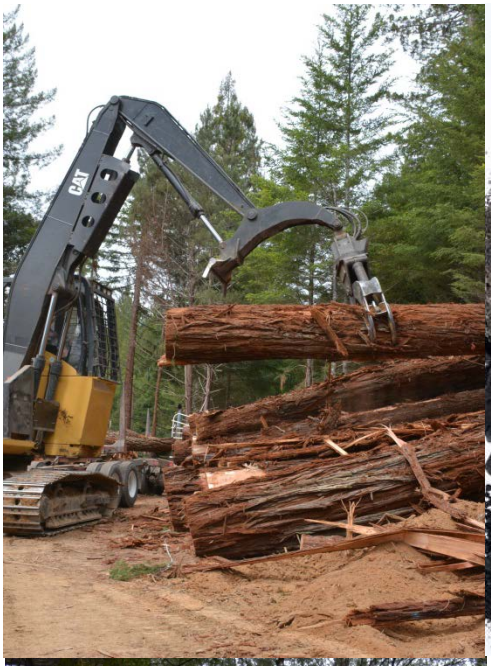

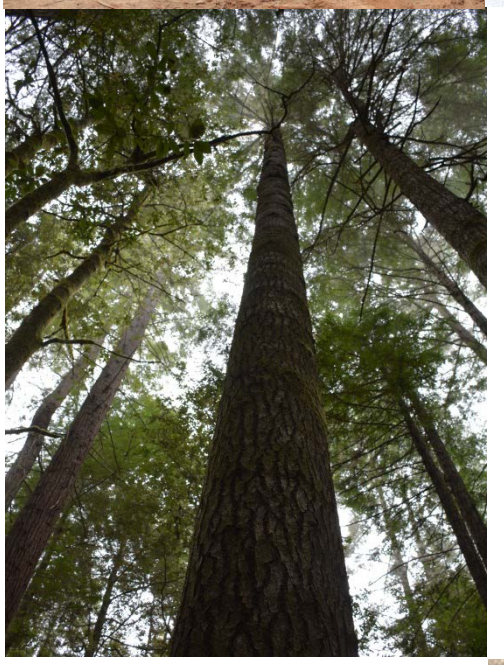

# Recommendations to Expand Wood Products Markets in California

Investing in communities and California's climate resilient future

**SB 859** Wood Products Working Group

OCTOBER 2017

# A Report to the California State Legislature in Compliance with S.B. 859 (2016)

Submitted by the California Natural Resources Agency
on behalf of the Wood Products Working Group
October 2017

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The California Natural Resources Agency (CNRA), in completing this report, also reached out to leadership and staff at the agencies, departments, and offices that may play a role in enacting the recommendations. Their critical thinking and input is appreciated.

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# OVERVIEW

On September 14, 2016, Governor Edmund G. Brown Jr. signed Senate Bill 859 into law, which in part directed the Secretary of Natural Resources to, "…establish a working group on expanding wood product markets that can utilize woody biomass, especially biomass that is removed from high hazard zones…," and directed the working group to submit recommendations to the Legislature. This report is submitted to the Legislature in compliance with S.B. 859.

The Working Group designed these recommendations to address both the urgent need to utilize dead and dying trees in the Sierra and long-term forest management needs in the Sierra and statewide.[1] Forests in California are under increasing stress associated with climate change and underinvestment in management and restoration. The unprecedented die-off in the Sierra in the wake of drought and pest infestation presents a management challenge that far exceeds the capacity of local, forested communities and available State and federal resources. This die-off is expected to continue for another decade. There is a need for biomass processing capacity to handle dead trees removed for hazard control in the short term, and an ongoing need for this capacity to process felled trees in the Sierra and throughout the state as part of continuing forestry and restoration activities. The need for increased forest management and the associated wood processing and biomass utilization infrastructure exists in every forest-dependent region of the state. The Working Group did not directly address facilitation of consistent access to material inputs, although implementation should consider opportunities to incentivize consistent supply through longer-term contracts.

These recommended actions, policies, and pilot programs are aimed at increasing demand for forest products and the knowledge and skills needed to develop and manufacture them. At the outset, the Working Group identified **three goals** that expansion of wood products markets must serve. Recommendations were selected based on their expected ability to advance these three goals:

1. **Utilize material that is removed from High Hazard Zones**, particularly in ways that can substitute or complement bioenergy production;[2]
2. **Promote forest health and carbon sequestration**, as described in the Draft 2017 Forest Carbon Plan and Draft 2017 Scoping Plan Update, and advance other statewide climate change goals; and
3. **Promote rural economic development**, including job creation.

These goals integrate the expansion of the wood products markets with other state priorities, and can provide guidance and reinforcement when selecting and implementing strategies and actions to advance the recommendations described in this report.

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[1] These conditions are described in detail in the Draft Forest Carbon Plan (January 2017). Available online: http://www.fire.ca.gov/fcat/. Accessed Oct. 10, 2017.

[2] The High Hazard Zones identified through the Tree Mortality Task Force can be viewed online: http://egis.fire.ca.gov/TreeMortalityViewer/

The expense of forest restoration and sustainable management on both public (federally, state, and locally owned) and private lands can be supported through sale of biomass and wood products. One of the core challenges facing forest health restoration activities, however, is the lack of economically sustainable demand for smaller diameter trees, dead trees, and other woody biomass that may be removed during restoration. The absence of this financial driver can result in sub-optimal management of forestlands and biomass flows to uses that are less economically, socially, or environmentally beneficial than desired. This can be especially true for forestry practices that best advance California's forest carbon and overall forest health goals, such as multi-age class management and selective removal of dead and dying trees in the Sierra. The Working Group does not expect the actions recommended here to meaningfully alter global forest products commodity markets, which ultimately drive the majority of investments in the forest products industry and influence commercial forest management activities. Rather, they are intended to reduce barriers to entry and facilitate in-state investment that encourages the forest products industry and rural forested communities across California to pursue value-added production that can support forest health objectives on both public and private lands.

Therefore, the Working Group decided to focus on **increasing demand for higher-value products** and **promoting localized manufacturing** rather than facilitating supply of raw material. This approach is expected to best serve the parts of the Sierra hardest hit by tree mortality, where wood processing infrastructure is limited (see map of existing and closed facilities in Exhibit 1). It is also expected to address some of the public health and air quality concerns associated with forestry activities and biomass utilization by reducing the need for and therefore incidence of both open pile burning and heavy-duty trucking of material to existing bioenergy facilities. These recommendations will complement other programs and policies aimed at promoting resource management for forest and human health.

Noting the interdependence of social, environmental, and economic well-being, and the essential elements of a thriving market, the Working Group recommends three **core strategies**:

- ✓ **Remove barriers to market and create pathways for success**
- ✓ **Promote innovation**
- ✓ **Invest in human capital**

Initiatives recommended to advance these strategies would supply three elements necessary to support a strong market: a market environment that appeals to investors, a skilled work force, and opportunities for financing and innovation.

The recommendations in this document were informed by the expertise of Working Group participants, four written reports, and additional information on an ad-hoc basis, including consultation with other state agencies and a number of stakeholders. See Appendix A for more information on the Working Group process. The four reports include two solicited specifically to inform this Working Group (a CNRA report on U.S. State and Federal policies to support expansion of wood products markets and a white paper on community-scale rural economic

development wood utilization needs and opportunities); one existing public document (California Assessment of Wood Business Innovation Opportunities[3]); and an early draft of the Dead Tree Utilization Assessment that was contracted to inform the Tree Mortality Task Force. All of these reports are available for review.

The recommended actions are intended to enable market expansion broadly rather than favor specific end products or material uses. That said, based on the available information, the Working Group determined that the most promising markets for using large volumes of small-diameter trees, bark beetle-killed trees, and other forest biomass include (a) engineered mass timber and wood-based composite panel products used in building construction, retrofits, and remodeling,[4] and (b) wood processed for use in other industries and applications, including wood cellulosic nanotechnology applications and biochar.[5] The recommendations below target growth in these markets and related manufacturing and applied industries. **Business model innovation**, such as development of community-led, diversified wood products campuses,[6] could advance a wide range of opportunities and should be encouraged across all strategies.

The report includes a set of **recommended pilot projects**. These pilot projects are opportunities to engage multiple strategies and produce early feedback for state and local agencies and others working to expand wood products markets.

The report concludes by recommending the establishment of two organizing bodies to undertake and coordinate these initiatives – a **State-led steering committee** and an **academic institute** – as well as specific actions to advance the three strategies. The Rural Economic Development Steering Committee will lead implementation of these recommended actions and pilot programs and serve as the organizational body for the state and federal agencies and local and regional partners identified as essential to implementation. The Governor's Office of Planning and Research will establish the Steering Committee, which will begin to implement recommendations achievable within existing authorities and resources. The proposed Joint Institute for Wood Products Innovation would align California academic centers to perform product research, development, and testing; promote business innovation; and connect diverse

[3] From National Forest Foundation/the BECK Group, 2015. Available Online: https://www.nationalforests.org/who-we-are/regional-offices/california-program/california-assessment-of-wood-business. Accessed Oct. 10, 2017.

[4] "Mass timber" is a pre-fabricated wood product consisting of not less than three layers of solid-sawn lumber or structural composite lumber where adjacent layers are cross-oriented and bonded with structural adhesives to form a solid wood element." (2015 International Building Code). Mass timber can also be laminated veneer lumber (laid up so the grain is in the same direction), nail-laminated, dowel-laminated, and made from numerous layers of veneer, some cross-oriented to provide additional strength (also known as "mass plywood product"). "Wood-based composite" is a generic term for a material manufactured from wood veneer, strands, flakes, particles, fibers or other lignocellulosic material and a synthetic resin or binder (Wood Handbook, 2010 edition, FPL-GTR-190, USDA Forest Service, Forest Products Laboratory, Madison, WI, https://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr190.pdf). Accessed Oct. 10, 2017.

[5] "Biochar" refers to charcoal made for uses other than fuel, such as soil amendments and filtration.

[6] "Wood products campuses" refer to co-located businesses with complementary production processes and/or product lines.

disciplines to accelerate research, development, and adoption, including forestry, wood engineering and nanotechnology, business administration, marketing, architectural design, and forestry workforce development. These efforts would be coordinated through the Steering Committee and assist the Steering Committee in meeting its goals, although, activities need not be limited to those that directly serve the Steering Committee. The interdisciplinary Joint Institute should engage with the Steering Committee and working groups therein to facilitate outreach activities and contribute to human capital development as needed and as resources allow. The Steering Committee will collaborate with California's higher education institutions and private industry and other partners to pursue the authorities and funding necessary to support creation of the Joint Institute.

Some of these recommendations can be accomplished using existing resources and state authorities. Others will require new investments and legislated authorities. The recommendations in this report should be viewed as one element of a broader set of efforts taking place. The State's role in market development will by nature be limited. The main actors are entrepreneurs, investors, wood products industry leaders, local governments, community based groups, tribes, local land owners, and the USDA Forest Service. These recommendations reflect actions that the State could engage in to encourage and enable market development in partnership with these key actors.

# RECOMMENDATIONS

## STRATEGIES AND ACTIONS

The Rural Economic Development Steering Committee, in coordination with the Joint Institute for Wood Products Innovation, would serve to advance the three core strategies – remove barriers to market and create pathways for success, promote innovation, and invest in human capital – through the following set of actions. The work of the Steering Committee will be carried out by cross-sector working groups assigned to each strategy as appropriate, with the following agency and institutional leads:

1. **Remove barriers to market and create pathways for success:**
   *Redevelopment and Innovation– California Environmental Protection Agency (CalEPA) and OPR*
   *Financing – Governor's Office of Business and Economic Development (GOBiz)*

2. **Promote innovation:**
   *Rural Economic Development Steering Committee and Joint Institute for Wood Products Innovation*

3. **Invest in human capital:**
   *Employment Development Department (EDD)*

## 1. Remove Barriers to Market and Create Pathways for Success

A good market environment will appeal more broadly to investors. Facilitating permitting prerequisites, supporting product testing, aligning regulatory requirements, and addressing financing challenges could eliminate some of the real and perceived barriers to investing in and developing wood products manufacturing.

The focus of this strategy would fall into the following two categories:

- ***Redevelopment and Innovation****:* CalEPA will lead a team focused on navigating site permitting, liability, and other barriers related to the remediation and redevelopment of former mill and other previously developed sites and barriers to the use of engineered mass timber in building construction.
- ***Financing****: GOBiz will lead a team focused on* creating pathways for success by providing financing and business development assistance targeted to rural businesses, better communicating existing financial assistance programs, and addressing resource gaps as needed.

CalEPA, OPR, and GOBiz will identify appropriate federal, state and local agency, business community, and non-governmental partners for these actions in consultation with the Steering Committee.

### *Working Group Actions: Remove Barriers to Redevelopment and Innovation*

1. **Improve Process for Remediation and Redevelopment**
   The Steering Committee will establish an interagency team charged with identifying and, where appropriate, navigating state barriers to redevelopment of former sawmill and rural industrial sites in a manner that protects public health and the environment. The team may engage regional or local permitting agencies where appropriate. The team will assist in navigating liability, financial assurance, and regulatory processes associated with the cleanup and reuse of sites, with an initial focus on community-owned or prospective community-operated sites.
2. **Accelerate Use of Mass Timber Construction**
   Mass timber[7] is a growing category of wood products that has the potential to grow significantly in California and advance the State's climate change and green buildings objectives. Mass timber is more commonly used for construction in Europe and saw a dramatic increase in use as a structural element in the past decade; Canada and Oregon have recently pushed to mainstream its use in North America. As a construction material, mass timber is favored by designers for its strength, affordability, aesthetics, construction efficiency, structural performance, small carbon footprint, and ability to achieve substitute for or work alongside concrete, steel or masonry as a structural element.

[7] Mass timber is typically characterized by the use of solid wood panels for wood, floor, and roof construction. It refers to products including cross-laminated timber, nail-laminated timber, glue-laminated timber, dowel-laminated timber, structural composite lumber, and wood-concrete composites. For additional information, see Footnote 4.

The 2016 version of the California Building Standards Code,[8] which went into effect in January 2017, defines the allowable wood use in buildings and includes references to Mass Timber systems, such as the decade-old mechanically laminated decking (2304.9.3) and, more recently, cross-laminated timber (2303.1.4). Informing developers and design professionals of these recent code provisions and encouraging low-carbon building may help facilitate the increased use of mass timber, build its acceptance within the building industry, and encourage the development of mass timber manufacturing in California.

The state could facilitate greater use of mass timber in construction through:

a. *Building Code Outreach*
   The State could engage local and county planning offices, developers, and architects on the use of wood and mass timber in buildings by providing a targeted description of current California Building Standards Codes, particularly new elements that went into effect in 2017.
b. *Encouraging Low-Carbon Building Statewide*
   The state could develop and use life cycle assessment of building materials and encourage builders and local and county planning offices to select and incentivize, respectively, those materials which have the lowest lifecycle GHG emissions and support other statewide climate change mitigation policies, as described in the 2017 Scoping Plan Update and the Forest Carbon Plan. Acceptable methods of such a whole building life cycle assessment are codified in the voluntary measures of the 2016 Green Building Standards Code (CALGreen Part 11 of Title 24) Section A5.409.
c. *Encouraging Low-Carbon Building for State Facilities*
   The state could establish guidelines that encourage use of cost-effective building materials with lower lifecycle GHG emissions for new State-owned and/or state-occupied buildings.

## *Working Group Actions: Removing Financing Barriers*

1. **Create a Finance Information Clearinghouse**
   The State could create an information clearinghouse on financial resources and incentives through online tools, resource fairs, and workshops that are applicable to wood products industry investors and developers. This information clearinghouse would include information on the range of GOBiz and California Infrastructure and Economic Development Bank (IBank) programs that may apply to the wood products industry, including, but not limited to, the California Competes Tax Credit, the Small Business Loan Guarantee Program, and Industrial Development Bonds.
2. **Identify Resource Gaps**
   The State could identify and seek to address gaps that exist in state and federal financial assistance programs, either through existing programs at GOBiz and IBank or through

[8] The 2016 Edition of the California Building Standards Code, California Code of Regulations, Title 24 (CBC) was published July 1, 2016 and has been effective statewide since January 1, 2017. It is based on based on the 2015 Edition of the International Building Code.

new financing programs. These may include *grants and subsidies* for product testing, wood products innovations, value-added processing, and the expansion of processing facilities; *tax incentives or deductions* for new wood products businesses or the use of wood in building infrastructure; and/or *loans or loan guarantees* to businesses for small-scale equipment purchases or facility expansions.

## 2. Promote Innovation

Innovation and expansion into new markets will be imperative in order for the California wood products industry to be competitive and sustainable in the long-term. However, expanding into new markets comes with a certain amount of risk. Addressing financial challenges and assuring a fertile environment for innovation could help to address these risks. The long-term success of new wood products innovations could be bolstered by building California's capacity for research and product development and supporting the academic experts and entrepreneurs already leading wood products innovation within the State. New cross-disciplinary partnerships may be needed to ensure that this research and development is relevant to industry partners' needs and is ready for market.

The Steering Committee will initiate a working group focused on promoting innovation while developing the resources and authorities to launch the Joint Institute for Wood Products Innovation. Once the Joint Institute is functioning, the Steering Committee will shift to an advisory role for strategies related to promoting innovation and the Joint Institute will assume a leadership role.

### *Working Group Actions: Promoting Innovation*

1. **Applied Research and Development**
   The State could support businesses and academic institutions performing early-stage research and development in cutting-edge materials and industries such as cellulosic nanotechnology. This work could be coordinated by the Joint Institute and should include industry partners, business associations, local forested communities, and the USDA Forest Service and other federal agencies, at a minimum. The "Waste to Wisdom" Biomass Research and Development Initiative at Humboldt State University, which is investigating the conversion of forest residues into renewable fuel and other bio-based products, is an example of focused research in this space.[9]
2. **Product Testing**
   The State could incentivize and encourage investment in any necessary seismic, fire, and other material testing within California for mass timber construction, building off of testing underway for specific projects in California and elsewhere. The State could utilize academic institutions and third-party testing, inspection, and certification organizations to perform product testing that accelerates the development, utilization and commercialization of new wood products, including mass timber, biochar, and nanotechnology.[10] These activities could

[9] For more information on the "Waste to Wisdom" initiative, see: http://wastetowisdom.com/.

[10] For example, QAI Laboratories is a third-party testing organization in California that performed a flame spread test that assured the flame spread and fire resistance of CLT made by D.R. Johnson. For more

be coordinated by the Joint Institute.

3. **Promote California-grown and California-manufactured Wood Products**
   By promoting California wood products in domestic and international markets, the State, with assistance from industry partners, could increase the competitiveness of California's wood product industry. The State could help conduct outreach and education on California wood products and wood construction.
4. **Strengthen Partnerships Between the Wood Products Industry, Rural Economic Development Organizations, and Academia**
   California's colleges and universities are hubs of incubation and innovation. Stronger partnerships across industry, rural economic and community development organizations, and academia could harness the resources needed to accelerate market growth. For example, university extension programs could assist businesses with planning, outreach, training, and education, as well as strategic business planning tailored to match supply from nearby forests.

## 3. Invest in Human Capital

This strategy will aim to develop a well-trained workforce of individuals prepared to enter wood products and forestry-related jobs as those jobs become available. The following recommendations are designed to create a work force pipeline that provides economic development opportunities for residents of forested communities and supplies the human capacity that companies will need to develop and expand wood products operations.

The Employment Development Department (EDD) will lead this work group and will identify additional work group members in consultation with the Steering Committee. The recommendations will be refined and implemented in coordination with impacted communities, educational partners, businesses, and experts in workforce development, among others.

### *Working Group Actions: Investing in Human Capital*

1. **Assess Workforce Potential**
   EDD will perform an analysis of the current jobs available to the work force in forestry and wood products sectors.
2. **Expand Accredited Associate Degree and Certificate Programs**
   Based on EDD's expertise, the state could expand the reach of existing accredited associate's degree and certificate programs for forestry, forestry technician, and wood products technology at community colleges throughout the state to create a larger pipeline of students entering these fields as the industry develops. There are at least 15 community colleges that offer certificates and associate's degrees in forestry, engineering and industrial technologies, woodworking and cabinetmaking, woodworking manufacturing technologies, and other related topics (see Appendix C for listing).
3. **Strengthen Career Pathways**
   Stronger connectivity between wood products-related high school, work force training, and

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information, see: http://oregonclt.com/d-r-johnson-passes-two-critical-tests-safety-cross-laminated-timber-panels-flame-spread-fire-resistance/. Accessed Oct. 10, 2017.

college programs would help to develop workforce capacity. Career pathways could be strengthened in the following ways:

a. *Create Career Pathway Roadmaps*
   The Human Capital Work Group could create clear pathways that guide students into the field directing them to accessible and appropriate certificate and vocational school programs, providing information and guidance on transferring to bachelor and advanced degree programs such as the accredited forestry schools at Humboldt State, Cal Poly San Luis Obispo, and UC Berkeley. Assuring that graduates are connected to job opportunities available at each level of educational attainment would increase the likelihood that students will enter and remain in the field.[11]
b. *Increase Partnerships with the California Conservation Corps*
   California Conservation Corps could increase their partnerships with forestry and wood products industries and interested community colleges. This would (1) help Corps members obtain forestry and forest technician degrees and certificates; (2) train individuals to operate equipment in forestry and related industries, and; (3) create pathways from the Corps to degree programs and well-paying jobs.
c. *Invest in Scholarships*
   The State could expand scholarships to improve accessibility to related training and higher education for low-income students. The UC Berkeley Forestry Field Camp[12] in the Sierra is one example of a program that could improve access through scholarships.
d. *Invest in Youth Programs*
   Youth programs help expose young people to the idea of a career in forestry. The State could invest in existing youth programs such as the California Forestry Challenge,[13] an academic event for high school students in technical forestry and current forestry topics; the Forestry Institute for Teachers,[14] which trains K-12 teachers to teach their students about forest ecology and forest resource management practices; the Sierra Outdoor School Science Program, a hands-on exploration of the Stanislaus National Forest;[15] and Project Learning Tree, which provides forest-related instructional materials for children through grade 12.
e. *Foster Apprenticeship Programs*
   The State could expand apprenticeship and on-the-job training programs with industry

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[11] An example of a Career Pathway Roadmap for forestry is available here: https://www.cocc.edu/forestry/career-pathways-roadmap/. Accessed Oct. 10, 2017.

[12] At the UC Berkeley Forestry Field Camp, students spend eight weeks in the Plumas National Forest immersed in topics such as wildland ecology, range and wildlife management, forest resource inventory, forest products and harvesting practices, and many other subjects. The program costs approximately $7,000 for UC Berkeley Undergraduate Students and $8,000 for non- UC Berkeley Students: https://forestrycamp.berkeley.edu/experience-camp/costs/. Accessed Oct. 10, 2017.

[13] For more information on the California Forestry Challenge, see http://forestrychallenge.org/what-is-forestry-challenge. Accessed Oct. 10, 2017.

[14] For more information on the Forestry Institute for Teachers, see: http://www.forestryinstitute.org/. Accessed Oct. 10, 2017.

[15] For more information on the Sierra Outdoor School, see: http://sos.cusd.com/about/our-program. Accessed Oct. 10, 2017.

partners, especially for key populations like veterans, recent high school graduates, and recent community college degree earners. Apprenticeships could benefit both industry and communities. Veterans programs have the added benefit of utilizing military training veterans already possess.[16]

# ORGANIZING BODIES

To assure implementation of the recommendations, the Working Group identified the need for a steering committee made up of state and federal agencies, local governments, tribal governments, local community organizations, entrepreneurs, industry leaders and other appropriate partners. The Governor's Office of Planning and Research will convene the recommended Steering Committee, which would begin implementing recommendations within existing authorities and resources. The Working Group also identified the need for an academic center to promote interdisciplinary research and development and supplement state agency activities.

## RURAL ECONOMIC DEVELOPMENT STEERING COMMITTEE

The Governor's Office of Planning and Research (OPR) will establish the Rural Economic Development Steering Committee to prioritize sustainable rural economic development in alignment with the State's existing climate goals. The initial focus of the Steering Committee will be to encourage economic development in forest-dependent communities; to advance businesses and jobs that improve forest health and restoration, increase the harvesting and utilization of smaller-diameter trees and other biomass, and make the transportation of wood products more fuel efficient; to align these activities with bioenergy programs and policies; and to complete all other activities the Steering Committee deems necessary to achieve expansion of wood products markets. The California Natural Resources Agency will serve as co-lead for the Steering Committee's wood products agenda. This Steering Committee will serve as a coordinating body for implementation of many of the recommendations described in this report where the state has existing authority and resources. The Steering Committee will also identify gaps in authorities and resources and coordinate activities to address those gaps. Finally, the Steering Committee will coordinate actions with other actors, such as local governments, tribes, the USDA Forest Service, and others to achieve the goal of expanding the wood products market in California.

### *Steering Committee Actions: OPR*

OPR and CNRA will first establish Working Groups and agency leads for each working group focused on advancing each of the three strategies. The Working Groups will recommend Steering Committee members. Once established, the Working Groups will report to and be coordinated by the Steering Committee. Each Working Group will identify and engage additional participants, as necessary, to advance the recommended actions described in this

[16] Information on veteran apprenticeship and on-the-job training programs can be found at: https://www.calvet.ca.gov/VetServices/Pages/Apprenticeship--On-The-Job-Training-Programs.aspx. Accessed Oct. 10, 2017.

report and other actions to be determined by each Working Group.

Steering Committee members will be selected based on recommendations from the Working Groups and others to achieve a balance among State agencies, federal agencies, local governments, tribes, industry leaders, and others essential partners. The Steering Committee may include representatives from the following agencies and groups:

- Governor's Office of Planning and Research (OPR)
- California Natural Resources Agency (CNRA)
- Governor's Office of Business and Economic Development (GOBiz)
- California Employment Development Department (EDD)
- California Environmental Protection Agency (CalEPA)
- Department of General Services (DGS)
- California Department of Housing and Community Development (HCD)
- California Department of Food and Agriculture (CDFA)
- California Department of Forestry and Fire Protection (CAL FIRE)
- Liaison from the Joint Institute for Wood Products Innovation and additional representatives from public and private academic institutions as needed
- Federal agencies with forest management and rural development responsibilities
- Local and Tribal governments and community organizations
- Industry leaders
- Others as determined by the Steering Committee and Working Groups

## Joint Institute for Wood Products Innovation

The Wood Products Working Group proposes establishment of an interdisciplinary academic Joint Institute for Wood Products Innovation across universities and community colleges in California to assist in meeting the goals of the Rural Economic Development Steering Committee. The Steering Committee would identify appropriate initial partners. Together with the identified partners, the Steering Committee would collaborate to identify funding to support creation of the Joint Institute. This Joint Institute would align academic centers to perform product research, development, and testing; promote business innovation; and connect diverse disciplines to accelerate research, development, and adoption, including forestry, wood engineering and nanotechnology, business administration, marketing, architectural design, and forestry workforce development. Emphasis should be placed on sharing knowledge and skills from diverse disciplines to advance common problems and market challenges. The leading partners should ensure that their efforts align with the "Invest in Human Capital" Working Group to create a pipeline for professional development and ongoing education of students and workers. The Joint Institute should include representation from California accredited forestry schools and related interdisciplinary departments, among others.

# CROSS STRATEGY PILOT PROJECTS

The work group identified four pilot projects that would generate near-term feedback to the Steering Committee, working groups therein, and other entities working to expand wood products markets. Each pilot demonstrates the interdependence between the three core strategies.

## WOOD PRODUCTS SUMMIT

**Lead: Rural Economic Development Steering Committee**

The State could host a day-long wood products summit to catalyze problem-solving and investment to grow the California wood products industry. Such an event should also serve to demonstrate statewide and localized demand for and activity across the three core strategies: remove barriers to market and create pathways for success, promote innovation, and invest in human capital. The Steering Committee working groups could design three (or more) sessions within the summit that will best showcase and advance their work. The summit should include emerging high-value wood material uses that align with California's climate goals, and should draw on and serve the wood utilization objectives of the Tree Mortality Task Force.

The targeted audience should be manufacturers, investors, financial institutions, rural economic development organizations, and end-use customers. The Summit could be an invitation-only event, or it could be designed to attract a wider public audience. The 2017 International Mass Timber Summit, held in March, attracted more than 800 product manufacturers, architects, engineers, policymakers, and investors from around the world. The third annual International Mass Timber Summit will be held in Portland, Oregon in spring 2018. The California Wood Products Summit might be scheduled either before or after this event to attract the best possible speakers and attendees.

## SITE REDEVELOPMENT AND WOOD PRODUCTS MANUFACTURING

**Lead: CalEPA and the Barriers and Innovation Working Groups**

- ✓ Remove barriers to market and create pathways for success
- ✓ Promote innovation

The State could address existing barriers to aid in the redevelopment and expansion of former mill sites to mixed-use wood products campuses in rural forested communities. Co-locating complementary wood products manufacturing facilities, as well as small-scale bioenergy businesses, can create regional job hubs and efficiently pool resources.[17] Currently, barriers to development include difficulty associated with remediation and use of brownfield sites and insufficient access to capital for new manufacturing equipment and property acquisition. This

[17] Wood products campuses create common transportation and utility infrastructure and produce a variety of wood products in efficient, low-waste mills.

pilot program could address those needs through (1) the assistance of a cross-agency team, as described within the "remove barriers to market" strategy above; (2) a competitive small grants program, the California Wood Innovations Small Grants Program, aimed at promoting manufacturing innovation; and (3) financial assistance for capital investments such as loan guarantees and tax incentives through existing programs at IBank.

The California Wood Innovations Small Grants Program could model itself after aspects of two successful grant programs: the USDA Forest Service Wood Innovations Grants Program and the California Energy Commission Energy Innovations Small Grant Program. Like the USDA Forest Service Wood Innovations Grants, funding could support projects that promote the expansion of innovative non-energy wood products markets. Like the Public Energy Research Innovations Small Grant Program, this grant program could also serve to fund research, development, and demonstration for innovative wood products and manufacturing concepts. Grants ranging from $50,000 to $150,000 could be awarded to small businesses, non-profit organizations, and academic institutions to develop and deploy new wood products manufacturing capacity. To leverage external funds and help ensure that the State invests in financially viable projects, applicants may be required to contribute an amount equal to at least 50% of the amount requested from the State. In Oregon, the State provided targeted funding of $150,000 to support cross-laminated (CLT) testing research at Oregon State University and to develop CLT production at a family-owned wood products company that became the first U.S. CLT manufacturer to pass standardized 'flame-spread' and 'fire resistance' tests, and obtain American National Standards Institute structural certification.

The State may also be able to use existing programs to provide early-stage financing for project developers that could help them attract private investment. Existing state loan guarantee programs and financing tools such as those at IBank are one funding source that the Rural Economic Development Steering Committee could explore.

## California Mass Timber Building Competition

**Lead: OPR and the Barriers and Innovation Working Groups**

- ✓ Promote innovation
- ✓ Remove barriers to market and create pathways for success

A California Mass Timber Building Competition could be developed by the State to provide grants to pairings of local planning departments and developers (commercial or residential) to fund mass timber product testing and permitting for mass timber and/or tall wood buildings in two California municipalities. This may serve to catalyze stress testing of cross-laminated timber (CLT) and other engineered mass timber products for use in all elements of building construction and engineering; complement the state-level review of building safety codes; assist local planning departments in overcoming knowledge barriers to mass timber products; and accelerate demand for mass timber products. Preference could be given to projects that source material from California and/or the tree mortality High Hazard Zones.

A similar State program was piloted in Oregon, where a $200,000 grant was awarded for a design competition aimed at encouraging developers to utilize cross-laminated timber in construction in 2015. A similar one-time federal funding opportunity was created in 2014 when the USDA and Softwood Lumber Board held a Tall Wood Building Competition that resulted in awards to developers in Portland, Oregon, and New York City (see article in Appendix B for more information on these programs and tall wood buildings). There may be opportunities to collaborate with USDA through the federal Wood Innovation Grants Program and private organizations to increase funding available in California for mass timber and tall wood buildings.

## Wood Products Training and Workforce Development with the California Conservation Corps

**Lead: California Conservation Corps and the Invest in Human Capital Working Group**

- ✓ Invest in human capital
- ✓ Promote innovation

A California Conservation Corps (CCC) Wood Products Corps program could be developed by the State, modeled after the successful CCC Energy Corps. The Energy Corps is a partnership between the CCC, State agencies, utilities, energy efficiency companies and industry associations, local governments, and California Local Corps that delivers innovative workforce development opportunities to train and engage Corps members in saving energy and associated costs for Californians. Many companies in the energy industry regard the CCC as a good source for hiring qualified entry level employees, and the demand for trained and experienced Energy Corps Corpsmembers is much greater than the supply.[18] The CCC Wood Products Corps could follow the model of the Energy Corps and help rebuild the human capital needed to revitalize California's wood products industry while providing Corpsmembers with technical instruction, advanced training, continuing education, and apprenticeship in the wood products industry. The CCC and Human Capital Working Group would create and work with various training partnerships including community colleges and industry apprenticeships to connect graduating Corpsmembers to employment opportunities, related community college associate degree programs (listed in Appendix 1), and continuing education. As with other crews in the CCC, the Wood Products Corps crews would be composed of young adults ages 18 to 25, and could also include military veterans.

[18] California Conservation Corps. Status of Proposition 39 Funded Energy Corps Program (presentation). March 28, 2016. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiSp5q626LTAhXFKGMKHVOjBDIQFggrMAE&url=http%3A%2F%2Fwww.energy.ca.gov%2Fefficiency%2Fproposition39%2Fcitizens_oversight_board%2Fdocuments%2F2015_California_Conservation_Corps_Energy_Corps_Program_Report.pdf&usg=AFQjCNFr8otMIV5BK6giB74tadfQXCp93g&sig2=UKxqpoIUrXpVVdrlsTS1-A. Accessed Oct. 10, 2017.

# APPENDICES

# EXHIBIT 1: WOOD PRODUCT FACILITIES BY OPERATIONAL STATUS IN CALIFORNIA

The map above shows the location of closed or idled wood product facilities, along with operational or planned facilities (as of June 2017). Formerly active sites offer unique opportunities for redevelopment due to their proximity to abundant forest resources and existing infrastructure (transportation, electricity, communications). The facilities labeled "closed or idled" date to 1971.

# APPENDIX A: S.B. 859 WOOD PRODUCTS WORKING GROUP PROCESS

## *Senate Bill 859*

Senate Bill 859, Sec. 9, called for creation of the Wood Products Working Group in 2016:

*Section 717 is added to the Public Resources Code, to read:* ***717.***

*(a) The Secretary of the Natural Resources Agency shall establish a working group on expanding wood product markets that can utilize woody biomass, especially biomass that is removed from high hazard zones, as determined by the department. These markets include, but are not limited to, animal bedding, biochar, cross-laminated timber, mulch, oriented strand board, pulp, post, shredding, and veneer products.*

*(b) At a minimum, the working group shall include members of the working group on wood market products established under the Proclamation of a State of Emergency on Tree Mortality declared by the Governor on October 30, 2015.*

*(c) By June 1, 2017, the working group shall submit recommendations to the Legislature on actions that may be taken to encourage the development of the wood product markets, including the identification of potential pilot projects.*

The S.B. 859 Wood Products Working Group met four times between October 2016 and April 2017 to develop a scope of work; share information, including reports provided to the group; and generate a broad set of recommendations that were subsequently narrowed to those presented here. Members of the Working Group are listed below. The nine member agencies, except the California Energy Commission and the Department of Finance, are also members of the Tree Mortality Task Force Subcommittee on Wood Utilization. This facilitated information sharing between the groups.

## *Scope of Work*

The Working Group's scope of work included the following tasks:

- Scope the need to expand wood product markets in California and the purposes such expansion would serve, including:
    - Utilizing material that is removed from High Hazard Zones, particularly utilization pathways that can be alternatives or complements to bioenergy production
    - Promoting rural economic development, including job creation
    - Promoting forest health and carbon sequestration, as described in the Draft 2017 Forest Carbon Plan and Draft 2017 Scoping Plan Update, and advancing other statewide climate change goals
- Identify location and characteristics of material known or expected to be produced through tree mortality response and forest management activities identified for Forest Health (e.g., tree species, large vs. small diameter trees, quality of dead trees)
- Identify potential markets to pursue for in-state expansion or initiation
- Identify existing barriers to expansion of wood product markets and develop recommendations to mitigate them
- Identify opportunities to expand wood product markets and develop recommendations to promote them
- Identify pilot projects that can serve to demonstrate the value of mitigating barriers and

pursuing opportunities to aid expansion of wood products markets

### *Relevant Reports*

The Working Group received a number of reports and presentations to supplement the knowledge that individuals brought to the group. These included the following:

- *CNRA Report on State and Federal Policies to Support Expansion of Wood Products Markets*: written for this Working Group, this provides information on actions in other states to expand wood product markets, as well as complementary federal initiatives
- *White Paper on Community-scale Economic Development Wood Utilization Needs and Opportunities*: written for this Working Group by the Sierra Institute, this is intended to give the perspective of entities working to grow wood products markets in their communities to both grow rural economies and promote forest stewardship
- *Dead Tree Utilization Assessment* (*draft*): written for the Tree Mortality Task Force by the BECK Group, this report is focused on use of the dead and dying trees in the Sierra; a final draft is available
- *California Assessment of Wood Business Innovation Opportunities* (CAWBIOM): the National Forest Foundation, in conjunction with the USFS and through the services of a consulting team (The Beck Group, Carlson Small Power Consultants, Mason Bruce and Girard, and Fido Management),developed this an analysis of potential wood business innovations and markets within California[19]

These reports are available for review. The recommendations in this document are based on the findings of these reports, which were supplemented with additional information drawn from multiple sources and individuals during the Working Group's convening.

[19] National Forest Foundation/ The BECK Group. 2015. Available Online: https://www.nationalforests.org/who-we-are/regional-offices/california-program/california-assessment-of-wood-business. Accessed Oct. 10, 2017.

# APPENDIX B: ADDITIONAL INFORMATION ON MASS TIMBER BUILDING

BUILDING DESIGN +CONSTRUCTION

# Mass timber: From 'What the heck is that?' to 'Wow!'

The idea of using mass timber for tall buildings keeps gaining converts.
**Game Changers** | January 12, 2017 | John Caulfield, Senior Editor

Available online: **https://www.bdcnetwork.com/mass-timber-what-heck-wow**

*Brock Commons at the University of British Columbia, Vancouver, employs hybrid construction, combining mass timber with concrete and steel. Shown here, workers position a CLT panel with steel stud framing and preinstalled windows. The Building Team includes: Acton Ostry architects (architect), Architekten Hermann Kaufmann (tall wood advisor), Fast+Epp (SE), Stantec (ME and sustainability), GHL Consultants (fire science/building code), RDH Building Science (building science), and Urban One Builders (CM). Photo: Pollux Chung/Seagate Structures.*

Big timber is sprouting up in cities in North America and abroad. After years of feasibility studies and design proposals, buildings six stories or taller constructed primarily from pre- engineered wood products are being considered in cities around the world.

In London, one proposal, called the Splinter, would rise to 100 stories. In Chicago, Perkins+Will (in collaboration with Thornton Tomasetti and the University of Cambridge) has designed an 80- story

high-rise with 300 duplex apartments. If built, River Beech—a key component of P+W's master plan for the Riverline development—would be made almost entirely from mass timber.

So-called "plyscrapers" are still a tiny sliver of nonresidential construction. In the past five years, only 17 buildings seven stories or taller have been completed worldwide, mostly in Europe and Canada. Six more have started construction, according to the American Wood Council.

Mass production of timber for high-rise construction is still in its infancy in North America. Specifying these products in the U.S. faces resistance from insurers, regulators, and code officials. Steel fabricators and concrete suppliers disparage mass timber for taller buildings on the grounds of safety and durability.

Proponents cite the speed at which tall buildings can be constructed using pre-engineered wood and mass timber's ability to sequester carbon. Joey-Michelle Hutchison, RA, LEED AP BD+C, CSBA, Associate Vice Principal, CallisonRTKL, says, "The role of mass wood is going to grow because of the demand for sustainable design." Researchers from Yale and the University of Washington, in a study published in the *Journal of Sustainable Forestry* (March 28, 2014), postulated that using wood substitutes for constructing buildings (and bridges) could save 14– 31% of global $CO_2$ emissions.

"The barriers are eroding," says Iain MacDonald, Associate Director, National Center for Advanced Wood Products Manufacturing. "If wood took even 5% market share from steel or concrete, that would be major" in terms of reducing $CO_2$ emissions from new construction. The International Code Council's board has created a Tall Wood Ad Hoc Committee to look into possible code changes for the 2021 IBC.

MacDonald came to the center—a collaboration between Oregon State University's Colleges of Forestry and Engineering and the University of Oregon's School of Architecture—from the University of British Columbia, Vancouver. That's where the world's tallest wood building— Brock Commons, a 174-foot residence hall for 404 students—should be completed this spring.

The $38 million project employs a hybrid structural system: a one-story concrete podium, two concrete cores, and 17 stories of mass timber—glulam columns with steel connectors supporting five-ply cross-laminated timber (CLT) on a 2.85x4-meter grid—topped with a prefabricated steel beam and metal roof deck. The prefab façade is comprised of eight-meter-long steel stud frames with preinstalled windows. A 58-meter CLT canopy runs the length of the building base.

Mass timber is well suited for constructing high-rise student housing, says Paul Fast, Partner, Fast + Epp, the structural engineering firm on Brock Commons. The suites are only 14 feet wide, "so you could put in a lot of structural wood posts" for support, he says. Columns run every 10 feet, and the crawl spaces are less than 10 feet, "so it could go up really fast."

The construction management firm, Urban One, completed two stories per week; the structural system, consisting of 1,302 glulam columns and 464 CLT panels, was finished in 66 days. Fast says that with a few more cranes and carpenters, "You could build a floor a day."

*The 12-story Framework, whose construction in Portland, Ore., gets started in February, will be made primarily with CLT. To meet seismic objectives, the building will include a lateral-force resisting system with post-tensioned rocking wood shear walls, pioneered in New Zealand. In November, Framework's fully loaded exposed CLT and glulam connections were the first to achieve two-hour fire ratings. The Building Team: project^ (developer), Lever Architecture, KPFF (SE, CE), PAE (MEP), Arup (fire and timber engineer), StructureCraft Builders (timber structure delivery partner), and Walsh Construction (GC). Rendering: Lever Architecture.*

"The 21st century will be the age of wood," thanks to demand for sustainability and the prospect of carbon taxes, says Lucas Epp, Engineering and 3D Manager for StructureCraft Builders, the timber structure delivery partner on the seven-story, 224,000-sf T3 in Minneapolis's North Loop. T3—which stands for "timber, technology, transportation"—is the first tall wood office building in the U.S. It wrapped up construction in November.

StructureCraft installed 180,000 sf of timber superstructure, including 1,100 8x20-foot nail- laminated timber panels, in 9½ weeks. (Nail-lam, or NLT, is created by nailing individual units of dimensional lumber, stacked on edge, into a single structural element.) Michael Green Architecture and DLR Group designed the building.

Hines, T3's owner and developer, declined to be interviewed. But two sources familiar with the project told *BD+C* that Hines plans to build other tall wood buildings across the country. "They're looking to get a jump on the market," one source said.

StructureCraft is also involved in Framework, a 12-story mixed-use building in Portland, Ore., whose developer is the unusually named project^. Its structural system will consist of CLT and glulam beams and columns, supported by a reinforced concrete foundation. When completed in Q1/2018, Framework will offer 60 apartments, 39,000 sf of offices, and 9,000 sf of retail.

At 130 feet in height, Framework will be the first tall wood building in North America with post-tensioned rocking CLT shear walls. Coupled with replaceable energy-diffusing "fuses" on the periphery, the building will meet the required seismic performance criteria of "economically repairable" after a 1:500-year earthquake and "little or no damage" after a 1:100-year event.

"Mass wood has a high strength-to-weight ratio, which makes it good for protecting against seismic events," says Thomas Robinson, Founder, Lever Architecture, Framework's architect. Robinson is so enamored of mass wood that he recently moved his firm into the four-story, 16,000-sf Albina Yard in North Portland, the first market-rate office building in the U.S. constructed with domestically fabricated CLT.

Preconstruction planning is essential to familiarize subcontractors with these components. "A lot of thinking is done before the wood gets to the job site," says Valerie Johnson, President, D.R. Johnson Wood Innovations, Riddle, Ore., the sole CLT plant in the U.S.

Proponents hope mass timber catches on in the U.S. the way it has in Canada and Europe.
One such Canadian project is the Origine Condos, a 13-story, 92-unit residential tower in Quebec City. It took the NEB consortium—Nordic Structures (wood structure manufacturer), EBC (GC), and Synchro Immobilier (developer)—four years to get the 426-foot-tall structure approved. The project, designed by Yvan Blouin Architects (with engineering firms WSP Canada, Génécor, and Groupe Conseil SID), broke ground last June and is scheduled for completion in June.

## LEANING TOWARD HYBRID SOLUTIONS

Mass timber is less practical or cost effective for building typologies with large, open floor plans. That's one reason why most tall wood buildings are still hybrids with steel and concrete.

Last November, building crews completed the UMass Amherst Design Building, a four-story, 87,500-sf, $52 million project whose "zipper truss," a composite of mass timber and compressed elements, is reinforced with steel rods. "We needed the steel because of the length, which reaches up to 70 feet," says Tom Chung, AIA, LEED AP, Principal, Leers Weinzapfel Associates Architects, the design firm on the project.

At the Mass Timber Conference last March, structural engineer Benton Johnson, an Associate with Skidmore Owings & Merrill, stated that, after studying the feasibility of high-rise wood up to 42 stories, SOM had concluded that a composite structure with mass timber floors and walls connected by reinforced concrete joints is "more flexible" than wood alone would be.

"Hybrid is the only way to go for proper wind resistance and rigidity," says Amir Lotfi, LEED AP BD+C, Architectural Associate, CallisonRTKL. His firm has conducted a feasibility study for a 1,325-foot, 110-floor building in Seattle that would have a concrete and steel framework.

AEC firms are eager to integrate mass timber because it is a renewable resource that's environmentally friendlier than either concrete or steel, whose production and off-gassing leave enormous carbon footprints on the built environment. StructureCraft claims that the 127,133 cubic feet of wood used for T3 would sequester 3,200 tons of $CO_2$ during the life of the building.

## REMOVING A FEW ROADBLOCKS

Objections to tall wood buildings as potential firetraps are still embedded in codes and regulations, says Alan Bruton, NCARB, NCIDQ, Associate Professor at the University of Houston's College of Architecture and Design. Sandy Springs, Ga., recently banned wood buildings taller than three stories or bigger than 100,000 sf.

At press time, SHoP Architects was negotiating with the New York City Fire Department for approval of 475 West 18th Street, a 10-story, 15-unit condominium building that would be made primarily from mass timber.

"Our firm has gotten interest from other clients, but when we ask about getting approval, we usually don't hear back," says Russell Acton, AIBC, AAA, SAA, OAA, FRAIC, Principal, Acton Ostry Architects, the architect on Brock Commons.

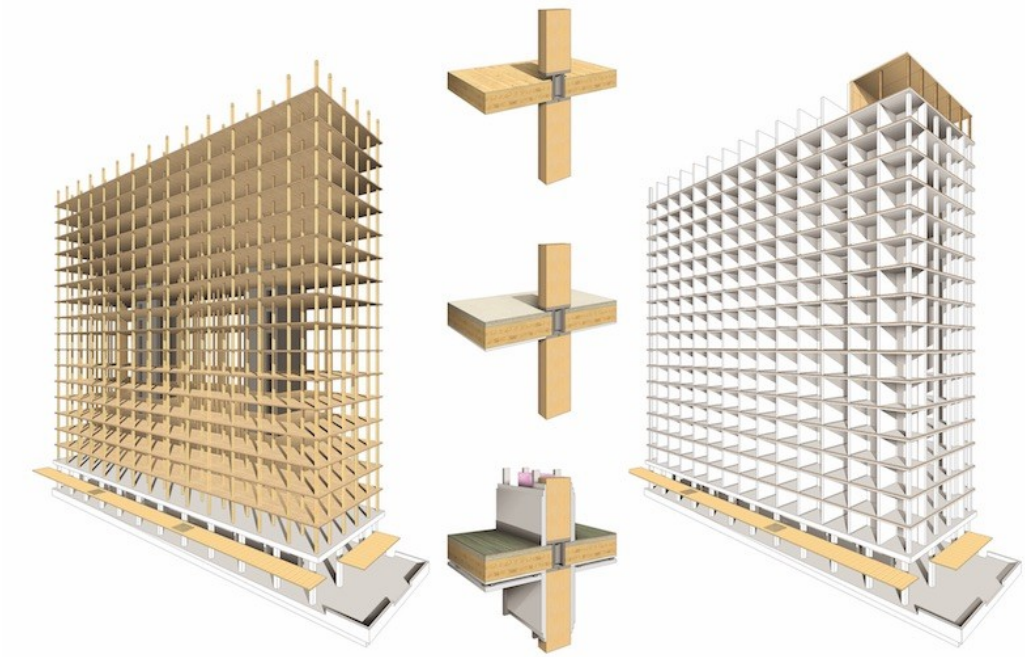

*Illustration depicts the hybrid structural system design at the Brock Commons project, at the University of British Columbia, Vancouver. 1] Hybrid mass timber and concrete core structure. 2] CLT floor slabs with glulam columns and steel connectors. 3] Partial encapsulation during construction. 4] Completed construction. Courtesy Acton Ostry Architects.*

To move wood projects to the next level, Bruton says the AEC community and manufacturers must conduct full-scale fire tests and provide consistent data to municipalities.

Last October, The Framework Project LLC (which owns Framework) announced that two fire tests of CLT and glulam had achieved two-hour fire ratings, which showed that mass timber could meet stringent fire code requirements. In August, D.R. Johnson's CLT panels met fire safety requirements under tests that gauge flame spread and fire resistance.

Regulations aside, any expansion in mass timber's market penetration would require more production capacity. Only three plants in North America are certified to make CLT, compared to 14 in Europe. Right now, it's cheaper to ship mass timber from Europe to the U.S. than to truck it in from Oregon or Canada.

MDS 10 Architects, Asheville, N.C.—designer of the six-story Veterans Village with 88 units for homeless vets, which is under construction using CLT—is shifting its business to manufacturing. The firm is raising money to build a CLT plant in Stuart, Va. The plant would be the first to use Southern yellow pine as its base material.

MDS 10's co-owners, Crawford Murphy and Michael DeVere, see mass timber as "the technology of now and the future." They say that when they present mass timber products to developers and builders, the reaction has gone from "What's that?" to "Wow!"

# APPENDIX C: ASSOCIATE'S DEGREE AND CERTIFICATE PROGRAMS

Associate's degree and certificate programs for forestry, forestry technician, and wood products technology at California community colleges include:

- *Bakersfield College*, Certificate of Achievement, A.S. Degree, and A.A. Degree in Forestry; Engineering and Industrial Technologies Certificate of Achievement in Woodworking & Cabinetmaking; and Engineering and Industrial Technologies A.S. Degree in Industrial Technology: Woodworking & Cabinetmaking
- *Cerritos College*, Engineering and Industrial Technologies A.A. Degree in Woodworking Manufacturing Technologies; and Engineering and Industrial Technologies Certificate in Woodworking Manufacturing Technologies
- *Citrus College*, Certificate of Achievement in Wildland Resources and Forestry
- *College of the Redwoods,* A.S. Degree in Forestry Technology; Certificate of Achievement in Forestry Technology; and Engineering and Industrial Technologies Certificate of Achievement in Fine Woodworking
- *Columbia College,* A.S. Degrees in Forestry Technology, Forestry Technology (Occupational), and Watershed Management Technology; and Certificates of Achievement in Forestry Technology and Watershed Management Technology
- *El Camino College,* Engineering and Industrial Technologies Certificate of Achievement in Construction Technology – Cabinet and Fine Woodworking; and Engineering and Industrial Technologies A.S. Degree in Construction Technology – Cabinet and Fine Woodworking
- *Fullerton College,* Engineering and Industrial Technologies Certificate of Achievement in Cabinetmaking and Millwork Technology
- *Laney College,* Engineering and Industrial Technologies Certificates of Achievement in Mill & Cabinet Maker Apprenticeship and Wood Technology
- *Long Beach City College,* Engineering and Industrial Technologies Certificate of Achievement in Wood Products Manufacturing; and Engineering and Industrial Technologies A.S. Degree in Wood Products Manufacturing
- *Palomar College,* Engineering and Industrial Technologies A.S. Degrees and Certificates of Achievement in Cabinetmaking and Millwork; Carving Technology; Case Furniture
- Construction/ Manufacturing; Lathe Turning Technology; Table and Chair Manufacturing; Veneering Technology; and Woodworking Skills Technology
- *Modesto Junior College*, A.S. Degree in Forestry; and Certificate of Achievement for Forestry Technician
- *Reedley College,* A.S. Degree in Forestry/ Natural Resources; and Certificates of Achievement in Forest Surveying Technology and Forestry Technician Firefighting Emphasis
- *San Joaquin Delta College,* Engineering and Industrial Technologies Certificates of Achievement in Mill Cabinet Technology and Apprenticeship: Mill Cabinet Technology
- *Santiago Canyon College,* Engineering and Industrial Technologies Certificates of Achievement and A.S. Degree in Apprenticeship: Carpentry, Millwriting
- *Shasta College,* A.S. Degree in Forest Science and Technology