated with readily available dimensional lumber. Some NLT is made in a bespoke manner for a particular project as was done by StructureCraft for the Hines T3 project in Minneapolis. It can be constructed onsite as was done for the Hudson Office Building in Vancouver, WA and the Bullitt Center in Seattle. StructureFusion of Quebec offers a predesigned factory-produced NLT product.

Implications for California: NLT represents a potentially lower cost to entry product that could be made in California. It does not require the expensive machinery needed to make some mass timber products such as CLT. However, the apparent simplicity of the manufacturing can be misleading. To successfully produce NLT takes considerable knowledge and a high degree of feedstock control. As it is not nearly as widely known and understood as CLT, any enterprise designed to exploit it would need to take that factor into consideration.

1.2.4 Dowel-laminated timber (DLT)

DLT panels are like NLT panels in that boards are lined up on edge next to each other but in this instance fastened by wooden dowels rather than nails or screws (Figure 5). DLT production is well established in Europe where a handful of companies have produced it for some time. As with NLT, panels of DLT can be used for walls, floors and roofs, stairs and elevator shafts as well as bent and assembled to create curved structures. DLT's all-timber design, with no metal connectors, means it can be easily processed and cut using computerized numerical control (CNC) machinery.

Figure 5. Dowel-laminated timber sample. Photo courtesy of Fast+Epp (https://www.fastepp.com/concept-lab/material/dowel-laminated-timber-dlt-4/)

The only current DLT production in North America is by StructureCraft in British Columbia, though some U.S.-based companies are seeking to enter this market in the longer term. StructureCraft has successfully placed DLT from coast to coast. It has been used in buildings as large as the T3 Building in Atlanta. Because the look and feel of DLT is different from CLT and the engineering attributes are different, the selection of DLT as a solution needs to be done early in project planning. Some may hesitate to make this choice when there is only one vendor of the material available. As there is only one North American vendor at this time, the speed of spread of this product will likely be slower than CLT.

Implications for California: California can expect to see the continued spread of the use of DLT though the pace and scale of it is unlikely to match CLT in the near term. As the use of DLT expands, this should be considered as a possible product candidate for in-state production. The investment would be less than a CLT plant. If there is enough market to support a second North American plant, there could be pros and cons to expanding along with the current unique producer.

1.2.5 Mass plywood panels (MPP)

MPP is a new entrant to the mass timber arena. It is actually a form of CLT but is distinct from other CLT products in that the lamella are veneers of wood rather than dimensional lumber. Generally, it is used in applications like more conventional CLT for floors, roofs, and walls. Because to the ability to control product thickness to a greater degree than CLT it is sometimes selected on that basis for specialized applications such as stairs.

Figure 6. A mass plywood panel made by Freres Lumber Company. Photo Photo courtesy of Freres Lumber Company https://www.flickr.com/photos/frereslumber/44238527941/in/album-72157671902713093/

There currently is only one manufacturer of MPP in North America, Freres Lumber Company of Oregon (Figure 6). They added a MPP product line to the plywood operation they have managed for decades. In order to make MPP, plywood veneer is needed. It is impractical practical to build a MPP plant at a location that does not already produce plywood veneer at this time.

Implications for California: MPP is likely to see wide use in California. California currently has two industrial-scale veneer manufacturing operations including Roseburg Forest Products (RFP) operation in Weed, California, and Timber Products (TP) operation in Yreka, California. Without a plywood plant in the State prepared to add MPP to its product line this is a material that will likely remain impractical to produce within the State. Furthermore, MPP is patented by Freres Lumber Company, meaning any production facilities would likely need to partner with Freres to bring a new manufacturing facility to market. As the market conditions for mass timber will drive the opportunities to generate mass timber production within the State, it would be worthwhile to include MPP in any broad efforts to encourage mass timber usage even if there is not an immediate expectation it will be produced in the state in the near future.

1.2.6 Other timber technologies

1.2.6.1 Heavy timber

The use of heavy timber components for column and beam frameworks was widespread 100 years ago but has remained an occasional structural solution since then. In heavy timber construction, large lengths of wood are sawn into thick rectangular pieces which can be used individually as structural elements or sometimes attached together with parallel pieces to achieve needed performance. Heavy timber widths are at least 8" as are depths. Quite often heavy timber has been left exposed within the structure either due to cost expedience or architectural expression. With the advent of the mass timber movement in the U.S., heavy timber has moved into a broader range of applications. It is often combined with ceiling or flooring systems made with products such as CLT, NLT, and DLT.

Implications for California: While it is anticipated that heavy timber components will continue to be produced in California, the overall needs for this material should be met by existing capacity for the near-term and thus this is not a likely area for expected near term expansion and has not been addressed further in the current review. Furthermore, heavy timber is produced using larger trees. Given that the public usually expresses concern over the harvesting of larger diameter wood that may or may not be old-growth, this may present a significant barrier to expanding this market in the state.

1.2.6.2 Structural round timber

Structural round timber takes advantage of the inherent structural attributes of wood as it has grown in the trees themselves. Some iconic early 20th Century buildings used structural round timber as a celebratory connection with nature. Some of these structures still stand today including notable examples in Yosemite and Glacier National Parks. The uses are as columns and beams.

Advanced use of structural round timber has been pioneered by Whole Trees based out of Madison, Wisconsin. They have added a west coast sales office in Seattle. More recently, Original Mass Timber Maine in Ashland, Maine has entered this space as well.

Implications for California: While in some ways this is a very new entrant into the market, in some other ways it is very much the rebirth and modernization of a proven technology. While it is unclear what portion of the addressable market this solution will capture, the thresholds for manufacturing this product are less than for many forms of mass timber. This is an area where an evaluation of the potential for production within the State may be well worthwhile. Like with heavy timber, public sentiment is likely to play a role for any potential manufacturers in-state.

1.3 California's market is large and growing

Considering structures in design and construction started or built, California leads the way in demand for mass timber with a market that is about two-thirds bigger than the next highest state of Washington (Table 4). Additionally, California accounts for about 15% of all mass timber projects identified by WoodWorks, a nonprofit organization that supports and tracks commercial and multi-family wood buildings in the U.S. These data account for the number of buildings rather than size and scope of mass timber projects, which can be estimated based on average non-residential building size (of 16,000 sq. ft.) to be about 2.5 million square feet of mass timber buildings.

Table 4. Mass timber building projects by state as of June 1, 2021[9]

State	Construction started or built	In design	Total mass timber projects
CA	**69**	**109**	**178**
WA	69	48	107
OR	61	23	84
TX	31	46	77
FL	20	40	60
MA	25	34	59
NC	26	28	54
NY	13	32	45
CO	19	21	40
WI	20	16	36
GA	11	21	31
IL	15	15	30
SC	18	5	23
MT	12	11	23
AL	8	13	21
MO	8	8	16
OH	7	9	16
VA	7	9	16
ME	5	10	15
UT	6	9	15
PA	7	8	15
MN	11	3	14
AR	6	7	13
CT	7	6	13
DC	5	8	13
MI	2	11	13
VT	2	11	13
NJ	1	11	12
TN	8	3	11
ID	7	3	10
MD	4	6	10
NE	3	7	10
IA	3	4	7
KY	4	2	6
OK	3	2	5
AZ	2	3	5
KS	2	2	4
MS	1	3	4
NH	1	3	4
RI	3	1	4
IN	3	1	4
LA	1	3	4
HI	2	1	3
WY	2	1	3

9 Accessed on August 20, 2021 from https://www.woodworks.org/publications-media/building-trends-mass-timber/

Furthermore, CLT accounts for 44% of the built or in-construction projects and 59% of the in-design projects (Table 5), suggesting that the market is trending toward increased use of CLT over other mass timber product types. There are some mass timber building projects that are not included in the WoodWorks database, which means these data are incomplete.

Table 5. Mass timber building projects by mass timber type as of June 1, 2021[10]

Stage	Mass timber type	Number of projects	% of Total
Construction started or built	CLT*	249	46%
	DLT*	15	3%
	NLT*	18	3%
	Heavy timber decking	107	20%
	Post & beam	156	29%
	Subtotal	*545*	100%
In design	CLT	365	58%
	DLT	5	1%
	NLT	12	2%
	Heavy timber decking	48	8%
	Post & beam	194	31%
	Subtotal	*624*	100%
Combined	CLT	614	53%
	DLT	20	2%
	NLT	30	3%
	Heavy timber decking	155	13%
	Post & beam	350	30%
	Total	*1,169*	100%

**CLT: cross-laminated timber; DLT: dowel-laminated timber; NLT: nail-laminated timber*

Since CLT and other forms of mass timber are relatively new products, there is an apparent lack of uniformity in how mass timber products are categorized in the harmonized tariff system used to track global trade. Nevertheless, data on imports into the U.S. for a variety of products, some of which include mass timber, were gathered for 2019 and 2020 (Table 6). The category *Fabricated Structural Wood Members* likely includes mass timber panels. It shows a rise in import levels from 2019 to 2020 while the others decreased or stayed flat due to the low lumber prices in Europe relative to U.S. prices.

Table 6. 2019 and 2020 imports of mass timber products into the United States (in kilograms)

Harmonized Tariff System Code Number	Harmonized Tariff System Code Description	2019	2020
4418999010	Arches and Laminated Wood	3,401,563	1,480,683
4418999040	Fabricated Structural Wood Members	434,688,024	445,031,331
4418999050	Prefabricated Partitions and Panels of Wood for Buildings	32,422,225	33,471,289
4418999095	Builder's Joinery Not Elsewhere Specified	223,911,363	160,126,035
Total		**694,423,175**	**640,109,338**

10 Accessed on August 20, 2021 from https://www.woodworks.org/publications-media/building-trends-mass-timber/

Most mass timber production facilities are located near the source of the feedstock materials to minimize haulage costs. The proximity to final markets can also factor into site location. While there are profitable mass timber operations located quite far from primary markets, location nearer to markets could affect success in a number of ways, particularly ease of customer access, growth of business relationships, access to highly skilled workforce, and transportation costs for finished products.

Transport of mass timber in North America is almost exclusively by truck. In addition to mileage, costs are affected when oversize loads are involved, and may also be impacted by the number of state lines crossed and restriction on allowable hours for drivers. Drivers are constrained to 11 hours of drive time before taking a 10-hour break, thus can represent one of the highest costs of typical shipments. Although shipping costs are often less than 1% of delivered mass timber costs, considerable savings can be achieved when facilities are located where round-trip deliveries can be completed within the allowable 11 hours.

Much of the current interest in mass timber is being driven by its ability to sequester carbon and offset greater carbon emissions associated with other building materials. Exactly how much of the carbon stored in mass timber buildings can be credited as sequestered is under active review, but thus far all indications are that there is a real net carbon benefit to building with wood. Carbon costs associated with transport have yet to be reflected in the costs of mass timber and this may change in the future as more projects are informed by life cycle analysis.

1.4 Mass timber facility context

Considerable attention has been given previously to whether there are sufficient and appropriate forest resources in the state to support mass timber manufacturing. The abundance of small to mid-size material in California's forests, the need to remove and utilize this material to reduce risk of catastrophic wildfire, and increase employment are key factors that have prompted further interest in this sector. Despite California leading the country in mass timber projects, no mass timber is currently manufactured in the state. The 69 mass timber buildings that have either been built over the last seven years or are currently under construction in the state have all relied on materials from elsewhere. Mass timber used in California is imported chiefly from Oregon and Canada, with smaller volumes shipped from Washington, Montana, Alabama, and Europe.

CLT building in construction in Quincy

While some prospective businesses say that the lack of supply guarantees and limited availability of federal timber are key variables affecting investment in mass timber production, others wonder whether there will be sufficient demand to sustain production. Multiple mass timber production facilities from across North America and beyond already serve the state, with only one, Fabric Workshop, making headway at establishing a facility. Nonetheless, this situation is likely to change soon given interest in the material and incipient demand represented by the number of projects in the design phase.

Demand for mass timber has grown rapidly in recent years, and none of the experts interviewed for this project indicated it was likely to slow, especially in light of recent trends in mass timber building projects in the state. The first use of CLT as a component in a building was in 2013. Prior to 2017, all mass timber buildings in the state had to be authorized via Alternate Means and Methods Requests in the Code system. Changes in the system led to rapid growth in use of the material and by 2017, a total of eight buildings using the material had been recorded in California by WoodWorks, with four additional projects completed in 2017. Of the 69 buildings cited above, 61 one of them have come about in the last four years. The state's first full CLT building was constructed in 2017 in Quincy by the Sierra Institute for Community and Environment. The 2017 BAR Architects design competition for a conceptual CLT tower set in San Francisco only furthered interest in mass timber.

As of June 2021, WoodWorks reported 109 additional mass timber projects in the design phase in California, more than have been constructed in the entire history of the modern mass timber movement in the U.S. This count does not include single-family homes that may have been constructed.[11] It also does not capture the increasing size of projects, some of which is characterized below.

In addition to being part of the broad mass timber movement sweeping across the U.S. at this moment, California has multiple factors that distinguish it as a prime market for mass timber going forward. These include:

- The immediate need for restorative, sustainable forest management as a part of catastrophic wildfire risk reduction;
- California's large and growing construction market;
- Broad recognition by the state and leading businesses regarding the beneficial climate implications of lower embodied carbon emissions and carbon capture through wood construction;
- Californian's aesthetic appreciation for the use and exposure of wood in structures;
- Use of mass timber by technology-based companies looking to quickly grow their campuses and develop associated residential real estate;
- Recognition in major metropolitan areas that off-site, prefabricated mass timber construction can address affordable housing needs; and
- Adoption of the 2021 International Building Code to allow for mass timber construction up to 18 stories.

The greatest concentration of mass timber activity in California is in the Bay Area. It likely will soon become the greatest concentration of mass timber activity in the U.S.

In Silicon Valley:

- Microsoft's Mountain View campus featuring North America's largest mass timber building at 645,000 ft^2;
- Westbank's San Jose Campus;
- McEvoy's affordable housing in San Jose;
- Google's office building in Sunnyvale;
- Google's North Bayshore Mountain View project;
- Facebook's Willow Village in Menlo Park;

In San Francisco:

- BAR Architects' design competition for a conceptual CLT tower in San Francisco;
- The California College of the Arts winning State of California design;
- The first all CLT building in San Franscico and California's first multi-story mass timber building: a 4-story 1 De Haro building in SOMA and Portero Hill[12];
- Brookfield properties Pier 70 project featuring a six-story mass timber structure at 310,000 ft^2;

11 Due to the nature of data collected around mass timber buildings, the Wood Innovations Network (https://www.woodworksinnovationnetwork.org/projects/) only collects volunteered information or publically available information. Many residential projects are not disclosed.

12 https://perkinswill.com/news/1-de-haro-a-case-for-mass-timber/

Additionally, some Bay Area-based construction businesses are looking at how to include mass timber, including Juno Residential, Timber Quest, and Factory_OS, suggesting that there will be increasingly strong demand for mass timber in California in the future. The scope and scale of the mass timber market in California will likely exceed what it was nationally just a few years ago, meaning that the past is not a good indicator for what the future of mass timber holds.

1.5 Models of production

There is a wide array of production methods used to produce mass panels and other mass timber products. Several are cited here to highlight the range of variability rather than a comprehensive review of production differences.

The value of proximity to material sources has thus far meant that much of recently built mass timber capacity in the U.S. is in rural communities. To that point present architectural grade mass timber panel production in the U.S. is located in:

- Colville, WA;
- Columbia Falls, MT;
- Dothan, AL;
- Durango, CO;
- Heber City, UT;
- Lyons, OR;
- Riddle, OR; and
- Spokane, WA.

1.5.1 Mill expansion

Most of the major mass timber production facilities in Europe, those capable of sizable production for both domestic and export markets, consist of fabrication plants that have been directly added onto existing sawmills. These vertically integrated operations conferred distinct advantages.

Many of the mass timber manufacturers interviewed as part of this study expressed a desire for vertical integration in the early stages of the supply chain (i.e., integrating lumber production with CLT manufacturing) to buffer overall costs against increases in raw material costs such as those that as occurred with the COVID-related increase in North America. This is because manufacturers could control raw material costs from standing timber through the various manufacturing steps leading to lumber. Indeed, extraordinarily high costs for lumber in the summer of 2021 were coupled with some of the lowest costs of timber paid to independent loggers and private owners of forest land in California. Manufacturers recognize there is an opportunity cost to this approach (i.e., supplying lumber to the mass timber plant at values discounted relative to market prices). However, in a vertically integrated company this is more a matter of which part of a company's operations generate profit.

A sawmill processes lumber

If a vertical integration opportunity is identified, in addition to possible protection from swings in raw material costs, other benefits to such an arrangement include more efficient utilization of fiber. For example, rather than planing lumber after kiln-drying and then again prior to applying adhesive for the panel pressing process, it would only need to be planed once to activate the lumber's surface for effecting adhesive bonding. This would save fiber and allow CLT manufacturers to produce a thicker overall panel if needed. Similarly, most sawmills already have kilns, which would be useful in a situation where a sawmill and CLT plant have a partnership. Finally, the industry convention is to trim lumber to the nearest 2' length interval. Eliminating this practice to allow the mills to produce true random length lumber would reduce lumber waste and significantly increase the marketable volume of lumber produced by a sawmill.

In North America, examples of vertically integrated facilities include Nordic in Quebec, Kalesnikoff in British Columbia, and Freres in Oregon. Of note, there are also two vastly smaller vertically integrated CLT operations discussed below under the Specialty Operations category (TimberAge Systems in Colorado and Euclid Timber in Utah). In the U.S., the mill expansion model has been slow to take hold but may increase as the market for mass timber construction expands.

1.5.2 Freestanding primary mass timber production

In North America, most of the mass timber production to date is done at facilities that purchase lumber from the open market and fabricate it into mass timber products. Examples of this include SmartLam in Montana and Alabama, DR Johnson in Oregon, and StructurLam in British Columbia and Arkansas. Katerra in Washington was also an example of this.[13]

1.5.3 Mill expansion/freestanding hybrid

There is at least one example where the mass timber fabrication represents something of a hybrid between the mill expansion model and the freestanding model: Vaagen Timbers in Coleville, Washington. Vaagen Timbers lies adjacent to the Vaagen Brothers Lumber mill in Colville, and is technically a free-standing operation because it purchases lumber from a separately owned mill.

1.5.4 Specialty operations

While most mass timber operations are somewhat similar to each other as they take wood products already suitable for use in frame-based construction and turn it into standardized structural commodities, there are a few specialty operations that have been uniquely formed. These are worth noting both to reflect the range of options available, but also because their small scale and low required capital investment make them attractive for consideration for rapid deployment.

The first of these is Euclid Timber in Heber City, Utah. Euclid makes a unique product, interlocking CLT, that requires no glue or mechanical bonding such as with nails, dowels, or screws. The wood components are elaborately cut in three-dimensional puzzle-like patterns that lock together. Critically, this means they did not invest in what is generally the most expensive part of a CLT production line: the massive press. The company has harvested beetle kill material from National Forest System lands, milled it, and turned it into interlocking CLT panels all with perhaps fewer than 20 employees involved. They have constructed a series of public and private buildings with this material.

TimberAge Systems has scaled their CLT business to meet the needs of their rural community (photo courtesty of TimberAge Systems)

13 https://www.inlander.com/spokane/a-year-and-a-half-after-opening-its-spokane-valley-timber-factory-katerra-suddenly-shuts-its-doors/Content?oid=21813659

The second specialty operation is TimberAge Systems based in Durango, Colorado. Like Euclid, Timber Age Systems is a micro business that purchases logs and mills them into dimensional lumber themselves. They produce 4x10′ panels that are pressed are using a small manually operated vacuum press. Like Euclid Timber, TimberAge bypassed high-cost production presses used in large volume plants. Based on their community-scale model, TimberAge envisions a network of franchises serving local market areas. In addition, both of these companies are able to bypass issues facing industrial operations that require a greater supply of lumber. They can be more nimble with log procurement given that they do not produce at the industrial scale.

1.5.5 Secondary manufacturing

While multiple states have targeted manufacturing of mass timber panels, few have concentrated on secondary manufacturing. This includes a wide range of activities but can be largely split into two main groups: doing demanding detailed finish work on mass timber components to customize them for specific uses and building niches, or making products such as modular housing units to be transported elsewhere for installation as a whole unit.

1.5.5.1 Cutting mass timber panels to size

Virtually all mass timber panel production facilities include some capacity to customize their products for a particular construction project. Much of this is accomplished using Computerized Numerical Control (CNC) machines that perform complex cutting and drilling functions. The use of CNC's at glulam production facilities making beams and columns is more sporadic. In part because of the impracticality of designing a volume-based production facility around the most demanding item going through it, highly complex CNC work is commonly farmed out to specialists who do nothing but that most demanding work. Some CNC work is also farmed out due to large size of certain components being processed. Additionally, stand-alone CNC operations have been successfully used as an entry point to mass timber fabrication where an operator purchases blank mass timber components and does all CNC work for a particular project.

One manufacturer estimated it may take hundreds of CNC machines to keep pace if there is significant growth in demand for mass timber buildings. Thus, there may be an opportunity for developing additional CNC machining capacity to support the needs of mass timber manufacturers (both panels and glulam). In fact, this is already beginning to happen as evidenced by businesses recently started in the Portland Oregon area such as Cut My Timber and Timberlab, Inc. In the case of Timberlab, Inc. the business is owned by Swinerton, which is a large construction contractor. Thus, the idea for Timberlab is to leverage the firm's deep knowledge of construction with the needs of mass timber building developers and mass timber panel manufacturers. More CNC facilities are currently under development on the West Coast.

While almost all mass timber production facilities have CNC systems that do custom cutting for windows, doors, etc., there are also businesses that do only that work. These businesses have one or more CNC machines and do custom order work for a variety of customers including primary mass timber producers. Sometimes these secondary manufacturers become involved because of the volume or complexity of secondary manufacturing needed. Sometimes they may also serve as a general contractor fabricating small-scale custom projects such as single-family homes that the large-scale production facilities may not want to deal with. Until quite recently, this form of secondary processing in the U.S. has been as free-standing enterprise. Most recently, one of the large-scale general contracting companies involved in erecting mass timber buildings has added an internal unit for this kind of secondary manufacturing as well.

1.5.5.2 Off-site prefabrication

Another form of secondary manufacturing may be emerging as well. This involves the off-site prefabrication of units, generally for the purpose of building larger structures out of a series of prefabricated units. These can range from flat-pack products for delivery to fully assembled units transported to the construction site. Particularly for the fully assembled units, there may be a preference for siting the manufacture of these products close to where they will be used in order to cut down on "shipping air." Either of these secondary manufacturing niches can be a key to growth of the mass timber sector as a whole and both represent opportunities of sector expansion that do not involve the production of mass timber panels. However, both are complementary sectors that can serve as kernels from which to attract and grow a wider mass timber manufacturing sector.

As to the modular off-site stand-alone facility there are roughly a dozen separate projects under consideration across the U.S. to look at this model. More than half of these are subject to NDA considerations. Only one of these, Factory_OS, is based in California. Some are being considered outside of California but have California markets as part of their planning, including Intelligent City. While most of these projects under consideration are of somewhat modest scale, the work that SideWalk Labs is considering for the Pacific Northwest would be an effort to approach this niche at a large scale.

Another example of off-site modular building from mass timber includes TimberQuest, a Bay Area company providing prefabricated mass timber classrooms for California K-12 schools and community colleges.[14] The CLT structures are pre-checked and approved by California's Division of the State Architect. The company describes this approach as reducing permitting time from six months to a single day. Nine separate building layouts are included in the pre-check ranging from three- to nine-classroom sizes.

This Timberquest model is of interest for a number of reasons. One is the role the Division of the State Architect played and whether it represents an opportunity for further pre-checks. Another is the rapid deployment possible for high quality mass timber school additions which can largely be done during summer breaks reducing the impacts on schools and students. The first TimberQuest school project in Atherton, CA was completed in August 2021 following eleven weeks of construction that allowed returning students to occupy the building immediately.[15] A few years ago the State of Washington funded the successful design and deployment of somewhat similar mass timber additions to five K-12 schools.[16] This tends to lend support to the concept now being put to use in California and also raises the question about whether this might be a model ripe for broader use.

Off-site prefabrication of mass panel is an area where there is near-term opportunity to get a foothold in mass timber manufacturing. The capital requirements are nominal in comparison to establishing a full-scale CLT factory. This could involve an investment of less than two million dollars in comparison to tens of millions of dollars required for a full-scale mass panel production facility. It is important to point out, however, that the technical skills required are demanding, requiring entrepreneurs launching such operations understand that challenges associated with this work go beyond that of a small custom sawing operation.

1.6 Technical challenges facing mass timber manufacturing in California

1.6.1 Lumber moisture content

Lumber used in CLT manufacturing must be dried to 12% moisture content (plus or minus 3%). This is important because dimension lumber (e.g., 2" thick by 4" to 12" wide boards) are only required to be dried

14 https://www.prnewswire.com/news-releases/xl-construction-aedis-architects-and-daedalus-structural-engineering-partner-to-develop-new-timberquest-school-construction-product-301307793.html
15 https://www.shschools.org/z-2021-hpr-news-detail?pk=1183993&fromId=275977
16 https://www.mahlum.com/projects/clt-modular-classrooms/

to 19% moisture when used for conventional applications such as studs in walls, headers and footers over windows and doors, trusses in roofs and joists in floors. CLT manufacturers interviewed as part of this study indicated that they were planning to develop their own kiln-drying capacity. This is problematic in the California context because only about 50% of the lumber produced in California is sold as a kiln-dried product. A higher percentage of lumber is typically kiln dried in other states. For example, Idaho and Washington reported kiln drying 94 and 69 percent, respectively, of their softwood lumber production in 2019. The lower percentages in Oregon and California are likely driven by a long-standing trend of using green (undried) Douglas fir lumber to frame houses. This suggests that there is likely a limited kiln-drying capacity in California needed for CLT manufacturing.

A solar kiln to dry lumber to desired moisture content for CLT fabrication (photo courtesty of TimberAge Systems)

Also, kiln-drying generally involves combusting biomass, or in some cases natural gas, to generate the thermal energy needed to drive moisture out of lumber. Since any combustion process produces particulates and noxious compounds associated with emissions, such operations require air quality permitting. Given California's strict air quality regulations and the uncertainty and risk associated with a permitting process, how heat will likely determine whether kiln-drying is a barrier to siting a mass timber plant in California. Manufacturers could overcome this barrier by co-locating at an existing sawmill site that already dries lumber and negotiating with them to dry lumber down to the desired state, or by co-locating with operations that produce excess heat that can be efficiently used for drying lumber.

1.6.2 Utilizing small diameter roundwood

Small diameter trees are generally considered those to be 12 to 14 inches and smaller in diameter at breast height. When such trees are harvested and bucked into shorter lengths (e.g., 8 to 16-foot lengths) for conversion into lumber, the taper in the diameter along the stem means that the overall average diameter of the bucked logs processed in a small-log sawmill is typically in the range of 7 to 8 inches. When these logs are processed into the lumber, the width mix of the lumber produced is about 60% 2x4, 35% 2x6 and 5% 2x8. Current CLT manufacturers are using somewhere between 80 to 90 percent 2x6 material as their primary raw material input. Smaller lumber cannot be used in the minor strength axis of a CLT panel because the width to thickness ratio is less than 3.5. This means that less than half of the lumber produced by a small-log sawmill is suitable for use in CLT manufacturing. Additionally, after accounting for grades that cannot be used in CLT manufacturing, only 25 percent to 33 percent of sawmill's total output would meet the specifications for mass timber manufacturing. The implications of this are that the scale of the CLT plant has to be carefully matched to the output of the sawmill if the objective for a sawmill to wholly supply a paired CLT manufacturing operation.

Much of the standing timber to supply a sawmill specializing in processing small diameter logs would most likely come from publicly owned lands where there are well documented issues related to poor forest health arising from overstocked stands made up of small diameter trees. Thus, as previously described, without significant changes in timber harvesting policy on federal lands it is doubtful that any entity could obtain financing to construct a sawmill without having a secure log supply. Nevertheless, potential areas for securing bankable supply agreements are long-term stewardship contracts. For example, in Arizona the U.S. Forest Service is currently evaluating offers related to a 20-year stewardship agreement for treating nearly 30,000 acres per year. Efforts are underway in California to secure feedstock agreements and other mechanisms involving master stewardship agreements with the U.S. Forest Service to implement landscape restoration activities (e.g., fire hazard mitigation and tree thinning) with processing facilities. Similarly, the Good Neighbor Authority is a relatively new administrative ruling that allows the U.S. Forest Service and Bureau of Land Management to partner with state agencies to plan and implement forest restoration projects. These contracting opportunities may offer strategies around which businesses could demonstrate raw material supply surety to financiers.

A sawmill sorts logs for processing

Related to both of the preceding points, sawmills that specialize in processing small diameter logs rely on two key factors for viability. The first is maximizing the amount of lumber recovered from each log. This is accomplished with: 1) technology that allows for logs to be scanned, 2) a computer to calculate the optimal position for the log relative to saws/chipping heads, and 3) equipment that can slew, skew, and rotate logs to optimally orient the logs as it encounters saws and/or chipping heads. It also means that there is little opportunity for mill managers to attempt to control the production of lumber widths to a mix more suitable for CLT production. Second, small log sawmills process logs in a single-pass through saws. The lines operate at speeds of more than 600 lineal feet per minute. To achieve production levels that are on par with sawmills that process larger size logs, small log sawmills must process a significantly larger number of logs, which relates to the surety of supply issue. However, more importantly, if a small log mill does not operate at higher speeds as a strategy for mitigating supply constraints, production costs rapidly rise and quickly render a mill economically unviable for both its own survival and that of an associated CLT manufacturer.

A potential solution to the issue of too much narrow width lumber produced at a small log sawmill is for the mill to produce 1" thick lumber rather than 2" lumber. According to architects and mass timber building construction companies interviewed as part of this study, there is demand for this type of CLT panel in certain applications where a less massive panel is needed, but which still preserves the mass timber look and feel of a structure. The same contacts indicated that at the current time the only source for such products is European CLT manufacturers. Thus, while there appears to be a market demand for CLT made from thinner lumber there do not appear to be any North American manufacturers seeking to capitalize on the opportunity.

Furthermore, there is a general lack of sawmilling capacity, especially at the non-industrial scale. The lack of timber processing capabilities at medium or smaller scales makes it challenging for small landowners, or for loggers servicing fuels reduction needs on federal lands have no guaranteed processing opportunity. This has proved to be a significant bottleneck to ensure fuels reduction work is carried out given that small diameter roundwood is less profitable for industrial sawmills. Loans or incentives could target small and medium sawmill operators to ensure they have adequate processing infrastructure and support.

1.6.3 PRG320 certification

American National Standard Institute (ANSI) and The Engineered Wood Association (APA) PRG 320 is the overwhelmingly dominant norm for assuring product performance for CLT. PRG320 is the standard of performance for CLT that has helped to grow the industry through ensuring compliance and confidence in the product. The process that went into creating PRG320 standards was collaborative and involved the input of many experts over a number of years. The oversight of the process itself is extensive. Ongoing production of CLT is subject to continuous PRG320 sampling and testing along with oversight inspections of those processes.

Every production site and every panel configuration is subject to approval and monitoring. For smaller manufacturing facilities, this is proportionately a big lift, but is essential to the viability of the industry, especially as customers and approval officials are getting more and more used to it as the norm. To certify a material as PRG320 requires extensive product testing that can cost around $50,000. This cost supports the necessary rounds of panel testing, a shop tour for process review and certification, and a report for submission. One adhesive company has offered one small manufacturer free testing, which would require panel shipment to the adhesive manufacturer facility. There are several rounds of testing required, and many manufacturers face the most challenges to permitting as it relates to weathering and related delamination, especially given that these effects vary significantly by species. Independent testing is necessary, but can be costly, so wherever manufacturers can secure free testing, they will try to gather as much data as possible prior to coming up for certification.

Inspection is another key point of entry for manufacturers given that they are often trained to look for stamped and graded studs during inspection, neither of which is relevant for a mass timber structure. Furthermore, where mass timber panels are built with electrical services buried inside the panel, it is not available for inspection at all and appears as non-standard to inspectors. This may lead inspectors to raise concerns over the structural integrity of mass timber buildings.

Smaller buildings can be built with panels that are not PRG320 certified, however that decision is left up the local jurisdiction. Manufacturers need to review the municipal code for the specific building location, determine which IBC code is applicable, and identify the most appropriate path forward. Small companies can also get creative in their communication about the quality of their product. A city or county planning department may require PRG320 certified panels or they may offer an alternative model to use a non-certified panel. Some companies have had success integrating the expertise of professional engineers into this process to help explain the product and assure the planning or permitting staff that the mass timber product is structurally sound. In this way, for smaller single-story or small multi-family homes, planners and permitting agents can use their best judgement on a case-by-case basis. However, PRG320 makes the process more efficient as it proves product standardization and minimum requirements are met.

1.7 Final considerations

The mass timber sector is evolving rapidly and there are many technologies not fully explored here. Within the CLT category alone there are dowel laminated, nail laminated, and interlocking CLT technologies not cited here. Omission does not imply potential is not recognized in each of these. In the U.S. market, each of these is quite formative at this time and is not seen as among the most likely starting place for California production.

Similarly, there are a wide range of hybrid technologies where a mass timber product is combined with wood, steel or concrete to provide a construction solution. This can even involve two mass timber products being combined as in CLT panels with glulam ribs applied either in the factory or in the field. While the details of these hybrid systems are important as the mass timber market develops, they were seen as secondary considerations for the present discussion.

Finally, there remains much to be understood about under what conditions and the ways in which mass timber production can contribute to forest restoration and utilization of small trees. Many are unaware that mass timber panels rely on 2x6" lumber that is more efficiently produced from mid-sized and larger timber. Yet, one industrial manufacturer in North America has been successful using small diameter logs that are guaranteed from the Canadian government. Supply security, unavailable from U.S. federal agencies, offers the necessary security for this company to invest in top of the line machinery to process trees down to 4" in diameter. Some timber operators in the United States have been successful at securing contracts on federal lands when bundling fuels reduction work with some higher value timber harvests, but few have been able to secure the long-term contracts needed to justify investment on mass panel or other small tree production facilities. Increasing catastrophic wildfires on California and elsewhere, however, are compelling a push to reinvest in working forests along with investment in utilization technologies that are essential for forest restoration. Mass timber facilities by themselves are unlikely to address the scale of the problem, but can be and perhaps should be part of the solution.

CHAPTER 2

WHY SHOULD CALIFORNIA PURSUE GROWTH OF THE MASS TIMBER SECTOR?

Photo courtesy of TimberAge Systems

Recommendations

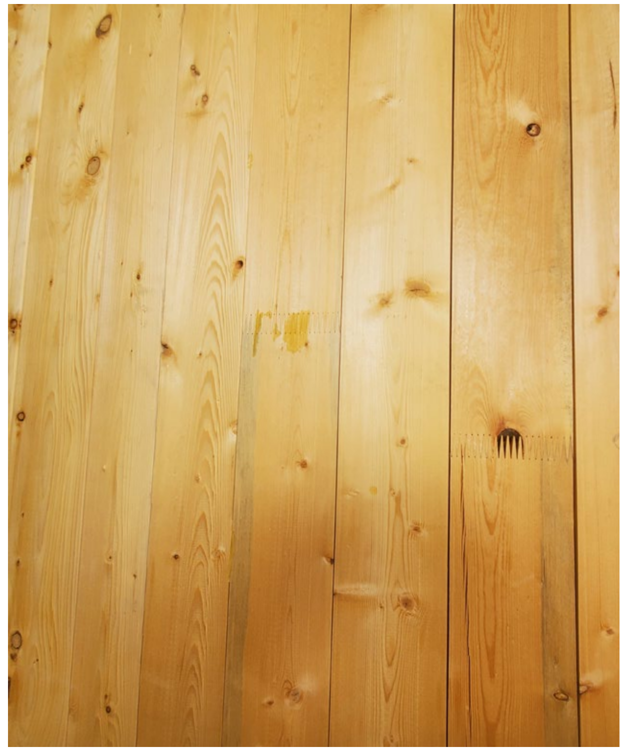
- Funds should be established to support innovative mass timber housing development to help meet the state's substantial housing deficit. Innovative housing strategies that use mass timber can help the state address both urban and rural housing needs
- Incentives should be provided to innovative mass timber manufacturers seeking to use low value, smaller diameter roundwood harvested from high hazard forests, including support for machinery such as advanced sawmilling infrastructure capable of processing small diameter roundwood; and
- The state should allocate funding for research to better advance understanding of the performance of mass timber. Studies are needed to better understand many different facets of the technology, such as the differences between mass timber and traditional stick frame constructions in wildfire events, human response to indoor environments using mass wood, and the carbon costs and benefits through improved life cycle analysis of long-lived mass timber building.

Highlights

- Mass timber can help the state meet climate change targets by reducing embodied carbon of new buildings and by reducing CO_2 emissions associated with the construction process;
- With appropriate incentives and chain of custody requirements, mass timber use can contribute to improved forest management in California by encouraging use of smaller diameter trees that need to be removed from forests to reduce the risks of catastrophic wildfire.
- Speed of erection and reduced community impacts during construction make mass timer suitable for construction in a variety of communities, especially through infills and overbuilds;
- Mass timber has been embraced by the technology sector for its ability to quickly meet the state's housing needs through off-site and modular building; and
- Compared to traditional stick frame homes, preliminary data suggest mass timber construction can more effectively withstand destructive environmental hazards such as wildfire and seismic activity.

2.1 Mass timber can help the state meet carbon goals

2.1.1 Wood products substitution in construction materials


A CLT wall with finger joints

The building construction sector, comprised of manufacturing and installation of steel, cement, glass, wood, and other shell and core building materials, contributes 5% of global energy and 10% of total CO_2 emissions globally.[17] This number rises significantly when considering walls, finishes, and other building details. The world is projected to add 230 billion m^2 of building space by 2060, the equivalent of adding a New York City to the planet every 34 days until 2060.[18] Given that the building sector represents an important pathway to sustainability, the United Nations Environment Program created the Global Alliance for Buildings and Construction with the goal of achieving net-zero carbon by 2050. Although interest in green building is increasing, almost half of carbon-related achievements in the building sector gained from 2015 to 2017 were lost in 2018 and 2019,[19] indicating that decarbonization of the building sector is a matter of increasing urgency and a sector where government policies and programs can make a real impact.

Materials used in construction are heavy by weight and large by volume. As such, embodied carbon emissions associated with construction materials are significant contributors to greenhouse gas emissions in terms of their production, manufacturing, and capacity to store carbon. Despite restructuring of the industry, technological improvements, and increased scrap steel use leading to significant reductions in CO_2 emissions from iron and steel and metallurgical coke production in the United States, the Environmental Protection Agency identified that production of steel and cement were the third and fourth, respectively, largest sources of CO_2 emissions in 2018.[20] Specifically, iron and steel production and metallurgical coke production contribute 42.6 MMT CO_2 per year, while cement production contributes 40.3 MMT CO_2 per year.

Estimates from within the steel and concrete industries indicate that 1.9 tons of CO_2 are emitted for every ton of steel produced,[21] while concrete-making produces 1 ton of CO_2 for every ton of concrete produced.[22] The amount of CO_2 produced by concrete-making is heavily influenced by the mixture of cement used in concrete, because cement-making is where most CO_2 emissions occur, and is responsible for 8% of the world's carbon emissions.[23] While steel has a higher rate of CO_2 emissions per unit weight than concrete, it is also stronger and less of it is required for structural support.

Mass timber, however, is a structural material that can substitute both steel and concrete in construction, presenting an opportunity for considerable reductions in carbon emissions associated with buildings. There are several key mechanisms by which this happens, including the avoidance of carbon emissions during the manufacturing process, the potential for carbon storage in the material, the avoidance of the use of fossil

17 https://globalabc.org/sites/default/files/2021-03/Buildings-GSR-2020_Report_24-03-21.pdf
18 https://achieving-zero.org/framework/new-construction/
19 https://globalabc.org/sites/default/files/2021-03/Buildings-GSR-2020_Report_24-03-21.pdf
20 https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-chapter-executive-summary.pdf
21 https://www.worldsteel.org/en/dam/jcr:c3acc5fd-e3c2-458c-a2cc-8c4880b9334c/Steel%2527s+contribution+to+a+low+carbon+future.pdf
22 https://www.ecori.org/climate-change/2019/10/4/global-warming-has-a-co2ncrete-problem
23 https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete

fuels and biomass energy associated with the manufacturing process, and the long-term life cycle of building materials, especially concerning end of life questions.[24]

To address avoided carbon emissions during the manufacturing process, both steel and concrete require significant energy for production, and that energy is a large source of carbon emissions. In order to produce steel, iron ore is refined at high temperatures by the burning of coke, which is high quality coal. Similarly, cement used to produce concrete is generally made by heating limestone. Both heating processes require large energy inputs which have made steel and concrete production among the largest sources of carbon emissions. Carbon emissions associated with the production of mass timber is generally through the drying process,[25] manufacturing process and in creating wood adhesives. Because of the high level of emissions associated with steel and cement, there are increasing calls to move toward low carbon construction materials like green cement, recycled steel, and mass timber.

Second, although cement does absorb some CO_2, and new technologies may enable cement to absorb CO_2 more efficiently in the future,[26] wood and mass timber represent nature-based opportunities to reduce carbon emissions and sequester carbon in buildings today. Wood contains 50% carbon by weight, storing carbon that was once in the atmosphere as greenhouse gases. By one estimate, the University of British Columbia's Earth Sciences building used 573,360 board feet of wood, storing 1,005 metric tons of CO_2, and avoiding 1,168 metric tons of CO_2 through materials substitution, with a total potential carbon benefit of 2,173 metric tons of CO_2.[27] One recent study compared embodied emissions of steel, concrete, and mass timber, and showed that for every ton of material, steel stored negligible amounts of carbon and concrete stored up to 0.12 tons max of carbon after hundreds of years, while mass timber stored up to 0.52 tons of carbon.[28] Furthermore, as compared to steel and concrete, mass timber requires less energy intensive processing. Studies have shown that substituting harvested wood products for non-wood materials can reduce greenhouse emissions associated with the building sector when forests are sustainably managed.[29] The long-term CO_2 storage capabilities of mass timber can buy time for other major emitting industries, like transportation, to reduce their emissions.

In life cycle analyses that examine climate change mitigation, the majority of studies agree that there are climate advantages associated with the use of timber in construction.[30] One meta-analysis of research into the potential for wood buildings to serve as part of a climate solution showed that mass timber buildings had many carbon benefits as compared to conventional materials. Furthermore, they found that substituting conventional building materials with mass timber in half of new urban construction projects could provide a 9% reduction in global emissions needed to meet 2030 targets to keep warming below 1.5 C.[31] Another study found that mass timber produced from low-quality wood can increase the carbon capture effect from 25.1 to 50.98 MT CO_2/year by 2030.[32]

Finally, studies concerning carbon emission benefits of wood products substitution reveal some gaps in knowledge and unknowns in underlying assumptions. For example, many sawmills capture energy from biomass produced at harvest sites and sawmills, though associated avoided carbon emissions have historically not been included in relevant chapters of national greenhouse gas inventories.[33] Carbon emissions calculations are further complicated by the fact that, for example, changing technologies in recycling of materials will inevitably

24 Sathre, R., & O'Connor, J. (2008). A synthesis of research on wood products and greenhouse gas impacts. Canada: FP Innovations. Accessed from: https://library.fpinnovations.ca/fr/permalink/fpipub39868

25 *ibid*

26 https://www.fierceelectronics.com/electronics/researchers-find-a-way-to-cut-co2-emissions-from-concrete

27 Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts. FPInnovations. Accessed from: https://library.fpinnovations.ca/fr/permalink/fpipub39868

28 Churkina, G., Organschi, A., Reyer, C. P., Ruff, A., Vinke, K., Liu, Z., Reck, B., Graedel, T.E., & Schellnhuber, H. J. (2020). Buildings as a global carbon sink. *Nature Sustainability*, *3*(4), 269-276.

29 Geng, A., Yang, H., Chen, J., & Hong, Y. (2017) Review of Carbon storage function of harvested wood products and the potential of wood substitution in greenhouse gas mitigation. *Forest Policy and Economics*, 85(1), 192-200.

30 Hill, C., & Zimmer, K. (2018) The environmental impact of wood compared to other building materials. *NIBIO Rapport*, 4(56).

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

32 Pau, B. N., Hubert, J., Giuseppe, C., Klaus, R., & Bart, M. (2021). Climate mitigation by energy and material substitution of wood products has an expiry date. *Journal of Cleaner Production*, 127026.

33 Stewart, W., & Nakamura, G. (2012) Documenting the Full Climate Benefits of Harvested Wood Products in Northern California: Linking Harvests to the U.S. Greenhouse Gas Inventory. *Forest Products Journal*, 62(5), 340-353.

change long-term carbon consequences. Additional assumptions exist in accounting for the scale of climate benefits, for example sustainable forest management produces substantially different impacts than a focus on a single stand of trees or carbon pool.[34] To fully understand wood products carbon substitution benefits, carbon accounting could better account for changes in harvest practice, sectoral leakage, technological changes, and potential displacement given price and market fluctuations.[35]

2.1.2 Mass timber innovations can improve forest management

Manual layup of a CLT panel (Photo courtesy of TimberAge)

Forests play important roles in removing and storing carbon in woody biomass and soils and offsetting carbon emissions from burning fossil fuels.[36,37] However, forest degradation and deforestation, driven by habitat loss and conversion through natural disturbance and catastrophic events such as wildfire, disease, or pest outbreaks, reduce the ability for forests to store carbon in the long-term.[38] When trees are cut down, soils disturbed, and stored carbon from trees is released into the air, forests become emitters of carbon for up to 50 years.[39] In recent years, forests in the United States have been a carbon sink due to overall forest regeneration, reforestation, and woody growth resulting from fire suppression.[40] Large-scale megafires such as those experienced in California in 2020, likely have different mortality rates than smaller fires,[41] and climate change is likely to worsen wildfires and related emissions, with the greatest increase of wildfire emissions in California occurring in the Sierra Nevada and Klamath-Siskiyou.[42] Forest thinning combined with wood products manufacturing can reduce carbon emissions associated with wildfire,[43] though researchers have cautioned that removal of live biomass from the forest could result in a net emission of CO_2 from the scale of efforts needed to make forests more resilient to catastrophic wildfire..[44]

When wood products are used in lieu of fossil fuel-intensive products, however, carbon is stored for the life of the product, which can be recycled into other wood products or used for biomass energy following the lifespan of the initial product.[45] Mass timber, specifically, is not only a wood products substitute the

34 Lippke, B., Oneil, E., Harrison, R., Skog, K., Gustavsson, L., & Sathre, R. (2011) Life cycle impacts of forest management and wood utilization on carbon mitigation: knowns and unknowns. *Carbon Management*, 2(3), 303-333.

35 Howard, C., Dymond, C., Griess, V., Tolkien-Spurr, D., & van Kooten, G. (2021) Wood product carbon substitution benefits; a critical review of assumptions. *Carbon Balance and Management*, 16(9), 1-11.

36 Bonan, G. B. (2008). Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science*, *320*(5882), 1444-1449.

37 Forests can absorb 30% of all emissions from fossil fuel burning and deforestation: Canadell, J. G., & Raupach, M. R. (2008). Managing forests for climate change mitigation. *Science*, *320*(5882), 1456-1457.

38 Lamers, P., Junginger, M., Dymond, C. C., & Faaij, A. (2014). Damaged forests provide an opportunity to mitigate climate change. *Gcb Bioenergy*, *6*(1), 44-60.

39 Law, B. E., & Harmon, M. E. (2011). Forest sector carbon management, measurement and verification, and discussion of policy related to climate change. *Carbon Management*, *2*(1), 73-84.

40 Wear, D. N., & Coulston, J. W. (2015). From sink to source: Regional variation in U.S. forest carbon futures. *Scientific reports*, *5*(1), 1-11.

41 Wiedinmyer, C., & Hurteau, M. D. (2010). Prescribed fire as a means of reducing forest carbon emissions in the western United States. *Environ mental science & technology*, *44*(6), 1926-1932.

42 Hurteau, M. D., Westerling, A. L., Wiedinmyer, C., & Bryant, B. P. (2014). Projected effects of climate and development on California wildfire emissions through 2100. *Environmental science & technology*, *48*(4), 2298-2304.

43 Stephens, S. L., Boerner, R. E., Moghaddas, J. J., Moghaddas, E. E., Collins, B. M., Dow, C. B., ... & Youngblood, A. (2012). Fuel treatment impacts on estimated wildfire carbon loss from forests in Montana, Oregon, California, and Arizona. *Ecosphere*, *3*(5), 1-17.

44 Law, B. E., & Harmon, M. E. (2011). Forest sector carbon management, measurement and verification, and discussion of policy related to climate change. *Carbon Management*, *2*(1), 73-84.

45 Malmsheimer, R.W., Heffernan, P., Brink, S., Crandall, D., Deneke, F., Galik, C., Gee, E., Helms, J.A., McClure, N., Mortimer, M. and Ruddell, S. (2008). Forest management solutions for mitigating climate change in the United States. *Journal of Forestry*, *106*(3), 115-173.

construction industry can use to lower a building's embodied carbon emissions, but it also presents an opportunity to mitigate against wildfire carbon emissions. Most of the carbon absorbed by trees gets stored in the wood where, when harvested and transformed into a wood product, the carbon can remain captured for the duration of the product. For forests across the Western U.S. and in California especially, this means wood products represent additional opportunities for carbon sequestration when trees are harvested from wildfire mitigation projects. When wildfire devastates a forest, carbon stored in live trees is emitted and can contribute significant quantities of carbon to the atmosphere. For example, the wildfires that ravaged California in 2018 emitted 68 million tons of CO_2, the equivalent of about 15% of all of California's emissions for the year.[46] Carbon storage in forests presents the opportunity to create carbon offset markets for avoided emissions associated with wildfires, and is currently being explored by Climate Forward. Carbon storage in wood, similarly presents carbon-related market opportunities that may make mass timber more attractive for in-fill, overbuilds, and new developments, alike.

A fuels reduction operation in the process of sorting biomass

To accurately account for the carbon opportunities of mass timber, it is critical to use a full-system accounting process. Specifically, while wood harvesting and processing is a net carbon emitter, biomass that is converted to energy in integrated wood utilization schemes at harvest sites, sawmills, and waste-to-energy plants provide additional reductions in carbon emissions. When full wood utilization, including biomass energy production and manufacturing from other woody residuals is considered, there is approximately twice the climate benefit when compared with historical wood utilization coefficients, and up to nearly four times the benefit of models that do not count contributions from full utilization of woody residuals.[47] Some wood products experts agree that full wood utilization that make forest restoration material economical is critical to the feasibility of the sector. For instance, in a community-scale wood utilization study for Crescent Mills, CA in the Northern Sierra Nevada, researchers showed that biomass hauled to distant processing facilities had haul costs that made up 42-45% of total delivered biomass costs, whereas haul costs made up only 26-33% when delivered to a local site.[48] Forest restoration that produces not only low-value biomass energy but also higher value wood products, especially mass timber, offers the possibility of being both economically efficient and a carbon benefit from avoided wildfire.

2.2 Mass timber offers a strategy for economic growth

2.2.1 Demand for mass timber in California and beyond

Demand for mass timber continues to grow around the world. The mass timber market has seen 8% annual growth in the European market since 2015, and this is estimated to grow as wood encouraging policies continue to roll out across Europe.[49] The number of buildings using mass timber keeps growing across the United States, and California is the current leader of that growth. Likewise, California can expect to see growth in the sector following adoption of the 2021 IBC code, increasing interest in mass timber and sustainable materials from the technology sector, and the exploration of policy levers that can further tip the scales in favor of mass

46 https://www.doi.gov/pressreleases/new-analysis-shows-2018-california-wildfires-emitted-much-carbon-dioxide-entire-years

47 Stewart, W., & Nakamura, G. (2012) Documenting the Full Climate Benefits of Harvested Wood Products in Northern California: Linking Harvests to the U.S. Greenhouse Gas Inventory. *Forest Products Journal*, 62(5), 340-353.

48 Swezy, C., Bailey, J., & Chung, W. (2021) Linking Federal Forest Restoration with Wood Utilization: Modeling Biomass Prices and Analyzing Forest Restoration Costs in the Northern Sierra Nevada. *Energies*, 14(9), 2696.

49 https://www.propertyfundsworld.com/2021/07/12/303275/cromwell-and-dasos-capital-establish-pan-european-wooden-building-property-fund

FULL 7(f)

timber. California already represents a substantial share of the mass timber market that will continue to grow as thestate's design and build community gains experience with the technology.[50] Mass timber manufacturers interviewed for this report were all interested in accessing the state's market, and many had experience selling mass timber to projects across the state.

2.2.2 Mass timber for affordable housing

2.2.2.1 Urban housing needs

Despite projections of a market slowdown in the housing sector during COVID, California's housing market continues to grow through new construction, the majority of which across the state are single-family detached units.[51] At the same time, California continues to face a severe housing crisis, and needs to increase the housing stock by up to 3.5 million new homes.[52] Yet the vast majority of cities and counties are falling behind in meeting housing needs, leading to increased costs of housing and increased commute times for those who are priced out of affordable neighborhoods.[53] Across the state, only 22% of jurisdictions are meeting low-income housing permitting needs, while 45% of jurisdictions are meeting upper-income housing permitting needs.[54] Taken together, in-fill and overbuild projects can help meet demand for housing in city limits where it may be difficult or costly to break ground.

Mass timber buildings outfitted with sprinklers for fire events makes the material appropriate for use in dense urban areas

A 2016 McKinsey report identified several key pathways to close the housing gap in the state.[55] Of the pathways identified that fall into one of four categories, including identifying housing hot spots, removing barriers to housing development, ensuring housing access, and unlocking supply by cutting the cost and risk of producing house, mass timber represents an important technology to meet housing needs, including by enabling building on vacant land zones for multifamily development and through overbuilds around transit hubs, and adding units to underutilized urban land zoned for multifamily housing. Mass timber can also help the state unlock supply by improving productivity of construction work and through modular construction.[56] Although California's residential housing market is not currently projected to drive demand for mass timber, California is currently leading demand for mass timber projects, and it is widely recognized that the state will be a major center of demand for the material.[57] This is likely driven by multiple factors, including the role of the technology sector in seeking materials and processes that are more efficient and sustainable.

Indeed, despite the enormous challenges California faces to meet affordable housing needs, in part driven by the growth of the state's technology sector,[58] the technology sector itself is catalizing innovations in the sector.

---

50 Brandt, K., Latta, G., Camenzind, D., Dolan, J., Bender, D., Wilson, A., & Wolcott, M. (2021). Projected cross-laminated timber demand and lumber supply analysis. *BioResources*, *16*(1), 862.

51 Bizjak, T., and Reese, P. May 12, 2021. California home construction hits 13-year high. It's not enough to slow skyrocketing prices. https://www.sacbee.com/news/business/article251324588.html

52 McKinsey Global Institute. 2016. A tool kit to close California's housing gap: 3.5 million homes by 2025. Accessed from: https://www.mckinsey. com/~/media/mckinsey/industries/public%20and%20social%20sector/our%20insights/closing%20 californias%20housing%20gap/closing-californias-housing-gap-full-report.pdf

53 https://www.ladbs.org/services/core-services/plan-check-permit/product-approval

54 Collins, J., and Johnson, N. Dec. 10, 2019. California needs more housing, but 97% of cities and counties are failing to issue enough RHNA permits. https://www.ocregister.com/2019/12/09/losing-the-rhna-battle-97-of-cities-counties-fail-to-meet-state-housing-goals/

55 https://www.mckinsey.com/~/media/mckinsey/industries/public%20and%20social%20sector/our%20insights/closing%20californias%20 housing%20gap/closing-californias-housing-gap-full-report.pdf

56 http://www.ccala.org/clientuploads/comms/2019/CCA__Mass_Timber_White_Paper_final.pdf

57 Brandt, K., Latta, G., Camenzind, D., Dolan, J., Bender, D., Wilson, A., & Wolcott, M. (2021). Projected cross-laminated timber demand and lumber supply analysis. *BioResources*, *16*(1), 862.

58 https://www.fastcompany.com/90531798/the-tech-industry-exacerbated-the-housing-crisis-heres-what-google-is-doing-to-fix-it

One report found that the Bay Area, alone, would need to produce 2.2 million homes across all income levels in the next 50 years to meet housing needs.[59] Given the housing crunch facing communities that are home to major technology firms, including Google, Facebook, Apple, and Microsoft, many have committed to investing significant funds, in some cases several billion dollars, into affordable housing. Given the size of the problem, technology firms are approaching the challenge from multiple angles, including through land redevelopment, working with city officials and community members, and exploring technologies that can be leveraged to rapidly meet housing needs at lower costs and at a quicker pace.[60]

Google, for example, has invested in Factory_OS, a company that produces housing at lower costs and in a shorter time than traditional building techniques, representing significant movement towards achieving more affordable housing.[61] Factory_OS uses a lean manufacturing model, building modular units off-site that are rapidly assembled on-site, and with significant waste reduction in the building process due to precision engineering. Other companies in California bring a similar approach, including Entekra, Plant PreFab, Bay Modular, among others, though these companies do not currently use mass timber in their products. Modular, off-site design also offers the opportunity to build taller buildings using mass timber, including mid-rise building for family housing. There is a growing sector outside of California seeking to meet this need.

Mass timber innovations to meet California's housing needs

Fabric Workshop is a young, California-based mass timber company driven by a mission to meet California's infill residential housing demands with regenerative forest management. Fabric Workshop is currently in the process of finalizing their production model and are working in collaboration with mass timber experts Hacker Architects, Holmes Structures, and Arup to increase utilization of undervalued California wood. The company will use automated fabrication to re-manufacture commodity wood products into lightweight, cost- and materially efficient cassette-style mass timber panels that integrate connectors, mechanical systems, and insulation. Fabric Workshop has identified that there is significant demand in the California market, and intends to target sales in-state to meet local needs for housing, reduce transportation carbon footprint and avoid complex product designs and inspection processes based on different state code requirements. Instead of targeting Type IV developments, which has thus far brought much attention to the mass timber sector, Fabric Workshop is focusing on Type III and V builds on brownfield redevelopments to push for infill developments, building up rather than out. As part of their business model, they will provide independent developers with limited resources for research and development with high tech, sustainable, and efficient building solutions. Although many mass timber manufacturers have expressed concern about ensuring long-term feedstock supply contracts, Fabric Workshop is not concerned about feedstock supply given that the scale at which they intend to operate is such that at the moment they are sure they can readily secure fiber from fuels reduction projects. Fabric Workshop has identified that major bottlenecks to their work are demand by Type III and V developers and a limited network of computer numerical control fabricators to process panels.

2.2.2.2 Rural housing needs

Rural California also faces considerable difficulty to meet housing demands. Across the rural West, housing shortages are in part a consequence of ex-urbanites and second home owners seeking to live in recreation and natural amenity-rich locations.[62] Many of those are part-time residents who price-out bluecollar workers,

59 https://www.spur.org/publications/spur-report/2021-04-21/meeting-need?utm_medium=redirect&utm_source=meetingtheneed
60 https://www.fastcompany.com/90531798/the-tech-industry-exacerbated-the-housing-crisis-heres-what-google-is-doing-to-fix-it
61 https://factoryos.com/modular-construction-innovation/
62 Rural research brief. 2020. Rural population change and growth. Housing Assistance Council. Accessed from: https://ruralhome.org/wp-content/uploads/2021/05/rrb_population_change.pdf

pushing them to leave rural areas for the suburbs or cities where they can more readily find work and housing.[63] For example, in Plumas County, California, where tourism and recreation represent a key economic sector, approximately 35% of total housing units are used only for seasonal, recreational, or occasional use.[64] Rural California lacks affordable housing options, and it is projected that over 26,000 affordable units in the state could exit USDA's rural housing program by 2050.[65] This represents a serious challenge given that the average income of tenants in these USDA properties falls below $14,000, and the majority of residents are seniors and/or disabled.[66]

The shortage of affordable housing options in rural California not only leads to divergent wealth outcomes for rural communities but challenges the ability of the state to support jobs in key rural sectors. In forested communities, this means that even where there is demand for workers, forest or forest product workers may be unable to find a place to live, compounding workforce declines already facing the timber industry.[67] This problem is well documented in the agricultural sector,[68] and the forest sector is little different. Employers who seek qualified workers coming from out of the area, especially workers with families are likely to be unable to assure reliable housing at a reasonable distance from the jobsite.

Like large wood product manufacturing companies that have historically invested in company housing, at least one mass timber manufacturer located in an extremely rural area has developed company housing to ensure that workers have a secure and comfortable place to live. However, company housing is an expensive solution that may not be practical or achieve goals of equitable and long-term development across the state. Only 5% of Californians are rural residents, and declines in the rural workforce present a serious challenge to grow the wood products manufacturing sector across the state. This problem is not unique to California, and at least one mass timber manufacturer located in a rural area reported that they has to recruit from abroad to secure the workforce needed to meet growing demand for the material.

2.3 Mass timber performs in the face of environmental hazards

Advocates of mass timber emphasize the material's performance in the face of environmental hazards. Wood offers high performing mechanical properties, including strength and flexibility. However, each piece of lumber has variable properties and can deform under stress. Many deformations are elastic, meaning the wood responds to compression by regaining its original form after removal of the compression. When the compression surpasses the maximum bending strength of a piece of wood, it will break. Because mass timber consists of many layers of wood joined together, the individual weaknesses of each layer are minimized and the material can withstand significant pressure loads. These include blast loads which make it a favorable material for military installations.[69]

Because of the strength and elasticity of wood, mass timber offers many performance advantages compared to other structural building materials. First, mass timber offers high strength-to-weight ratios, meaning a mass timber component weights 20% of a comparable concrete component.[70] Combined, these factors make it more advantageous in wind and earthquake situations. Mass timber buildings, therefore, require a smaller foundation and have overall reduced seismic loads.[71] Mass timber is lighter and more flexible than concrete and steel, and has a strength-to-weight ratio over 3 times higher than concrete and 30% higher than steel, making it stronger than both concrete or steel when compared pound-for-pound.

---

63 *ibid*
64 Data according to: http://www.ruraldataportal.org/
65 United State Government Accountability Office (2018). Report to the subcommittee on agriculture, rural development, food and drug administration, and related agencies, Committee on Appropriations, U.S. Senate. Rural Housing Service. Better data controls, planning, and additional options could help preserve affordable rental units. Accessed from: https://www.gao.gov/assets/700/691851.pdf
66 https://www.csmonitor.com/USA/Society/2018/1231/It-s-like-we-don-t-exist-California-s-invisible-rural-housing-crisis
67 Employment Development Department. State of California. List of Industries Employing Forest, Conservation, and Logging Workers. Accessed from: https://www.labormarketinfo.edd.ca.gov/iomatrix/Staffing-Patterns3.asp?IOFlag=Occ&OccCode=454000
68 https://ruralhome.org/draft-house-bill-proposes-higher-rural-housing-spending/
69 https://csengineermag.com/woodworks-leads-successful-blast-testing-loaded-mass-timber-structures/
70 https://www.architectmagazine.com/technology/t3-becomes-the-first-modern-tall-wood-building-in-the-us_o
71 https://www.newsweek.com/carbon-sequestering-construction-oregon-428745

Mass timber is also twice as flexible as concrete, and can be a better alternative to reinforced concrete in seismically-active zones,[72] or can be used as a material to retrofit existing buildings that do not meet seismic codes. Furthermore, while mass timber buildings perform well under seismic stress tests, some in the sector have been experimenting with mass timber hybrids, including steel beam-mass timber hybrid panels and rocking walls,[73,74,75] to understand how to further improve performance in seismically active zones. Oregon State University's Peavy Hall features the first CLT rocking wall in North America, with shear walls that move independently.[76] Mass timber has also been shown to perform well under high wind conditions, including when used as a lateral load-resisting system in a 20-story building.[77] However, mass timber is not currently included in the International Building Code as a prescriptive lateral system, meaning developers may need to pursue the more time-consuming Alternate Means and Methods Request process or use hybrid mass timber/steel/concrete systems.[78]

Moisture sensors at Oregon State University's Peavy Hall are used to detect moisture content of the mass timber panels

Mass timber also performs well under fire conditions. Following several historical catastrophic fires in dense urban areas in the 19th century, the use of wood in tall buildings was limited until the government enacted performance standards for both materials and building components. The industry still struggles to effectively dispel public misrepresentations and misunderstandings of mass timber as it relates to fire and safety standards.[79,80] Specifically, fire resistance ratings are determined by ASTM E119 and require that three criteria be met for at least two hours. These include:

- Structural resistance (an the material support the load for the duration of the test?);
- Integrity (Can the material can prevent passage of flame or gases that could ignite a cotton pad?); and
- Insulation (Can the material can prevent a temperature rise of greater than 325°F at any one location or 250°F averaged across locations?).

The time it takes for a material exposed to fire to no longer satisfy any of these three criteria define its fire-resistance rating. The American Wood Council found that a 5-ply CLT panel covered with a single layer of gypsum wallboard lasted over three hours before the material no longer satisfied required criteria.[81] A separate test conducted by researchers at Oregon State University found that five out of six exposed mass timber assemblies surpassed the two-hour benchmark before the material no longer satisfied required criteria.[82]

Mass timber can maintain structural capacity following significant exposure to fire because wood is structurally unaffected by heat until it catches fire. For mass timber that is exposed to fire, the outer layer chars while the inner

---

72 Timmers, M., & Jacobs, A. T. (2018). Concrete apartment tower in Los Angeles reimagined in mass timber. *Engineering Structures*, *167*, 716-724.
73 Zhang, X., Azim, M. R., Bhat, P., Popovski, M., & Tannert, T. (2017). Seismic performance of embedded steel beam connection in cross-laminat ed timber panels for tall-wood hybrid system. *Canadian Journal of Civil Engineering*, *44*(8), 611-618.
74 Ganey, R. S. (2015). *Seismic design and testing of rocking cross laminated timber walls* (Doctoral dissertation).
75 Pei, S., van de Lindt, J. W., Barbosa, A. R., Berman, J. W., McDonnell, E., Daniel Dolan, J., ... & Wichman, S. (2019). Experimental seismic response of a resilient 2-story mass-timber building with post-tensioned rocking walls. *Journal of Structural Engineering*, *145*(11), 04019120.
76 https://www.azuremagazine.com/article/in-oregon-a-hub-of-forest-science-rises-in-wood/
77 Chen, Z., & Chui, Y. H. (2017). Lateral load-resisting system using mass timber panel for high-rise buildings. *Frontiers in Built Environment*, *3*, 40.
78 https://www.smithgroup.com/perspectives/2021/in-support-of-mass-timber-strategies-for-reducing-risk
79 https://www.popsci.com/article/technology/worlds-most-advanced-building-material-wood-0/
80 Larasatie, P., Hansen, E.N., and Guerrero, J.E. (2018). What does the US Pacific Northwest public believe about tall wood buildings? Conference paper. World Conference on Timber Engineering. Seoul, Republic of Korea. Accessed from: https://www.researchgate.net/profile/Pipiet-Larasatie/publication/327164339_WHAT_DOES_THE_US_PACIFIC_NORTHWEST_PUBLIC_BELIEVE_ABOUT_TALL_WOOD_BUILDINGS/links/5b7de36ba6fdcc5f8b5de228/WHAT-DOES-THE-US-PACIFIC-NORTHWEST-PUBLIC-BELIEVE-ABOUT-TALL-WOOD-BUILDINGS.pdf
81 https://continuingeducation.bnpmedia.com/courses/think-wood/cross-laminated-timber/10/
82 Muszyński, L., Gupta, R., hyun Hong, S., Osborn, N., & Pickett, B. (2019). Fire resistance of unprotected cross-laminated timber (CLT) floor assemblies produced in the USA. *Fire Safety Journal*, *107*, 126-136.

layers remain unaffected. Because of the charring on the outside layer, fires in mass timber buildings can even self-extinguish. Adhesives could also affect fire performance, and the one panel referenced above in the Oregon State University study delaminated after 100 minutes when the polyurethane HBE adhesive bonds softened. However, ANSI/APA standards require that all mass timber adhesives retain their bonding capabilities under both heat and fire.[83] Questions remain about how mass timber compares to other building materials during real wildfire events, though results look promising especially when compared to light-frame building, and would perform better than many other building products given mass timber's fire resistance performance, even for relatively thin panels.[84,85]

Another major consideration for mass timber is water damage, which impacts both the construction process and the long-term life of the building. Because wood absorbs water, it can rot. Where wood is most exposed to water, especially around the exterior and plumbing systems, care must be taken to prevent water exposure given that rotting can reduce structural performance. Water-resistant coatings can be applied to the material to reduce exposure to water and the potential for failure. Other possible mechanisms for mass timber failure include insects and pest-related damage, exposure to fungus, and the potential breakdown of adhesives used in laminating mass timber.[86] Wood is hygroscopic, meaning it absorbs moisture from the environment. Moisture content must be carefully managed because it can impact almost every property of wood, and can lead to checking, shearing and delamination, among other problems.[87] The strength of connectors can also be compromised,[88] while the expansion of mass timber layers can lead to failure of the glue.

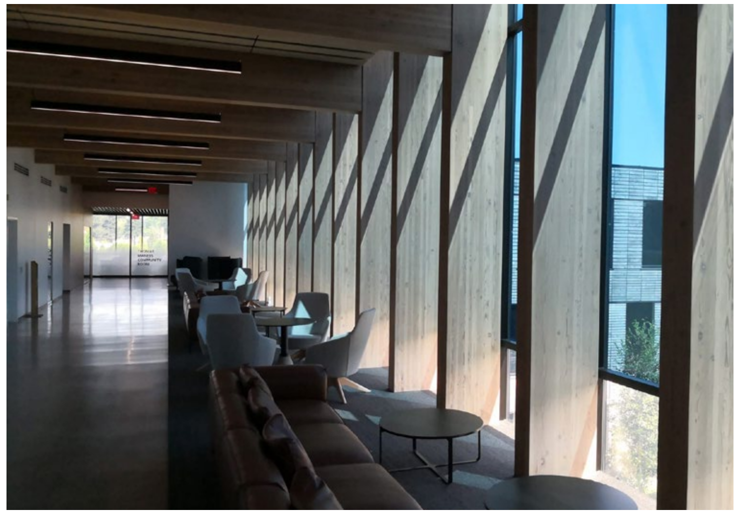
Moisture management is therefore critical, both during and after the construction process. For the most part, mass timber is not pressure treated as is commonly done for exterior lumber decking or fencing.[89] Precipitation events during construction, and plumbing leaks can introduce moisture. Elevated moisture can penetrate through multiple layers of a panel, leading to microbial growth or insect attack. During construction, plastic tarps or tents may be used to prevent water penetration, while longer term options including barriers, such as films, coats, and other water-shedding materials, may be used, but must be consistently reapplied for long-term efficacy. Preservatives or preserving treatments may also protect mass timber elements throughout the life of the material, though are infrequently used,[90] because it introduces questions of end-of-life disposal.[91]

When it comes to insects, the American Wood Council recognizes that no treatment is guaranteed to work. Instead, they recommend using multiple strategies in concert. The six S-strategy includes: suppression to keep insect populations from taking over a location, site management to remove any tree stumps and control for water sources, soil chemical or physical barriers, designing slab and foundations to prohibit insect entry, structural treatment with chemical additives of the mass timber elements, and surveillance and remediation to check for and treat insect populations.[92] With proper care and attention before, during, and after the construction of a mass timber building, these problems can be kept to a minimum, prolonging the life of a mass timber building.

---

83 https://continuingeducation.bnpmedia.com/courses/think-wood/cross-laminated-timber/10/
84 https://www.fastcompany.com/90545929/mass-timber-is-the-future-of-architecture-but-can-it-survive-a-world-on-fire
85 David Barber, fire engineer and Principal at Arup. Personal communication on June 20, 2021
86 *ibid*
87 Riggio, M., Schmidt, E., & Mustapha, G. (2019). Moisture monitoring data of mass timber elements during prolonged construction exposure: the case of the Forest Science Complex (Peavy Hall) at Oregon State University. *Frontiers in Built Environment*, *5*, 98.
88 Sinha, A., Udele, K. E., Cappellazzi, J., & Morrell, J. J. (2020). A method to characterize biological degradation of mass timber connections. *Wood and Fiber Science*, *52*(4), 419-430.
89 Wang, J. Y., Stirling, R., Morris, P. I., Taylor, A., Lloyd, J., Kirker, G., Lebow, S., Mankowski, M., Barnes, H. & Morrell, J. J. (2018). Durability of mass timber structures: A review of the biological risks. *Wood and fiber science*, *50*(Special), 110-127.
90 Wang, J. Y., Stirling, R., Morris, P. I., Taylor, A., Lloyd, J., Kirker, G., Lebow, S., Mankowski, M., Barnes, H. & Morrell, J. J. (2018). Durability of mass timber structures: A review of the biological risks. *Wood and fiber science*, *50*(Special), 110-127.
91 Morrell, J. J. (2017). Protection of wood: a global perspective on the future. In *Wood is Good* (pp. 213-226). Springer, Singapore.
92 https://www.awc.org/pdf/education/des/AWC-DES130A1-DesigningForDurability-1604.pdf

2.4 Mass timber offers performance advantages in the built environment



Sunlight on Oregon State University's Peavy Hall's mass timber walls bring a sense of warmth

As people spend more and more time indoors, there is a growing need to understand how human health is impacted by the built environment. Nature and natural elements have been shown to have positive impacts on people's sense of wellbeing, both psychologically and physiologically. Designers are finding ways to bring nature indoors, and mass timber is one opportunity to increase the use of natural materials. In recent years alongside the growth of the mass timber industry, scholars have begun to explore the biophilic nature of wooden buildings. Biophilia, or the human desire to connect with and be close to nature, is a common draw by designers to use natural materials. Wood meets all biophilic design principles used by architects. Wood connects people to nature by bringing the outdoors inside, and can also connect people to place when local species are used. Patterns in wood grain form natural shapes and patterns that are alive and full of movement, which is both aesthetically pleasing and evokes nature. Finally, wood is warm and has different coloration that can be stained without losing the natural quality.[93]

There is a growing body of research that points to the biophilic benefits of wooden building environments. One study showed that caregivers and medical professionals in a hospital preferred some amount of wood in hospital room interiors, while the least preferred room was all clad in pine,[94] suggesting that certain amounts of wood may be optimal. In one study that compared responses to wood versus wood laminate, participants had significantly more positive reactions to the wood as compared to the laminate, indicating that people appreciate wood for more than just its visual appeal.[95] People also respond better to wooden over plaster indoor environments, experiencing the material through touch, sound, and smell.[96] Wooden buildings have been shown to provide a better work and living environment, both in terms of health and well-being,[97,98] as well as productivity and performance of workers.[99] One experiment measured physiological responses of people in wooden and non-wooden rooms, and found that participants working in wooden rooms had less fatigue and tension.[100] Exposed interior mass timber is also shown to buffer indoor temperature variability, thereby improving the thermal comfort of occupants[101].

---

93 Burnard, M. D., & Kutnar, A. (2015). Wood and human stress in the built indoor environment: a review. Wood science and technology, 49(5), 969-986.

94 Nyrud, A. Q., Bringslimark, T., & Bysheim, K. (2014). Benefits from wood interior in a hospital room: a preference study. *Architectural Science Review*, *57*(2), 125-131.

95 Jiménez, P., Dunkl, A., Eibel, K., Denk, E., Grote, V., Kelz, C., & Moser, M. (2016). Wood or Laminate?—psychological research of customer expectations. *Forests*, *7*(11), 275.

96 Demattè, M. L., Zucco, G. M., Roncato, S., Gatto, P., Paulon, E., Cavalli, R., & Zanetti, M. (2018). New insights into the psychological dimension of wood–hu man interaction. *European Journal of Wood and Wood Products*, *76*(4), 1093-1100.

97 Zhang, X., Lian, Z., & Ding, Q. (2016). Investigation variance in human psychological responses to wooden indoor environments. *Building and Environment*, *109*, 58-67.

98 Sakuragawa, S., Miyazaki, Y., Kaneko, T., & Makita, T. (2005). Influence of wood wall panels on physiological and psychological responses. *Journal of Wood Science*, *51*(2), 136-140.

99 Shen, J., Zhang, X., & Lian, Z. (2020). Impact of wooden versus non wooden interior designs on office workers' cognitive performance. *Perceptual and motor skills*, *127*(1), 36-51.

100 Zhang, X., Lian, Z., & Wu, Y. (2017). Human physiological responses to wooden indoor environment. *Physiology & behavior*, *174*, 27-34.

101 Hameury, S., & Lundström, T. (2004). Contribution of indoor exposed massive wood to a good indoor climate: in situ measurement campaign. Energy and buildings, 36(3), 281-292.

While mass timber has been shown to be a net positive for visitors, acoustical performance is a key factor that also drives someone's experience in a building. Exposed mass timber is aesthetically pleasing for many, but offers poor acoustical performance. To maintain the aesthetic quality of exposed mass timber, WoodWorks recommends adding mass, noise barriers, or decouplers to improve acoustical performance.[102]

Finally, one of the theoretical benefits associated with mass timber is improved worker safety for those involved in constructing mass timber buildings. Although delamination panel failures represented both a missed safety hazard and a significant setback at Oregon State University's Peavy Hall mass timber redevelopment,[103] there is evidence that mass timber construction sites are safer than traditional construction sites due to fewer workers, tools, and traffic.[104] Together, this indicates that mass timber, and the new IBC codes that allow taller mass timber buildings with exposed elements may offer all-around improvements in environmental quality, with multiple benefits to society.

2.5 Remaining questions

Given the novelty of the use of mass timber in California and across the US, there is still much to learn in terms of real-world performance, both in the face of environmental threats like wildfire, and in terms of the human interface with the built environment. Similarly, there remain questions about how mass timber can contribute to improved forest management. Given that North American production is at a relatively nascent stage, the understanding of whether and how mass timber can change the dynamics of forest management will likely emerge as more businesses across different sectors gain experience with the technology.

Fundamental research questions nonetheless remain, including: How does mass timber perform in wildfire events, especially in comparison to other materials? What are the differences in construction worker safety in sites building with mass timber versus other materials? The evidence is powerfully suggestive but comprehensive research is needed. How might the health of a community be affected when entire neighborhoods are built with mass timber, as in San Jose where Google is making significant investments? Does investment in mass timber-built neighborhoods impact gentrification/community change?

There are many exciting research questions about the mass timber sector, from basic technological and performance questions to psychological, physiological, social and built environment questions. Some states have created departments and programs to help answer these questions. Given that there is no clear research body for mass timber within the state, California has the opportunity to imagine what kinds of research programs may be most impactful. This will require investments and directives towards the higher education system but enables the state to build capacity and leadership, and potentially to carve out a specialty in the sector.

---

102 https://www.woodworks.org/wp-content/uploads/wood_solution_paper-MASS-TIMBER-ACOUSTICS.pdf
103 https://www.enr.com/articles/45125-regluing-oregon-states-showcase-for-mass-timber
104 https://www.thinkwood.com/wp-content/uploads/2018/04/TALL-MASS-TIMBER-REPORT-2.pdf

CHAPTER 3

WHAT ARE KEY BARRIERS FACING THE GROWING MASS TIMBER SECTOR IN CALIFORNIA?

Photo courtesy of TimberAge Systems

FULL 7(f)

Recommendations

- California and the Department of Insurance should advance work with leading companies and insurers (e.g., WoodWorks and AXA XL, a global insurance company among others); to advance understanding of mass timber and identify programs to encourage mass timber developments in wildfire-prone areas;
- Like the State of Oregon, California should consider adopting state standards for mass timber product use to ease the lack of experience and knowledge by local building and code enforcement officials;
- The State of California has labeling schemes (Made and Grown in CA) that should be extended to the wood products manufacturing and mass timber sector to encourage not only mass timber manufacturers to locate in California but also harvest from California forests to increase marketability and perceived product value;
- California should consider creating a position at Go-Biz responsible for recruiting mass timber businesses and working to identify and eliminate barriers and aggregate financial incentives for new businesses; and
- California should invest in an easy-to-navigate online system in which site-level data are collated and mapped to improve information availability for prospective businesses.

Highlights

- Mass timber offers numerous performance advantages over traditional building materials, but lack of experience and familiarity with the product by insurers and code enforcement officials alike make it challenging and costly for developers and manufacturers interested in working with this new material;
- There are a variety of incentives offered by the State of California that could be used to leverage mass timber manufacturing, though the lack of targeted interest and specific financial support for the mass timber sector by the state may discourage applicants from the industry;
- California, Oregon and Nevada business recruitment strategies vary markedly and underscores both a comparative paucity of readily-available information and overall difficult navigation of California's web presence; and
- With respect to industrial recruitment costs, California is notably more expensive than Oregon and Nevada on its electricity rates, minimum wage, worker compensation rates and, for a larger employer, health care costs. However, these costs alone do not discourage manufacturers from locating in California. Active recruitment efforts accompanied by targeted incentives of neighboring states is relatively more important than direct operating expenses for manufacturers.

3.1 Moving projects to completion

3.1.1 Insuring mass timber construction

One of the major challenges facing the mass timber sector, especially as it relates to ensuring growth in demand for the product, is insurance. Insurance for mass timber buildings falls into one of two categories: builders risk insurance for construction and property insurance for the life of the building. Insurance allows policy holders to protect themselves from certain risks, and when those risks are poorly understood companies are often reluctant to offer it. Both contractors and developers have been quoted high insurance premiums for mass timber projects as insurance companies classify mass timber projects as light wood frame construction despite the differences in performance between materials.[105] Mass timber, despite passing fire safety tests and being approved for use in high rise buildings, is seen by the insurance market as a new product with little historical data on which to base insurance rates. Establishing risk ratings and rates are further complicated because mass timber does not easily match categories long used by the insurance industry.[106]

A CLT panel gets lifted into place at the construction site

Early in 2021, AXA XL, a global insurance company, launched an insurance program for mass timber construction, called Builders Risk Insurance, to help de-risk sector innovation and to improve utilization of newer and proven technology, including mass timber.[107] AXA XL and Woodworks, a non-profit company providing critical information about the product, both recommended that builders interested in using mass timber work with a broker who understands the technology and can negotiate an appropriate classification for the project. Key information that can influence how risk is understood by an insurer include: materials test reports, strategies for moisture management during construction, water damage mitigation strategies, site security plans, sprinkler protection plans and coordination with fire department, complete construction schedule with a description of how timeline differs from other materials, and general risk management plans.[108,109]

Despite limited understanding, mass timber construction offers insurers, builders, and owners' advantages that will likely prove up in the long run. The shortened schedule for mass timber building project delivery can reduce the time needed to insure the construction of a building. Smaller building foundations combined with prefabricated and just-in-time delivery also reduce costs associated with labor and assembly. As more developers and contractors build with the technology, improved understanding will likely translate to lower cost insurance for mass timber structures, but the initial challenge of establishing rates and for those seeking property coverage,

105 McLain, R., and Brodahl, S. Insurance for mass timber construction: Assessing risk and providing answers. WoodWorks. Wood Products Council.

106 Kahn, D. 2018. The Mass Timber Revolution. ISO. A Verisk Business. Accessed at: https://www.verisk.com/insurance/capabilities/underwriting/commercial-property/construction-briefs/

107 https://axaxl.com/insurance/products/builders-risk-insurance

108 McLain, R., and Brodahl, S. Insurance for mass timber construction: Assessing risk and providing answers. WoodWorks. Wood Products Council.

109 Cheri Hanes of AXA XL on IRMI podcast. https://irmi.podbean.com/e/insuring-mass-timber-%E2%80%93-a-look-across-lines/

FULL 7(f)

identifying insurers and securing insurance remains.

Given the dramatic increase in destructive catastrophic wildfires, insurance companies are refusing to issue new or renew insurance policies for structures in high hazard areas. Based on their fire ratings, homes constructed with a mass timber exterior may reduce the risk of catastrophic loss from wildfire. Mass timber may well represent the "hardened home" of the future, and an opportunity for traditional products used in new ways to withstand wildfire. California's Department of Insurance should consider supporting WoodWorks in their efforts to work with insurance companies to advance understanding of mass timber. The Department of Insurance can play a role in consideration of how mass timber construction can address wildfire risk.[110] In the event a mass timber building is damaged by fire, it is possible to rehabilitate the material to ensure structural performance, making this material especially well-suited to changing climatic conditions and fire intervals.[111]

3.1.2 Jurisdictional differences leads to increased demands and costs

Jurisdictional differences in permitting requirements represent another barrier to expansion of the mass timber sector. Some mass timber manufacturers expressed concern over costs associated with materials testing required by certain locales. Of specific note, the city of Los Angeles publishes a list of approved materials through the Los Angeles Research Report,[112] a material testing process that several mass timber manufacturers noted costs $30,000 per material per year to ensure they are code approved. If the value of product sales makes the test costs worthwhile, manufacturers are likely to supply projects in that locale, but these requirements represent entry barriers that are too steep for some, and considered excessive by others. Growth in the sector will likely reduce these cost-related barriers in the long run, but will hinder adoption of mass timber materials in the near term.

Another way that jurisdictions challenge the growth of the sector is when city and county code officials have little experience with a new technology and they refuse to accept work done elsewhere as acceptable proxies assuring product safety. The burden of proving safety, even with proven products, falls on developers and manufacturers and drives up costs. When developers work on projects in different jurisdictions, they often have to add additional permitting costs each time, regardless of success with past projects using the same material. Similarly, a code official familiar with CLT but not DLT will need to gain experience with DLT, regardless of their comfort with CLT, the compatibility of products, or proven successful substitution elsewhere. As mass timber technology is used with increasing frequency and successful builds are communicated to the wider public, these costs too will decline over time. Invoking state-level permitting, as the State of Oregon showed, helped reduce barriers for mass timber developments in Portland and across the state.

3.1.3 Skilled installation labor

The construction industry lacks skilled construction laborers.[113] Many workers that left after the Great Recession have not returned to the sector, and longtime skilled laborers are aging out.[114] As an example of the shortage, a recent major CLT building that was erected in Cleveland, OH was completed by an installer from British Columbia. While it represents a challenge for the construction industry in general, it represents both a challenge and an opportunity for the mass timber industry. As described above, mass timber introduces efficiencies in the building process that reduce labor needs. The build and design community is developing ways to increase construction capacity and experience. Swinerton, for example, has established TimberLab, while Skanska is building its own installation capacity. Other companies, such as TimberAge, have developed a mass timber panel that is smaller in size (4 x 8-foot panels), which removes the challenge of needing to hire a big crew and finding cranes to install panels for its community scale projects. Still, aside from ensuring

---

110 Chiglinsky, K., and Chen, E., 2020. Many Californians being left without homeowners insurance due to wildfire risk. Insurance Journal Accessed at: https://www.insurancejournal.com/news/west/2020/12/04/592788.htm

111 Research Institute of Sweden Fire Research. 2021. Post-Fire Rehabilitation of CLT - Summary Video. Accessed at: https://youtu.be/69DQ70tbe0M

112 https://www.ladbs.org/services/core-services/plan-check-permit/product-approval

113 https://www.cnn.com/2021/07/08/economy/construction-worker-shortage/index.html

114 https://www.giatecscientific.com/education/the-impact-of-the-labor-shortage-in-the-construction-industry/

that skilled installation labor gains the hands-on experience through training programs or on-the-ground experience, more innovation in the sector, whether through vertical integration or rescaling products, is likely to reduce this sectoral barrier.

3.2 State incentives and recruitment efforts

3.2.1 Incentives and opportunities

California offers a variety of competitive incentives that mass timber manufacturers could use to reduce the costs associated with developing a new manufacturing facility. Some of these are managed through the Governor's Office, while others are managed through the Treasurer's Office. Table 7 below provides an overview of the key subsidies and incentives made available by the state for which mass timber businesses could qualify.

Table 7. Overview of the main incentives made available by the state that could be leveraged by mass timber manufacturers.

State incentive program name	Managing office	Type of incentive	Program overview
CalReUse[115]	Treasurer	Grants and loans up to $5 million	Brownfield redevelopment in economically distressed communities
California Pollution Control Industrial Development Bonds[116]	Treasurer	Industrial bond up to $10 million	Projects involving a pollution control facility and also feature a manufacturing component
The Sales and Use Tax Exclusion Program[117] (CAEATFA)	Treasurer	Sales and use tax exclusion, capped at $10 million	Excludes sales and use taxes of Qualified Property for advanced manufacturing in alternative energy or of recycled feedstock
California Competes[118]	Governor's office (Go-Biz)	Tax credit to businesses of variable sizes: Fiscal year 2022's budget is over $280 million	Tax credit for businesses creating jobs in high unemployment and poverty areas

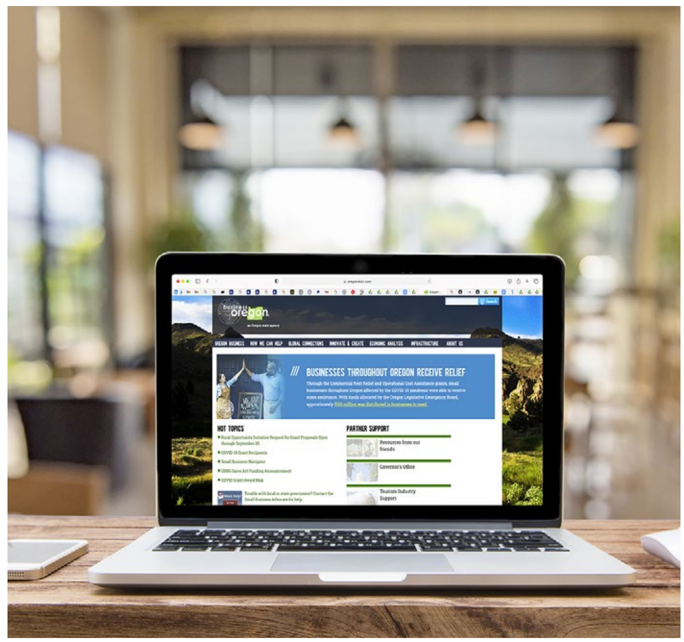
Funds available to businesses vary in size and number, though as of July, 2021, only four wood products or lumber and milling businesses have received a California Competes tax credit. These include Fruit Growers Supply Company for a small-log sawmill and corrugated carton plant; the Truckee-Tahoe Lumber Company for a new lumber yard in Truckee; California Pacifica Speciality Woods, LLC, a firewood and specialty wood products business with a small-scale sawmill; and Golden State Lumber for a lumber yard and design center. Given that over 1,000 tax credits have been awarded to-date, the small number of wood products-related awardees may discourage other

115 https://www.treasurer.ca.gov/cpcfa/calreuse/text.pdf
116 https://www.treasurer.ca.gov/cpcfa/cpcfaidb.asp
117 https://www.treasurer.ca.gov/caeatfa/ste/index.asp
118 https://business.ca.gov/california-competes-tax-credit/

eligible wood products businesses from applying for the credit.

The State of California has a few unique product labeling schemes that could bring significant advantages to in-state mass timber manufacturers. One label, California made (https://camade.ca.gov/), enables businesses selling products that are substantially made in California to certify their product. This allows products to bear the CA Made logo, a listing on the CA Made website, and product promotion through Go-Biz. Another opportunity includes the California Grown labelling scheme (https://californiagrown.org/about-ca-grown/). This label is currently restricted to food grown in-state but could be expanded to include wood products made from California-grown wood.

By creating more incentives targeting the suite of desired industries, including mass timber manufacturers, fabricators, prefabricated modular builders, among others, the state can move towards desired conditions whereby manufacturers have an ecosystem of both technological and human capacity from which to build business. Furthermore, although the state has created some demand-side incentives to spark experimentation with the technology, one developer noted that the mass timber competition provided $500,000 of support across 4 different projects was minimal compared to what incentives would be most impactful to change the materials cost-benefit equation.[119]



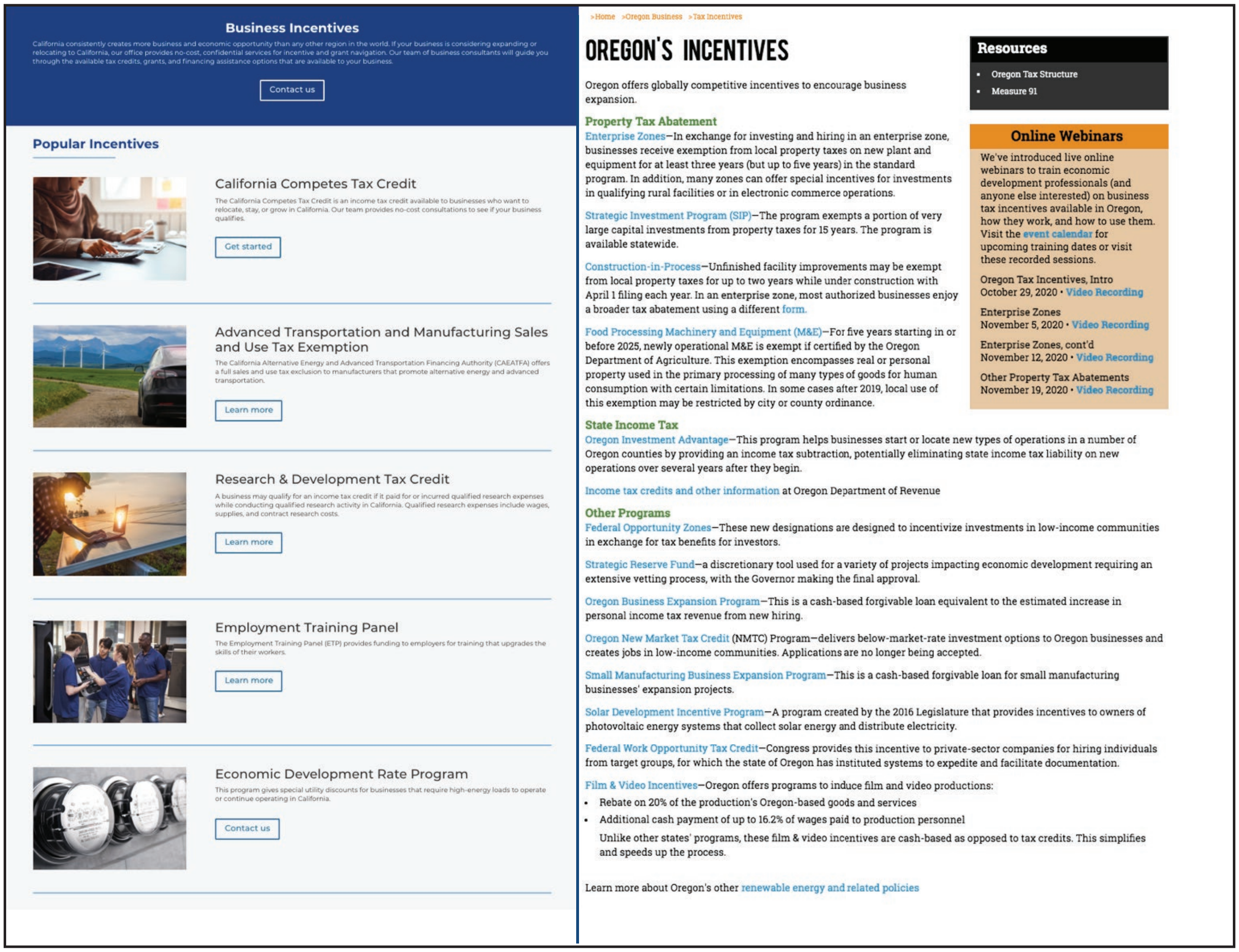
Oregon4Biz.com's website (photo courtesy of Chris Oldroyd)

3.2.2 Outreach and recruitment

Beyond the types of subsidies and incentives available to businesses, the research process identified several key challenges to identifying relevant information on the Go-Biz website. Specifically, when comparing aspects of the California Governor's Office of Business and Economic Development (Go-Biz) website with both the Business Oregon (Oregon4Biz) and Nevada Governor's Office of Economic Development, several key aspects differed in terms of the quality of information and overall availability of information. First, in comparison to Go-Biz's list of incentives that focus exclusively on incentives offered through the Governor's Office, Oregon4Biz shared a wider array of incentives available to prospective businesses, including federal opportunities (Figure 7). Nevada outlines incentives for businesses looking to develop in urban and rural areas within the state. By offering a host of possible incentives businesses may consider, and by compiling as many as possible in one location, potential businesses are likely to have an easier time than when the information is found across multiple webpages.

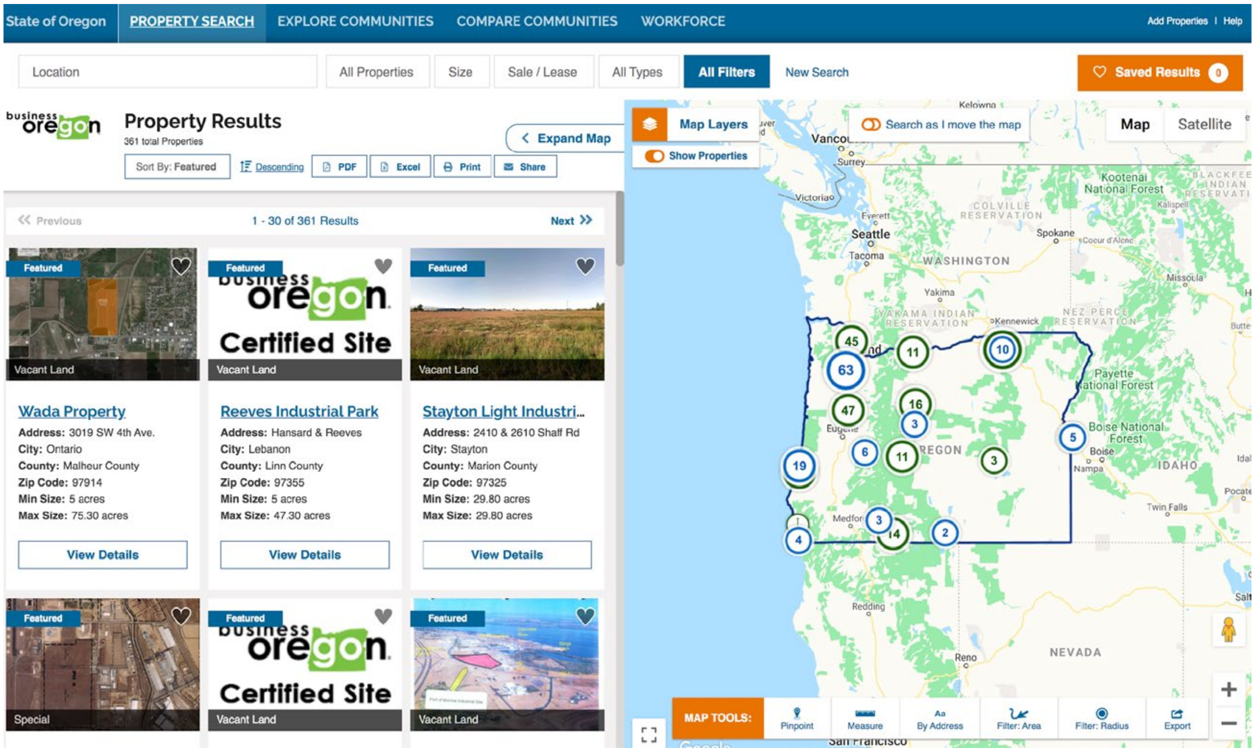
119 https://www.archdaily.com/935985/california-promotes-architectural-innovation-through-mass-timber-competition

Figure 7. California's Go-Biz business incentives main page, on the left, offers information that is specific to Go-Biz-offered incentives, while Business Oregon's incentives main page, on the right, offers diverse state and federal incentive information in a one-stop-shop.



Second, both Oregon and Nevada offer online tools that help prospective businesses explore and compare different locations. Site comparison tools make it easy for businesses to explore key guiding information on their own. Oregon, specifically, has also collated properties for sale that businesses can explore. This tool, called Oregon Prospector, is user friendly and offers exceptional depth of data, allows users to search not only for available properties, but also explore and compare communities, identify workforce availability and readiness, and facilitates site comparisons across state lines (Figure 8).

Figure 8. Business Oregon's website (http://www.oregonprospector.com) where prospective businesses can search for specific available properties, explore communities, compare communities, and identify the workforce availability and readiness.



Nevada, similarly, has invested in comparative tools to help prospective investors decide on a location that best suits their needs. Although the tool is focused on urban areas, the data provide an overview of different price comparisons that provide a general overview, including side-by-side comparisons of various urban communities across the U.S. to highlight the comparative advantages of locating in Nevada (Figure 9). Additionally, Nevada's Office of Economic Development has pulled together an incentive reference guide[120] that provides an overview of tax abatement programs available for businesses looking to locate in either urban or rural areas.

In contrast, California's Go-Biz website offers minimal information in comparison to neighboring states, and instead offers a point person located within the office to help the prospective business connect with relevant agencies and offices and navigate policies and procedures. One drawback of this approach is that it requires a business having an idea of where they may want to locate and introduces a level of opacity to an already complex decision-making process.

California should invest in an easy-to-navigate online system where site-level data are collated and mapped to improve information availability for prospective businesses. This system will allow California to share relevant information that could tip the scales in favor of California for prospective businesses, including workforce educational attainment, business park developments, average sales for relevant business categories, among others. While Nevada boasts low cost electricity and a zero percent tax rate, California could showcase strengths that make businesses more interested in siting in the state, such as access-to-market, proximity to other industrial development, and workforce capacity.

120 https://goed.nv.gov/wp-content/uploads/2020/08/202008_GOED_incentive_guide.pdf

Figure 9. Nevada Governor's Office of Economic Development website location comparison report allows prospective businesses to compare and contrast side-by-side various urban communities across the United States to highlight comparative advantages of locating in Nevada. This particular report compares Metropolitan Statistical Areas of Las Vegas, Reno, Portland, and Sacramento.

Nevada Governor's Office of ECONOMIC DEVELOPMENT Empowering Success

ECONOMIC PERFORMANCE DATA | ECONOMIC DEVELOPMENT DATA | LOCATION COMPARISON | DETAILED OVERVIEW REPORTS

< BACK TO LOCATION SELECTOR

Location Comparison Report

Economic profile		Las Vegas MSA	Reno MSA	Portland MSA	Sacramento MSA
Population	[1]	2.3M	475.6K	2.5M	2.4M
Establishment-Based Employment	[2]	940.7K	245.7K	1.2M	983.2K
Labor Force	[3]	1.1M	269.1K	1.3M	1.1M
Unemployment Rate	[4]	9.0%	4.9%	6.1%	6.6%
Average Annual Wage - Private	[5]	$49.1K	$51.8K	$61.5K	$55.5K
Average Annual Wage - Manufacturing	[6]	$56.6K	$61.7K	$82.7K	$67.9K
Per Capita Personal Income	[7]	$48.8K	$63.3K	$59.9K	$58.8K
Economic Development					
Workers Compensation Cost (per $100 in Payroll)	[8]	$1.18	$1.18	$1.15	$2.87
Payroll Tax	[9]	1.48%	1.48%	9.00%	n/a
Unemployment Insurance Tax (Max Rate)	[10]	5.4%	5.4%	5.4%	6.2%
Corporate Income Tax Rate (Highest Bracket)	[11]	0.00%	0.00%	7.60%	8.84%
Individual Income Tax Rate (Highest Bracket)	[12]	0.00%	0.00%	9.90%	13.30%
Sales Tax Rate (State Minimum)	[13]	6.85%	6.85%	0.00%	7.25%
Property Tax Rate	[14]	0.66%	0.66%	0.98%	0.74%
Office Market Avg. Asking Rents PSF	[15]	$2.07	$1.66	$2.59	$2.01
Industrial Market Avg. Asking Rents PSF	[16]	$0.68	$0.38	$0.60	$0.66
Commercial Electric Rates (Per kWh)	[17]	$0.076	$0.076	$0.090	$0.177
Industrial Electric Rates (Per kWh)	[18]	$0.056	$0.056	$0.061	$0.144
Commercial Natural Gas Rates (Per 1000 cu.ft.)	[19]	$7.25	$7.25	$7.88	$9.86
Industrial Natural Gas Rates (Per 1000 cu.ft.)	[20]	$6.06	$6.06	$4.62	$7.64
Cost of Living Index	[21]	104.8	112.8	134.3	123.5

DOWNLOAD REPORT [PDF]   DOWNLOAD DATA [EXCEL]

Several mass timber manufacturers noted that California is perceived as being unfriendly to business given the strict regulatory environment. In describing the regulatory environment challenges, manufacturers focused on minimum wage requirements, worker's compensation, and the regulatory environment more generally. To test the idea that wages and other worker-related requirements makes California unfriendly for business, a site comparison was conducted to compare costs for a mass timber manufacturer who must choose between siting a plant in California, Nevada, or Oregon (Table 8).

Table 8. Costs associated with siting a manufacturing plant in California, Nevada, and Oregon. Costs that represent a disadvantage to California-based manufacturers are bolded for emphasis.

Siting-related costs	California	Nevada	Oregon
Occupational safety	(state OSHA plan – Cal/OSHA) Electrical permit, fire (Certified Unified Program Agency) inspection (fire and toxic substances)	(state OSHA plan)	(state OSHA plan)
Breaks	Paid 10-minute break/4 hours of work; unpaid 30-minute lunch break for 8 hours of work	Paid 10-minute break/4 hours of work; unpaid 30-minute lunch break for 8 hours of work	Paid 10-minute break/4 hours of work; unpaid 30-minute lunch break for 8 hours of work
Minimum wage	**$14/hour**	$9.75/hour (without qualifying benefits), or $8.75/hour (with qualifying benefits)	$12.75/hour
Overtime	1.5x regular rate: for hours worked in excess of 8 and up to 12 hours/workday; for the first 8 hours of work on the 7th consecutive day or work; 2x the regular rate for anything more	1.5x regular rate: for either over 8 hours/day of work or for more than 40 hours/week of work (capped at those making $10.89 w/ health benefits and $12.38 w/o health benefits)	1.5x regular rate of pay for all hours worked in excess of 40 hours/work week
Unemployment insurance (Max rate)	**4.3% (on first $7,000)**	2.95% (on first $33,400)	2.6% (on first $43,800)
Corporate income tax rate (highest bracket)	**8.84%**	0.00%	7.60%
Individual income tax rate (highest bracket)	**13.30%**	0.00%	9.90%
Property tax rate (state level)	0.74%	0.66%	0.98%
Sick leave	1 hour of sick leave for every 30 hours worked	>50 employees – 40hrs/year <50 employees -- none	1 hour of sick leave for every 30 hours worked (up to 40 hours)
Health insurance	**Affordable Care Act (50+ employees must provide health insurance)**	No state law	No state law
Workers compensation (per $100 in payroll)	**$2.87**	$1.18	$1.15
Payroll tax	Unemployment 4.3% Employment Training Tax 0.1% (both paid by employer on first $7,000) Disability 1.2%	1.48%	9.0%
Industrial electric rates (per Kwh)	**$0.14**	$0.06	$0.06
Industrial natural gas rates (per 1000 Cu. Ft.)	**$7.76**	$6.00	$4.62
Right-to-work state	No	Yes	No

Although businesses rely on a combination of factors, including some not quantifiable, this comparison revealed that for minimum wage, worker compensation rates and, for a larger employer, health care costs California is notably more expensive than Oregon and Nevada. With respect to an operating mass timber facility, one of the major costs associated with doing business in California are electricity rates. Electricity may be negotiable for industrial companies, but based on non-negotiated rates, a business that needs 95.1 kWh/ ft^2 can expect to spend over $1,664,250 per year to operate in California, as opposed to $713,250 per year to operate in both Nevada and Oregon (Table 9), a difference of 133 percent. These costs will decrease if a manufacturer were to pair its business with biomass to energy facility, which can convert low value material generated during timber harvest, fuels reduction and lumber milling to electricity.

Table 9. Company specifications for a hypothetical company. Rough costs are calculated for a CLT company with 27 minimum wage employees, 3 managerial staff earning double minimum wage, working in a 125,000ft2 building and using 95.1kWh/ft2.

Cost categories	California	Nevada	Oregon
Wages (employees x wage x hours)	33 x $14/hr x 40hrs/wk x 52wks/yr = $960,960/yr	33 x $9.375/hr x 40hrs/wk x 52wks/yr = $643,500/yr	33 x $12.125/hr x 40hrs/wk x 52wks/yr = $832,260/yr
Energy Costs (area x use/area x rate)	125,000ft^2 x 95.1kWh/ft^2 x $0.14/kWh = $1,664,250	125,000ft^2 x 95.1kWh/ft^2 x $0.06/kWh = $713,250	125,000ft^2 x 95.1kWh/ft^2 x $0.06/kWh = $713,250
State Payroll Tax - paid by employer (wage threshold x rate x employees)	$7,000 x 4.4% x 30 = $9,240	$19,500 x 2.95% x 27 = $15,531.75; $33,400 x 2.95% x 3 = $2,955.90; total = $18,487.65	$25,220 x 2.6% x 27 = $17,704.44; $43,800 x 2.6% x 3 = $3,416.40; total = $21,120.84
Total Cost (wages + energy + payroll tax)	$960,960 + $1,664,250 + $9,240 = $2,634,450	$643,500 + $713,250 + $18,487.65 = $1,375,237.65	$832,260 + $713,250 + $21,120.84 = $1,566,630.84

One prefabricated modular home building company currently based out of California does not use mass timber because they perceive the material as too expensive. However, they use CNC machining to fabricate components of homes, providing essential infrastructure and workforce development for the wider manufacturing sector that can service the mass timber sector. They explained that electricity costs are not really a problem for their operations because their work is less energy intensive, and they also receive negotiated rates of electricity by cities in California hoping to recruit them. What has tipped the scales for them, however, are substantial competitive offers from neighboring states looking to recruit their kind of industrial manufacturing where they could also access large markets with substantial housing crunches. They even had a phone call directly with the governor of one state. They explained that, “We would love to see the state [California] have a vested interest in more companies that are doing manufacturing; producing skilled, well-payed jobs, and developing affordable housing. It would be in the state’s best interest to give people like us incentives to grow this sector.”

CHAPTER 4

WHAT POLICIES CAN ENABLE CALIFORNIA TO PROMOTE MASS TIMBER AND OTHER INNOVATIVE WOOD PRODUCTS?

Recommendations

- The state should examine whether and how mass timber procurement may align with the Buy Clean California Act (AB262) to support climate-friendly public infrastructure investment;
- The state should allocate funds to craft carbon protocol for mass timber buildings and developments;
- A well-designed public information and marketing campaign could help strengthen public support for the mass timber sector. Better communication and marketing should link sustainable wood products, a forestry workforce, and wildfire risk reduction;
- The state should examine the possibility of creating a formal working partnership with a mass timber-producing country to ensure continuing growth of the sector, identification of improved technology and best practices, and to guide strategic investments; and
- Significant investment into research and development should be made to build a sustainable wood products engineering program at a university campus or across campuses to build workforce capacity and to attract mass timber-related businesses. This program should not only focus on key research areas, including carbon analysis and mass timber development impacts, but should also seek to meet the research-related needs of small community-scale wood products manufacturers working to experiment with an add value to smaller diameter roundwood.

Highlights

- Regulation of the building sector is one important mechanism used to reduce associated greenhouse gas emissions associated, including through the direct promotion of wood as well as the promotion of less carbon-intensive materials increasingly gaining traction across the United States;
- Procurement policies offer the state an important mechanism to reduce embodied carbon in buildings, but thus far no mechanism has been established specific to mass timber;
- Other states are pursuing carbon market options for carbon sequestering wooden buildings, though this economic instrument is still in its infancy;
- Public perception of the forestry and wood products industry continues to challenge whether mass timber will become widely accepted across the state; and
- The state has many different forestry and wood products-adjacent university research programs but lacks a coherent program with the stated purpose of developing and improving the mass timber sector.

4.1 Policies play a key role in growing the mass timber sector

Government policy plays a key role in advancing the use of wood in buildings. These wood encouraging policies can take many different forms, and in a 2014 survey conducted in 33 countries around the world with 100 stakeholders and supporters of the forestry and timber sectors of the United Nations, 42% of respondents noted that their country has at least one policy in effect targeting the promotion of sustainable building materials, 15% identified that they have a policy in development that will be implemented in the next two years, and 18% noted that their country has no such policy in place.[121] Those seeking to promote certain building materials may pursue diverse policy pathways, though there has been very little systematic research to date on the effectiveness of these policies.

Governments have a variety of policy instruments at their disposal to shape development decisions in particular ways. Policy instruments can be attractive incentives that make certain decisions more attractive to investors and developers, but they can also be punitive in nature, intended to discourage certain decisions, thereby making others look more attractive by default. Key policy instruments generally fall into one of five categories: Regulatory instruments, economic instruments, information tools, voluntary policy tools, and research and development tools.[122] These tools can be applied at different temporal and spatial scales. For instance, much of the available information on mass timber-supporting policies are focused at the national or state-level, although municipalities can also play key roles in implementing a wood encouraging policy. In this section, each of the different policy tools are explained, using examples from around the world as they relate to the green building sector, with a focus on mass timber where possible.

4.1.1 Regulatory instruments

Governments, thus far, have been heavily focused on developing and enforcing **regulatory instruments**, and to date there is extensive documentation of these types of policies. Regulatory instruments can be mandatory technology-based standards which describe approved technologies for certain applications, or they can be performance-based standards that focus on the outcome without getting into a prescriptive mode. Regulatory instruments are some of the most popular policies used to promote green building standards, harvested wood products, and mass timber, specifically.

Some key characteristics of mass timber regulatory instruments include:

- Accounting for greenhouse gas emissions in the bidding process for public-financed buildings and infrastructure;
- Requiring a complete life cycle analysis and setting greenhouse gas emission targets for all materials used in public-financed buildings and infrastructure;
- Priority given to locally-sourced materials for use in in public-financed buildings and infrastructure; and
- Articulation of a common vision for setting greenhouse gas emission targets.

These include wood encouraging policies used in North America, Japan, Australia, and other major wood producing regions. Indeed, wood encouraging policies are more likely to succeed where they support an important local industry, and governments may leverage local cultural values and traditions to garner public support around particular regulatory instruments. Wood encouraging policies mainly target climate change, the reduction of greenhouse gas emissions associated with the building sector, and the promotion of a local wood economy and culture. Wood encouraging policies also have been known to receive pushback from industries of other carbon-intensive building materials, such as the cement industry that lobbied against passage of AB2518

121 https://www.unece.org/fileadmin/DAM/timber/publications/SP-38.pdf

122 All categories and definitions are pulled from: Kibert, C. J. (2001). Policy instruments for sustainable built environment. *J. Land Use & Envtl. L.*, *17*, 379.

that called for increasing mass timber use and other innovative wood products in California (as well as the development of this report). In some cases, those industries develop strong lobbying powers and pursue legal action based on claims of sector favoritism.[123]


Stacked lumber (photo credit: Adobe stock photos)

Across the world, many countries have implemented wood encouraging policies across various scales, including federal, state, and municipal. Regulatory instruments may develop as public procurement policies, given that the public sector is responsible for significant amounts of goods purchases. By harnessing the power of a triple bottom line goal to advance environmental, social, and economic criteria, the public sector can select goods and services that meet a range of desirable criteria. One example is United Kingdom's BES6001 Responsible Sourcing of Construction Products that requires the full life cycle analysis of materials construction procurement process and sets standards for Environmental Product Declarations.[124] Information is contained in the British Research Establishment Green Book Live Responsible Sourcing of Construction Products, which includes a searchable online database of certified products and sellers.

Regulatory instruments may also develop as policies that focus on the proportion of wood in buildings. The Swiss Wood Resource Policy, for example, established targets and standards for the use of wood in buildings to reduce embodied energy, with a focus on increasing opportunities for the development of a sustainable local wood industry. Additionally, this policy informs broader national and regional climate goals.[125] Switzerland also has created and advanced the 2000-Watt Society Energy Vision that establishes long-term goals for energy and GHG emissions for buildings, and includes a full life cycle analysis of operational and embodied emissions related to buildings and transportation. This policy plays a regulatory role for both the building industry and materials manufacturing sector.

One of the better-known policies in the mass timber sector is Canada's Wood First initiative that advances technical developments and structural norms. It was developed to ensure that wood is considered first as a feasible building material, stimulates research and development in new wood markets, and supports local wood markets. The Wood First Initiative also aims to strengthen regional capacity to produce high quality wood products and grow the culture of forestry in British Columbia and Quebec—two major wood producing provinces of Canada. Through this policy, North America, more generally, has built complimentary social and political infrastructure, for example the Binational Softwood Lumber Council and the Softwood Lumber Board, as well as WoodWorks that provides support to architects and engineers. By using a multi-pronged approach, the government has the power to drive prolonged investment in the sector with increased likelihood of genuine impact.

Green procurement policies, more generally, are regulatory instruments commonly used across the U.S. and in California. Marin County, for example, has a low-carbon construction ordinance that requires low-carbon concrete. This policy includes a prescriptive compliance option for embodied carbon limits of cement in all private and public construction projects using concrete in the county[126]. This low-carbon concrete code amendment targeted both a prescriptive pathway, determining a maximum ordinary Portland cement content,

---

123 Status of public policies encouraging wood use in construction – an overview. Draft background paper prepared for the 61st Session of the FAO Advisory Committee on Sustainable Forest-based Industries, April 2020.

124 Information from: https://www.unece.org/fileadmin/DAM/timber/publications/SP-38.pdfF

125 *ibid*

126 https://achieving-zero.org/bay-area-concrete-carbon-code/

and a performance pathway, determining embodied carbon limits for concrete usage.[127] The state of California, more broadly has passed the Buy Clean California Act (AB262), which relies on a performance path to reduce greenhouse gas emissions for state-funded infrastructure.[128] In addition to requiring greenhouse gas emission calculations from contractors engaged in the bidding process, the state has created a maximum acceptable global warming potential for each material category, meaning materials must adhere to strict limits.[129]

In the mass timber sector, specifically, California was an early adopter of the 2021 International Building Code, which allows for taller wood buildings and opens up a large segment of the market that would have been restricted to concrete and steel. Starting July 1, 2021, California now allows construction of buildings with engineered wood up to 18 stories. What had formerly been categorized as Type IV construction will be sub-categorized into IV-A, IV-B, and IV-C construction. These new categories provide guidance for new heights based on how much mass timber is protected with fire resistant material. Designers and architects see California's adoption of the new code as creating opportunity, rather than restricting what can be done, for example by allowing exposed mass timber in residential buildings of up to eight stories tall.[130] In this case, significant design and environmental benefits are apparent, such as the aesthetics of exposed wood and biophilic benefits, a reduction in need of other materials, like gypsum board, a reduction of material waste at the construction site, and quicker build times.

By looking at the regulatory power of the state in terms of supply-side dynamics, California may consider how manufacturing regulations could be fostered to account for the net carbon and social benefit provided through mass timber manufacturing from restoration material harvested in rural, forested parts of the state. Specifically, as discussed in Chapter 3, some mass timber manufacturers noted that the stringent regulatory environment in California may be a hindrance for developing the sector in the state, for example, in terms of air quality permitting. These manufacturers suggested that the state could account for mass timber production-related air quality benefits as they relate to potential reductions in wildfire-related emissions. Specifically, this could take the form of additional air allowance offsets, which could make it easier for a manufacturer to install a dry kiln. Furthermore, by linking wood encouraging policies across goals, especially as they relate to rural development and working forest landscapes, regulatory policies can have greater impact.

4.1.2 Economic instruments

Economic instruments are another commonly used policy tool. When governments use economic instruments, they work through markets, fees, and bonds, among others, to use monetary incentives to push and pull policy outcomes. Economic instruments, sometimes referred to as "polluter pays", enable the calculation of costs that are not accounted for in the value of a good or service, but that are incurred to the public during the production, sale, and transport of a good or service.[131] Economic instruments are commonly used in tandem with regulatory instruments. Commonly used economic instruments are:

- Cap and trade, cap and invest, and cap and dividend;
- Tradeable permits;
- Pollution taxes;
- Carbon markets;
- Deposit-refund systems; and
- Financial incentives and subsidies to targeted industries for innovation and technology.

California is a world leader in developing economic instruments to encourage desired policy outcomes, especially in the environmental sector. The state itself along with numerous non-profits and businesses have

---

127 https://www.stopwaste.org/sites/default/files/MarinLCCCProcessSummary2021.pdf
128 https://achieving-zero.org/buy-clean-california-act/
129 https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act
130 Carpenter, A. and Knize, S. (2021). California catches up on mass timber. Perkins & Will
131 https://www.who.int/heli/economics/econinstruments/en/

created carbon markets associated with forest and land conservation. California is advancing carbon market protocols that support wildfire risk reduction on forest land in the West, both by creating markets for management actions that reduce fuel loading, and more recently by exploring the potential for a biochar market. Mass timber and wood products, more generally, are currently considered only insofar as the allowances are made for wood harvesting from forests for carbon storage. A carbon offset credit program targeting building sector emissions could incentivize greater adoption of mass timber,[132] and economic instruments could be more widely leveraged to increase both the supply and demand side of the mass timber market.

Some states are exploring policy mechanisms to account for the embodied carbon in buildings (photo credit: Adobe stock photos)

There are a few examples of economic instruments being leveraged for the adoption of mass timber. Some examples include the state of Oregon and Clackamas County, Oregon. The state of Oregon, generally, has created a position for mass timber recruitment through Oregon4Biz, the state's economic development engine. Within this position, they have reduced the transaction costs for potential new businesses by paying for full-time staff that work on specific barriers, for example negotiating international trade arrangements and collating financial incentives. Of particular import is Oregon's Strategic Investment Program, a property tax exemption program for large capital facilities that site in counties and cities that receive approval from the state.[133] While this is not specific to mass timber, mass timber manufacturing is a qualifying business and Oregon4Biz has made a one-stop shop for potential businesses to locate resources and to reach out directly to recruiters.

Georgia's House Bill 1015, which was introduced in the Georgia State Legislature in 2019 and was referred but, as of writing, has a current status of *Engrossed - Dead*. This bill relates to the Georgia Carbon Sequestration Registry, to include building products in construction given carbon sequestration capabilities of particular materials.[134] This voluntary carbon market would encourage voluntary carbon offsets through the use of carbon sequestering materials in buildings, among others. This provides an additional market incentive for builders to consider wood first. Given the state of California's advanced carbon markets and the current movement to build out a protocol for biochar through the Climate Action Reserve, the state may consider whether a potential carbon market exists for mass timber developments, thus enabling builders to access markets for their choice of building material, or whether the production of mass timber panels merits consideration. Regardless, the Climate Action Reserve has extensive experience moving forward experimental markets to encourage certain behaviors over others.

Another example of an economic instrument is the Netherlands' chain-oriented waste policy that targets the environmental impacts of the whole material supply chain, including end of life of products.[135] Their national waste management plan aims to reduce the environmental costs across the supply chain and to bring a supply chain approach to reduce waste. Included are targets to prevent waste by encouraging materials recovery along the supply chain. They have committed to reusing and recycling building material, and an estimated 90% of building material is reused or recycled. For example, demolished asphalt and concrete are reused in road building. End of life is designed into the cost of the building, rather than being an afterthought. Though leakage

132 Himes, A., & Busby, G. (2020). Wood buildings as a climate solution. *Developments in the Built Environment*, *4*, 100030.
133 https://www.oregon4biz.com/Oregon-Business/Tax-Incentives/SIP/
134 https://legiscan.com/GA/text/HB1015/id/2163636
135 Oosterhuis, F. H., Van Beukering, P. J. H., Bartelings, H., & Linderhof, V. G. M. (2009). *Economic instruments and waste policies in the Netherlands. Inventory and options for extended use* (No. IVM-R--09-01). Institute for Environmental Studies IVM.

is a primary concern of economic instruments, they can still be effective mechanisms to achieve desired end goals. California may also consider how subsidies and taxes can be built into products to discourage the use of non-renewable materials or to account for the end of life of the product. This may also encourage planners to build for future over present needs and concerns.

4.1.3 Information tools

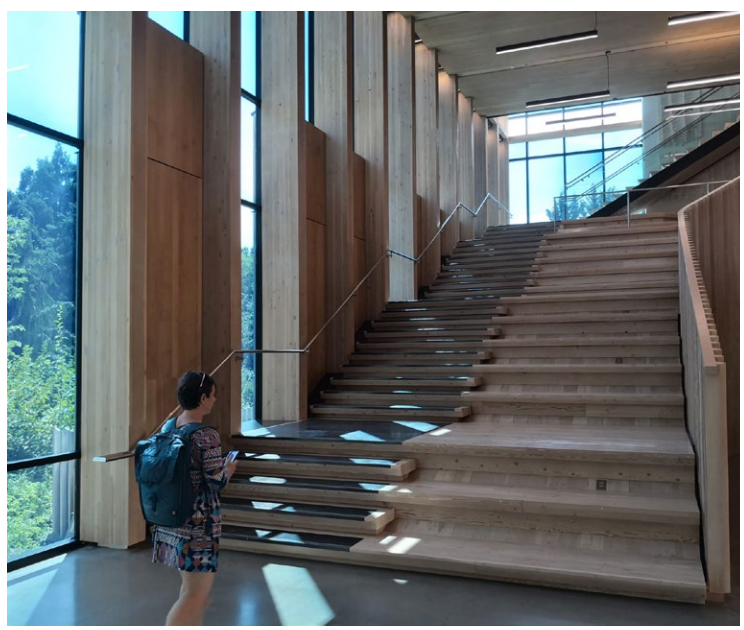
Another policy tool commonly used by governments to shape outcomes is information. **Information tools** include:

- Public information campaigns to raise awareness of key issues;
- Environmental labeling schemes, certified by a third party of producers; and
- Technological information diffusion programs, including demonstration projects.

Simply by making information available, governments can introduce choices to decisions that end users may not previously have been aware of, with the goal of highlighting the problem and presenting readily adoptable solutions. Information tools, when used alone, are often not effective at changing people's minds, but can work well when used in tandem with a suite of complementary policies.[136] Information tools are commonly used by governments and organizations as a way to introduce new ideas, and are therefore fairly popular in the mass timber sector.

Sustainability certifications are increasingly popular across both the forestry sector (e.g., Forest Stewardship Council (FSC) certification and Sustainable Forestry Initiative (SFI) certification), as well as the building and construction sector (e.g., LEED and Passive House certifications[137]). Forest product certification signals to consumers that their products meet minimum environmental and sometimes social criteria, and is widely valued by architects and end consumers who see the certification as a guarantee that forests are sustainably managed. Green building certifications, similarly, serve to encourage a set of design decisions to reduce the carbon footprint of a building. In the mass timber sector, both of these types of certifications are widely used by architects as shortcuts to design decisions, and certifications are marketed by manufacturers who may try to show that their product is of higher value than another.

This presents a challenge for the marketability of timber products from the majority of California's forests given that 58% of the state's 33 million acres of forests are federally owned and not likely to receive certification due to the cost burden being passed onto the public. Instead, some working in the sector have suggested that a new labelling scheme can signal products harvested from fuels reduction projects. One opportunity is to build California-grown wood products into the California Grown marketing scheme that, thus far, is focused on food products.[138] Although there is a challenge of ensuring chain-of-custody from forest restoration or fuels reduction work, one effort in Tuolumne County is exploring how



A college student walks through Oregon State University Peavy Hall

136 Weil, D., Fung, A., Graham, M., & Fagotto, E. (2006). The effectiveness of regulatory disclosure policies. *Journal of Policy Analysis and Management: The Journal of the Association for Public Policy Analysis and Management*, *25*(1), 155-181.

137 https://passivehouse.com/03_certification/02_certification_buildings/03_certifiers/01_accredited/01_accredited.html

138 https://californiagrown.org/

aggregated harvests from high hazard zones in the area can prove chain of custody for marketing purposes. Others in the mass timber manufacturing sector have suggested more education directed at consumers, especially where high standards of care under business as usual scenarios can match certification standards. For example, while FSC certified forests in Washington and Oregon sequester more carbon than non-certified forests,[139] that difference would be minimal in California where the California Forest Practices Act is comparable to FSC standards. Some mass timber manufacturers and USDA Forest Service representatives, alike, suggested that forest certifications represent only a mark-up in price where forest management standards set a high bar, and that education should be used to speak to the standard of management on federal lands.

This kind of information campaign could be most effective when used in tandem as a part of a wider campaign. For example, one example of a policy that provides information and encourages voluntary action is Austria and Germany's WOODBOX travelling public outreach program. WOODBOX was an interactive display for the public to present solutions to sustainable building challenges. WOODBOX was complemented by WOODDAYS, an event featuring lectures, and presentations on sustainable cities. What made WOODBOX impactful was that it was integrated across a wider array of policies and programming to holistically support wood-based solutions.[140] Canada, similarly developed the Green Construction through Wood program, which led to the construction of high-rise and non-residential mass timber buildings and bridges.[141] A fund of almost $40 million dollars was allocated over 4 years to demonstration projects and revisions to building codes and has been shown to have broadened the market for mass timber through regulatory and social acceptance of the technology.[142]

In the U.S., the Forest Service developed the Wood Innovations Grant, which is supported by the Agriculture Improvement Act of 2018 and Rural Revitalization Technologies, as a way to promote economic and environmental health of American communities.[143] Launched in 2015, this program has a national focus on mass timber, renewable energy, and sustainable forest management, generally. In 2021, $8.9 million was awarded to 44 projects, 21 of which involved mass timber and making mass timber buildings visible.[144] By funding publically-accessible buildings, members of the public can get first-hand experience inside of a mass timber building and see and feel the difference from concrete buildings. This approach of giving the general public the opportunity to experience the inside and outside of a mass timber building is critical to democratize the material and technique.

California has leveraged information tools similarly. Specifically, the California Government Operations Agency's Mass Timber Building Competition provided a financial prize to four different projects using mass timber across the state.[145] Two grand prize winners won $200,000 each. Although the prize money represented just a fraction of the cost associated with developing in mass timber, it is likely that these projects would have moved forward in mass timber without the prize money since developers are interested in the other benefits associated with mass timber, including biophilia and rapid construction speed. One interview with a developer from the Bay Area noted that more and higher-value prizes might tip the scales for prospective mass timber projects, especially for affordable income housing developments.

4.1.4 Voluntary policy tools

Voluntary policy tools comprise voluntary commitments or declarations by private businesses, agreements or commitments to support various causes, and general voluntary commitments established by governments that private enterprises may decide to participate in. Voluntary policies allow industrial firms to collaborate through programs to improve how they are perceived by others, though voluntary policy tools may

139 Diaz, D. D., Loreno, S., Ettl, G. J., & Davies, B. (2018). Tradeoffs in timber, carbon, and cash flow under alternative management systems for Douglas-Fir in the Pacific Northwest. *Forests*, *9*(8), 447.

140 https://www.unece.org/fileadmin/DAM/timber/publications/SP-38.pdf

141 https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/forest-sector-funding-programs/green-construction-through-wood-gcwood-program/20046

142 Mohammad, M., Tourrilhes, J., Coxford, R., & Williamson, M. (2019). Canadian Mass Timber Demonstration Projects Initiatives. *Modular and Offsite Construction (MOC) Summit Proceedings*, 51-58.

143 https://www.fs.usda.gov/science-technology/energy-forest-products/wood-innovation

144 https://www.usda.gov/media/press-releases/2021/05/07/usda-awards-15-million-grants-expand-wood-products-wood-energy

145 https://www.govops.ca.gov/mass-timber-building-competition-objectives-eligibility/

also help protect the bottom line, through job creation and environmental protection.[146] There are four main types of voluntary approaches:

- Unilateral commitments to meet certain goals;
- Private agreements between industry and others;
- Agreements between industry and public authorities; and
- Voluntary programs developed by public authorities targeting specific firms.[147]

Voluntary policies represent great options where no other policy tools are available, for example when there is no clear centralized authority to regulate a particular domain. Voluntary action should be welcomed, though there is some disagreement as to how impactful the action is when used as a stand-alone, especially considering that the costs associated with the action may be relatively high.[148]

While voluntary policy tools are typically embraced by private enterprise, or negotiated between firms and other stakeholders to reduce negative environmental externalities, there is increasing interest of public governments to grow specific sectors, in part through this pathway. Specifically, several states in the United States are entering into agreements with the government of Finland to support the development of a sustainable forest bioeconomy, including the states of Maineand Arkansas.[149,150] Maine's formal agreement with Finland targets academic and policy initiatives, wood utilization, best practices, and more, and both governments have agreed to promote fruitful exchange of ideas and collaboration. By formally declaring their intention to collaborate to further investments into the mass timber sector, Arkansas and Maine have both made clear their interest in evolving the industry beyond their own expertise. It is noteworthy that both Arkansas and Maine have robust forest products economies and university research programs, meaning that they are both targeting sector growth through complementary pathways.

California, similarly, has started down this path with some of the initiatives coming from the sector, such as funding prizes for innovation. However, the state could benefit from more public declaration of their intention to pursue mass timber as an economic development and forest health strategy. Much of the voluntary policy tools in California's mass timber sector are driven by the technology sector. Google, specifically, is pursuing a strategy of voluntary investment into sustainable development in their new corporate campus in San Jose, which will not only incorporate mass timber throughout, but ensure that Google's campus is integrated in city planning and includes affordable housing.[151] Microsoft, similarly, used CLT in their renovated Mountain View, California headquarters,[152] and some representatives interviewed for this report noted that there is increasing interest from the technology sector to show the positive environmental and social benefits associated with their new infrastructure investments. This movement towards corporate social responsibility also links with mental and physical benefits for people who work and live in mass timber buildings as part of a trend towards green human resource management.[153]

California could complement its robust policy approach leveraged through other policy pathways by pursuing a multi-strategy voluntary policy approach. Specifically, given the state's international economic importance, California could develop formal relations with another nation that bring a comprehensive understanding of the mass timber sector and represent strategically-aligned partnerships. This kind of partnership represents the opportunity for the state to develop workforce capacity, grow international trade agreements, and invest in the technology needed to ensure that mass timber manufacturing is meeting the state's diverse needs. Alternatively, given the role of the

---

146 Dietz, T. (2002). Understanding voluntary measures. *New tools for environmental protection: education, information, and voluntary measures*, 319.
147 https://read.oecd-ilibrary.org/environment/voluntary-approaches-for-environmental-policy_9789264101784-en#
148 Madarang, K. (2014). Environmental policy instruments (direct regulation, marked-based tools and voluntary programs: Better together. Environmental Sustainability & Policy.
149 https://www.maine.gov/governor/mills/sites/maine.gov.governor.mills/files/inline-files/Maine%20and%20Finland%20MOU.pdf
150 https://www.businessfinland.fi/en/whats-new/events/business-delegations/2021/arkansas-finland-high-level-online-roundtable-on-forest-bioeconomy
151 https://www.archpaper.com/2020/10/google-shares-vision-for-sprawling-sustainable-downtown-west-in-san-jose/
152 https://www.archpaper.com/2017/12/microsoft-reveals-renderings-silicon-valley-campus-upgrade/
153 Lowe, G. (2020). Wood, Well-being and Performance: The Human and Organizational Benefits of Wood Buildings. Accessed from: http://grahamlowe.ca/wp-content/uploads/2020/06/wood-well-being-and-performance_report_graham-lowe.pdf

technology sector in driving innovation and development within the state, the state could convene a working group of key members within the sector to articulate a shared vision for sustainable building needs, and to identify and invest in markets that could match these criteria. It will be critical that the state leverage the private technology sector's interest in sustainable investment in order to effectively grow the sector.

4.1.5 Research and development

Finally, one significant policy pathway is through investment into **research and development tools.** Investment into research and development can provide support for the attraction and retention of private sector development and/or public/private partnership. Strategic growth of this sector is often first established at the university level where concentrations of expertise can be cultivated, often resulting in the seeding of an industry sector. Other times, dominant industries within a state will invest in programs as a way to grow an elite sector. Regardless of which comes first, the existence of a dedicated university program and the co-locating of industry often occur in a virtuous cycle, and is seen across the country in states that have simultaneously grown desired industries alongside research and development programs at universities. Table 10 compares a few different states that have invested into a wood innovations center, though there are many different forms this kind of approach could take.

Table 10. A comparison of some states and the wood products programs they have developed, broken into several key categories of comparison.

State	Oregon	South Carolina	Maine
Wood innovations center name	Tallwood Design Institute (TDI)	Wood Utilization + Design (WUD) Institute	Advanced Structures and Composites Center
University	Oregon State University and University of Oregon	Clemson University	University of Maine
Affiliated colleges or departments	College of Forestry (OSU); College of Design (U of O); College of Engineering (OSU)	College of Agriculture, Forestry, and Life Sciences; School of Architecture; as well as Departments of: Civil Engineering; Construction Science and Management; Material Science and Engineering	Stand-alone center, with faculty and students from: civil engineering, forest resources, wood science, economics, international trade and commerce, and business, among others
Mission	"To advance the adoption of mass timber building materials and systems"	"To design advancements in wood-based construction materials"	"For research, education, and economic development encompassing material sciences, manufacturing, and the engineering of composites and structures"
Model type	Cross-university	Multidisciplinary	Multidisciplinary
Relationship with industry	Collaborative; industry helps prioritize research agenda	Industry membership; seeks to attract industry to the state	Product development and testing for industry; formed spinoff companies
Focal areas	Wood products, engineering, sustainable design, including social sciences and economics	Architecture, engineering, forestry, and material and wood sciences	Materials science, manufacturing and engineering
Example impact on industry development	Developed mass plywood panel with Freres who then opened a highly automated plant in rural Oregon	Student-led research determined the performance of CLT in high wind events, such as tornadoes	Tested 10 different local species of trees for use in mass timber; now testing two new grades of CLT from Maine-sawn lumber

The development of a university-based research program for mass timber may be critical given that there are many technological, political, environmental, and design questions remaining about mass timber within the state. Despite interest and momentum from within state agencies to foster growth of this sector, those very agencies are largely unable to identify resources within the state to answer even basic research questions. This ultimately leads to the identification of support from researchers outside of the state, and the loss of funding that could help the state's own sector development. When considering the human capacity for research and development in the mass timber sector in California, there are many programs and departments that have potential to take the lead (Table 11). However, California largely no longer has a wood products science program, and the biggest one that was in operation at UC Berkeley was discontinued in 2003. Although a mass timber research program would fit easily into a design and architecture program, it would also greatly benefit from forestry expertise given the interdisciplinary nature of the material. A state-wide competitive application process for significant start-up funds for a university research program could allow the state to identify a pathway for growing the mass timber sector.

Table 11. Overview of select wood product-related programs and people affiliated with California's university system

	Program/Department	Select Professors
Natural resources/ Forestry/ Wood science	UC Agriculture & Natural Resources: Forest Research and Outreach, Forest Resources UC Berkeley: Dept. of Environmental Science, Policy, and Management *UC Berkeley: Wood Science and Technology program discontinued in 2003* Berkley Center for Fire Research and Outreach (Berkley Forests) Humboldt State Dept. of Forestry & Wildland Resources Cal Poly: B.S. in Forest and Fire Science UC Davis: Environmental Science and Management UCSB: Bren School of Environmental Science and Management	UC Berkeley: Jodi Axelson (forestry, wood anatomy), John Battles (forest ecology), Matt Garbelotto (forest and tree management), Matthew Potts (forest management), William Stewart (forest management, resource economics), Robert York (forest science and management) Humboldt State: Hunter Harrill (forest operations) UC Santa Cruz: Gregory Gilbert (temperate forest ecology)
Design/Architecture/ Art/ Engineering	UCLA: Architecture and Urban Design UC Berkeley: College of Environmental Design USC: School of Architecture, specifically the Human-Building Integration Lab and the Landscape Features Lab UC San Diego Jacobs School of Engineering; UC San Diego's NSF-funded shake table UC Santa Cruz, UC Davis, and UC Santa Barbara: Wood workshops	UC Berkeley: Gail Brager (Director, Center for Environmental Design Research), Edward Arens (Director, Center for the Built Environment) USC: Joon-Ho Choi (Director, Human-Building Integration Lab), Aroussiak Gabrielian (PI, Landscape Features Lab) Cal Poly: Richard Emberley (structural mechanics)
Social science/ Technology/ Policy/ Economics	UC Berkeley: Dept. of Agricultural & Resource Economics CSU Chico: North State Planning & Development Collective	UC Berkeley: J. Keith Gilless (forest economics), Dan Sanchez (carbon removal, wood products); Sam Evans (forest carbon and economics)

Research and development in mass timber and other innovative wood products can help the state grow capacity and attract businesses (photo credit: Adobe stock photos)

Funds for development should not just stop at a university program, however. Businesses and nonprofits are also at the forefront of trialing new processes and products, and often need significant investment to move from pilot project to implementation given the challenges associated with scaling up. The Oregon Wood Innovation Center, for example, provides testing support for new products, supporting small business owners' needs.[154] The US Government offers research and technology grants to support small businesses working in priority areas.[155] California does offer a tax credit for qualified research activities,[156] and may consider developing alternative versions that target the mass timber and wood products sector, more specifically. By explicitly articulating the state's intentions to support innovation in this sector, the state can accelerate movement towards fuels reduction and wood products development.

154 http://owic.oregonstate.edu/
155 https://www.sbir.gov/about
156 https://www.ftb.ca.gov/file/business/credits/california-research.html

CHAPTER 5

WHAT ARE KEY BARRIERS TO THE GROWTH OF A FORESTRY WORKFORCE AND HOW CAN CALIFORNIA PURSUE A WORKFORCE GROWTH STRATEGY?

Highlights

- The state must ensure that workforce development utilizes a range of tools and resources, including on the job training, K-12 programs, community colleges, apprenticeships, and other training opportunities that offer case management services and innovative industry/training partnerships;
- Networking opportunities must be created to ensure professional and business development across the forest industry. Networking opportunities, including job fairs and virtual platforms, can help current and future workers identify and secure quality job opportunities, and can help businesses increase worker retention in the sector;
- State funding for forest health work must include funding to pay forest restoration worker wages and benefits that are comparable to fire response wages and benefits;
- The state should fund programs that seek to support nontraditional forestry workers, including underrepresented communities and women, to attract and retain more workers to the sector;
- A trained and available workforce to conduct forest management activities and to produce value added forest products is essential for meeting forest health goals and providing a much needed economic boost to forested regions of the state; and
- To ensure that potential workers stay in the industry, state investments must emphasize job quality, family wages, building partnerships between industry and training entities, and rural infrastructure investments, including housing and broadband.

Recommendations

- Workforce development efforts must recognize that there are multiple pathways to the range of jobs within the forest management and wood products sectors, and avoid reliance on single programs and one size fits all approaches. A scaffolding framework comprised of many interconnected ladders with transferable skills should be adopted as a model for training and workforce development;
- Many current training programs (e.g., apprenticeships, associate's degrees, etc.) center workforce resources on fire response and post-fire treatment rather than forest management. Effective development of a workforce in this sector will involve strategies that integrate workforce training pathways that are focused on forest health, including Traditional Ecological Knowledge and cultural burning, and value-added forest products businesses;
- Workforce development strategies should be tailored to meet the economic and social conditions of workers in rural communities, and respond with work that offers year-round, family-supporting wage jobs; and
- Marketing and communications should highlight the role and importance of forest workers play in sustaining forests and watersheds to improve public sentiment and appreciation for the sector, to encourage more to join the workforce.

5.1 A snapshot of California's current state of forest employment

As timber processing capacity has been in steady decline across the state since the early 1990s, so has employment in the forestry sector.[157] Whereas in 1998, the forestry sector employed over 90,000 workers in the sector, that number dropped to just over 50,000 in 2010, its all-time low, and has rebounded to over 57,000 in 2016. Most of the recent growth is led by secondary wood products manufacturing.[158] While 20% of workers in the agriculture, forestry, fishing and hunting sector are low wage workers,[159] the average employee in the sector earns just over $60,000 per year, though those in the wood products manufacturing sector earn roughly $48,000 per year.[160] Given that there are a wide variety of jobs in the forestry sector, spanning commercial felling, logging, primary and secondary processing, as well as noncommercial thinning and fuels reduction, among others, it is challenging to track trends in the sector as more businesses are transitioning to wildfire-related work.

A robust forest products workforce is needed to ensure that forest restoration efforts can grow across the state (photo credit: Adobe stock photos)

In 2019, private sector employment accounted for 43% of all forest sector jobs in the state. The primary forest products industry that employed the most workers was Corrugated and Solid Fiber Box Manufacturing employing 10,781 individuals[161], followed by sawmills at 3,514 individuals and Veneer, Plywood and engineered wood products at 3,339 individuals. Key forest employment figures for 2020 by industry can be found in Appendix 2. Given that many forest industry businesses are small family businesses, or are owner operated establishments without paid employees, employment records for these businesses are captured separately from businesses with paid employees (Table 12).

157 Marcille, K. C., Morgan, T. A., McIver, C. P., & Christensen, G. A. (2020). California's forest products industry and timber harvest, 2016. *Gen. Tech. Rep. PNW-GTR-994. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p., 994.*

158 *ibid*

159 Even, W. E., & Macpherson, D. A. (2019). Where Does the Minimum Wage Bite Hardest in California?. *Journal of Labor Research*, *40*(1), 1-23.

160 Marcille, K. C., Morgan, T. A., McIver, C. P., & Christensen, G. A. (2020). California's forest products industry and timber harvest, 2016. *Gen. Tech. Rep. PNW-GTR-994. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p., 994.*

161 Quarterly Census of Employment and Wages, 2020 Annual Average, Employment Development Department, Labor Market Information Division

Table 12. Non-employer establishments (e.g. owner operator with no paid employees) for 2018 from U.S. Census Bureau, Nonemployer Statistics

Sector	Number of non-employer establishments
Forestry and logging	1,687
Support activities for forestry	829
Utilities	1,207
Wood product manufacturing	1,918
Paper manufacturing	175
Basic chemical manufacturing	118
Machinery manufacturing	1,873
Furniture and related product manufacturing	2,447
Lumber and other construction materials merchant wholesalers	647
Machinery, equipment, and supplies merchant wholesalers	2,010
Paper and paper product merchant wholesalers	680
Specialized freight trucking	5,541
Commercial and industrial machinery and equipment rental and leasing	5,669
Scientific research and development services	8,145
Vocational rehabilitation services	1,910
Commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance	3,938
Total	**38,794**

5.2 Employment barriers facing forestry and forest products businesses

5.2.1 Hiring and labor shortage issues

Hiring issues precede workforce development issues because without access to and availability of workers, training strategies will be ineffective. In many cases, workforce development strategies must also include outreach, training and worker readiness investments to develop a pipeline of workers. The focus of this chapter is primarily on workforce development barriers and solutions, and not on labor issues. Nonetheless, some key labor and social challenges that impact workforce development efforts within the forest sector are briefly outlined.

In a June 2021 seminar series on workforce development within California's forest industry, a Sierra Pacific Industries representative explained the serious labor shortages they face. At their Quincy and Red Bluff mills, they have openings for 30 workers each, while at their Burney mill, they have openings for 20 workers. They noted a reliance on H-2B work visas to secure seasonal migrant workers for replanting work that is essential to their vertically integrated business model. Industry and labor experts estimate that H-2B workers account for 10 to 15 percent of the contracted forestry services workforce in the state.[162]

162 https://laborcenter.berkeley.edu/putting-california-on-the-high-road-a-jobs-and-climate-action-plan-for-2030/

Recruiting unskilled but ready-to-work individuals is a primary barrier for many forest sector employers. Current workforce development programs are unable to support this need given that they target training efforts on higher skilled employment (e.g., millwrights). The cost of housing and living in rural areas, despite on average being lower than urban areas, often exceeds what low-wage workers can afford, exacerbating hiring shortages. For example, preliminary survey results from CSU Chico's Forest Workforce study found employers cited small pools of candidates (23.4%), lack of housing (14.9%), and high cost of living (12.8%) as major challenges facing the sector.[163] Across all interviews for this study, housing was consistently identified as a primary barrier to increasing the forest industry workforce. For more information on rural housing needs, see section 2.2 (Mass timber offers a strategy for economic growth).

Another barrier to recruiting workers is job quality. One interviewee who works with manufacturers noted that many forest processing facilities could benefit from simple improvements in working conditions, including attention to ergonomics, lighting, and generally designing facilities to attract potential employees.

5.2.2 Worker readiness

Workforce development and training entities, as well as wood products manufacturers, noted the challenges of worker readiness and worker turnover as major barriers for meeting employer needs. One manufacturer explained that for every two or three hires, only one is likely to last beyond the training period. For employers conducting on the job workforce training in forest management, social challenges including substance abuse, poor worker health, lack of transportation and lack of housing were identified as main barriers. Additionally, in many of the rural communities closest to the forest resource, there is limited social support and lack of healthcare to meet mental, behavioral and physical health needs.[164]

Contrary to the perspective that employers want workers who are skilled and ready to work, many wood products manufacturing jobs have a fairly low barrier to entry and often provide on the job training. Once an employer is ready to hire, they are able and indeed expect that they will provide training specific to their machinery and work. One community college workforce development program leader noted their industry partner, a wood products manufacturer, had the philosophy that: "We can really train anyone, we just need a warm body that can pass a drug test."

Northern Arizona University Forestry Workforce Center

Under a $350,000 grant from the U.S. Department of Commerce's Economic Development Administration, Northern Arizona University's Ecological Restoration Institute is working to build a skilled forest management workforce through a new program, known as the Forest Operations Training Center. In 2019, the local population of Coconino county experienced economic and job losses through the closure of the Navajo Generating Station, as well as cuts of 250 jobs from the Kayenta Coal Mine Complex. The goal of the program is to provide steady and well-paying jobs to local residents, while simultaneously building a skilled workforce to expand the pace and scale of forest restoration work in Northern Arizona. The Forest Operations Training Center will provide career development opportunities and training for forestry equipment operators, logging truck drivers, and heavy equipment repairs mechanics, with special efforts to recruit workers who had previously lost their jobs from the shuttering of the coal mine and generating station, as well as young adults and veterans. Overall, the center will help to promote forest health, while simultaneously promoting the well-being of local rural economies.

163 Forest Sector Workforce Study: Preliminary Findings (2021), Center for Economic Development, CSU Chico.
164 Sierra to California All Lands Enhancement (SCALE) virtual meeting, June 2021. Organized by Sierra Institute for Community and Environment.

5.2.3 Lack of investment in local businesses

For in-woods work, including road building, logging, chipping, pruning, among others, many smaller businesses located close to the forest lack the investment they need to expand their businesses, purchase needed equipment, or compete for contracts with large corporations and out-of-state entities. Without capacity to compete with out-of-state entities that typically pay their employees less and who do not hire locally, in-state businesses are less competitive for public contracts when preference is not given to local businesses.[165]

This trend has been exacerbated by destructive fires and disaster declarations that lead to mega-contracts for which no local entities can compete. National and even multinational cleanup enterprises secure these contracts and consider "local" hires to be contractors within the state. This creates a cycle of disinvestment from the local forest industry in favor of businesses elsewhere, resulting in less opportunity both for local workers and local businesses and continued local decline, especially in the case of mega-fire cleanups. This cycle persists when businesses are unable to innovate or expand into new markets and new forest products. This has serious implications for workforce development efforts since it is impractical to train workers for jobs that do not exist, or where there is not a commitment to hire from an industry partner. In California where the forestry sector appears at the early stages of a renaissance, few businesses can offer workers employment guarantees, which, in effect, translates into reduced opportunities to train workers to support their needs.

Nevada's Workforce Integration Tool:

In early 2020, the Nevada Department of Employment, Training, and Rehabilitation received the Data Insights and Innovations award, presented by National Association of State Workforce Agencies' Workforce and Labor Innovation Committee, for their Demographic Reporting Enhancement Tool. The tool was developed by the Department of Employment, Training, and Rehabilitation Research and Analysis Bureau and provides a detailed picture of Nevada's underserved communities for the purpose of providing them with targeted assistance. The data generated by the tool is shared statewide and facilitates the agency's outreach. Specifically, it aids them in finding employment solutions by identifying challenges and opportunities for job seekers in those specific areas, as well as employers engaging with underserved populations.

5.2.4 Need for evaluation and standardization of training programs and credentials

There is little available data on current training programs pertaining to key metrics, such as job placement, retention, wages, and wage progression. Similarly, there is no consensus for what industry-recognized credentials through a training program should look like. Community college leaders noted a lack of outcome data is an issue for their training programs. For the industry overall, standardized and articulated job pathways are limited. This is in part because large employers often provide on-the-job training and track individuals' skills based on company-specific criteria. In addition, job training in the sector lacks standards for required skills and occupational safety, both of which are key to articulate the need for, ensure demand for, and to signal the skills needed by the workforce.[166]

Outcome data from workforce training programs in the state is limited, though community colleges, universities and workforce development agencies are launching outcome assessments. Currently, the California Conservation Corps is working to track individuals after they exit their program, but at present have only preliminary data. Shasta Community College lacks a system to track or follow up with program participants after they exit the program. However, a new tracking system, *Job Speake*r (the community college version of *Handshake*, a platform

165 *ibid*
166 Collier, R. 2020. Putting California on the High Road: A jobs and climate action plan for 2030. Accessed from: https://laborcenter.berkeley.edu/putting-california-on-the-high-road-a-jobs-and-climate-action-plan-for-2030/

to connect college students and employers), will in a few years allow community colleges to begin to have better access to cohorts, and improve tracking of program participants. Investments for tracking individuals and evaluating programming are essential to improve effectiveness of training programs.

5.3 Barriers facing potential or current workers

5.3.1 Broadband

Lack of access to broadband continues to be a major hurdle for programs working to educate and train in rural forested regions of California. While some urban counties have broadband coverage just shy of 100%, rural broadband access often trails far behind. Sierra County, for example, has just 2% broadband coverage, Plumas County has 12.5% coverage, and Trinity County has 26.2% coverage.[167] Coverage rates also do not address speed or quality of service, and typically ignores service cost and the number of provider options. Too often, rural residents lack a choice of provider, speed, or cost of service.

Low coverage rates and lack of choice represent a significant challenge for online opportunities, and workforce development staff at community colleges all stated that broadband must be expanded and improved for thriving training programs to thrive. Many types of career technical education programs require online training, which may be especially challenging for extension programs or community colleges that serve rural residents. While efforts are being made to bring greater broadband to rural areas, this is a long-term effort, and many training programs must adapt programming in the short-term.

5.3.2 Worker expectations

Some workers, especially those with young families or elder care responsibilities, may be interested in working in the forestry sector, but may require more scheduling flexibility and overall support. For these potential workers, production and manufacturing facility staffing needs are often not aligned with their needs and may exclude a ready workforce. Manufacturing facilities that rely on a lean manufacturing model and require strict management to meet production goals lose potential employees because of this. Two community college workforce program leaders noted that industry partners faced challenges with employees who needed time off or more flexible scheduling. One interviewee also noted that younger workers are considered unreliable for production-style facilities with rigorous routines. Industry partners were noted as seeking to hire veterans who are seen as more likely to prefer the structured environment of a manufacturing facility.

Living wages and a clearer progression of job opportunities are also needed to attract workers. Many forestry and entry level wood product manufacturing jobs that offer little upward mobility, and some neither pay a living wage to start nor support workers adequately during training, though this latter issue is starting to change in order to attract workers. In other industries, like construction, with clear apprentice "steps," a low wage during training is an investment toward future mobility at a much higher wage. These pathways are typically lacking for forest work and wood products manufacturing.

5.4 Key legislative efforts to build a forest workforce fall short

While various non-profit and private entities across the state have pursued bottom-up workforce development strategies, the state has pursued policy measures to enact necessary investment. One example includes SB-462 (Community colleges: Urban and Rural Forest and Woodlands Restoration and Fire Resiliency Workforce Program). This bill was introduced in 2019 but died in appropriations. This bill outlined a path for community college investment in forest and fire protection through partnership between state community colleges, the University of California extension system, apprenticeships and vocational programs. The program

167 https://broadbandnow.com/California

Sterling University

Sterling Solutions is a company that produces TerraLam CLT mats, with a focus on catering to energy infrastructure. As a company, they have prioritized relationships with local communities and have held events with high school students from the area in order to build awareness of employment options and opportunities. Additionally, they have developed a workforce educational program called Sterling University. This training program is focused on helping their employees to be successful both within the company, as well as the local communities. Examples of courses included in the program include English as a second language and budgeting.

was to be enacted through a forest and woodlands restoration workforce model curriculum developed by the California Community College Chancellor's Office in collaboration with the California Community College Academic Senate.

The California Community College Academic Senate initially voiced opposition to the bill on the grounds that curriculum "should be inherently driven by local economies and workforce needs expressed by employers of the region,"[168] and because writing elements of the curriculum into statute limited the ability of colleges to adapt to industry expectations, as well as to the needs of individual communities and regions. The bill was modified to address these concerns, ensuring that programming is adapted to regional needs, but it still failed. It reportedly departed from the state's traditional curriculum development and program execution process, including requiring the development of a curriculum and providing funding to California Community Colleges to implement a specific workforce program.

Overall, the state's emphasis has been on policies to increase fuels reduction work, firefighting, and bioenergy, but legislative support for training the needed workforce has been lacking. For example, recent legislation indicates state commitment to turning restoration into value-added bioenergy and wood products, including SB-901, SB-1122, and others, and the state's Forest Resilience and Wildfire Task Force (formerly the Forest Management Task Force) has recommended increasing markets for value added wood products as a way to increase pace and scale of forest management work and as critical to a new forest economy that can help meet the state's carbon neutrality goals. Workforce training and development, however, have lagged behind.

5.5 Solutions and Approaches

5.5.1 Scaffolding of opportunities in the forest economy

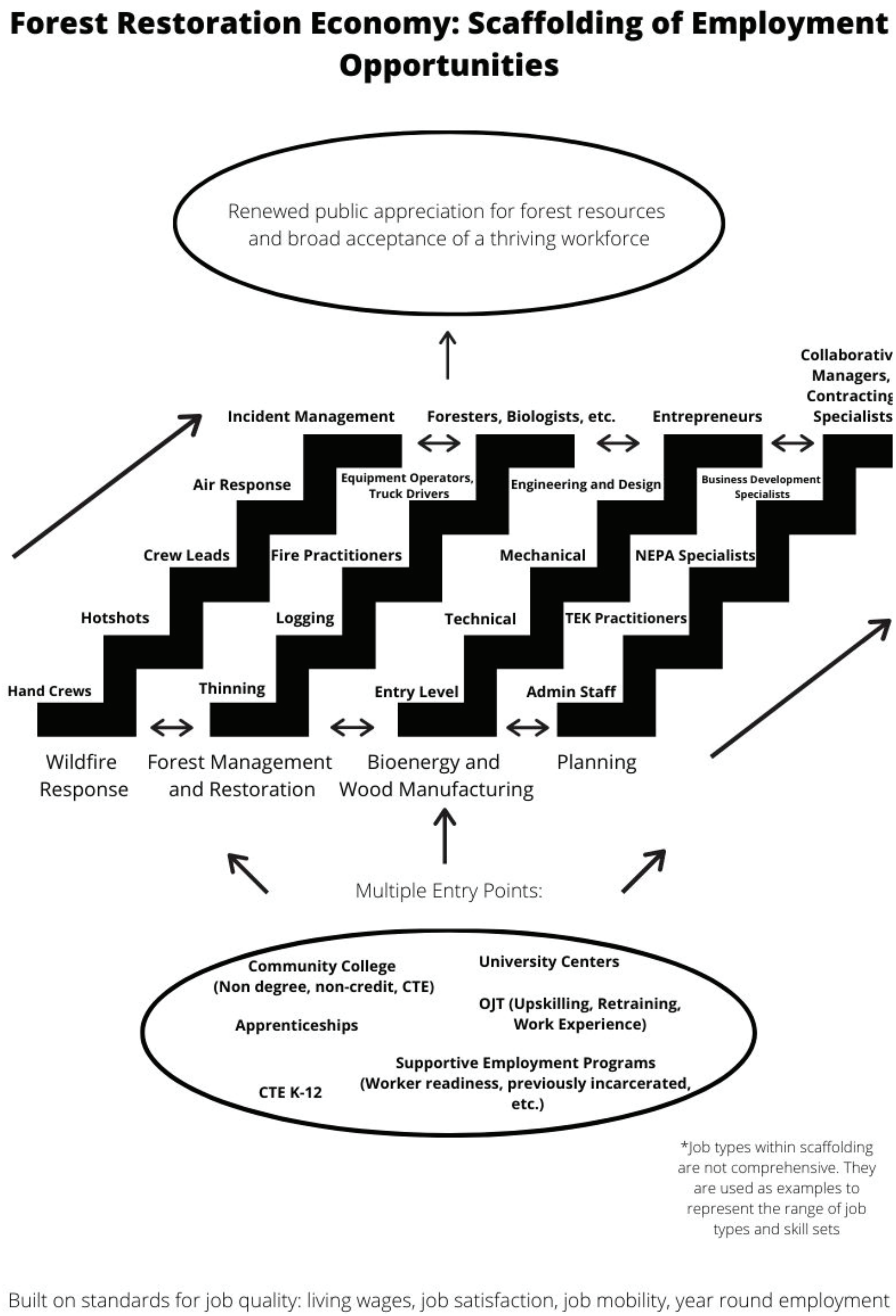
Across the forest sector there are many job types with varying levels of training needed for each job, but initial entry into the field remains a challenge within the sector. Often, once employed, workers are tracked into specific job types, with limited opportunity for upskilling, professional development and opportunities to advance or follow specific interests. In many rural forested regions of the state, there is not only a shortage of entry level workers but very few resource management professionals including foresters, biologists, archeologists and engineers who are also critical to the industry.

The "scaffolding of opportunities" approach represents a support system for individuals to access high quality job opportunities, becoming better equipped to access higher wage or more desirable employment. This scaffold also represents the diverse set of job types that must exist within a forested region in order to meet the economic needs of the communities that exist there and the demand for forest management activity. A foundational principle for this framework is that workforce development must ensure that workers have

168 Stanskas, J. (2019, April 8). *SB462 (Stern) Community colleges: Forestland Restoration Workforce Program*. Academic Senate for California Community Colleges. https://www.asccc.org/sites/default/files/SB462%20%28Stern%29%20Community%20Colleges%20Forestland%20Restoration%20Workforce%20Program.pdf

opportunity both in terms of access to high quality and high wage jobs, as well as to training opportunities to move up and across the scaffolding filling the range of job types critical to the forest restoration economy (Figure 10).

Figure 10. A scaffolding of employment opportunities that is built on high job quality standards



With traditional job training it is not always the case that workers can progress into better paying jobs. When there is progression, professional development is envisioned as a ladder whereby a worker can gradually build the skills needed to access better and higher paying jobs. In this traditional model, the worker starting at the bottom is actually standing on the ground, usually earning low wages and facing physically challenging, often repetitive work. This model also does not account for the transferability of skills between different, related careers. In this case, workers would have to essentially start over again when looking to make any lateral moves or move into a new natural resource job, for example when moving from work in a mill to work in the forest and restoration-related activities.

The scaffolding framework offered here, by contrast, is comprised of many interconnected ladders requiring a stable platform from which to build. Jobs that comprise the forest restoration economy have many transferable skills in addition to the highly specialized skills required for each unique position. Workforce development efforts therefore build from a platform of family-supporting wages with a focus on worker well-being and safety, and with recognition that other different opportunities are available. Ergonomics and general safety can ensure workforce longevity, while entry-level jobs that pay family-supporting wages can ensure better recruitment and retention in the sector.

The platform of this scaffold displays how entry level jobs are not dead-end jobs, but can open up many different career possibilities, thereby enticing more workers to move into the field. A nascent example of the framework implementation exists at Shasta College that requires students in their heavy equipment operator program to take a field ecology course. Similarly, they require students focused on field ecology to take a course related to industrial timber operations to better understand what their industry-focused colleagues face.

The scaffold framework shows how a robust forest restoration economy can be built from a stable platform with multiple entry points to recruit, train, and retain a skilled, experienced, and growing workforce, and entice more workers to move into a field with opportunities to move laterally into other productive occupations in the broad field.

5.5.2 Regionally-driven approaches

The High Road Training Partnership (HRTP) in forest restoration,[169] located in several decentralized locations across the Sierra Nevada and surrounding regions, is an example of the scaffolding being launched in practice. HRTP is a partnership of Tribes, employers and nonprofits including Calaveras Healthy Impact Product Solutions and the Sierra Institute for Community and Environment working to provide critical skills-building and training opportunities, build regional capacity, provide employment opportunities and improve forest management worker capacity within some of the most underserved Tribal and rural communities in the state. This partnership builds on over a decade of tribal forestry crew development between CHIPS and regional Tribes, and is an effort to create a new restoration worker with more skills, greater opportunity, and more economic security. When the impacts are multiplied across the region, it can increase resilience across underserved and disadvantaged rural communities. It also is an important example of efforts underway to incorporate traditional ecological knowledge and practices into current landscape restoration and work.

Though it builds on long term tribal workforce development efforts led by Tribes and CHIPS, the most recent and robust iteration of the workforce development effort was developed through actions taken by the Inter-Tribal Stewardship Workforce Initiative (ISWI). ISWI is made up of Tribal leaders and Tribal natural resource staff that work directly with their Tribal members. They identified job training and workforce development in the forest industry as a critical and pressing need for their communities. In light of this need, ISWI members convened to write a letter to the governor's office and visit Sacramento to advocate on behalf of Tribes and tribal work crews in January 2020, based largely on their exclusion from Camp Fire clean-up work and the hundreds of millions of dollars of contract work associated with it.

ISWI continues to advance action to build tribal restoration workforces and advocate for local and Tribal contracts within the sector. This type of effort facilitates restoration and fuels reduction work and fills a critical need workers in the Sierra Nevada and surrounding regions where economic opportunity, ecologic health and public health are threatened by drought, wildfire, and climate change. Communities closest to the forest resource have faced some of the greatest hardships from recent wildfires that compound with historical social and economic challenges, many tied to the decline of the timber industry and the lack of new economic opportunities. This work also offers opportunities for Tribes to work their ancestral homelands and rebuild cultural connections and workforce capacities.

A key challenge that regionally-driven approaches like HRTP must rise to meet is providing the support and resources that translate initial entry into forest restoration (or the base of the scaffolding framework) into high quality jobs. When individuals have access to training opportunities that result in family supporting

169 https://cwdb.ca.gov/wp-content/uploads/sites/43/2021/05/2021.HRTP_.Sierra_ACCESSIBLE.pdf

wages, they are not only able to access economic opportunity and mobility for a higher quality of life, but they are able to reside within the region to serve as land stewards. This mobility is critical to meeting forest health and climate goals, for which a range of workers with specific training are needed, ranging from "in field" forest crews, environmental planning specialists, and Traditional Ecological Knowledge practitioners, to mechanics, foresters, heavy equipment operators and truck drivers. The scaffolding framework represents not just the range of pathways between employees, jobs and training opportunities, but also the range of resources that can be made available through creative traditional and nontraditional learning approaches to advance skills and professional workforce development.

The scaffolding framework applies to individual workers and highlights the need to increase opportunities for workers in the forest restoration economy. It also applies to communities in forested areas and the diversity of job types that are essential for them to thrive. The lack of a well-rounded workforce (e.g., all the job types needed to complete a restoration project) slows the pace of completing forest management and landscape restoration projects. Building a restoration workforce that includes entry level-to-professional workers that are based in rural communities will help increase the pace and scale of landscape restoration projects. Further, the inclusion of additional trainings and paradigms such as Traditional Ecological Knowledge is essential for reshaping the forest industry to approach the forest resource not just as an economic resource, but as a cultural and ecological one. Tribes have long maintained mixed conifer and other ecotypes through cultural burning practices. These practices are needed more than ever to restore landscapes and reduce the risk of catastrophic wildfire. The forest industry more generally needs new approaches to improve environmental sustainability and bring benefit to local communities.

California does not have sufficient workforce to enact change at the pace and scale needed. By advancing regionally-placed efforts such as these, and by building partnerships between employers, training entities and communities that are challenged to develop restoration work crews or wood utilization facilities, investments can provide much needed employment, address worker shortages and complete more critical forest restoration work. Partnerships that advance tribal crews and tribal wood utilization efforts, like the HRTP, also fill a critical need to advance equity in the forest restoration workforce by providing pathways to training and career advancement that results in dignified livelihoods for Tribal workers on their ancestral homelands.

Employment is critical to improve social wellbeing within long-ignored rural communities. Investment in support services that make sustained employment more tenable for those facing serious social challenges is critical within the forest restoration and wood utilization economies. Regional employers note that after prolonged and rampant unemployment within rural communities in Sierra Nevada, the Klamath Region, and other forested regions, many individuals are digging themselves out of financial holes. These regions are also some of the least served by social and healthcare services, especially preventative and specialty care. For those with substance abuse disorders, special physical health needs like diabetes care, and other social, emotional, behavioral and physical health challenges, access is limited due to short supply of social and health care workers and facilities. Meanwhile access to support services is further limited by small town dynamics of confidentiality, limited access to providers that can provide specialty care, or sometimes even professional, confidential and culturally and socially appropriate care. A lack of public transportation options combined with high poverty rates also means many individuals lack transportation options to access necessary services available in larger towns and cities.

The creation of employment opportunities and the provision of support services must both be linked to address the needs of rural workers in order to address workforce shortages. Providing jobs without such support can lead to high turnover, challenges for employers, and limited work being completed where it is needed most. Providing social and financial support, improved healthcare access accompanied with clearly articulated pathways for employment, and dignified, living wage jobs will directly address worker shortages, reduce poverty and help other social challenges in rural forested communities. Linking these services with job opportunities advanced through the scaffolding framework offers the foundation needed for successful development the forestry workforce.

5.5.3 Building capacity in rural forested regions

Communities located in forested regions in the state are also many of the most economically depressed. Generally, people living in rural areas tend to face higher burdens from physical isolation, limited economic diversity, and poverty than their urban counterparts, with fewer institutional and financial resources available to respond to both internal and external stressors.[170] In the Sierra Nevada region in particular, contraction of the mill and timber industries has contributed to limited economic opportunity, as well as a shrinking tax base.[171]

Given their proximity to forested areas, rural communities are heavily impacted from the effects of severe wildfire. Many mountain communities are dependent on income from outdoor recreational tourism, an industry which generated $3.6 billion in taxable sales and supported 36,400 tourism jobs in the Sierra Nevada in 2019.[172] However, smoke events and other threats from wildfire constrain these activities. For example, the 2018 Ferguson fire was estimated to have caused a direct and indirect spending loss of $45.1 million and a reduction of $1.1 million in visitor related local government taxes in Mariposa County.[173] Additionally, impacts from the fires go beyond tourism, and can have devastating outcomes for mountain communities in the form of infrastructure damage, private property loss, and more. In the 2020 wildfire season, the North Complex, Creek, and SQF fires burned through the Sierra Nevada, resulting in 16 lives lost and more than 3,500 homes and businesses destroyed.[174] This year's Dixie Fire (2021) is the second largest in California's history, with CalFire estimating it burned 963,309 acres, and destroyed 1,329 structures including 700 homes, the majority of which were in small rural regions. The Caldor Fire, starting just after the Dixie Fire, burned 221,775 acres, with 1,003 structures lost, including 782 homes. Ultimately, these catastrophic disasters have compounding effects on communities already impacted by social disadvantage.

Fortunately, rural forested regions also present opportunities for wood product business development. Most former timber hubs are located in current opportunity zones with promise for redevelopment and remediation of former mills and industrial sites. Forested communities in the state also have historical and cultural ties to wood utilization, with many families having multiple generations of forest sector workers. Innovative wood product businesses present an opportunity to bolster or rebuild rural communities and allow the next generation to be employed locally, rather than moving to urban centers or elsewhere.

A robust forest restoration workforce can also generate the resources and infrastructure needed to assure a consistent supply of wood biomass for energy production through bioenergy and value-added forest products businesses. As new wood biomass to energy or biofuels technologies become available and as markets emerge for innovative wood products, rural regions have a unique opportunity to capture investment in a reinvented industry and develop business and wood industry campuses that serve as hubs for forest biomass processing and high wage jobs.

Tribal communities in rural forested regions have faced a legacy of colonial exploitation including the exploitation of valuable resources. Without owning land, many tribes struggle to build capacity, start businesses, manage resources, and use their knowledge on the landscape. Still, a growing number of Tribes are interested in starting and managing forest crews, including those involved in the aforementioned HRTP program. The ability of tribes to obtain contracts on the land, while not a solution to historical injustices, are essential for Tribal employment in the Sierra Nevada and surrounding regions, homeland stewardship, and community and economic resilience. Resources including forests and watersheds are culturally important and essential for tribal members' livelihoods. Federally recognized tribes have unique entitlements to obtain federal work contracts because they are sovereign nations. Increasingly, forest industry contracts suggest or require incorporation of Traditional Ecological Knowledge and acknowledge its importance to ecosystem health. This focus on ecologic benefit and traditional knowledge, combined with increasing investment by the state in the forest sector, largely driven by wildfire mitigation and carbon

---

170 David Hales et al., Ch. 14 Rural Communities. Climate Change Impacts in the United States: The Third National Climate Assessment, (U.S Global Change Research Program, 2014), https://nca2014.globalchange.gov/downloads/low/NCA3_Full_Report_14_Rural_Communities_LowRes.pdf.

171 Sierra Nevada Conservancy, Protecting and restoring the health and resilience of Sierra Nevada watersheds and communities: The Sierra Nevada Conservancy Strategic Plan 2019-2024, (2019), https://sierranevada.ca.gov/wp-content/uploads/sites/326/2019/12/StrategicPlan_web_a11y-20191217.pdf.

172 Wilson, Jackson, Patrick Tierney, and Carl Ribaudo. Impact of Wildfire on Tourism in the Sierra Nevada Region: Synthesis of Research Findings and Recommendations. 2020. https://calmatters.org/wp-content/uploads/2020/09/fire-tourism-study.pdf.

173 *ibid*

174 Sierra Nevada Conservancy, "2020 (mega) wildfire season," last modified April 7, 2021, https://sierranevada.ca.gov/2020-mega-wildfire-season/.

capture concerns, presents an opportunity to retool the forest industry and integrate ecologic, social, and economic benefits.

This investment must include capacity support for rural workforces and businesses within communities closest to the forest resource. Without investment in rural communities and in businesses that add value to biomass harvested from restoration activities, it is often left in the forest, or piled and burned, while the state continues to import the vast majority of wood products from neighboring states and Canada. This represents a loss of material that could contribute to bioenergy and wood products manufacturing sectors and bring economic benefit to struggling rural economies. The opportunity for rural development through wood utilization businesses and subsequent increases in family supporting wage jobs is coming at a time when rural communities are facing uncharted challenges. Along with annual devastation from wildfire, the Covid-19 pandemic has worsened economic conditions and opportunities within rural forested communities, which are now often reliant on tourism that has proven to be a volatile economic driver in the wake of wildfire evacuations, power safety shut offs and Covid-19 lockdowns.

Kindergarten through 12th grade programming can introduce children to careers in the forest restoration economy (photo credit: Adobe stock photos)

5.5.4 Investment in forestry and natural resources programs across K-12

Education, training and multiple pathways to career advancement are key to creating and sustaining interest in forestry and natural resources careers. Although more could be done to develop education, outreach, and awareness about the forest industry and the range of jobs, including entry level jobs, several creative solutions already exist, including the Forestry Challenge – an academic challenge for high school students in forestry that serves 400 California high school students annually. This program is designed to stimulate interest from high school students and educate them about opportunities in and pathways to forest sector careers.

In California, overall, the current education pathways that exist include: 18 high schools offering forestry coursework, 16 community colleges offering degrees in forestry and/or natural resources, two apprenticeships within the community college system, and eight universities offering degrees in natural resources.[175] Some nonprofits have developed complementary programs to support high school students engaged in forest restoration work, including Sierra Institute for Community and Environment's Plumas Conservation Restoration and Education in Watersheds program. This program brings together high school youth from rural areas in the northern Sierra and the Bay area and, more recently, has expanded to include students from across the country. These students work together on forest restoration projects in Plumas and Lassen Counties and beyond.[176] Some youth from this program return as leaders to train and guide future youth crew work, some go on to natural resource programs in higher education, while still others leverage their initial forest restoration experiences to obtain work in the sector.

5.5.5 Community colleges

The California Community Colleges System is an asset to the state and a strong resource for workforce development efforts. Often community colleges are tasked with meeting workforce development needs across all sectors. For many of the forested regions of the state, this means students often must travel distances to attend a course in person. Further, while program-industry partnerships increase job attainment chances upon program completion, only some programs have successfully built these partnerships as a part of the program. Although the community college system is robust across counties, community colleges operate with substantial bureaucratic

175 See linked map to current education programs in the State: Forestry Education Programs in CA
176 https://pcrew.sierrainstitute.us/

Community college programs offer important opportunities for early career forest workers

barriers, making it difficult to quickly pivot to industry needs. One community college workforce program lead noted that industry partners shared that their college training program is outdated and needs to be modernized.

Despite these challenges, many creative solutions are emerging from the community college system. These include: credit for prior learning, worksite learning, community education and non-credit learning. In order to speed up training times, individuals can take pre-assessments to test out of classes and more quickly obtain a certificate. Shasta Community College is currently developing a pre-assessment option. In this model, a student with a number of skills in a specific field can demonstrate knowledge proficiency and be required only to take those classes from an established curriculum that they are lacking in order to meet program competency. This means students spend less time in school, need fewer resources and less time to complete programs, and are available for employment sooner. Community colleges, like Shasta, are also working to ramp up non-credit non-degree vocational programs to pivot more quickly to meet industry needs.

On-the-job training is another key step in ensuring training leads to job attainment. Both Shasta Community College and Butte Community College require work experience as part of their associates degree and certification programs. This allows student workers to gain understanding of the job they are working towards and allows employers to gain experience with the students. These programs are also exploring interdisciplinary coursework in their natural resources programs, including business and accounting in career technical education programs to spur entrepreneurship and increase mobility of students. Another approach is for community colleges to prepare students through a general trades curriculum from which employers can hire out of a pool of certificate or degree holders from the college or through company-provided on the job training.

On the job training separate from educational institutions should be recognized as a viable pathway for workforce recruitment and development, especially for those who have been unsuccessful in school, have struggled with addictions, or have family or other financial commitments that preclude traditional educational pathways. Many of these individuals do not view traditional educational programs as appropriate pathways to work. Programs like the Calaveras Healthy Impact Product Solutions (CHIPS) has hired workers, many of them Tribal members, to work on woods crews involved in a variety of forest restoration projects. Work is a training program and is supported as such, as crews build skills and progressively improve performance. Workers progress by learning basic to advanced skills while in the field and being paid, with some moving into management roles. Some of these workers go on to seek educational opportunities to advance their jobs and careers.

Overall, community college career technical education is an important pathway for workforce training and development, but as appropriate as such programs may be, they are still challenged by low population communities and impoverished residents with long travel time to community colleges. Programs must be developed to meet workers and potential employees where they are. Alternative pathways involving on-the-job training and other regionally driven solutions that train workers where they live, where activities are conducted, and close to the source forests are needed.

5.5.6 State-certified apprenticeship programs

A state-certified apprenticeship creates a clear pathway to a high-quality job and ensures early investment in low wage on-the-job training leads to a high-quality, family-supporting wage career. For example, the California Firefighter Joint Apprenticeship Committee (Cal-JAC) has become a cornerstone of professional standards for firefighters throughout the state of California. Cal-JAC is co-sponsored by the Office of the California State Fire Marshal, representing management, and the California Professional Firefighters, AFL-CIO, representing labor. A similar state-certified apprenticeship program for forest restoration workers would serve the state's long-term goals of forest management, provide workers with assurances around job quality and provide standards for types of training and skill requirements. This provides assurances for businesses that a workforce is available, signaling wider commitment to the state's forest and forest products industry. This also enables a shift in workforce resources from firefighting into forest health, wildfire prevention, and wood products manufacturing.

5.5.7 Job quality

5.5.7.1 Public lands contracts as levers for job quality and workforce standards

State and federal contracts provide the opportunity to set wage floors and job quality standards within the forest industry. This mechanism offers the possibility to change industry practices. Standards for forest workers and wood manufacturing job quality are quite low compared to many other trade jobs. Through contract language, state and federal land management and climate mitigation, contracts can be leveraged to meet co-benefits of job quality, industry needs, and forest health. These contracts can also support on the job training, provided expectations and payment are aligned with training needs and crew skill progression.

California Conservation Corps CalNat Course:

The California Conservation Corps has partnered with the University of California Agriculture and Natural Resources to develop a California Naturalist (CalNat) course, designed to enhance California Conservation Corps members training, while also providing them with an additional credential in support of their continuing education and careers in natural resource management. Required topics in the course include biodiversity and ecosystem services, geology, climate, and soils, water, invasive species, and more. The program combines a science-based curriculum, experiential learning, problem solving, citizen science, and community service as a part of a 40-hour (over five weeks in duration) course. Overall, the CalNat partnership and program will help to address the workforce development needs of California Conservation Corps youth and provide them with opportunities to further their education and experience in natural resource management.

5.5.7.2 Partnership building and regional investment

Lacking a robust in-state forest management apprenticeship program or forest restoration specific labor organizations, community college natural resource programs and career technical education programs rely heavily on dedicated staff and committed community/industry partners. Workforce coordinators at both Butte and Shasta Community Colleges noted that the investment in working partnerships between training organizations and industry or agencies is critical for the success of their programs. Leadership staff at Butte Community College's natural resource program attributes success in job placement after program completion to partnerships with natural resource agencies. These are partnerships built on longstanding respect and collaboration between program staff and regional agencies like the Forest Service, U.S. Fish and Wildlife Service, and the County Parks and Recreation Department.

Shasta Community College staff also attribute much success to effective training programs with industry partners. In Shasta's rural forested region, the college must partner with multiple and often small employers and enterprises to develop workforce training partnerships and programs. In this way, the career technical education program relies on collaboration with many small operators to build the pathway for their training program. This takes extra coordination and relationship building to enable competitor businesses to work together to articulate workforce needs. These approaches highlight the need to bridge gaps that may exist between training programs and industry.

Shasta College Heavy Equipment and Logging Operations and STEP-UP Programs

Shasta College launched its Heavy Equipment and Logging Operations program in the fall of 2019. The program offers students the opportunity to receive a certificate in Heavy Equipment and Logging Operations, while providing them with hands-on opportunities to gain experience in the field, from actual logging and running the equipment to shipping logs to the local mills. This program is the result of successful collaboration from a wide variety of industry partnerships including Sierra Pacific Industries, Del Logging, Inc., Creekside Logging, Pape Machinery, Sierra Cascade Logging Conference, Peterson Timber, the Loggers Association of Northern CA, and Associated California Loggers. Specifically, Shasta College obtained a commercial timber operator license. This, with a logging contract and land use agreement with Sierra Pacific Industries, has allowed students the opportunity to train on active mechanized logging sites. Additionally, Shasta College also manages a program called STEP UP, in which people with criminal records are given the chance to obtain certificates and learn trades as skilled laborers. Students are referred to this program through the Shasta County Sheriff's Office and the Probation Department, and Shasta college has worked with local law enforcement agencies for roughly four years in order to facilitate the program.

5.5.8 Elevating forestry jobs and increasing inclusivity

For the past several decades, environmental and political tensions, and economic challenges related to the timber industry resulted in an overall denigration of the forest industry and forest jobs. Threats of catastrophic wildfire, climate change and shifts toward longer term planning in resource management along with state carbon reduction goals warrant new approaches and characterization of the need and value of forest restoration. Public education campaigns must be part of a comprehensive plan to educate the public about forest management practices, and create a culture that values forestry, forest workers, and locally-sourced forest products. For example, the Oregon Forest Resources Institute publishes Oregon Forest Facts to share data with Oregonians and to foster a culture of forest pride.[177]

The social media effort #ForestProud is another public information campaign aimed at building pride in forest sector employees, attracting and retaining diverse talent, providing material to members to communicate their role as environmental stewards, and connecting forests to everyday lives of citizens.[178] Media campaigns that show more diverse representation in the workforce, or highlight the diversity of skills needed for a robust forest restoration economy will also prove to be effective tools to appeal to and attract a more diverse workforce.[179]

Education and training programs that rebrand to focus more on aspects of sustainability and ecosystem health will be more successful at attracting and retaining a more diverse cohort. For instance, one key stakeholder who worked with mass timber manufacturers noted that when his college program changed names from a focus on forest products to a focus on renewable materials, the program grew not only in numbers but in diversity of students. In a similar way, when the U.S. Forest Service rebranded their Woody Biomass Utilization Grant Program to the Wood Innovations Grant, interest and excitement grew. Careful rebranding can attract new and diverse talent to the sector, bringing along innovative ideas and enthusiasm.

A retooling of the forest industry must include targeted efforts to reach Tribal groups, women and other underrepresented groups who face barriers to entry in the forestry sector, including historical exclusion from the field, and lack of access to capital, among others. Building a forestry sector that celebrates local knowledge, ecological diversity and the opportunity for creative value-added businesses can help grow the number of people attracted to forestry and restoration professions. Efforts to include underrepresented groups in forestry must recognize the importance of leaders that come from within specific groups. For example, efforts to include women in forestry may be more successful if presented by a women who shares a similar background, communication style and set of lived experiences.180 Efforts to promote workforce development in Tribal communities must be culturally responsive and respectful of traditional homeland stewardship practices and cultural norms around work and relationships to the land.

177 https://oregonforests.org/forest-facts-figures
178 https://forestproud.org/
179 Larasatie, P., Barnett, T., & Hansen, E. (2020). The "catch-22" of representation of women in the forest sector: the perspective of student leaders in top global forestry universities. *Forests*, *11*(4), 419.
180 Redmore, L. E., & Tynon, J. F. (2010). WOWnet: A communication and networking model for women. *Journal of Extension*, *48*(5), 1-8.

CHAPTER 6

WHAT ARE SOME OTHER INNOVATIVE WOOD PRODUCTS THAT CAN BE MANUFACTURED AT THE COMMUNITY-SCALE IN CALIFORNIA?

Recommendations

- More investment into research and development at the community-scale can ensure high-quality production and the most efficient use of wood fiber. These investments should be linked with a university-based extension program to ensure that community-scale enterprises have access to capacity and know-how to drive innovation and meet product standards;
- The state should consider how to provide targeting support for community-scale wood product operations, especially given their role in processing lower-value timber. Targeted support should include necessary infrastructure and processing capacity across the state, including small and medium-sized sawmill enterprises, as well as wood products campuses where multiple businesses can co-locate to share infrastructure and know-how; and
- The state should invest into a wood products innovation fund targeting local, community-scaled businesses. Investments could provide necessary support to small companies looking to develop, test, and bring wood products to market, with a focus on adding as much value as possible to lower-value biomass and timber.

Highlights

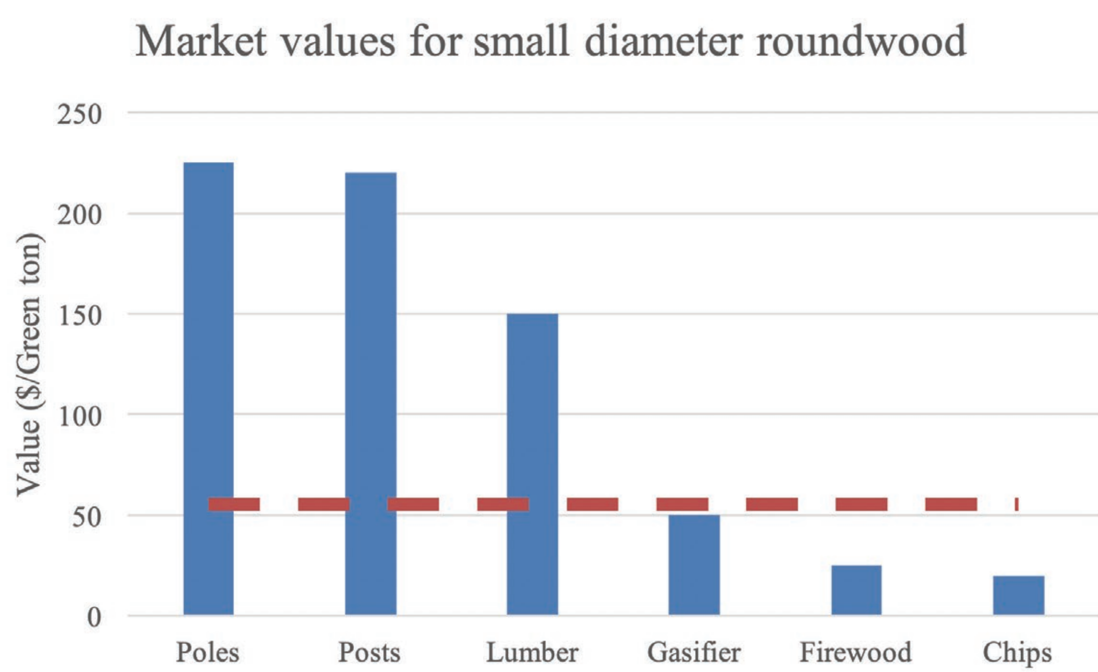
- Community-scale wood product manufacturing presents an opportunity to meet goals of rural development and fuels reduction and forest management. Efforts in other states have shown that community-driven operations can catalyze the Forest Service to offer fuels reduction or restoration projects since they know there will be an outlet for processing even lower value wood;
- Community-scale operations are nimble, innovative, and can manufacture a wide range of wood products to serve local, state, and national wood product needs;
- Many different and innovative wood products can feasibly be produced at the community-scale, though without significant investment into research and development, many products will struggle to make it to market;
- Wood product campuses offer the possibility to ensure economies of scale for community-scale wood product businesses, though more research is needed to understand challenges they face in recruiting and serving wood product businesses; and
- Some innovations in community-scale forestry and wood product manufacturing offer successful examples for how to solve problems around fiber supply chains and business models.

6.1 Defining the community-scale

This chapter examines a variety of other innovative wood products that are suited to be manufactured at the community-scale. This chapter uses "community-scale" to explore products that could be manufactured, marketed, and sold by community-based businesses. They involve wood production technologies that do not operate at the industrial scale in the tens of millions of dollars and more. The role of the wood products campus is also considered, an idea that has in recent years gained attention for its ability to support both in-woods and manufacturing jobs in rural, forested areas across the state. There are numerous groups in areas across the Sierra Nevada and North Coast regions of the state advancing campuses.

To make forest treatment economical, costs associated with harvest must be exceeded by the value of wood being harvested (Figure 11). For this reason, small diameter roundwood product manufacturing is most feasible when residuals are sold to different markets to capture the maximum value from fuels reduction work. this chapter explores products that have market potential beyond biomass energy, which constitutes one of the lowest value added products for lower value wood. This chapter concludes by highlighting the continued barriers facing community-scale innovative wood product manufacturing, presenting some potential solutions, and showcasing a few creative solutions to challenges associated with the harvest and transformation of low value material.

Figure 11. The orange dotted line shows the cost to harvest small diameter roundwood in comparison to different wood products. Currently most small diameter roundwood harvest from forest treatments is not economically viable without significant subsidy given than most trees under 10 inches diameter at breast height are chipped or pile burned in the forest (data from USDA Forest Service, Presentation by Mark Knaebe, USDA Forest Products Laboratory. Uses for Forest-Thinning Material).



In contrast to large-scale wood products manufacturing facilities that may process significant quantities of wood into commodity products for the global marketplace, community-scale wood products manufacturing facilities may be better aligned to achieve dual goals of rural development and sustainable forest management.

Community-scale wood product manufacturers have long been an important part of the forest sector, servicing timber and non-timber forest product needs regionally. Community-scale operations are also able to fill expressed needs within a community, providing goods and services that are in demand locally. Community- scale enterprises can add value to forest products that may otherwise be left to burn as waste wood in the forest, and can create jobs in the process. Critically, community-scale enterprises draw from a limited area—balancing raw material demands with sustainable production—and reducing haul times and distances. They can catalyze the Forest Service project offerings for fuels reduction or restoration projects since they can create an outlet for processing lower value wood, with benefits accruing to different sectors in a community.

Heartwood Biomass processes firewood on a bucking saw with a merchandizing line. Photo courtesy of Heartwood Biomass

A vision for community-scale manufacturing

Interest in community-scale operations is growing across the state of California as the forest sector is experiencing a sort of renaissance, driven by interests in growing a sustainable bioeconomy, meeting fuels reduction needs across the state, and addressing climate change. There are few successful examples from which to draw. One example is Heartwood Biomass (www.heartwoodbiomass.com/), formerly Integrated Biomass Resources, in Wallowa County, Oregon. Recognizing that economic development is a critical component of a working forest economy, Heartwood has been working since 2009 to link forest restoration harvest to markets, creating jobs and building rural economies in the process. Heartwood identified a market for low value timber harvested during forest restoration work, and they currently produce firewood, posts and poles, and wood chips, employing 25 people in the operation. Heartwood relied on a combination of local government and non-profit support to get started. Specifically, Wallowa County purchased the site, offering it to Heartwood under lease with a buy option that allowed the business to get started. Wallowa Resources, similarly, helped secure grant funding to catalyze the start-up While the challenge of securing feedstock contracts on federal lands is seen as a prevailing barrier to business growth, Heartwood played a key role in ensuring forest restoration happens on public lands. “Once the facility was built, they [the Forest Service] realized there was an outlet and they started offering stewardship sales once a year,” said Matt King of Heartwood Biomass. For the past 11 years, the Forest Service has released stewardship projects on which Heartwood has bid. Since no other business entity can make enough profit on these projects, the Forest Service has granted these projects to Heartwood for 10 of the last 11 years to add value to low value material. The Forest Service was able to retain receipts locally, which benefits local schools, the county and leads to improved forest conditions. Given their success, Heartwood is currently in an expansion phase, and is exploring how to replicate its business approach elsewhere.

6.2 Selected innovative wood products

In this section, a series of ten different select innovative wood products are examined, with a product overview, a brief description of the production and manufacturing process, and the potential market locally and beyond. Each product is considered for how it may support forest treatment by giving life to California markets that currently do not exist or are niche. Where possible, regional climate change-related benefits are considered as well. The products chosen represent a spectrum from short-term to long-term tangibility, and low investment costs on some operations might provide an opportunity for partial to full ownership by local residents or community-based businesses.

Products chosen feature use of wood chips, wood wool, modified wood, products extracted from wood, and sawn lumber. Wood chips and wool are viable methods of processing low value wood. While chips can be used as biomass, innovative wood products are possible markets as well. Insulation made from wood wool has thermal, as well as acoustic properties, which are likely to be in higher demand in more urban areas. Wood wool can also be used to make evaporative cooling pads, which are useful and efficient in California's increasingly dry climate. Among the overstocked tree species in California's forests, wood wool could potentially provide a market for ponderosa and Jeffrey pine, in particular. Modified wood can be produced through either chemical or thermal processes. Modifying wood with the following methods requires boards to be intact, so larger diameter trees are needed when compared with wood chips or wood wool.

At a cellular level, wood contains lignin, resins, cellulose, etc., that have industrial value as products. While manufacturing the following products at community-scale sites could be viable for, and valuable to, local communities, it also might be outside of the scope of the community-scale to produce finished products. It may be more viable for community-scale manufacturers to extract the primary product onsite and ship it to larger facilities for secondary processing. This kind of arrangement where initial processing takes place in communities close to natural resources would also reduce the shipping cost of bulky wood and help rural communities capture more value.

Summary scores are also provided to describe various aspects of the suitability of each product to needs and constraints. Scored categories include: overall use of forest material, anticipated speed to build a business, ease in securing a workforce, current economic viability for a business manufacturing a product, safety of inputs and manufacturing process, suitability for production and consumption in California, and potential market and profitability. Scores range from 5 to 1, and summary scores are out of a total possible 35 points. Scoring is informed by the 2020 Joint Institute for Wood Products Innovation report *Literature Review and Evaluation of Research Gaps to Support Wood Products Innovation*.

Description of indicators and scores

Overall use of forest materials	**1 - lower volume** **5 - higher volume**
Anticipated speed to build business from permitting to full production	**1 - long-term (several years required)** **5 - short-term (several months required)**
Ease in securing workforce (takes into account education and training)	**1 - significant training-education needed** **5 - minimal training needed**
Current economic viability of a business producing this product	**1 - low** **5 - high**
Safety of inputs and manufacturing process	**1 - low** **5 - high**
Suitability for production/consumption in California	**1 - low** **5 - high**
Potential market and profitability nationally and/or internationally	**1 - low** **5 - high**

Innovative wood product scores for selected products.

	Erosion control blankets and wood wattles	Wood fiber insulation	Evaporative cooling pads	Thermally modified wood	Wood chips as winter road treatment
Overall use of forest materials	4-5	3-4	2-3	3	4
Anticipated speed to build business from permitting to full production	4	3-4	4	3-4	4-5
Ease in securing workforce (takes into account education and training)	4-5	3	4	2-3	5
Current economic viability of a business producing this product	3-5	4	3-4	4	2
Safety of inputs and manufacturing process	4-5	Paraffin wax: 4-5; Polyurethane binder: 4	5	Nitrogen gas: 4-5	Magnesium chloride: 5
Suitability for production/ consumption in California	4-5	4-5	4	4	3
Potential market and profitability nationally and/or internationally	3-4	4	3	3-4	2
Summary score (higher is better)	**26-33**	**25-29**	**25-27**	**23-27**	**25-26**

Products are ranked from highest to lowest summary score. Where possible, scores are informed by the 2020 report, *Literature Review and Evaluation of Research Gaps to Support Wood Products Innovation*, compiled by the Joint Institute for Wood Products Innovation. Summary scores assume that all indicators are of equal value.

Innovative wood product scores for selected products (cont'd).

	Wooden pallets and crates	***Chemically modified wood***	***Bio-based adhesives and dust palliatives***	***Wood wool cement board***	***Cellulosic nanocrystals with cement***
Overall use of forest materials	4-5	3	1-2	2	1
Anticipated speed to build business from permitting to full production	4	3-4	3-4	3-4	1-2
Ease in securing workforce (takes into account education and training)	4-5	2-3	2-3	3	1-2
Current economic viability of a business producing this product	2	4	3-4	3-4	1
Safety of inputs and manufacturing process	5	Acetic acid/acetic anhydride: 2-4; Furfuryl alcohol: 1-2	Various extractive agents: 2-4	Cement and plaster: 4-5	Mineral acid hydrolysis: 2-3; Organic acid hydrolysis: 4-5; Acetic acid as solvent: 3-4
Suitability for production/ consumption in California	3	4	4	3	3
Potential market and profitability nationally and/or internationally	2	3-4	3-4	3	5
Summary score (higher is better)	**24-26**	**20-26**	**18-25**	**21-24**	**14-19**

6.2.1 Erosion control mats and wood wattles

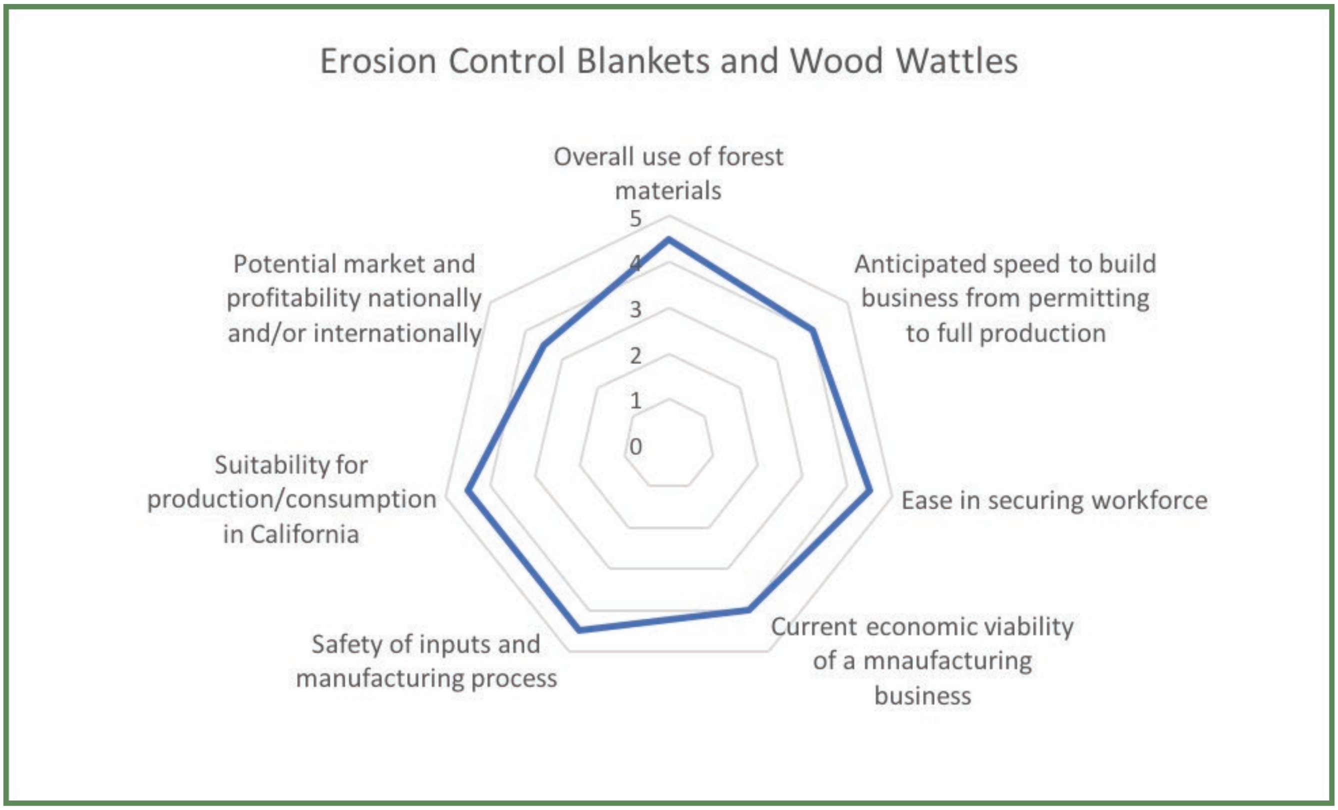
Product overview: Erosion control is an increasingly salient issue in California, and several erosion control products can be made from low-value wood. Climate change is ushering in fire and flood regimes that contribute to significant erosion, particularly in mountainous landscapes. Prolonging droughts are increasing fire severity, yielding more barren slopes. At the same time, precipitation is becoming increasingly flashy, and occurring more often in the form of rain. Taken together, these processes are resulting in significant erosion in California. The good news is that treatments to thin overstocked forests can also produce material to make two kinds of erosion control products. The first products are erosion control mats. These blankets can be spread over a surface to mitigate erosion, and mats made of wood wool sell in the $150-$250 range for 100 x 100 ft. sections. More commonly used products in California today are wood wattles. These long tubes can utilize wood wool or wood chips, stuffed inside a sleeve, stretched out across a surface in order to prevent perpendicular erosion. Wood wattles made with wood wool can be found for approximately $40 for a length of 25 ft. Wattles made from straw are slightly cheaper at approximately $30 for the same length. While wattles made from straw and other fibers, like coconut fibers, might have some cost advantages, products made from wood have alternative advantages that make them more viable in mountainous parts of California.

Production and manufacturing: Wood wool is often made from Aspen wood because of durability of the long fibers and the amount of water that Aspen wood can soak up. Preliminary research indicates that wood wool could also be made from ponderosa and Jeffrey pine and have similar properties, but one of the primary disadvantages of ponderosa and Jeffrey pine might be the presence of sap. While this could bear negatively on other products that utilize wood wool, erosion control products would be minimally influenced by the presence of sap. The utilization of ponderosa and Jeffrey pine as feedstock opens up a large market of low-value ponderosa and Jeffrey pine in California. Straw wattles are currently being produced and sold in California at a lower price point than wood wattles utilizing aspen wood. Replacing aspen wood with ponderosa and Jeffrey pine would likely bring wood wattles down to a more competitive price point.

Additionally, wood wool can hold more water than straw, and the weight gained by wood wattles when they become wet makes them a sturdier product; this is particularly important in steep terrain. Wood wattles also tend to be made in smaller diameters, which makes shipping size more efficient. Compared to straw wattles, wood wattles are smaller products to ship, and they gain more weight when wet, which suggests that bringing the price point down by using ponderosa and Jeffrey pine could make wood wattles a common-sense product. When shipped, wattles normally fall into the "oversized" category because of their shape and size, so local production is important for overall cost. Wattle sleeves are generally made from UV degradable plastic or biodegradable burlap. Seeds and fertilizers can be preloaded into wattles or erosion control blankets, although products are made with sterile base materials in order to prevent the transport of invasive species. It follows that the use of local materials could have purchase in erosion control products.

Potential market: The potential market for erosion control products in California is large. These are single use products that biodegrade in place, and the flood and fire regimes being endured in California are leading to more and more of these products being placed across the landscape. In the public sector, major users of erosion control products include the US Forest Service and Caltrans. The Forest Service has a history of purchasing erosion control products from an international company called North American Green, out of Indiana,[181] which may present a missed opportunity to support local, community-scale producers. In more ad hoc situations, the Forest Service has purchased from local vendors. For erosion prevention following the North Complex fire in 2020, the Forest Service purchased straw wattles from a hardware store in nearby Brownsville, CA. The straw wattles carried at that store are made in the Sacramento Valley town of Arbuckle, CA, by a company called CalVista. While straw wattle manufacturing is already occurring regionally, a niche for wood wattles and erosion control mats using wood wool from ponderosa and Jeffrey pine is a significant gap to be filled, both for California's community-scale wood products markets and for durable products using local materials. Wood chips can also be used in larger diameter wood wattles using thicker sleeves, opening up the potential to utilize white fir. While climate change poses many burdens to rural, forested communities, the market for erosion control products provides a useful outlet for low-value wood produced by forest thinning projects.

181 Information on US Forest Service supply chains was obtained through communication with staff.

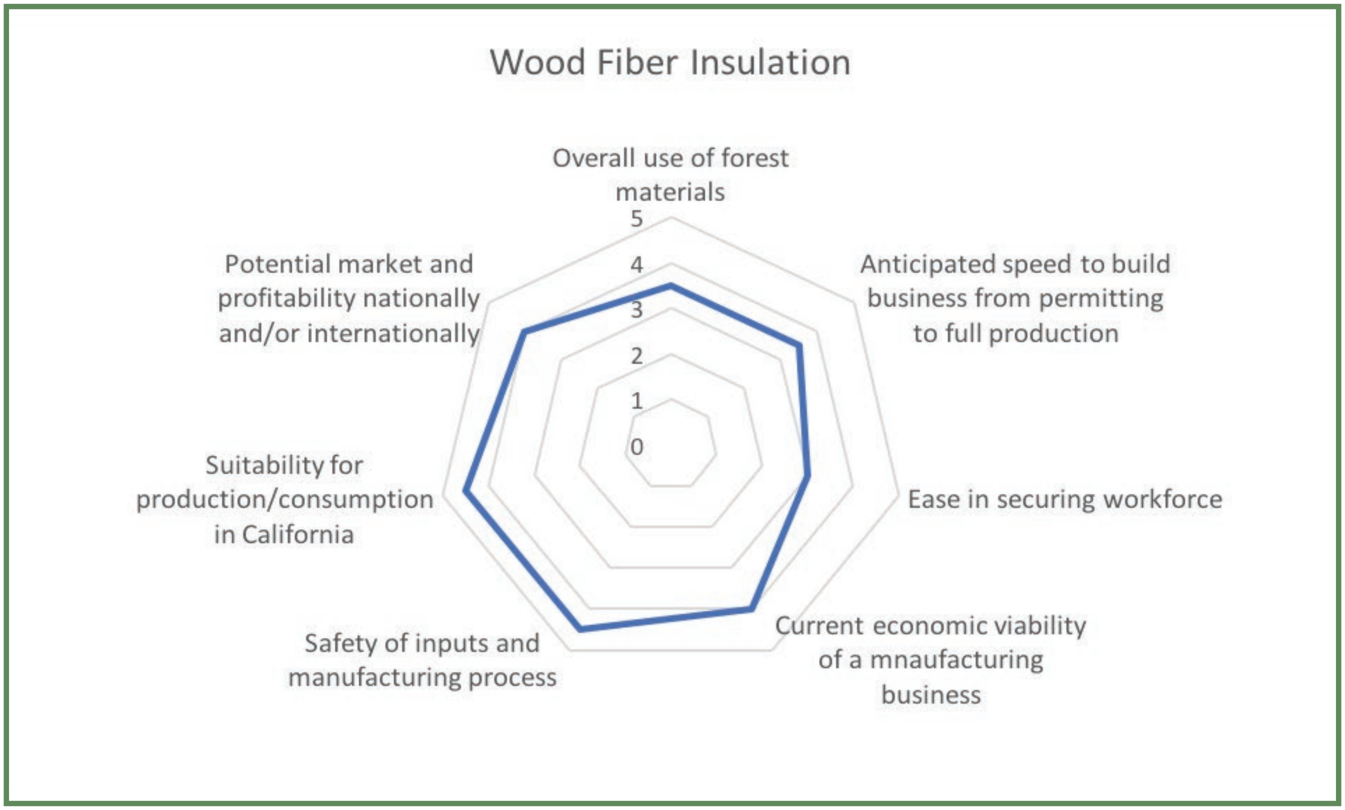


6.2.2 Wood fiber insulation

Product overview: Wood fiber insulation is a product that has potential to utilize wood chips from California's softwoods, while providing insulation that is well suited for California's climates. This product works in concert with mass timber, but its use of small wood chips and wood waste is distinct from most mass timber products used in construction. Sometimes called low-density fiberboard, wood fiber insulation is made from low-value wood waste and soft wood chips that could potentially come from small-diameter ponderosa and Jeffrey pine and white fir. The technology has its origins in Germany in the 1930s and came to market in the 1990s, primarily in Germany. As an insulation product, wood fiber insulation performs similarly to rigid foam insulation. It can be manufactured in a variety of densities, R-values, thicknesses and edge styles. Several insulation characteristics are advantageous for climates in California. High thermal displacement properties contribute to cooler indoor temperatures, particularly when wood fiber boards are installed on a roof. Additionally, boards are water and fire resistant; instead of igniting in fire, the material chars. The high thermal storage capacity of wood fiber insulation would be beneficial in the Sierra Nevada, where elongated heat release can provide desired effects in the large, diurnal temperature swings between day and night. Barriers to production are minimal but include higher production costs than other insulation materials. These costs are likely to come down as supply of materials, and demand for insulation, increase. Taken as a whole, wood fiber insulation can be a favorable wood product for California.

Production and manufacturing: There are two ways to produce wood fiber insulation out of softwood chips and wood waste: a wet method and a dry method. The wet method is similar to the process of making paper, where wet pulp is compressed then dried. The dry method involves mixing wood fibers with a polyurethane binder, adding paraffin wax for water resistance. One of the few negative environmental impacts associated with the boards is that paraffin wax is produced with petrochemicals. After mixing, boards are compressed and cured. Altogether, the dry method uses about 40% less energy than the wet method. The dry method is the most common for boards in the United States, where boards are generally manufactured with tongue-and-groove edges on all four sides. The most common type of board composition is about 85% wood fiber.

Potential market: Manufacturing of wood fiber insulation in the United States is underdeveloped, and a market niche exists in California for production. To the extent that boards are sold in the United States, they are generally imported from Europe and sold on the East Coast. The primary manufacturing entities are in Brooklyn, Maryland, and Quebec for the Canadian market. A company called GO Lab is redeveloping an old paper mill in Maine to produce wood fiber insulation; however, that is situated in the East Coast market. Given that one of the primary qualities advertised about wood fiber insulation is the environmental benefit which is negatively impacted by shipping distances, a niche exists for wood fiber insulation that is made in California, and preferably close to source material. When used in construction, wood fiber insulation can contribute to green building certification for materials used, and when manufactured in a rural area, wood fiber insulation can contribute to the thinning of overstocked softwoods and the creation of jobs.

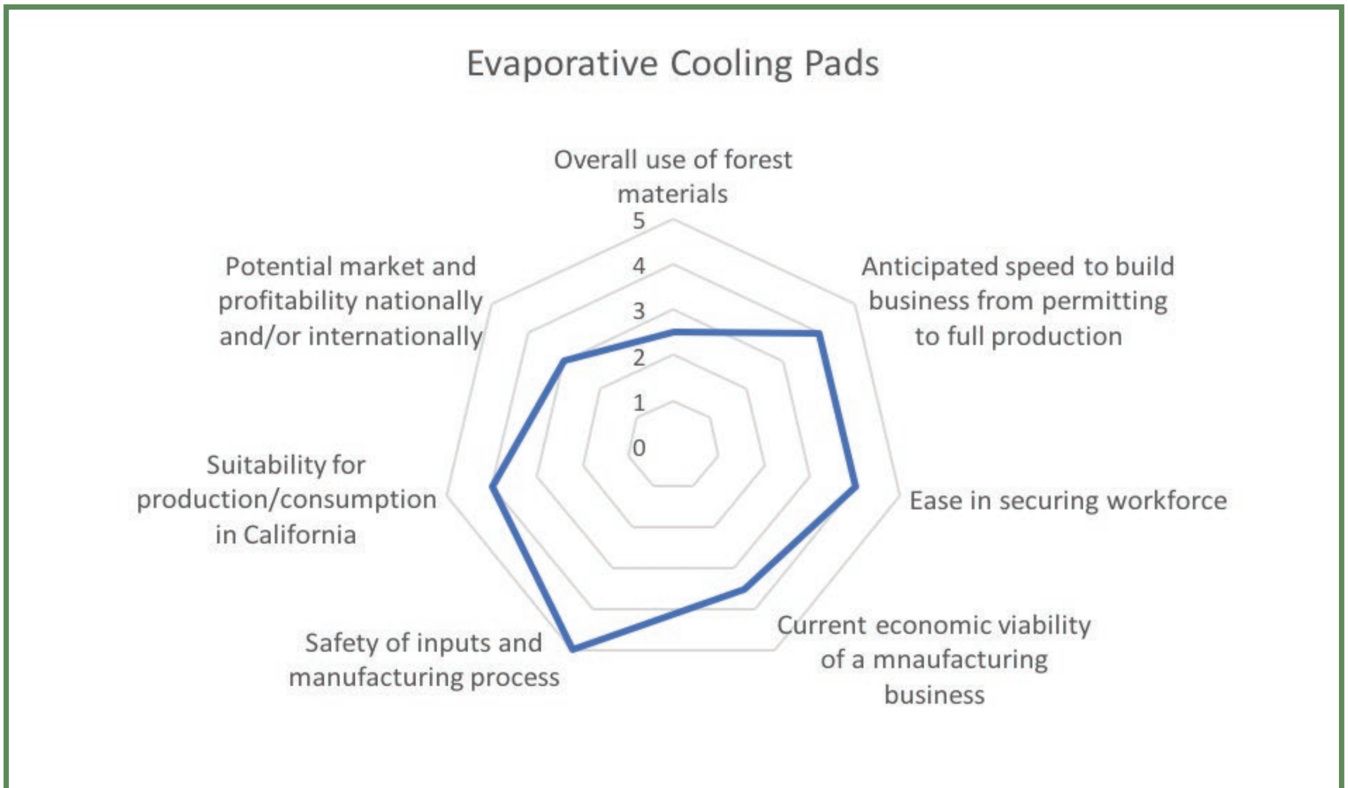


6.2.3 Evaporative cooling pads

Product overview: Evaporative cooling is an efficient substitute for air-conditioning in dry climates. Sometimes called "swamp coolers", evaporative coolers blow cool air by turning water into vapor using heat, which has a cooling effect in low humidity conditions. The process happens on an evaporative cooling pad, inside the cooling unit, where a water-soaked wood wool pad allows water to change phase to vapor. Evaporative cooling pads go through a lot of soaking and drying during their lifespans and need to be replaced after the life of the pad, ideally before they can grow mold. A pad generally lasts between three and eight years, depending on the material the pad is made from and the amount of use. Cooling pads made from synthetic material don't deteriorate like wood, though they do not generate the pleasant odor of wood pads. Replacement pads are sold in home improvement and hardware stores, and present a reliable market for wood wool. Community-scale manufacturing operations that make cooling pads could either make replacement pads to go on regional store shelves, or partner with a particular producer of an evaporative cooling system to supply pads for that brand. Either way, in the warming and drying climate of California, particularly in the Central Valley, there is a potentially burgeoning market for cooling pads.

Production and manufacturing: Cooling pads are currently made from several different materials. Among pads made from wood wool, the dominant product is made from aspen wood because it is a hardwood that planes well, has a pleasant odor, and expands to hold a lot of water, making it very effective. While there is aspen in California, other overstocked species of wood in California's forests could be used in cooling pads as well. Further research is needed to establish which type of feedstock could be viable for cooling pads, though a potential candidate is ponderosa and Jeffrey pine due to its pleasant odor. An additional type of cooling pad is made with solid paper in a honeycomb arrangement. There was a thrust in research on cooling pads around 2011 that included experimentation with novel cooling pad materials such as vetiver grass or coconut fibers.[182] Although it appears that various locally-available materials may be effective substitutes for synthetic cooling pads, wood seems to work best, translating to an advantage to the marketability of California's softwoods.

Potential market: Evaporative cooling has become an energy-conscious, commonplace alternative to air conditioning in parts of the American Southwest. While much of California is not quite as dry as Arizona or New Mexico, the need for air cooling systems, combined with high energy costs, could make evaporative cooling more attractive in California, especially as the climate becomes drier and warmer. Because evaporative cooling works best in climates with relative humidity less than 30%, this technology could allow much of California's population to cool spaces with less energy than traditional air conditioning, reducing its contribution to climate change. Lawmakers could further incentize the use of evaporative cooling systems through credits or tax breaks. If materials used in developing evaporative cooling systems could contribute to the thinning of California's overstocked forests, then the result would be a win-win for the state. Pads produced in the Sierra Nevada mountains could market to dry, hot climates to the west, in the Central Valley, and to the east, in Nevada.



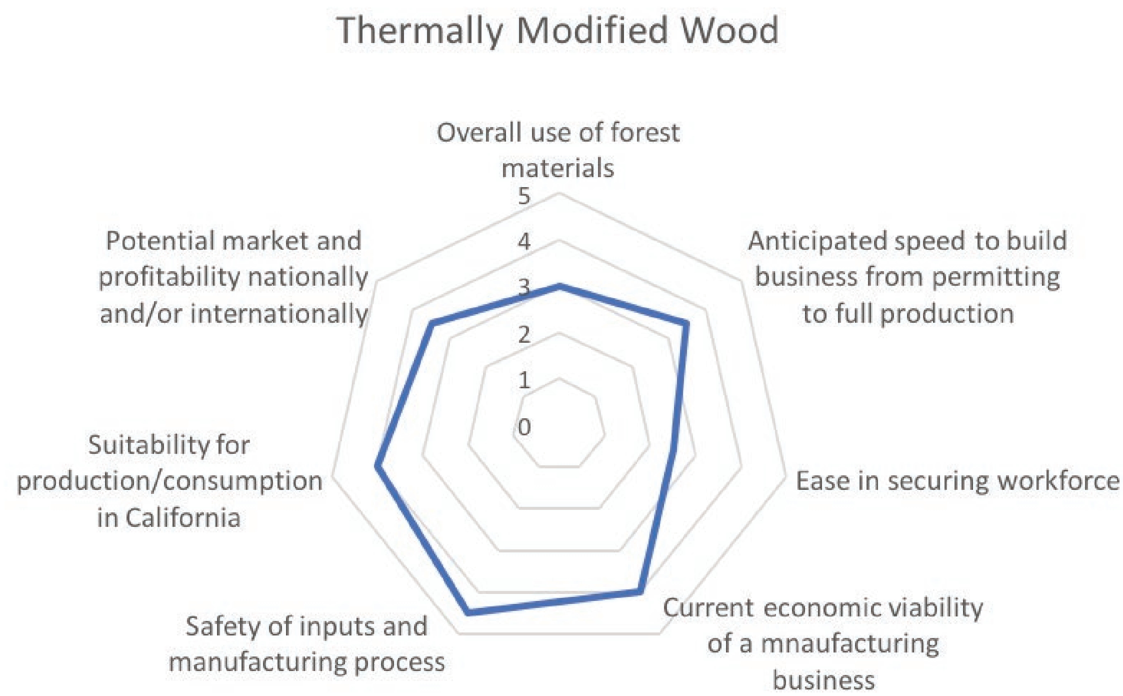
182 Jain, J. and D. Hindoliya. 2011. Experimental Performance of New Evaporative Cooling Pad Materials. Sustainable Cities and Society. Volume 1, Issue 4.

6.2.4 Thermally modified wood

Product overview: Thermally modified wood is already being produced in the region. Sunset Moulding in Chico, CA produces a product called Pakari out of thermally treated Monterey pine. That particular pine is scarce in California, so Sunset Moulding imports it from New Zealand and Chile. The thermal modification process effectively cooks the wood in order to remove lignin and other organic compounds from wood cells, similar to how steel is made from refining iron ore. Similarly, thermally modified wood is stronger than its parent material because of its lack of impurities. Thermally modified wood is also much more resistant to water, insects and decay, and in that way, the end product is similar to chemically modified wood. Thermally modified wood is darker than its parent wood as a result of the caramelization of lignin. The desired color of the end product seems to bear on the selection of the parent wood for aesthetic purposes, and could potentially create a market for a non-desirable wood that becomes desirable through modification. After heating, the final stage of thermal modification involves bringing steam into the kiln in order to bring the wood's moisture content back up to between 6% to 7%. The entire process takes approximately sixty-five hours.

Production and manufacturing: Thermal modification was developed in Finland and has been used commercially in Europe since the 1990s. A common product from Finland is called ThermoWood. Initial development of thermal modification focused on softwoods, where modification occurs at temperatures at or above 170 degrees Celsius. Softwoods that have been thermally modified include pine, spruce, fir and hemlock. More recently, modification testing has been done on hardwoods like American ash, birch and red oak. It is important to note that each species has a unique heating process that optimizes the modification of that particular wood.

Potential market: Thermal modification produces a good wood product for decking and siding because of its strength and resistance to moisture and rot. It effectively replaces the need to stain or paint exterior wood. The drawback is that thermally modified wood can be very stiff and brittle. As siding, it works well as tongue and groove boards because it expands and contracts less than regular boards. These kinds of decking and siding products are being produced in Chico, CA and the potential market for them is large. Many wood finishes consist of combustible hydrocarbons, and modified wood could present a more fire-safe alternative for exterior wood. There is local demand for these products and potential growth in national and international markets. There is already an established international market in Europe for thermally modified wood products. Technologically, the process of thermal modification is highly developed and there may be room for testing new wood types. Commercially, Sunset Moulding serves as an example of a viable business model, although it is not necessarily utilizing merchantable wood from California. The development of thermally modified wood from California is a market niche that could be filled, and the technology is established to experiment. Thermally modified wood is currently priced on the high side for products like siding, and can be found at approximately $8 to $10 per square foot. Utilizing local timber may be a way to bring the cost down into a range that is more competitive with exterior wood products that require stain or paint. Commercial barriers include the upfront cost of a kiln and training in the thermal modification process. A small-scale production facility might cost around or under $10,000 for the price of a kiln, and the cost increases significantly with increasing the size and power of the kiln. Research and experimentation on modifying locally abundant wood types has the potential to open up the market in California to modified wood products. Taken as a whole, modified wood seems to be a promising outlet for regional wood products.



6.2.5 Wood chips as winter road treatment

Product overview: In several parts of the world, wood chips have been used for winter road treatment as an alternative to salt and sand. The practice of applying wood chips for traction on winter roads originated in Switzerland and has more recently been employed in Quebec. The Colorado Department of Transportation has conducted research on the use of wood chips, and California appears to be a candidate for utilization of the wood product as well. Softwoods, such as spruce, poplar and birch, have been the preferred feedstock, making the softwoods of California viable source material. Pine, fir and cedar could be candidates for source material in the Sierra Nevada. Small, rectangular wood chips can be spread over road surfaces using the same equipment that spreads salt or sand, although some machinery requires minor modification to spread wood chips. The flat shape of wood chips results in approximately three times the surface area, per unit weight, compared to granular materials like salt. These flat wood chips are either dipped in, or impregnated with, magnesium chloride before application to accelerate the melting of ice and snow. Salt can alter the pH of soil and dehydrate vegetation on roadsides, which are already high-risk areas for the ignition of fire. Although magnesium chloride has a neutral pH and melts ice slower than salt, salt does not last as long and needs to be reapplied more frequently than impregnated wood chips. Wood chips additionally provide traction on top of snow and ice. For these reasons, wood chips with magnesium chloride may have advantages for longer stretches of cold weather. Additional advantages of wood chips over salt and sand include the distinctions that wood chips are biodegradable and do not salinate fresh water. These differences suggest that wood chips may have more value in California as higher-elevation winter road treatments.

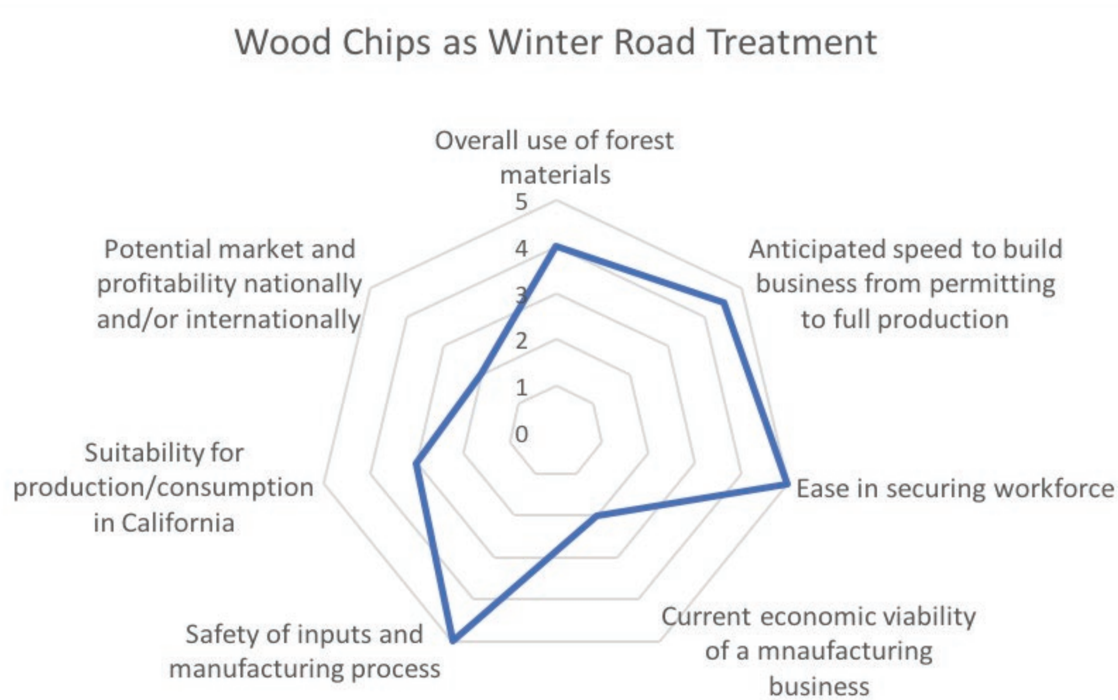
Production and manufacturing: Currently, there are no known cases in the United States of wood chips being used as winter road treatment. The nearest example is in Quebec, where woodchips used in the Montreal suburb of Rosemere are produced in the nearby rural town of Joliette. At his factory in Joliette, Andre Prevost has the exclusive license in Canada to make and sell these wood chips.[183] It is not known if and where licensing would be a barrier to production in the United States. A primary barrier to the utilization of wood chips appears to be cost effectiveness. Salt and sand are cheaper treatments, so finding niches where wood chips improve cost effectiveness, or comply with environmental regulations, may be key to finding locations where wood chips are more viable. If

183 https://www.cbc.ca/news/canada/montreal/rosemere-wood-chips-1.4499146

wood chips are already available at a site, barriers to production are significantly lower and include details like the infusion of a magnesium chloride brine; it is not entirely clear if brine infusion is essential in order for wood chips to be an effective winter road treatment. While cost of production may be higher than for salt or sand, the increased surface area and lighter weight of wood chips may reduce costs associated with transportation and wear and tear on machinery during the spreading process. The manufacturer in Quebec would not share his production costs, but indicated that he has developed a viable business model and has done so while acquiring chipping machinery. Source material in California is not a significant barrier because all that is necessary are basic wood chips, preferably from soft wood that breaks into a usable geometry; this could potentially come from a large range of sources. Wood chips as winter road treatment presents a business model with minimal production barriers as a value-added product for a facility that already makes wood chips.

Wood chips can be used in various innovative wood products (photo credit: Adobe stock photos)

Potential market: Market potential for wood chips as winter road treatment could include high-elevation areas, like Switzerland, and continental, high-latitude areas, like Quebec. In the United States, California and Colorado have high-elevation regions that are close to source material, while the Upper-Midwest and Northeast may be candidate areas as well given the long duration of cold stretches. The Northwest could also potentially be a viable region given the abundance of source material and need to restore overstocked forests. Within California, higher elevations toward the Central Sierra Nevada seem to have the most favorable combination of source material for production and longer cold stretches for winter road treatment. The benefits of using wood chips for winter road treatment



show promise in certain niches. Beyond the environmental benefits over salt or sand, wood chips are also not as corrosive on road surfaces. There may be aesthetic differences that the public might not initially support, but in the example of Rosemere, Quebec, the general public held some favorable views of the use of wood chips. In the Sierra Nevada, conditions of source materials, weather patterns, infrastructure and environmental concern/regulation exist that could foster the use of wood chips. It would likely require a local, county or state entity in charge of winter road maintenance to realize their niche in order for wood chips to be viable at a significant scale.

6.2.6 Wooden pallets and crates

Product overview: Wooden pallets and crates are essential in modern manufacturing operations. Some pallets or crates are plastic or metal, but the majority of pallets or crates are made from wood. Manufactured goods are stacked onto pallets, which provide a point of engagement for forklifts or other transportation devices to load and unload heavy stacks of goods. Pallets or crates can be loaded into containers, thus serving an important role in the movement of cargo in the international shipping industry. Pallets and crates are made in a variety of sizes and special-order configurations, and are not internationally standardized. Furthermore, there is a significant amount of pallet repair and reuse, so the market for producing usable pallets has an ad hoc character combined with substantial demand. A wood products expert with the Forest Service's Forest Products Lab indicated that nearly half of all cut wood ends up as pallets, and that pallet-grade wood is generally low-quality cut wood. Other wood products experts from the US Forest Service have indicated that pallets are a challenging industry. This inquiry explores the viability of a niche for pallet and crate production closer to source material and farther from urban/port areas where most pallet and crate manufacturing is found.

Wooden crates can be made from small diameter roundwood (photo credit: Adobe stock photos)

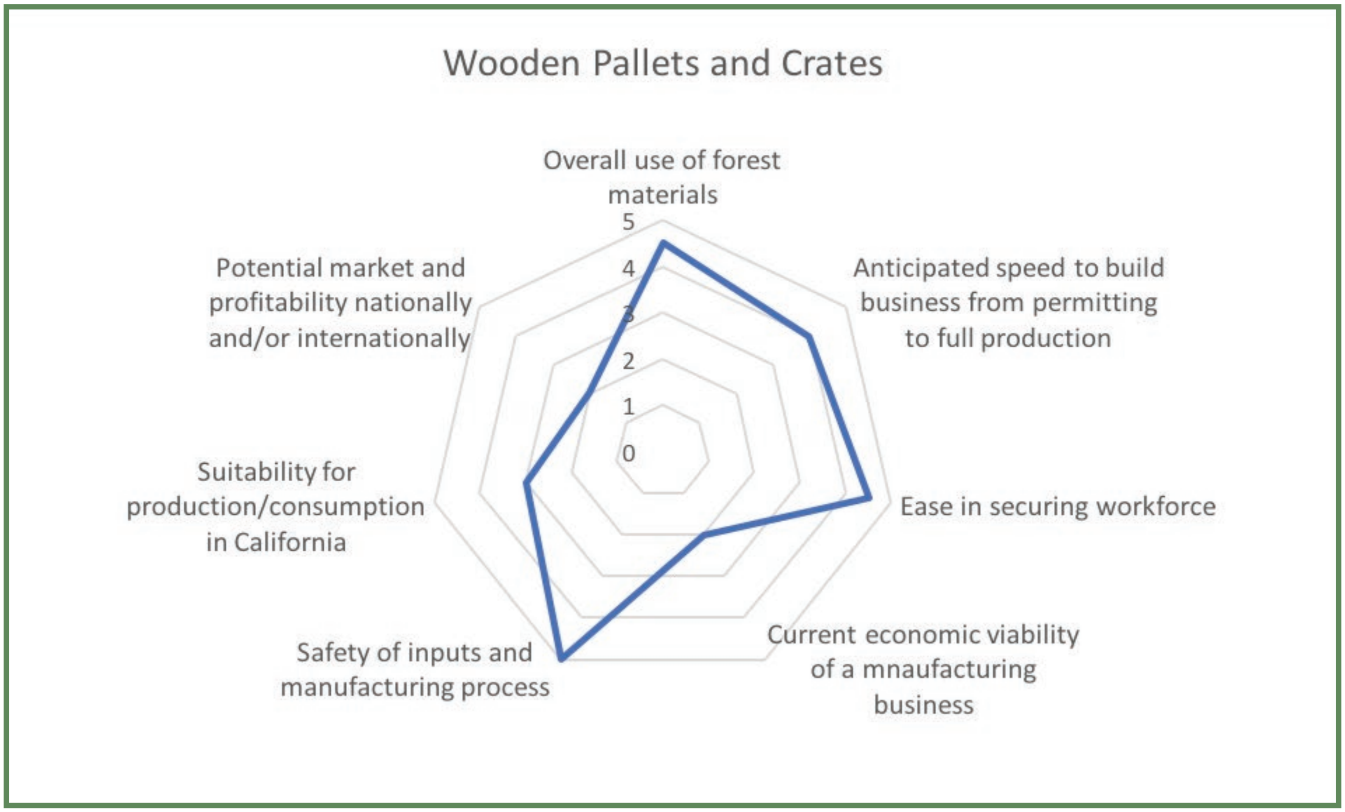
Production and manufacturing: In 2016, pallet production in the United States used approximately 55% softwood and 45% hardwood, although in the Western United States softwoods accounted for 98%.[184] The most common pallet is a 48"x40" pallet that is the standard for the Grocery Manufacturers Association (now the Consumer Brands Association). Pallet production used approximately 43% of all hardwood lumber produced in the United States in 2016, and approximately 15% of softwood lumber.[185] Softwoods utilized include spruce, pine and fir, and Douglas fir could be a candidate for rural pallet or crate production in California. The two most common types of pallets are stringer and block. Stringer pallets are cheaper, made from softwood, and are often thrown away after initial use. They can be found in the $10-15 range per unit. Block pallets cost about twice as much and are more durable because they incorporate hardwood. They can also be lifted from all four sides, whereas stringer pallets can only be lifted from two sides unless they have special notches that can make them lift-able from four sides. A community-scale manufacturing operation in California would likely focus on stringer pallets, which are made from 2"x 4" and 1"x 4" cut wood. With regard to using small diameter trees, it would

184 Gerber, N., Horvath, L., Araman, P. and B. Gething. 2020. Investigation of New and Recovered Wood Shipping Platforms in the United States. *BioResourses*. 15(2), 2818-38.

185 Madison's Lumber Reporter. 2018. North America full-year 2016 lumber production: WWPA. *Lumber Track*. Accessed from: https://madisonsreport.com/2017/03/16/north-america-full-year-16-lumber-production-wwpa/

be important to know if manufacturers join multiple 2″x 2″ dimensional cut wood in order to achieve the strength of preferred 2″x 4″ dimension. The strength of pallets can be improved by using better nails, and this method could provide an entry point into engineering stringer pallets with smaller-dimensional source material. Community-scale manufacturing could potentially be subject to less regulation on pallet standards if manufacturing does not cross state or international borders.

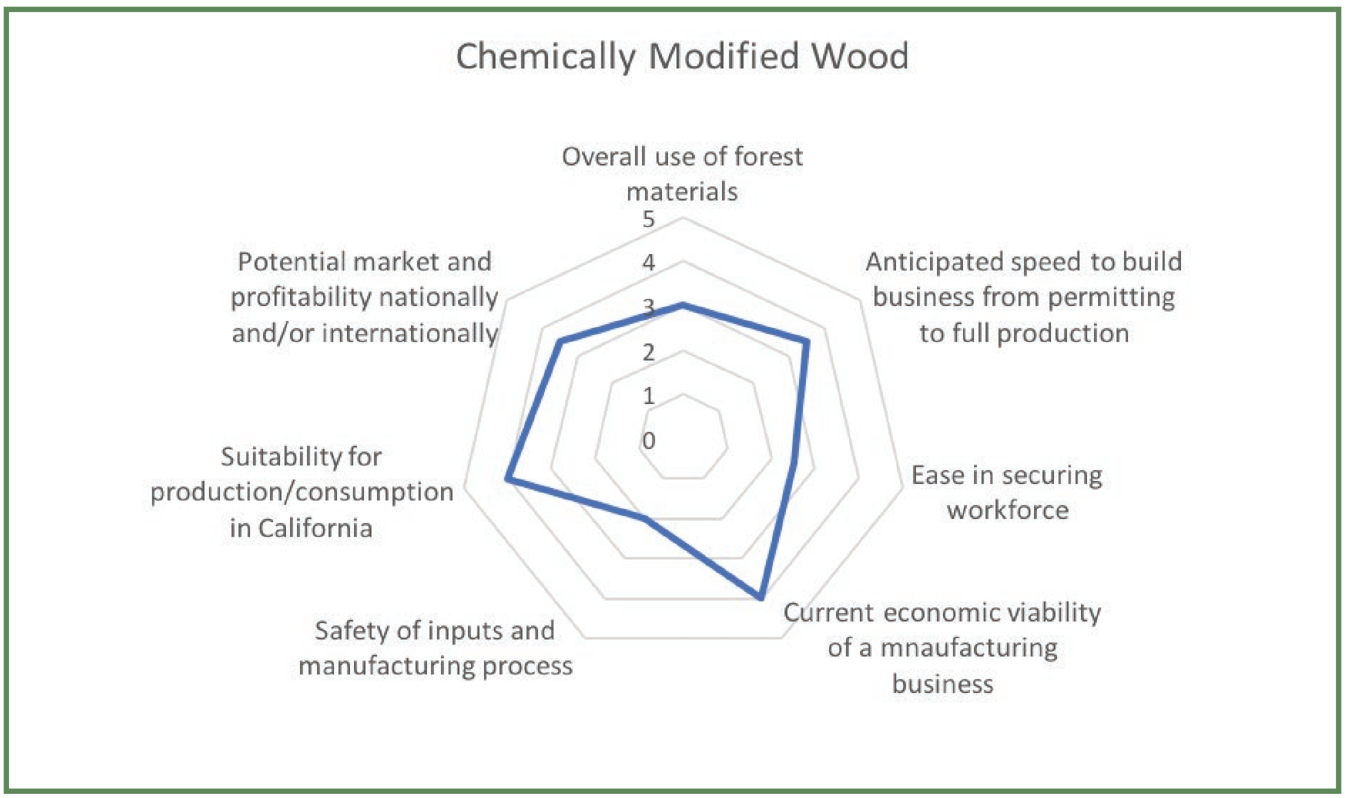
Potential market: California has a big pallet and crate market, and most of the large-scale producers are in urban areas. This is correlated with large transshipment ports in the Bay Area and Greater Los Angeles. In the Northern Sierra Nevada, there appears to be a gap in the production of new pallets between the IMI Pallet Factory in Redding and Sierra Pallet in Reno, NV. Pallet operations in Chico appear to focus on recycling old pallets. In Plumas County, neither Collins Pine in Chester, nor Sierra Pacific Industries in Quincy, appear to assemble pallets with their cut wood. A community-scale operation could potentially use residual, low-quality wood from those mills and assemble pallets or crates at a different location. Another option would be to both cut wood and assemble pallets or crates at a facility like a wood products campus. The primary barrier for production in rural areas is that pallets are most often needed in urban centers from where goods often get shipped. Community-scale manufacturing of pallets or crates would require further exploration of goods that could be shipped on pallets within rural communities, like hay, or nearby products that are exported on pallets, like fruit. Fruit or other produce shipping could be viable but is also an established industry in the region that could be difficult to get into. Another option would be to assemble pallets or crates near source material and then ship them to urban/port areas. Access to high-volume shipping, like railroad, could be advantageous in shipping assembled pallets. The market for pallets and crates in California is large, and while finding a market for community-scale operations could be challenging, it would provide an outlet for a lot of low-value wood.



6.2.7 Chemically modified wood

Product overview: Modified wood is a durable product for decking and siding, that does not need to be treated with combustible hydrocarbons. As such, modified wood is, to an extent, replacing tropical hardwoods and relieving some pressure on their burdened ecosystems. Chemical modification swells cell wall polymers so that moisture cannot penetrate into wood. Thermal modification produces a similar end product, but requires larger upfront investment for a kiln. While thermal modification is already showing to be a viable business model in Chico, CA, chemical modification could produce a similar product with lower upfront costs. Neither chemical nor thermal modifications are being done on woods logged from California forests, and comprise a market of great potential for California woods.

Production and manufacturing: Chemical modification of wood can be achieved through acetylation or furfurylation. Acetylation increases the acetyl content of wood, which makes wood more stable while greatly reducing its water absorption capacity. Softwoods generally have acetyl content from 0.5% to 1.5%, while hardwoods have a higher acetyl content of between 2% and 4.5%; acetylation takes acetyl content much higher than these levels. Experimentation still needs to be done, but the acetylation process uses acetic anhydride. These substances are commonly used in factory settings, and the resulting acetylated wood is nontoxic. The modification process was developed in Germany, and is now most notably done in the Netherlands by a company called Accsys Technologies. The products they manufacture are the result of modifying radiata pine (referred to as Monterey pine in California), specifically clear pine lumber, where the wood gains approximately 20% of its weight through acetylation. Monterey pine grows in California, but is protected to a level where it is not commercially viable as feedstock. Experimentation is needed to establish if redwood or incense cedar can be chemically modified. As a wood product from the Sierra Nevada, further research could include experimentation with ponderosa and Jeffrey pine. Furfurylation is a chemical modification process that employs furfuryl alcohol as its modifying agent. Although furfuryl alcohol is made from agricultural waste, like sugarcane and corn cobs, it is recorded on California's Proposition 65 list as cancer causing. While this may be limiting in the production of furfurylated wood in California, the end product is nontoxic. Additional work is needed to determine if furfuryl alcohol is viable in an industrial setting. Modification occurs by impregnating wood with furfuryl alcohol and a catalyst, then heating the wood to cause polymerization.



Potential market: Furfurylated wood is notably manufactured out of Norway, by a company called Kebony AS. They produce a hard furfurylated wood that gains approximately 35% of its weight through modification, as well as a soft furfurylated wood that gains approximately 20% of its weight through modification. The production of furfurylated wood in California has more uncertainty than acetylated wood because of furfuryl alcohol's presence on the Proposition 65 list, but both modification processes are in need of further exploration on California's abundantly available feedstock.

6.2.8 Bio-based adhesives and dust palliatives

Product overview: Bio-based adhesives are less toxic and more environmentally friendly than their petroleum based counterparts. A big question for bio-based adhesives concerns the extent to which they can compete with, and possibly replace, petroleum based adhesives. Tackifiers are chemical compounds that provide tack, or stickiness, to adhesives, and wood products like pine resin can serve that purpose. Products like pine resin and lignin are derived from biomass and are biodegradable. Bio-based adhesives are already being used in the packaging industry, where low grade adhesives are suitable. They are additionally being used in biomedical applications because the adhesives are biocompatible, meaning that the body more readily accepts the material. Biocompatibility is of high value for adhesives that are used on skin or body tissue. Some bio-based adhesives are being used in construction, and there is a lot of potential for growth in this sector if bio-based adhesives can continue to be manufactured for increasing strength and consistency. At a community-scale wood products facility, it is conceivable that mass timber and its adhesives are both sourced from the same location. This could be significant for the use of cross-laminated timber, and other mass timber products, on the inside of structures. The extent to which bio-based adhesives meet the standards to qualify for use in mass timber is an issue to keep a close eye on for the community-based manufacturing of wood products.

Production and manufacturing: Bio-based materials used in adhesives include starch, vegetable oil, proteins, lignin and natural resins. A recent review article explored the potential for lignin-based adhesives to be used in composite wood panels.[186] Lignin is the natural glue in plants that holds cellulose fibers together, and it can be easily obtained from spent pulping liquors. Lignin-based adhesives indeed can meet relevant standards for composite wood panels, but modification of the adhesive is needed. First, the reactivity of lignins needs to be enhanced. This can be done through demethylation, oxidation, methylolation, phenolation, reduction and hydrolysis. Second, crosslinkers are needed to ensure bonding quality. Crosslinkers capable of copolymerizing with lignins include phenolic resin, tannin, polymeric diphenylmethane disocyanate (pMDI), furfural and ethylenimine. While chemistry makes it possible, the primary barriers to production are economic and technical issues. Because these processes are so technical, a community-scale manufacturer could extract primary material from locally-available wood products for shipping to a secondary processing site with more technical capacity for final production

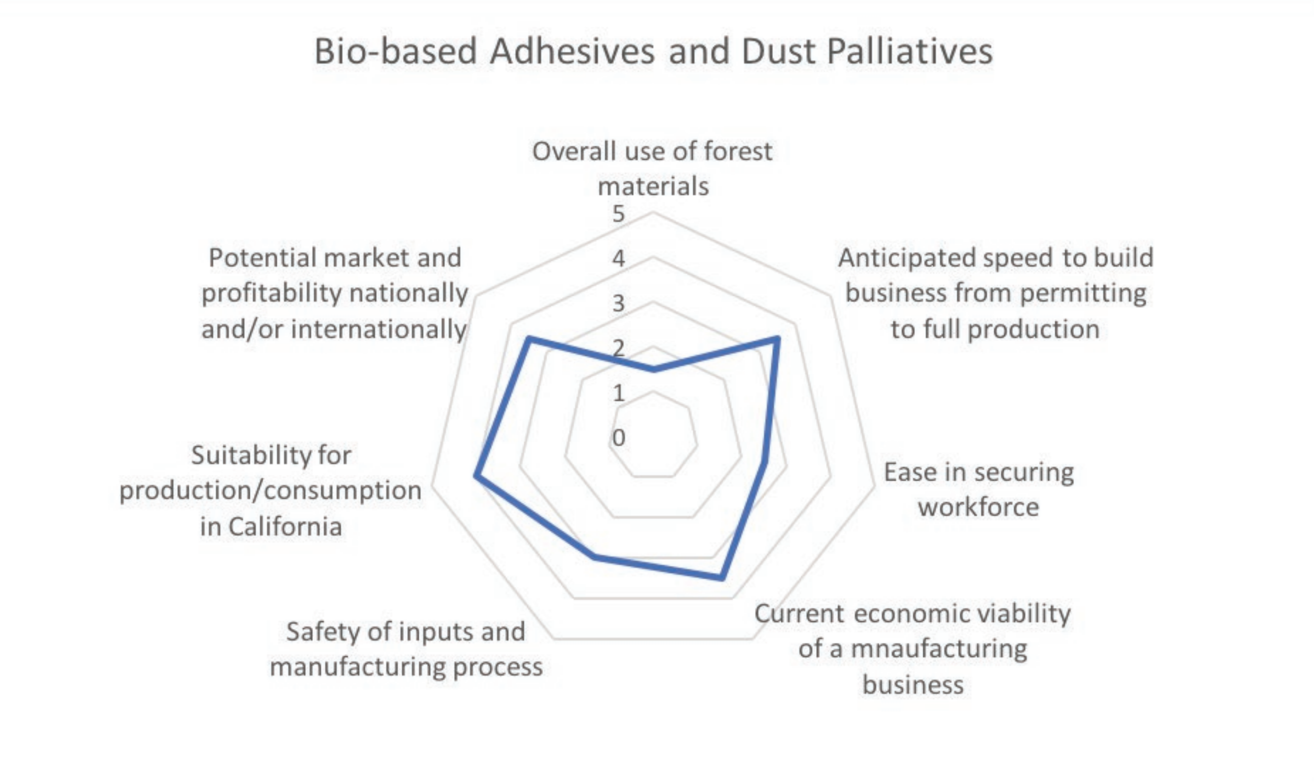
Potential market: It should be noted that other low-value wood products are currently used in road maintenance, and could fit into a large-scale scheme of wood utilization. Chunkwood is used in road stabilization, particularly in low-volume roads. Because of the relatively low density of chunkwood, it can be supported by weak subgrades that might not be able to support necessary gravel loads.[187] Additionally, wood products are used as dust palliatives on low-volume roads. When spread over road beds, lignin sulfonates and tree resin emulsions can improve excessively dusty conditions.[188] This is a product that the Forest Service is aware of and could potentially buy for forest operations. Supplying lignin sulfonates and tree resin emulsions to government agencies would tie in well with larger schemes to connect public and private actors; that kind of arrangement would use local forest products that support forest thinning to assist with low-volume road maintenance. Dust palliative and bio-based adhesives are wood products that get extra value out of wood. It remains to be seen what levels of extraction and processing could be compatible with and economically viable for community-scale manufacturers.

---

186 Ang, A., Z. Ashaari, S. Lee, P. Tahir, and R. Halis. 2019. Lignin-based Copolymer Adhesives for Composite Wood Panels – A review. International Journal of Adhesion and Adhesives. Volume 95.

187 Kester, M., S. Shoop, K. Henry, J. Stark, and R. Affleck. 1999. Rapid Stabilization of Thawing Soils for Enhanced Vehicle Mobility: A Field Demonstration. CRREL Report 99-3.

188 Federal Highway Administration. Roadway Surfacing Options Photo Album: Companion Document to Context Sensitive Roadway Surfacing Selection Guide. Publication No. FHWA_CFL/TD-05-004a. August 2005.

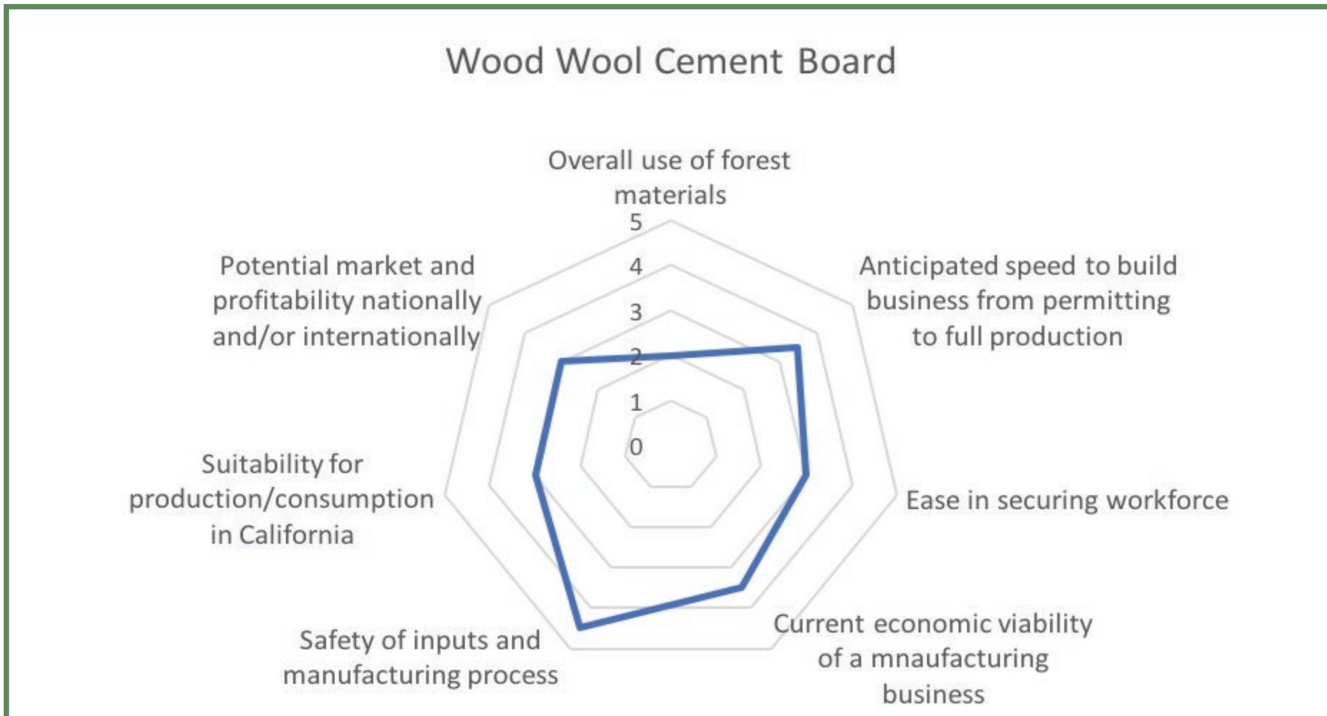


6.2.9 Wood Wool Cement Board

Product overview: Wood wool boards are among the oldest standardized insulation products made out of renewable, raw materials. Wood wool cement boards are commonly used in construction because of their good properties in acoustic insulation, thermal insulation, fire safety and moisture resistance. Acoustic insulation and absorption properties make wood wool cement board a viable product in the field of acoustic engineering. Boards can be placed in auditoriums and concert halls to engineer the way that sound moves through, and stays in, a space. Additionally, boards can be made to absorb sound and can break up a larger space into several smaller, acoustically-discrete spaces. The varying acoustic properties depend on the use of plaster in the binding agent. Thermally, wood wool provides insulation and is commonly used in roof panels.

Production and manufacturing: While wood wool has been around for a long time, sometimes called "excelsior", wood wool cement boards were first used in Europe nearly a hundred years ago. Parent wood is usually pine or spruce, making wood wool boards a suitable candidate product for California. Wood wool is made by planing logs into long, thin fibers using a wood wool machine. Because of the high porosity of wood wool, its volume is much larger than the parent wood. Fibers are generally between 1 to 3 mm in width, and are then coated with a cement of choice, then shaped and cut into desired board dimensions. The type of cement, or binding agent, used on the wood wool bears on the insulation properties of the board. There is currently not a clear, leading manufacturer of the boards. Some boards are made by relatively small-scale producers, while other are imported from China. This wood product, more than the others listed, is imported to an extent where price competition from abroad could be a barrier to production. Trade relations with China are likely to liberalize, so finding economies of scale domestically might be necessary to make for competitive prices. Wood wool cement board can currently be purchased for approximately $10-15 per square meter. A viable wood wool cement board production facility in California would require access to pine logs, a wood wool machine ($2,000 - $7,000), cement processing capacity, saws ($500 - $2,000), and some sort of transportation network. A small-scale production facility could cost less than $5,000, whereas a larger-scale facility could cost in the $10,000 to $15,000 range.

Potential market: While the uses of wood wool cement board as a construction material vary, sometimes even used for aesthetic purposes, there seems to be a larger market for it in larger indoor as well as outdoor spaces due to the board's durability. In commercial and civic spaces, acoustic and thermal engineering properties likely weigh on the selection of materials more than they do in residential design. Retrofitting of office space can include wood wool cement board to improve acoustics in tight work spaces. For outdoor uses, wood wool cement board can replace highway and rail line cement sound barriers, reducing the environmental impact of technologies used to buffer the noise level for pedestrians and residents living alongside major traffic corridors. While the supply chain of boards draws on rural materials, demand seems to have an urban character. Potential markets include civic and office spaces, both regionally and nationally. It may be beneficial to associate with a larger manufacturing entity because of the often-specialized nature of orders, or to be a supplier for engineering firms that utilize the acoustic and thermal properties of the boards. California, with overstocked pine forests and large, cosmopolitan cities has potential in the manufacturing of wood wool cement board. Abundant source material, combined with demand for acoustic and thermal engineering in modernizing urban areas, leaves California with a market niche to fill in producing and manufacturing this innovative wood product.



6.2.10 Cellulosic nanocrystals for cement

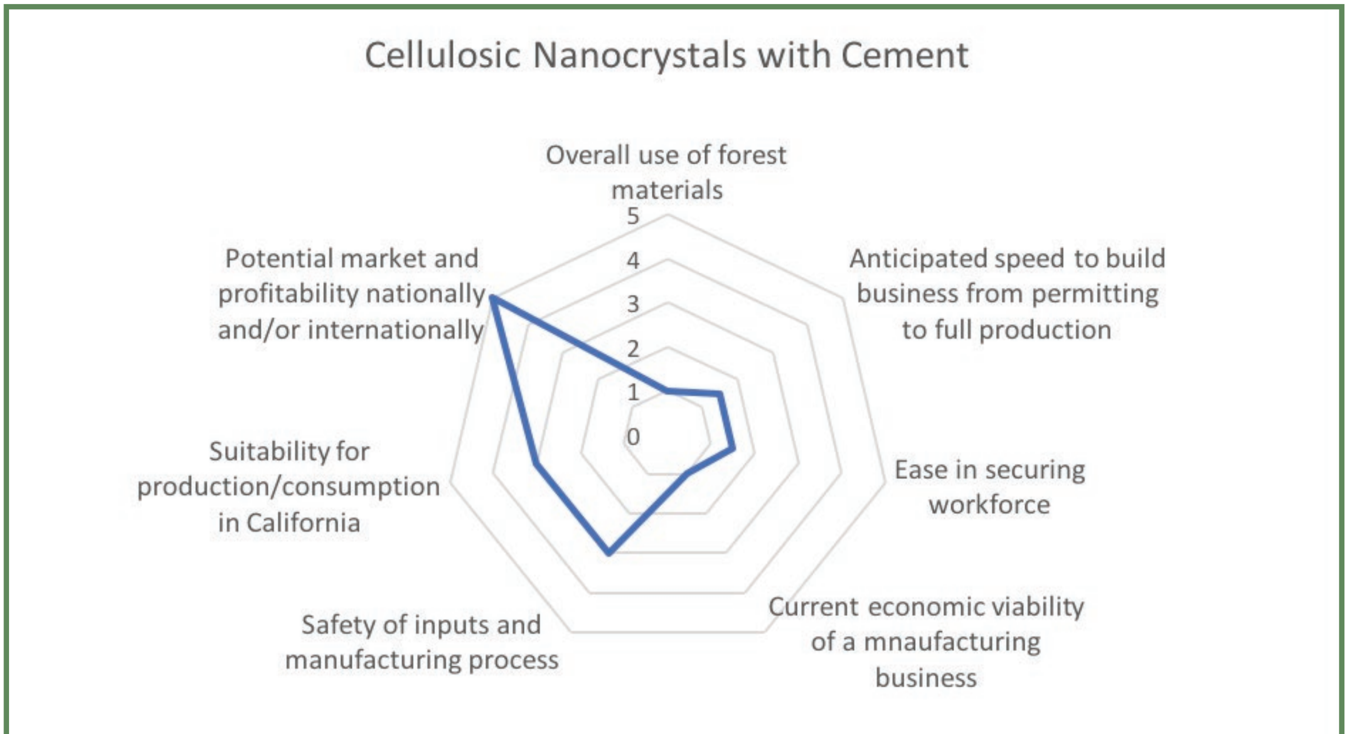
Product overview: When added to cement paste, cellulosic nanocrystals significantly increase the strength of the cement, once dried. Plant cell walls are comprised of cellulose, and cellulosic nanocrystals can be derived from wood. Acid can be used to dissolve wood, leaving behind only crystalline cellulose. These nanocrystals are so small and can only be detected with an electron microscope. Nanotechnology and nanocrystals are having a vanguard moment in science, with wood products playing an important role in the development of cellulosic nanocrystals.

Production and manufacturing: Cellulosic nanocrystals increase the degree of hydration in cement. The presence of nanocrystals in cement allows for water to use them as conduits to go where the water wants to go, resulting in a more even curing of the cement when it is dried. A commonly cited study showed that this increase in the degree of hydration increased the flexural strength of cement by approximately 30% with a

0.2% volume of cellulosic nanocrystals with respect to cement.[189] When water is added to cement paste, the mixture flows better but at the expense of the strength of the cement when it dries. With cellulosic nanocrystals in the paste, less water can be added while the strength of the cement increases. A collaborative project is underway to better understand the potential of this technology in large-scale applications by employing it in the construction of a cement bridge in Yreka, CA. Said project is a public/private partnership between the Forest Service, Purdue University, Oregon State University and a private nanotechnology company called P3Nano. With the goal of rapidly commercializing cellulosic nanomaterials, P3Nano represents the commercial viability of this technology, while the R&D is largely being done within public institutions.

Potential market: Currently, cellulosic nanocrystals are available for laboratory studies, and their cost and locations of production are not clear. However, cellulosic nanocrystals have potential as commercial products, and companies, such as P3Nano, are involved in research and bringing innovations to market. To develop a supply of cellulosic nanocrystals at a commercial-scale, nanocrystals could be co-produced alongside other wood products, increasing the economic viability of a wood products operation. For purchasers, cellular nanocrystals as an additive in cement would increase construction costs; however nanocrystals would reduce the quantity of cement needed for construction projects overall, in addition to reducing carbon costs. If research continues to show that nanocrystals can increase the strength of cement by approximately 30%, then approximately 30% less cement could conceivably be used. There is also value added in design considerations because of the need for less cement. The technology is in nascent stages, and the cost of commercially producing cellulosic nanocrystals is not well known, but the relatively low input-cost method of producing them with acid could make it competitive as a cost-effective product.

Additional barriers to production presumably include expensive, high-powered microscopes to be able to see nanocrystals, and a staff trained in the manufacturing and testing of nanocrystals. Given that this technology is still new, California nanocrystal producers could potentially supply both domestic and international markets, allowing rural communities to capture some of the value of wood products. On the construction end, the implementation of new practices in construction could be impacted by labor unions. Taken together, this wood product has such broad market potential that it could provide some stability to labor in wood producing, nanocrystal producing, and cement pouring industries. The potential for cellulosic nanocrystals in cement is high, but the utilization is still in development.



189 Cao, Y., P. Zavatierri, J. Youngblood, R. Moon, and J. Weiss. 2015. The influence of cellulose nanocrystal additions on the performance of cement paste. Cement and Concrete Composites. Volume 56.

6.3 Opportunities & challenges to grow community-scale manufacturing

While community-scale manufacturing and sale of innovative wood products offer an opportunity to scale up forest treatment efforts, develop rural economies, and build more locally-available solutions to California-specific markets, there remain numerous barriers to the establishment of community-scale enterprises. Specifically, many questions remain about the viability of community-scale wood product businesses, especially given that the markets for some innovative wood products are niche, underdeveloped, or underexplored. In particular, wood products developed in one part of the country may be subject to restrictions based on California regulations for occupational, residential, human, or environmental health. Other considerations relate to energy and water availability, especially given increasing drought conditions across the state. Any group interested in developing a community-scale business should do their due diligence to ensure they follow appropriate rules and regulations. Furthermore, other considerations may restrict marketability for some products, for example in fire prone areas where mulch used around a house may impact home hardening against fire.

However, innovative wood products from California are uniquely positioned to help the state reach climate goals, not only by reducing use of non-renewable materials and potentially by locking up carbon in long-lived products, such as with cellulosic nanocrystals that can reduce the amount of cement needed in construction, but also because the natural properties of wood fiber and related products offer unique solutions to reduce carbon-intensive practices. For example, in areas of low humidity where households rely on air conditioning for hot summer months, swamp coolers using wood wool pads offer an environmentally-friendly alternative for cooling the air.

Beyond production and market-related practical considerations, any community-scale wood products operation needs to consider access to feedstock, both in terms of availability and price. Federal harvests may or may not include forest treatment harvest options and this has the potential to impact reliable supply for businesses hoping to access low-value material harvested from public lands. Wood product business start-ups may struggle to secure a bank loan without a guarantee of at least a 10-year supply, but with a 20-year supply preferred. This can put potential businesses in a difficult situation of being unable to secure enough capital to start-up or grow. Creative solutions are being explored, though it is critical that these solutions are scalable throughout the state.

Tuolumne County's Biomass to Business feedstock aggregator:

The ability for community-based wood product businesses to secure financing is often dependent on their ability to prove feedstock supply that is consistent with the species, quantity, and quality needed to turn a profit on any given loan. Furthermore, when businesses rely on the open market to secure feedstock, they are subject to market rate fluctuations which may be volatile and reduce long-term profitability. Tuolumne County is developing an innovative solution to link buyers of low value feedstock to land owners seeking forest restoration and fuels reduction treatment. Tuolumne County s Business Directorate is seeking to connect wood product businesses to biomass producers by creating a public utility map of trees on private lands using LiDAR. Building from the Bufferwood concept proposed in the 2020 Joint Institute report[190] landowners located in proximity to maintained roads seeking forest treatment can sign up and aggregate their lands with others in the neighborhood seeking forest treatment. Collective land treatment has the potential to significantly reduce costs associated with harvest of low value material, enabling businesses to also connect with their target feedstock needs. Private landowners that sign up for forest treatment can benefit not only from collective fire resilience afforded to treated neighborhoods, but they can benefit from certified management efforts that could potentially reduce barriers to fire insurance. Furthermore, the traceability offered through this public mapping tool could allow businesses to certify their wood sourced from sustainable practices. Although a certification program for this kind of wood does not currently exist, this program or other related efforts, such as the Source Verified Good Wood program,[191] could serve as a model to add value to wood products sourced from sustainably managed forests.

190 Sanchez, D., Zimring, T., Mater, C., Harrell, K. 2020. Literature review and evaluation of research gaps to support wood products innovation. A report submitted to the California Board of Forestry and Fire Protection. Accessed from: https://bof.fire.ca.gov/media/9688/full-12-ajiwpi_formattedv12_3_05_2020.pdf

191 https://www.goodwoodverified.com/

Finally, there remain some questions about species suitability for certain products. Whether local softwood species can be suitable replacements for products tested-and-tried with other tree species remains to be known for many products. More research and development is needed to identify relevant products and to refine processing. While the USDA Forest Products Laboratory out of Wisconsin is a great resource for many potential community-scale products, that research is not always relevant to local species and local markets.[192] Furthermore, because many community-scale innovative wood products are not necessarily developing cutting-edge technology, but rather building from or modifying well-established manufacturing processes to scale, it is unlikely local producers would be able to secure outside funds needed to support the necessary research and development. This creates numerous challenges for smaller entrepreneurs that need support for sector innovation.

In Oregon, essential infrastructure for smaller wood products manufacturers is supported through the Oregon Wood Innovation Center, housed at Oregon State University.[193] Not only does the Oregon Wood Innovation Center support the necessary basic research to develop products and markets, but it serves as a networking site where wood product companies can sell or buy logs or wood products. In contrast, no such clearinghouse exists in California, which may limit the ability for community-scale entrepreneurs to effectively develop wood products businesses. Although the University of California Forest Products Laboratory regularly updates a map of wood processing facilities around the state,[194] more work is needed to identify and support networking of businesses in the wood products sector. Some key information that could facilitate growth of the sector includes, among others: Wood product businesses with product to sell, wood product businesses looking to buy product, wood product campuses with space to host businesses, logger/truck drivers/other heavy equipment operators looking for work, and landowners with available logs/woody biomass. This kind of centralized clearinghouse could also merge support for research and development-related to the needs of small and innovative wood products businesses.

Other key challenges facing small wood product businesses have to do with the logistical and legal challenges associated with starting a new manufacturing business in the state. Small businesses have to navigate CEQA, etc., and may face considerable costs in the establishment of a manufacturing facility when operating as independent businesses. Community-scale business approaches bring the added benefit of economies of scale to site development. For example, a new business located in a rural part of the state may need to identify and develop a site that is appropriately zoned, secure relevant permits associated with the manufacturing process, and likely may face challenges from neighbors with different ideas for how land use and zoning should impact their land. These all present potential uncertainties that may be too costly for a single business owner to handle alone.

Members of the forestry community have long considered the possibility of clustering wood products businesses,[195] in part to reduce the barriers facing new wood products businesses seeking to enter the market, develop a site, gain required approvals, etc. Wood products campuses, or wood products business zones, present the opportunity to 1) reduce costs associated with business development for individual businesses, 2) create economies of scale when associated businesses use complimentary materials (for example, bark to create mulch and small-sized logs for firewood) and shared infrastructure (for example a biomass cogeneration facility and dry kiln for lumber), and 3) pull from a skilled workforce that has experience in the wood products sector.[196] Although numerous locations across the state are pursuing wood products campus models, most are still at the early stages of development and face many challenges for getting off the ground.

Given that forest restoration requires scaled-up efforts, wood products campuses present many opportunities to meet both forest restoration and economic development goals.[197] Like cooperative models, such as the Oregon Woodland Cooperative (https://www.oregonwoodlandcooperative.com/), wood products campuses also have been associated with higher wage premiums for workers, estimated at between 7.4 and 13% higher for both in-woods work and for the manufacturing sector.[198] These numbers indicate that wood products campuses could also benefit the wider restoration economy. More research and development is needed to advance community-scale wood product campuses.

192 https://www.fpl.fs.fed.us/contact/index.php
193 http://owic.oregonstate.edu/about-owic
194 http://ucanr.edu/sites/WoodyBiomass/files/212812.pdf
195 Braden, R., Fossum, H., Eastin, I., Dirks, J., & Lowell, E. (1998). The role of manufacturing clusters in the Pacific Northwest forest products industry. *Center for International Trade in Forest Products. Seattle, WA. Working paper*, *66*, 43.
196 Aguilar, F. X., Grala, R. K., & Bratkovich, S. M. (2009). Use of georeferenced data to study clustering in the primary wood products industry of the US South. *Canadian journal of forest research*, *39*(12), 2494-2504.
197 Nicholls, D. (2014). Forest products cluster development in central Arizona—Implications for landscape-scale forest restoration. *Gen. Tech. Rep. PNW-GTR-898. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p., 898*.
198 Gibbs, R. M., & Bernat Jr, G. A. (1997). Rural industry clusters raise local earnings. *Rural America/Rural Development Perspectives*, *12*(2221-2019-2640), 18-25.

FULL 7(f)

Appendix 1: Methodology for this report

This report used multiple methods to identify key barriers and potential solutions. Primarily, research began with an extensive literature focused on mass timber and wood products manufacturing, workforce development, and community-scale businesses. From January 2021 through August 2021, Sierra Institute for Community and Environment staff and affiliated consultants conducted web searches and Google Scholar searches around these different topics to map out the sectors, generally, and to understand what work has been done in the state of California. We examined literature from around the globe to identify key policy mechanisms, government interventions and subsidies, technological and ecological changes, and social considerations that have been shown to accelerate or decelerate adoption of mass timber technologies.

Interviews were used to fill gaps in knowledge and deepen understanding of the subject area. From October 2020 through August 2021, a team of Sierra Institute staff and consultants conducted one-on-one and group semi-structured interviews. These interviews were held with 75 key stakeholders from the mass timber, wood products, and workforce development sectors, including the forestry and wood products manufacturing sector, the design and build community, research and development, and policy and government. Interviews lasted between half an hour long and up to two hours. In some cases, interviews were conducted in a group with multiple stakeholders from the same category. In total, 19 interviews were conducted with representatives of the mass timber manufacturing sector, ranging from newly created, small-scale businesses to large, industrial producers.

All interviews were conducted under conditions of confidentiality, meaning any details that may reveal company names were withheld to improve the quality of data gathered through interviews. Where specific details were necessary to include for contextual purposes, special permission was requested to showcase the work of companies and organizations using green pull-out boxes throughout the report. The summary table below is used to show the range of stakeholders interviewed to fill knowledge gaps.

Number of key stakeholders interviewed by category

Category of key stakeholder group	N
Mass timber manufacturer, machine sales, and related	19
Higher-education and research	18
Non-governmental organization	11
Government	9
Machines and hardware sales	7
Contractor	3
Advocacy association	3
Mass timber distributor	1
Building developer	1
Other	3

Brownfield remediation work to create a wood chips storage shed at Indian Valley Wood Products Campus in Crescent Mills, California

Several workshops and conferences were also attended and helped inform wider understanding of the sector, including the 3-day 2021 International Mass Timber Conference, a virtual event hosted by the Forest Business Network from March 30th through April 1st 2021. While there, multiple pre-recorded and live sessions were attended and informed the wide array of considerations facing the growth of the mass timber sector. Other workshops and webinars held both in California and across the Southwest region of the United States were also attended, including the Southwest Ecological Restoration Institutes conference in March 2021, forestry workforce development workshops for the Sierra region, among other workshops, seminars, and conferences. All data gathered were used to directly or indirectly inform this report.

Furthermore, we relied on insider, first-hand experience of the sector. That included both Sierra Institute for Community and Environment's experience as an organization that built the first all-CLT building in the state of California, and the role that Steve Marshall, a Sierra Institute for Community and Environment consultant, played in growing the sector through the USFS Wood Innovations Grant, through his time working with SmartLam, and in his role as President of Mass Timber Strategy, a consulting firm focused on growing the mass timber sector. Roy Anderson, Ph.D. contributed his extensive experience working in the sector with The Beck Group.

The Beck Group also attempted to conduct a sector-wide survey. A questionnaire was developed with eleven questions total, focused on topics of raw materials, manufacturing, product mix, and projects. Questions were developed from a combination of BECK's past experience in benchmarking and in consultation with an employee of one North American mass timber manufacturer. Much of the data gathered in the survey is quantitative in nature, which means the results could be aggregated and presented as averages, ranges, etc. without revealing any company-specific data.

Contact information for key staff at the fifteen largest industrial manufacturing operation was either already known, or gathered via industry contacts, websites, etc. Each manufacturer was emailed the survey with a request that it be completed, with a follow up on each email with an additional reminder or email, phone call, or both. Unfortunately, only one company completed the survey, meaning results could not be shared because it would be specific to that company.

Manufacturers that explained to The Beck Group why they did not fill out the survey felt that the information was too sensitive given that the North American industry was too immature for manufacturers to feel comfortable sharing detailed operating information. In the future it is possible that the industry will mature to the point that the manufacturers report and share certain operating information. This information can enable stakeholders such as certification agencies, customers, financiers, company owners, and more to have better information about the state of the North American mass timber industry.

Appendix 2: Key forest employment figures for 2020

All data presented here are taken from the Quarterly Census of Employment and Wages Program, a program with the U.S. Department of Labor's Bureau of Labor Statistics and the California Employment Development Department's (EDD) Labor Market Information Division. EDD cannot validate that all the information provided through their online Find Employers Tool, a tool that uses a webcrawler to collect anonymous third party data, is completely accurate. However, this is the most accurate, high-level data available at present for this sector.

Table 1. Forest Sector employment by general category, excluding Education and Research. See Tables 2 through 7 for detailed employment information.

Table 1. Forest Sector employment by general category

Sub Cluster	Annual Average Employment	Annual Average Employment Percentage
Primary Forest Products (Table 2)	27,354	8%
Forestry Support (Table 3)	34,089	10%
Secondary Forest Products (Table 4)	34,091	10%
Forest Management and Public Administration (Table 5)	215,018	60%
Forestry-Dependent Industries (Table 6)	18,388	5%
Transportation (Table 7)	29,446	8%
Total	**358,386**	

Table 2. Primary Wood Products (*Private employment only, no public employment)

Industry	Annual Average Employment*
Veneer, Plywood, and Engineered Wood Product Manufacturing	3,339
Sawmills	3,514
Wood Preservation	445
Paper Mills+	670
Paperboard Mills	451
Corrugated and Solid Fiber Box Manufacturing	10,781
Folding Paperboard Box Manufacturing	2,656
Other Paperboard Container Manufacturing	1,442
Paper Bag and Coated and Treated Paper Manufacturing	1,595
Stationery Product Manufacturing	825
Sanitary Paper Product Manufacturing	773
All Other Converted Paper Product Manufacturing	863
Total	**27,354**

+ California currently has no pulp or paper mills

Table 3. Forestry Support
(*Includes both private and public employment. Public employment makes up 0.08 percent of employment in this sub cluster.)

Industry	Annual Average Employment*
Forest Nurseries and Gathering of Forest Products	233
Logging	1,964
Support Activities for Forestry	2,273
Sawmill, Woodworking, and Paper Machinery Manufacturing	328
Construction Machinery Manufacturing	775
Construction and Mining (except Oil Well) Machinery and Equipment Merchant Wholesalers	3,180
Construction, Mining, and Forestry Machinery and Equipment Rental and Leasing	8,224
Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	17,112
Total	**34,089**

Table 4. Secondary Wood Products **(*Private employment only, no public employment)**

Industry	Annual Average Employment*
Biomass Electric Power Generation	385
Wood Window and Door Manufacturing	3,934
Cut Stock, Resawing Lumber, and Planing	577
Other Millwork (including Flooring)	2,993
Wood Container and Pallet Manufacturing	6,120
Manufactured Home (Mobile Home) Manufacturing	2,048
Prefabricated Wood Building Manufacturing	844
All Other Miscellaneous Wood Product Manufacturing	1,703
Cyclic Crude, Intermediate, and Gum and Wood Chemical Manufacturing	72
Wood Kitchen Cabinet and Countertop Manufacturing	9,512
Non-upholstered Wood Household Furniture Manufacturing	2,168
Wood Office Furniture Manufacturing	1,233
Custom Architectural Woodwork and Millwork Manufacturing	2,502
Total	**34,091**

Table 5. Forestry Management and Public Administration

(*Includes both private and public employment. Public employment makes up 99.9 percent of employment in this sub cluster.)

Industry	Annual Average Employment*
Timber Tract Operations	33
Executive Offices	2,352
Legislative Bodies	5,783
Public Finance Activities	43,337
Executive and Legislative Offices, Combined	99,257
American Indian and Alaska Native Tribal Governments	6,116
Other General Government Support	26,078
Administration of Conservation Programs	32,062
Total	**215,018**

Table 6. Dependent Industries (*Private employment only)

Industry	Annual Average Employment*
Lumber, Plywood, Millwork, and Wood Panel Merchant Wholesalers	10,291
Printing and Writing Paper Merchant Wholesalers	1,170
Industrial and Personal Service Paper Merchant Wholesalers	6,927
Total	**18,388**

Table 7. Transportation (*Private employees only)

Industry	Annual Average Employment*
Rail Transportation	30
Specialized Freight (except Used Goods) Trucking, Local	24,043
Specialized Freight (except Used Goods) Trucking, Long-Distance	5,373
Total	**29,446**

Intentionally Left Blank