Scaling Offsite and Volumetric Modular: Evolving Systems and Strategies for Success

MASS TIMBER+ SM

OFFSITE CONSTRUCTION CONFERENCE

PRODUCED BY WOODWORKS Wood Products Council

FEA Forest Economic Advisors

Credits: 1.0 AIA/CES HSW LUs, 1.0 PHD credit, 0.10 ICC credit

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Scaling Offsite and Volumetric Modular

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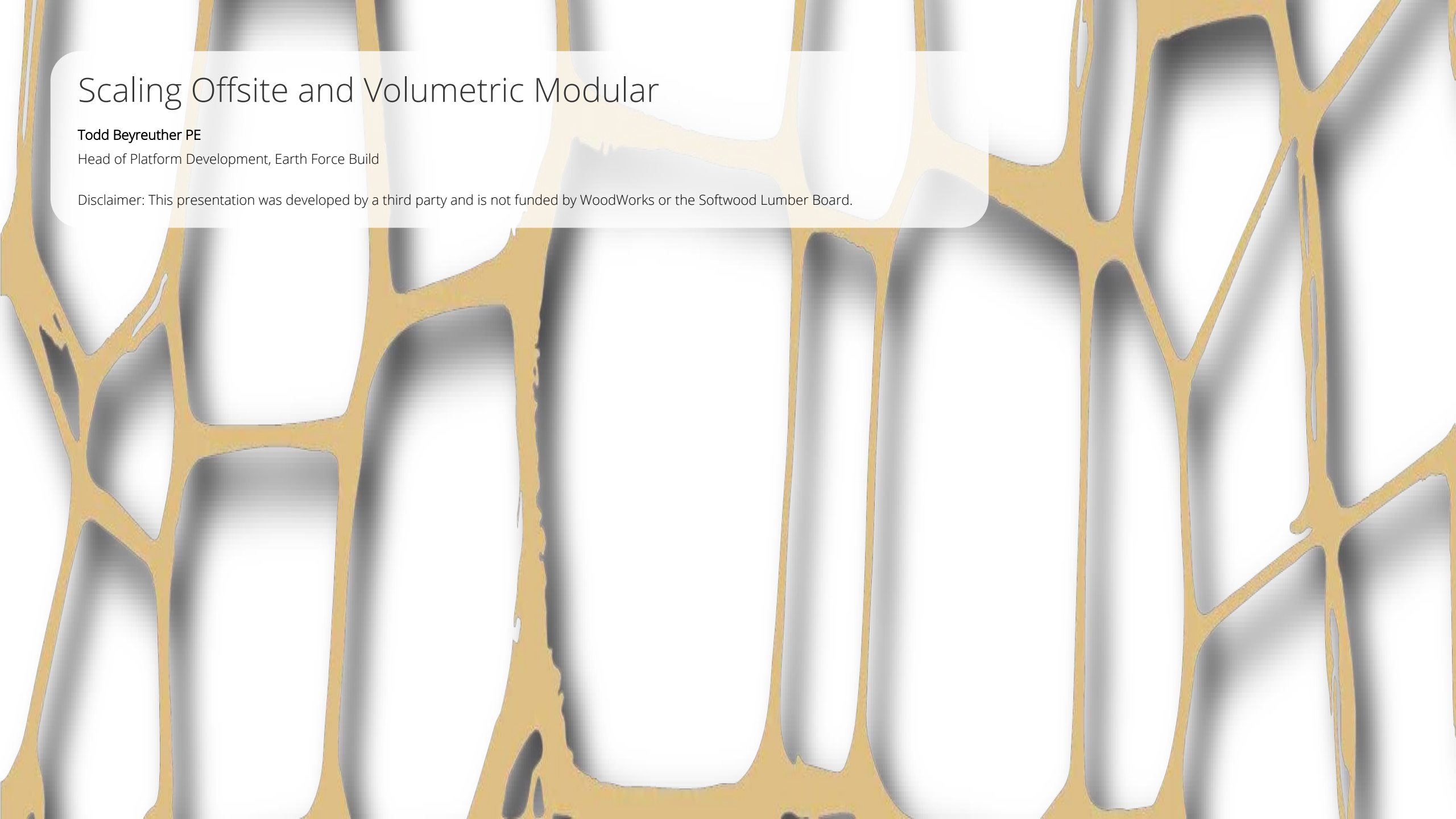
Head of Platform Development, Earth Force Build



Technoeconomics of **resources**

Strategic Intent: Connect natural environment offtakes with built environment offtakes

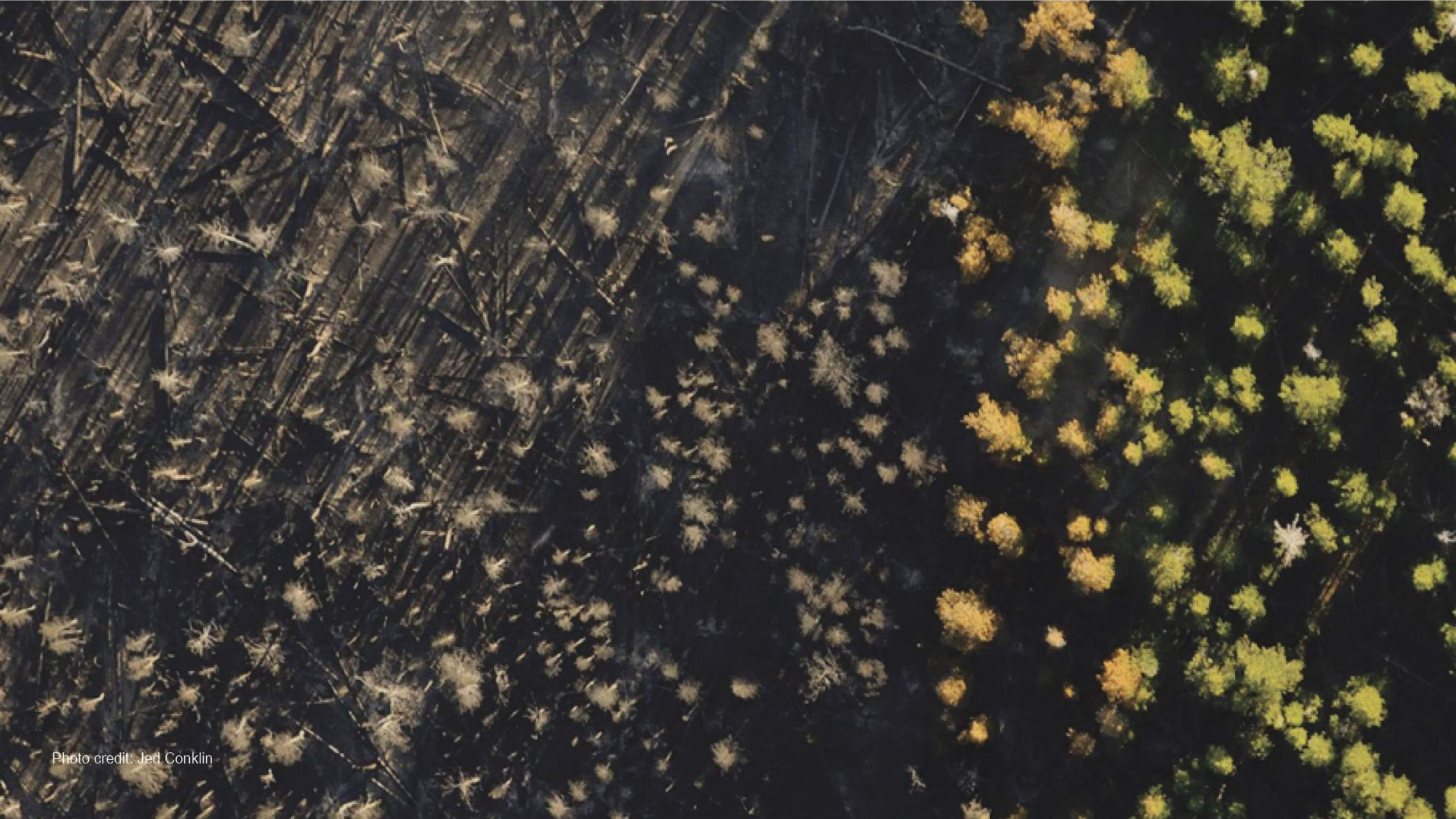
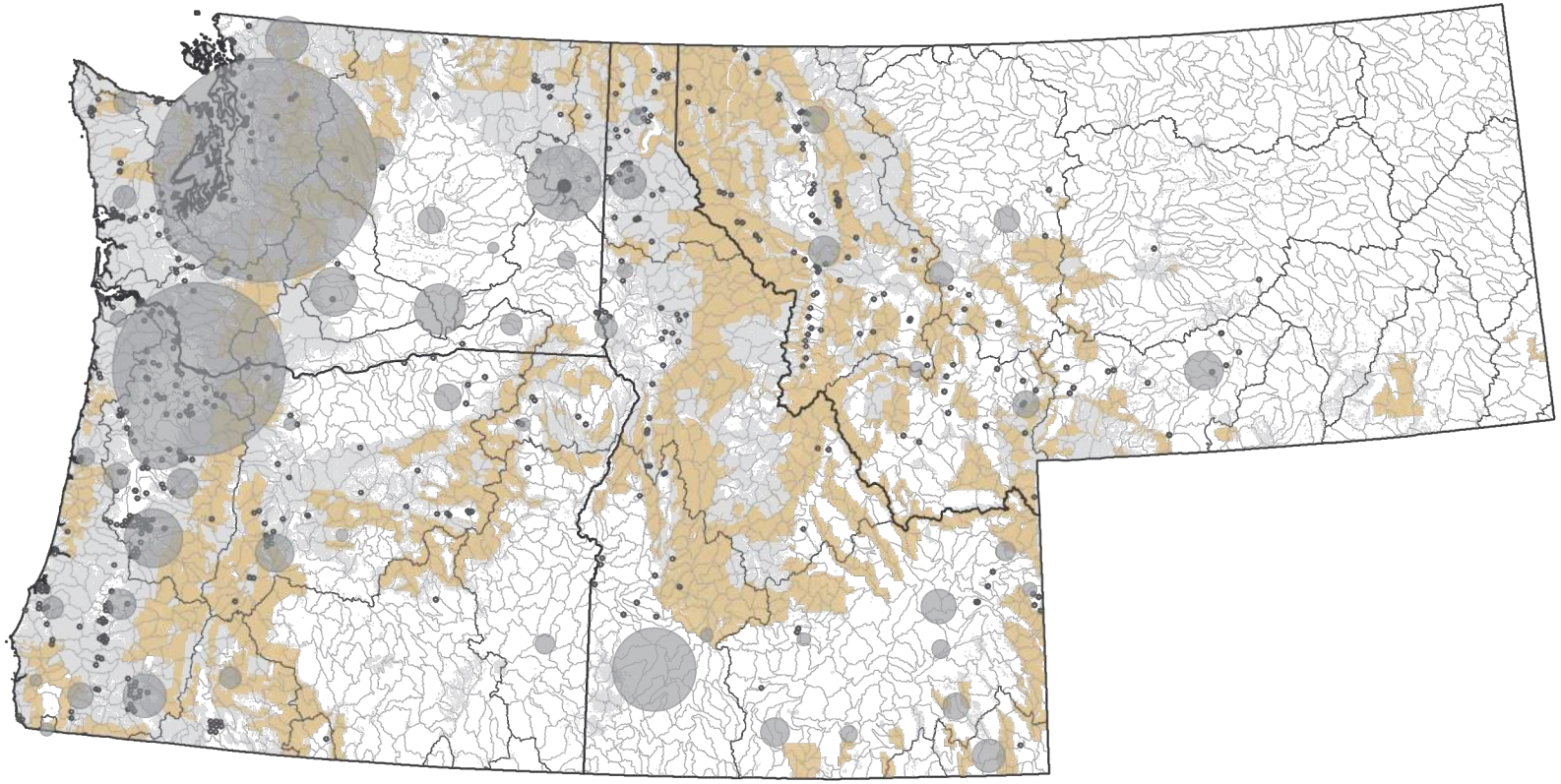
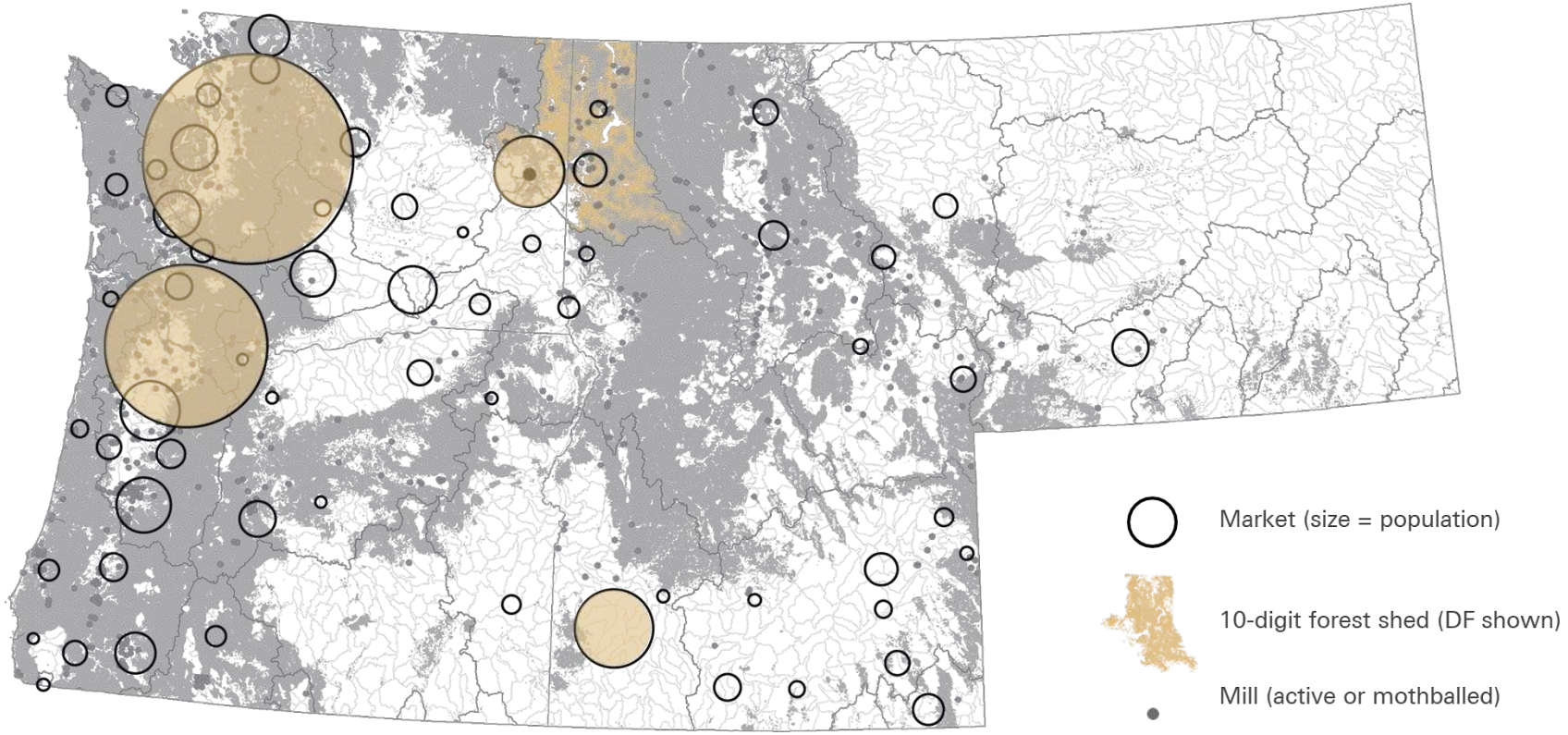


Photo credit: Jed Conklin



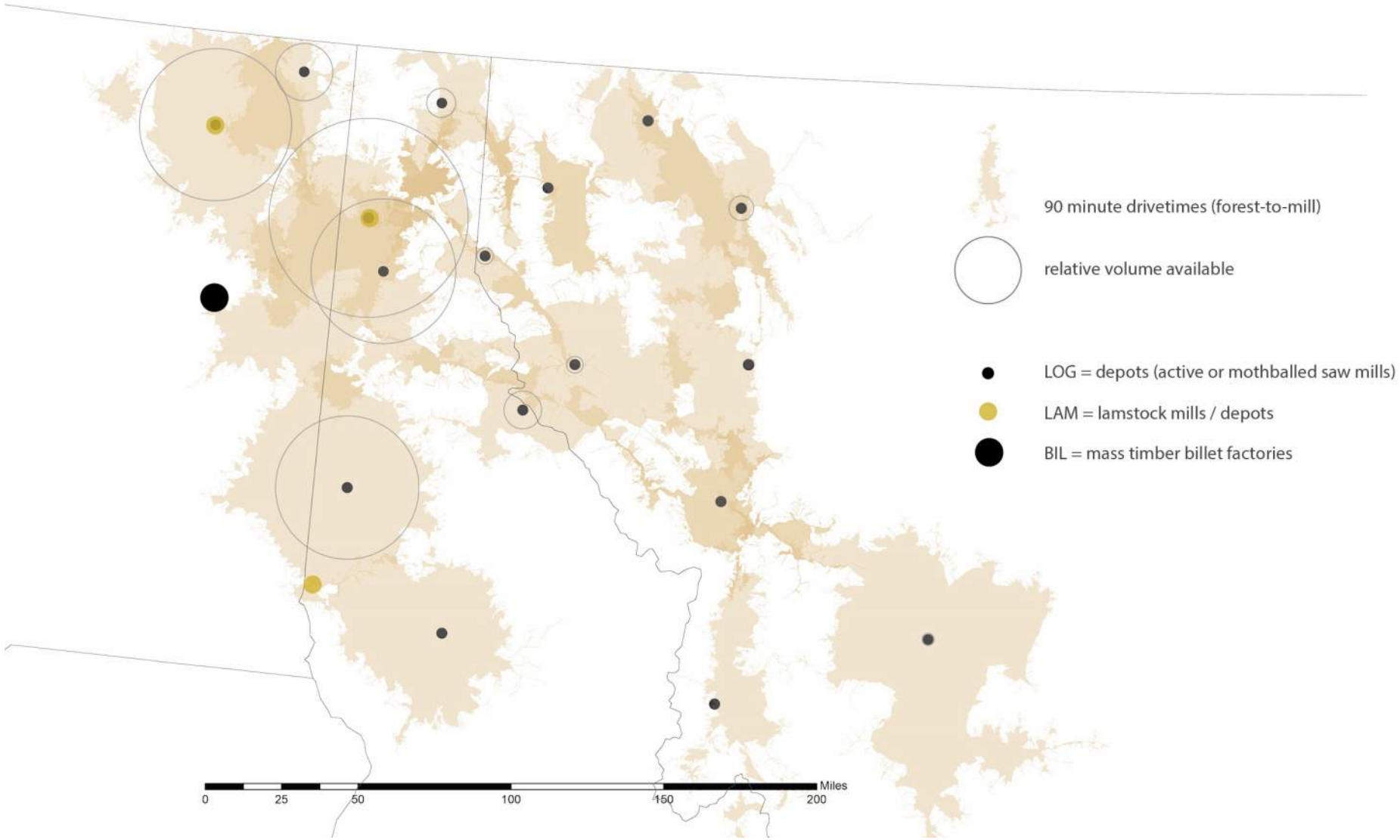
Technoeconomics of **stewardship**

Strategic Intent: Connect natural environment offtakes with built environment offtakes



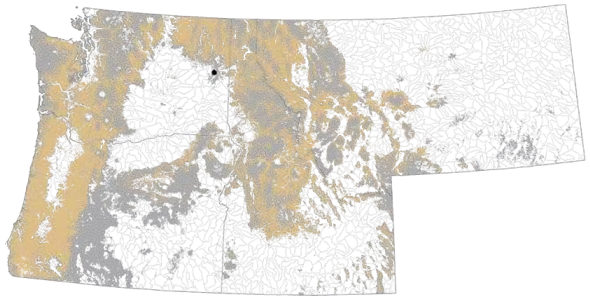
Technoeconomics of **markets**

Strategic Intent: Connect natural environment offtakes with built environment offtakes

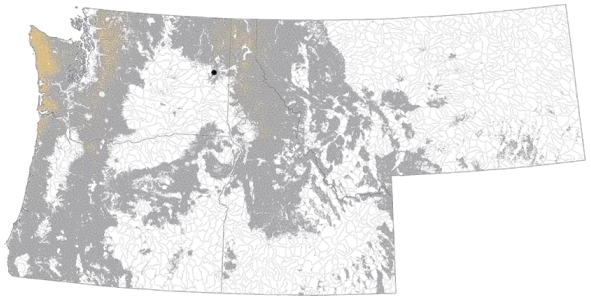


Technoeconomics of **community**

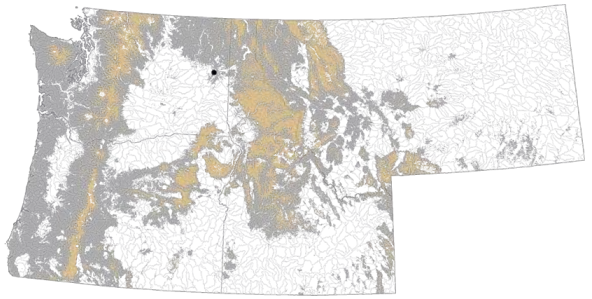
Strategic Intent: Connect natural environment offtakes with built environment offtakes



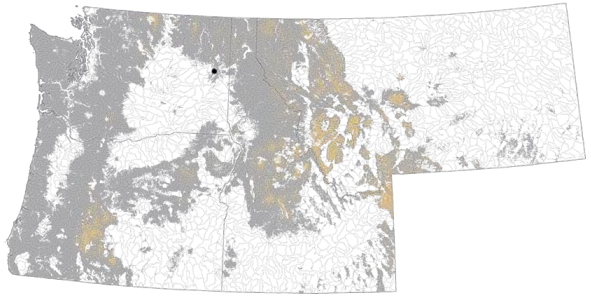
DF = Douglas-fir



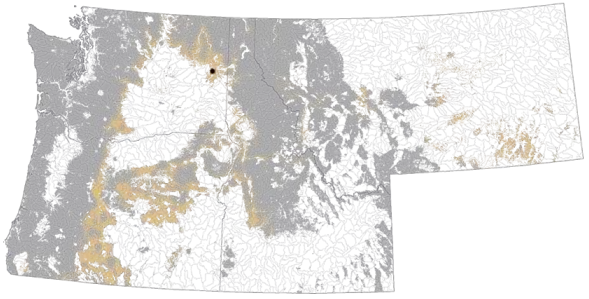
WH = Western Hemlock



GF = Grand Fir



LP = Lodgepole Pine



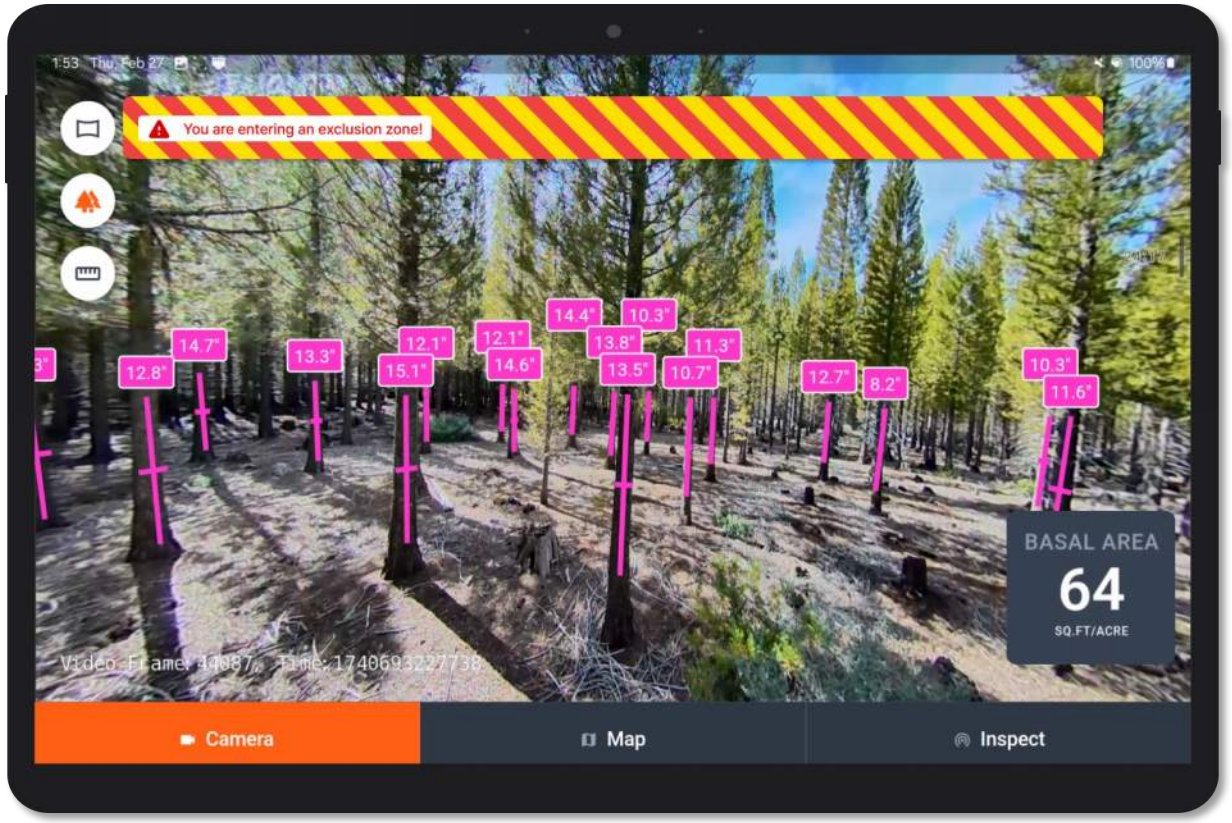
PP = Ponderosa Pine

Technoeconomics of **species**

Strategic Intent: Connect natural environment offtakes with built environment offtakes

Technoeconomics of **species**

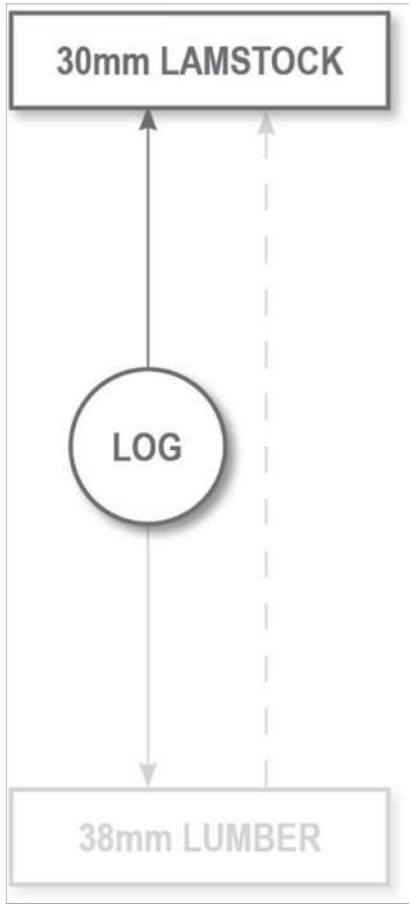
Strategic Intent: Connect natural environment offtakes with built environment offtakes



Technoeconomics of **restoration**

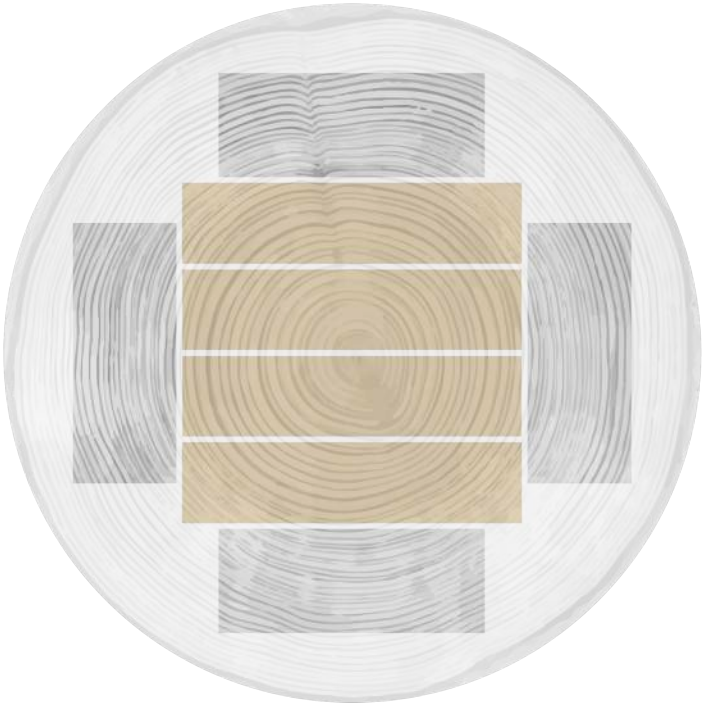
Strategic Intent: Connect natural environment offtakes with built environment offtakes

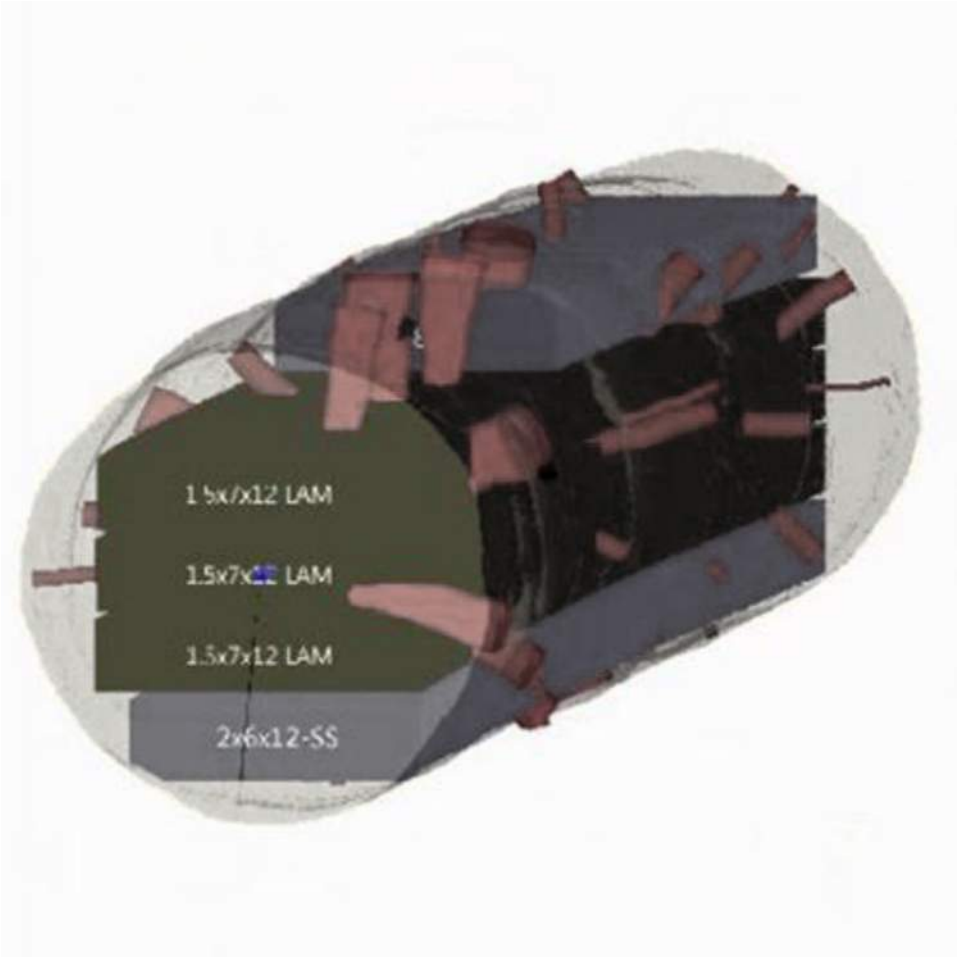
photo credit: Earth Force Technologies



Technoeconomics of **grading** and **sorting**

Strategic Intent: Connect natural environment offtakes with built environment offtakes





Technoeconomics of **milling**

Strategic Intent: Connect natural environment offtakes with built environment offtakes

DEVELOP 35mm and 30mm ELAM programs

Key Takeaway: BID projects are designed on a 35mm and 17mm basis (external specification).
MOD projects will be designed on a 30mm basis (internal specification).

Technoeconomics of **manufacture**

1.1 LUM = lumber development

prescriptive CLT from commodity lumber (edgewise properties)

2019

Visual Grade SPO (1.4V)
SPF 2x12 values + DF-L substitution
(875 fb, 450 ft, SG 0.42)
82.5mm 3-ply (min) - 315mm 9-ply (max)

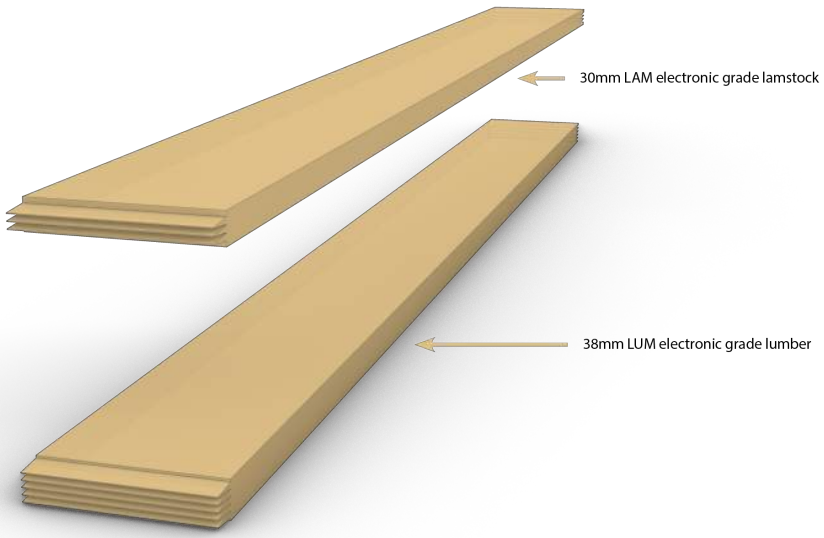
SYP 2x12 values
(750 fb, 450 ft, SG 0.55)
97mm 3-ply (min) - 175mm 5-ply (max)

MSR Grade SPO (1.5M)
SPF 2x6 or 2x8 values + DF-L substitution
(1650 fb, 1020 ft, SG 0.42)
105mm 3-ply

MSR Grade SPO (1.8M)
SPF 2x6 or 2x8 values + DF-L substitution
(2100 fb, 1575 ft, SG 0.46)
97mm 3-ply (min) - 175mm 5-ply (max)

MSR Grade SPO (2.0M)
SYP 2x6 or 2x8 values
(2400 fb, 1975 ft, SG 0.57)
105mm 3-ply (min) - 245mm 7-ply (max)

✓ Commodity 2x6 Lumber
varies mills (CAN, USA)
SPF, DFL, SYP



1.2 LAM = lamstock development

performance-based CLT from custom lamstock (flatwise properties)

2019

Cost Model Validation (E) ✓

Market Demand Model Validation (E) ✓

CLT Characterization (150mm - E) ✓
WSU Pullman (WA)
150mm 5ply – GF

CLT Characterization (90mm - E) ✓
WSU Pullman (WA)
90mm 3ply – GF, DF, WH

✓ ELOG Pilot Runs 1,2,3
IFG Lewiston mill (ID)
Grand Fir

✓ ELAM Characterization
TU Graz (AT)
GF, DF, WH, LP, PP

2025

Q1

Electronic Grade Qualified (1.5E MSR) ✓
performance lamstock-based CLT
90mm / 105mm 3-ply - 150mm / 175mm 5-ply

Q2

Electronic Grade Qualified (1.2E,1.8E MSR)
performance lamstock-based CLT
90mm / 105mm 3-ply - 150mm / 175mm 5-ply

ELAM 33/38x140/184mm GF
IFG Lewiston mill (ID)
Grand Fir = GF

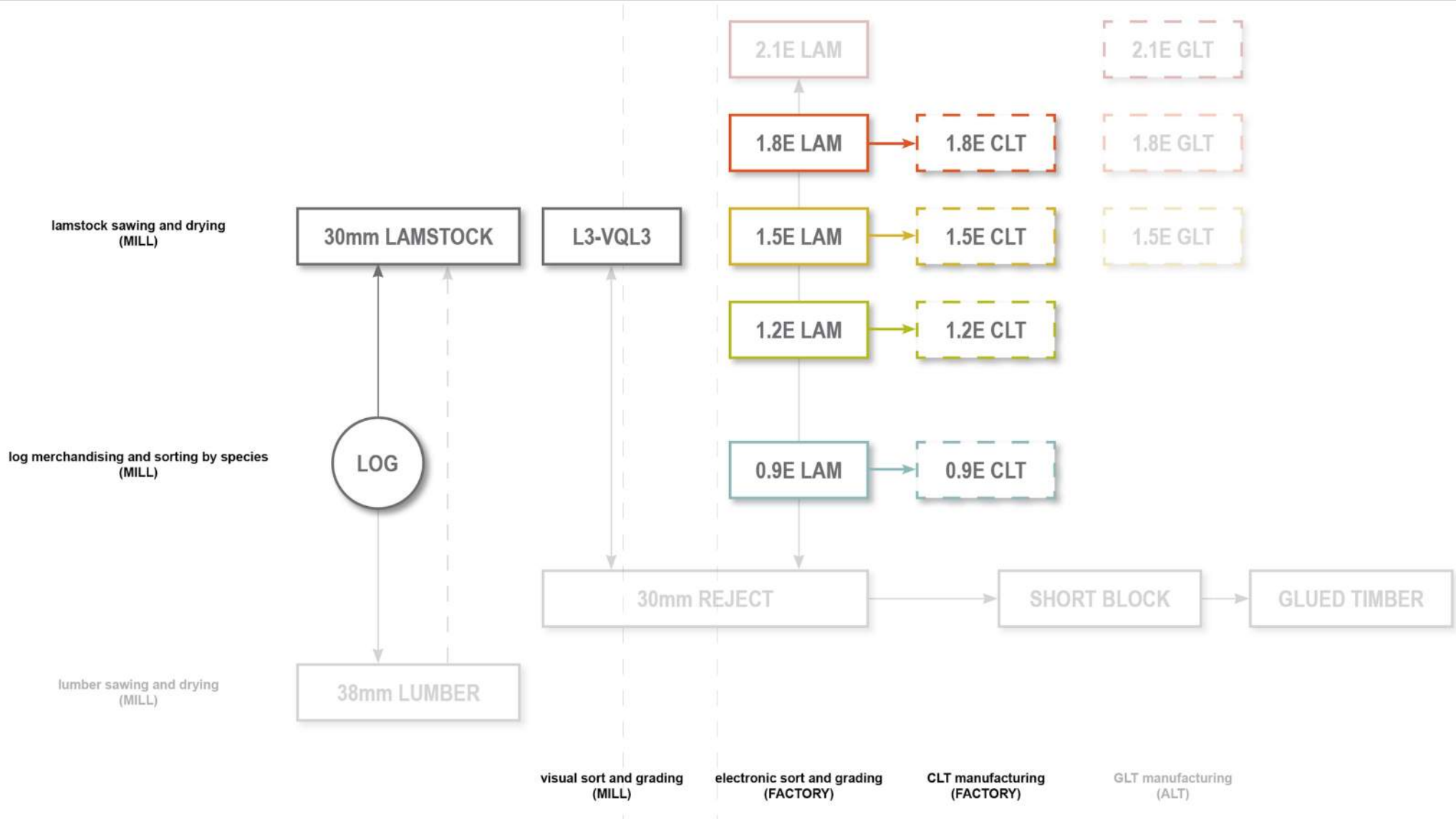
ELAM 33/38x140/184mm DF
IFG Chilco mill (ID), Yakama (WA), Vaagen (WA)
Douglas-fir = DF

Q3

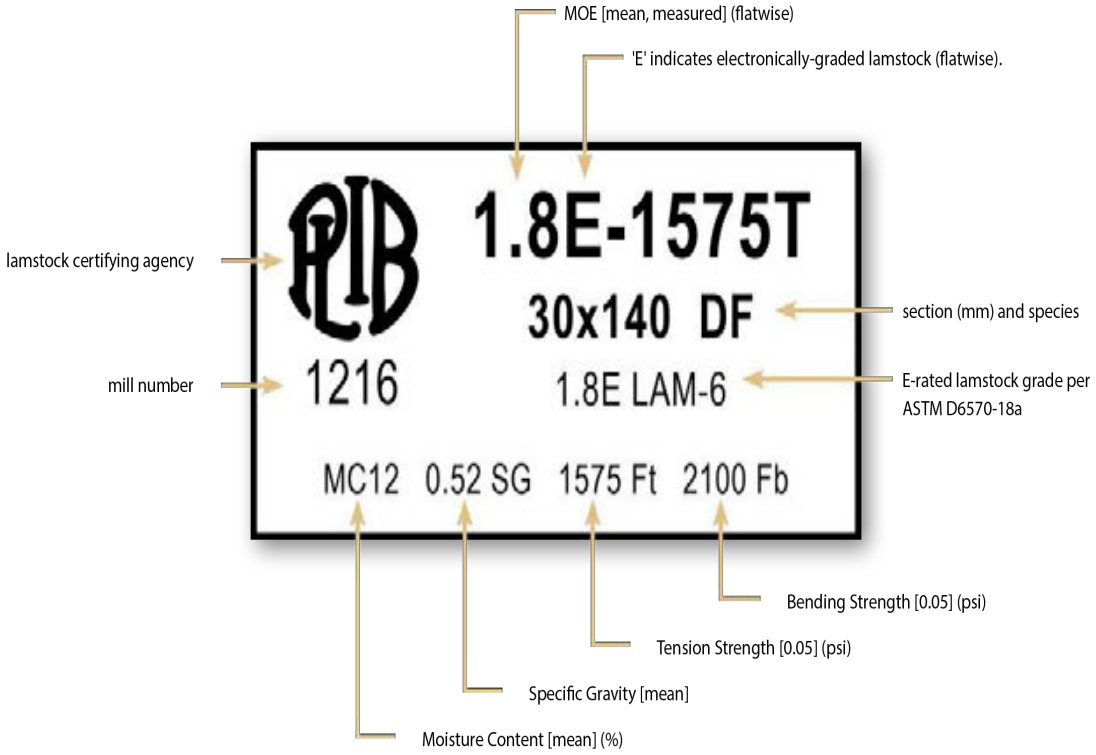
ELAM 33/38x140/184mm LP
IFG Chilco (ID) / Stolze (MT) / Vaagen Bros (WA)
Lodgepole Pine = LP

Electronic Grade Qualified (0.9E)
performance lamstock-based CLT
90mm / 105mm 3-ply - 150mm / 175mm 5-ply

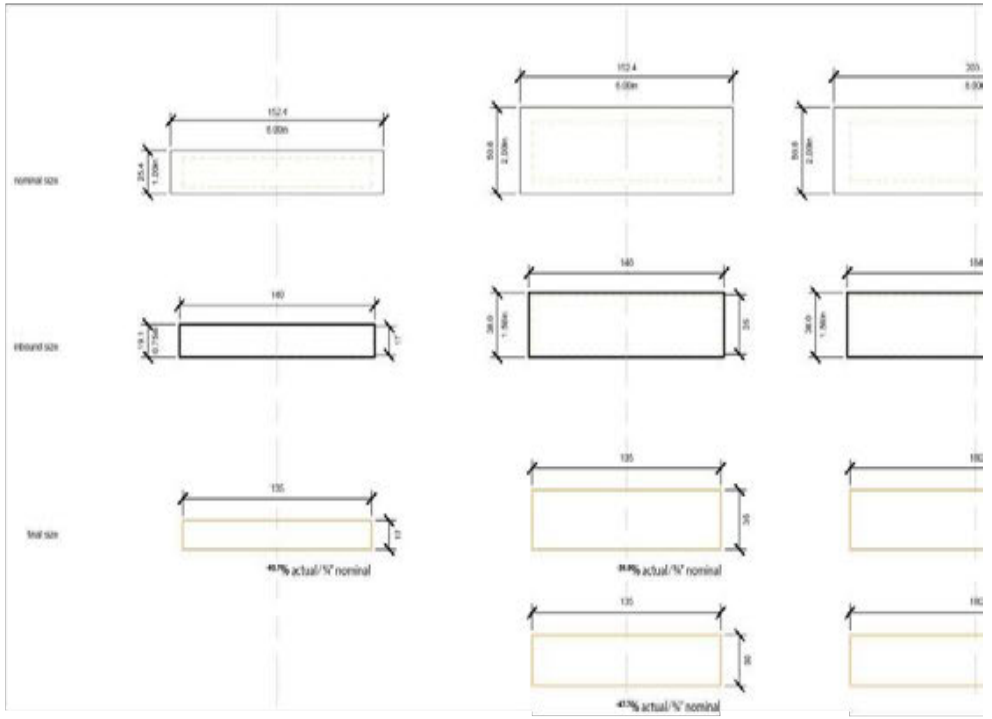
ELAM 33/38x140/184mm PP
IFG Laclede mill (ID)
Ponderosa Pine = PP


2.1E LAM
2.1E GLT
1.8E LAM
1.8E CLT
1.8E GLT
lamstock sawing and drying
(MILL)
30mm LAMSTOCK
L3-VQL3
1.5E LAM
1.5E CLT
1.5E GLT
1.2E LAM
1.2E CLT
log merchandising and sorting by species
(MILL)
LOG
0.9E LAM
0.9E CLT
30mm REJECT
SHORT BLOCK
GLUED TIMBER
lumber sawing and drying
(MILL)
38mm LUMBER
visual sort and grading
(MILL)
electronic sort and grading
(FACTORY)
CLT manufacturing
(FACTORY)
GLT manufacturing
(ALT)

1.3 LAM electronic grades (proprietary)

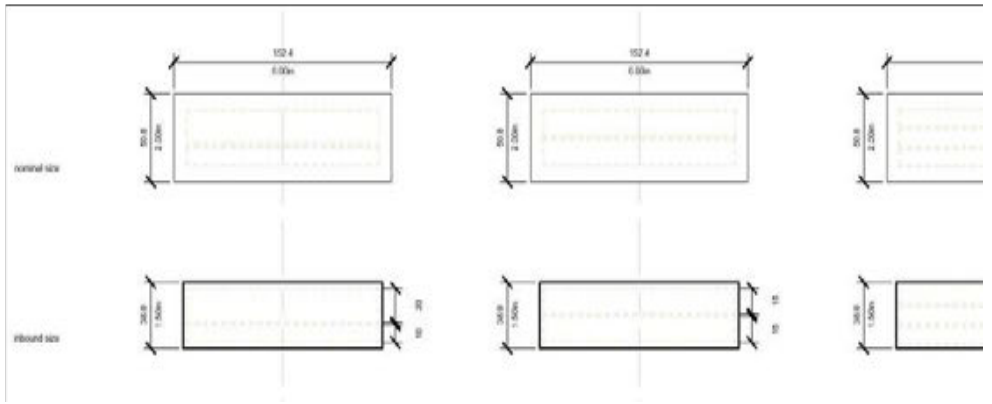


1.4 LAM sections

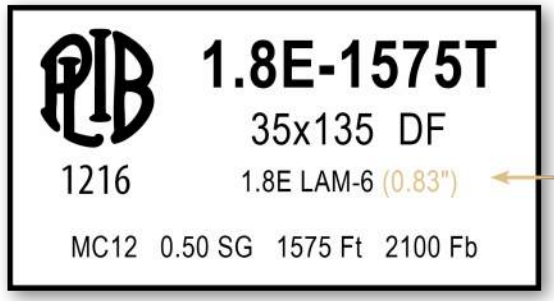


0.44 sf / bf

0.44 sf / bf

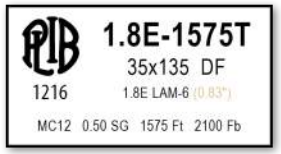


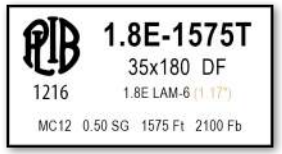
1.5 LAM strength and stiffness certifications

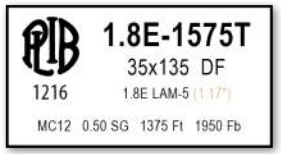


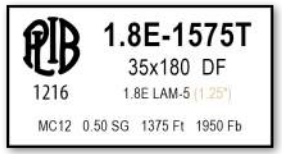
ELAM grading rules limit the percentage of the cross section allow for a combination of knots, knot holes, burls, distorted grain, an decay at the edges of the cross section. The actual size changes with graded width and can be expressed as a size for clarity with setting the grading machine.

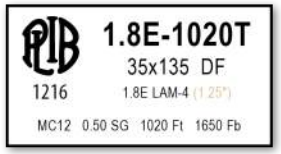
Normalization with external lumber grades to internal lamstock categories is possible after transformation to lamstock in the factories. All incoming lumber is sorted and remediated to lamstock specifications without negating the external strength and stiffness grading.











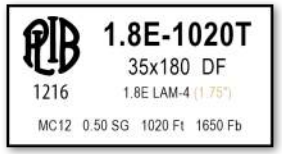


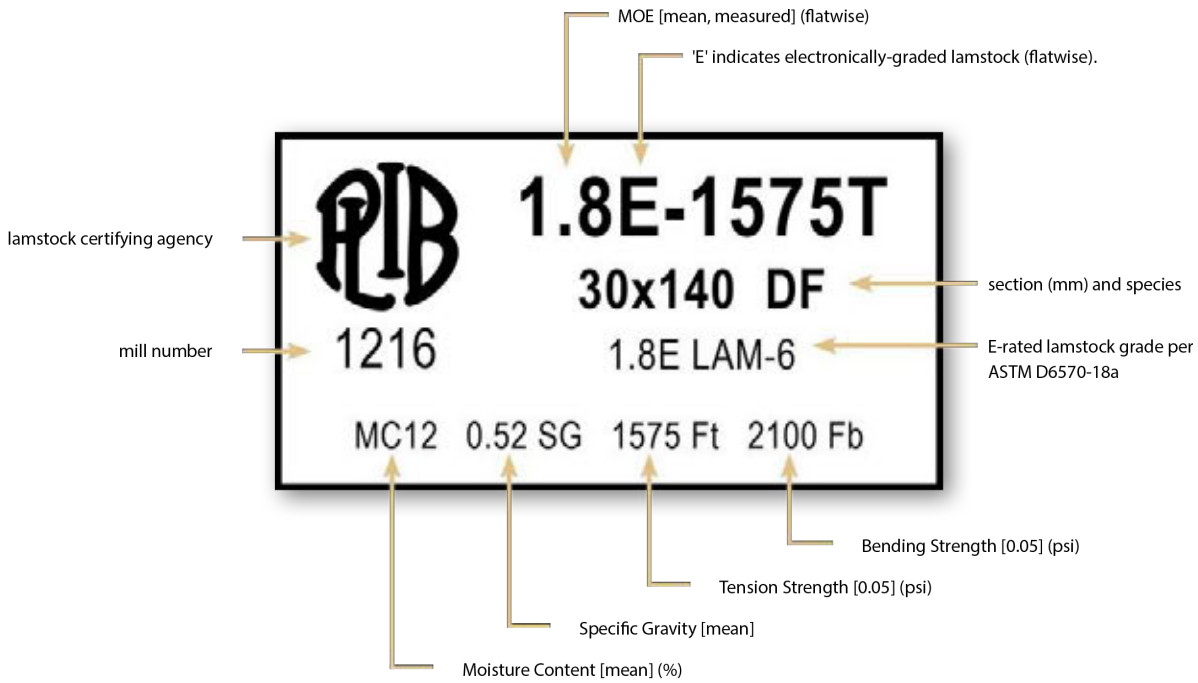
TABLE 1.X

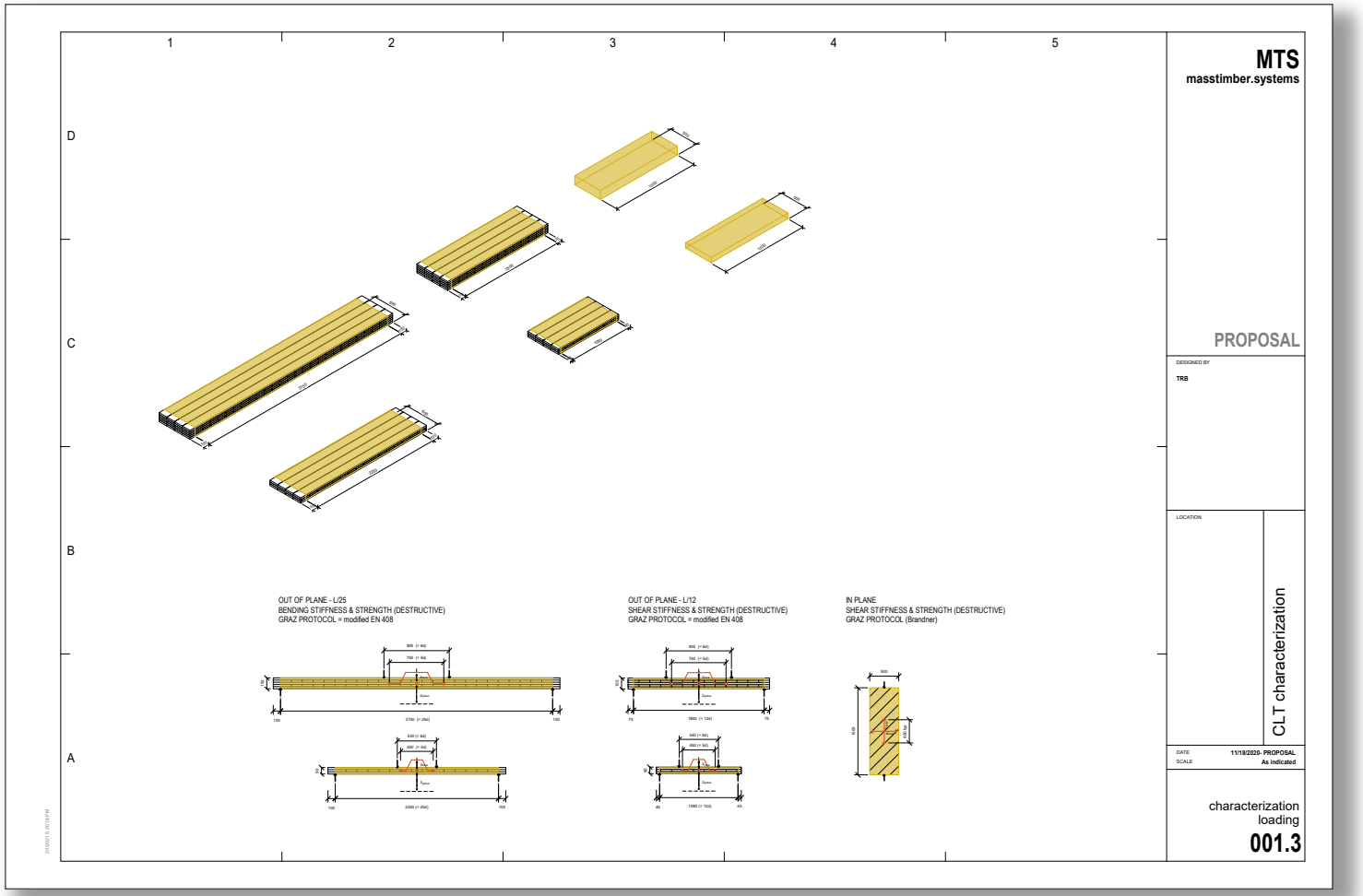
ASD Design Values[(a)] for Laminations Used in CLT and GLT

Allowable Design Properties for Laminations Used in CLT

LAM Grade	Laminations Used in Major and Minor Strength Directions (minimum properties allowed)			
	E (10^6 psi)	f_t (psi)	f_b (psi)	f_c (psi)
2.1E-2050T	2.10	2050	2550	2037
2.1E-1575T	2.10	1575	2100	1869
2.0E-1925T	2.00	1925	2400	1981
1.9E-1750T	1.90	1750	2250	1925
1.8E-1575T	1.80	1575	2100	1869
1.8E-1375T	1.80	1375	1950	1813
1.8E-1020T	1.80	1020	1650	1701
1.5E-1575T	1.50	1575	2100	1869
1.5E-1375T	1.50	1375	1950	1813
1.5E-1020T	1.50	1020	1650	1701
1.5E-0750T	1.50	750	1250	1552
1.5E-0500T	1.50	500	900	1421
1.2E-1375T	1.20	1375	1950	1813
1.2E-1020T	1.20	1020	1650	1701
1.2E-0750T	1.20	750	1250	1552
1.2E-0500T	1.20	500	900	1421
1.2E-0350T	1.20	350	750	1365
0.9E-0750T	0.90	750	1250	1552
0.9E-0500T	0.90	500	900	1421
0.9E-0350T	0.90	350	750	1365

SG	$f_{v,0,0.5}$ (psi)	$f_{c,90,0.5}$ (psi)
	$f_v = (266 \times SG) + 40$	$f_{c,90} = (232.4 \times SG) - 480$
	ASTM D6570-18a X1.1	**ASTM D6570-18a X1.2**
0.36	136	331
0.38	141	376
0.40	146	421
0.42	152	466
0.44	157	511
0.46	162	556
0.48	168	601
0.50	173	646
0.52	178	691
0.54	184	736
0.56	189	781
0.58	194	826


MOE [mean, measured] (flatwise)
'E' indicates electronically-graded lamstock (flatwise).
lamstock certifying agency
mill number
1.8E-1575T
30x140 DF
1216
1.8E LAM-6
MC12 0.52 SG 1575 Ft 2100 Fb
section (mm) and species
E-rated lamstock grade per ASTM D6570-18a
Bending Strength [0.05] (psi)
Tension Strength [0.05] (psi)
Specific Gravity [mean]
Moisture Content [mean] (%)



CLT characterization

out-of-plane BENDING strength and stiffness

out-of-plane SHEAR strength and stiffness

in-plane SHEAR strength and stiffness

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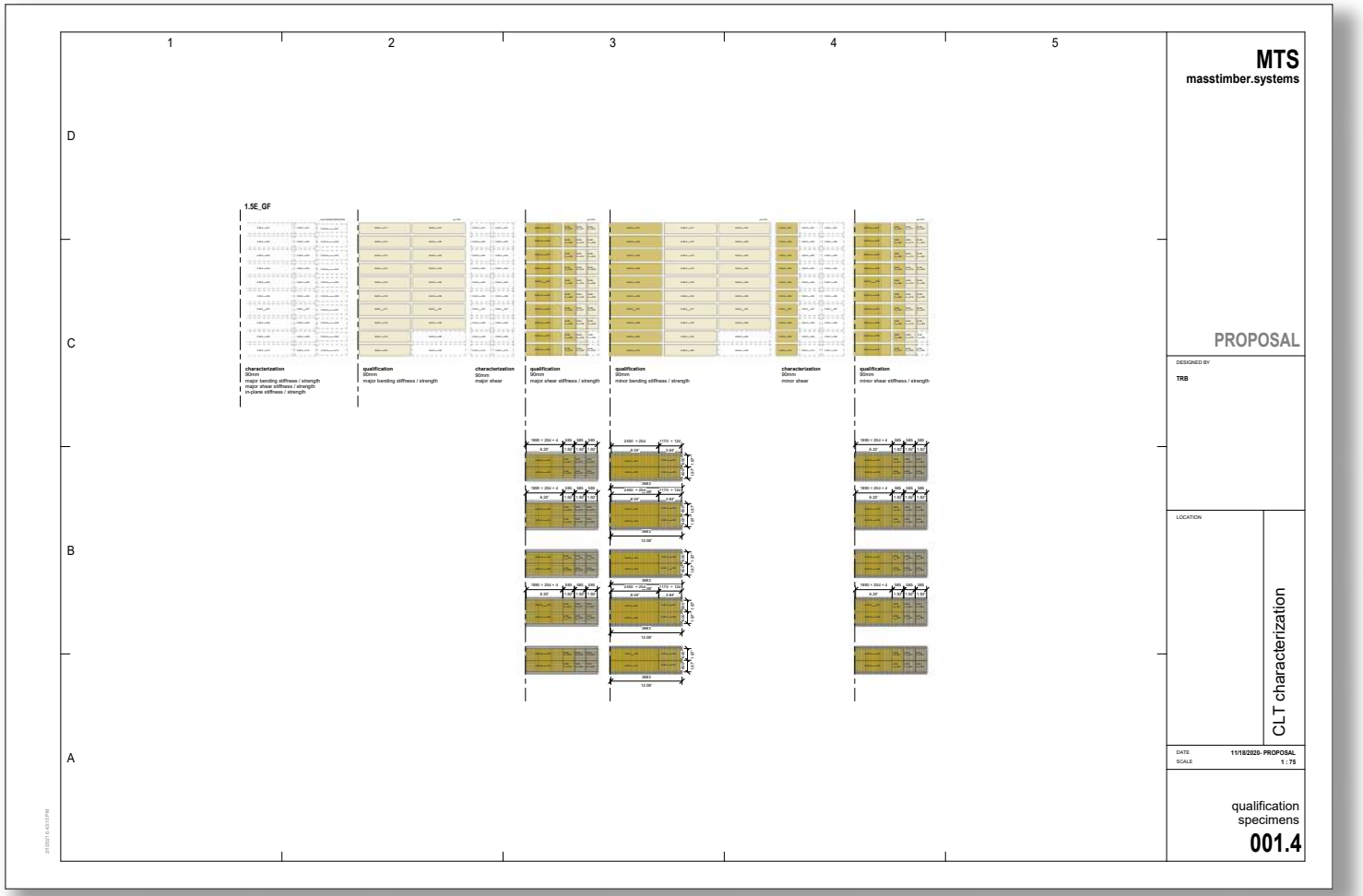


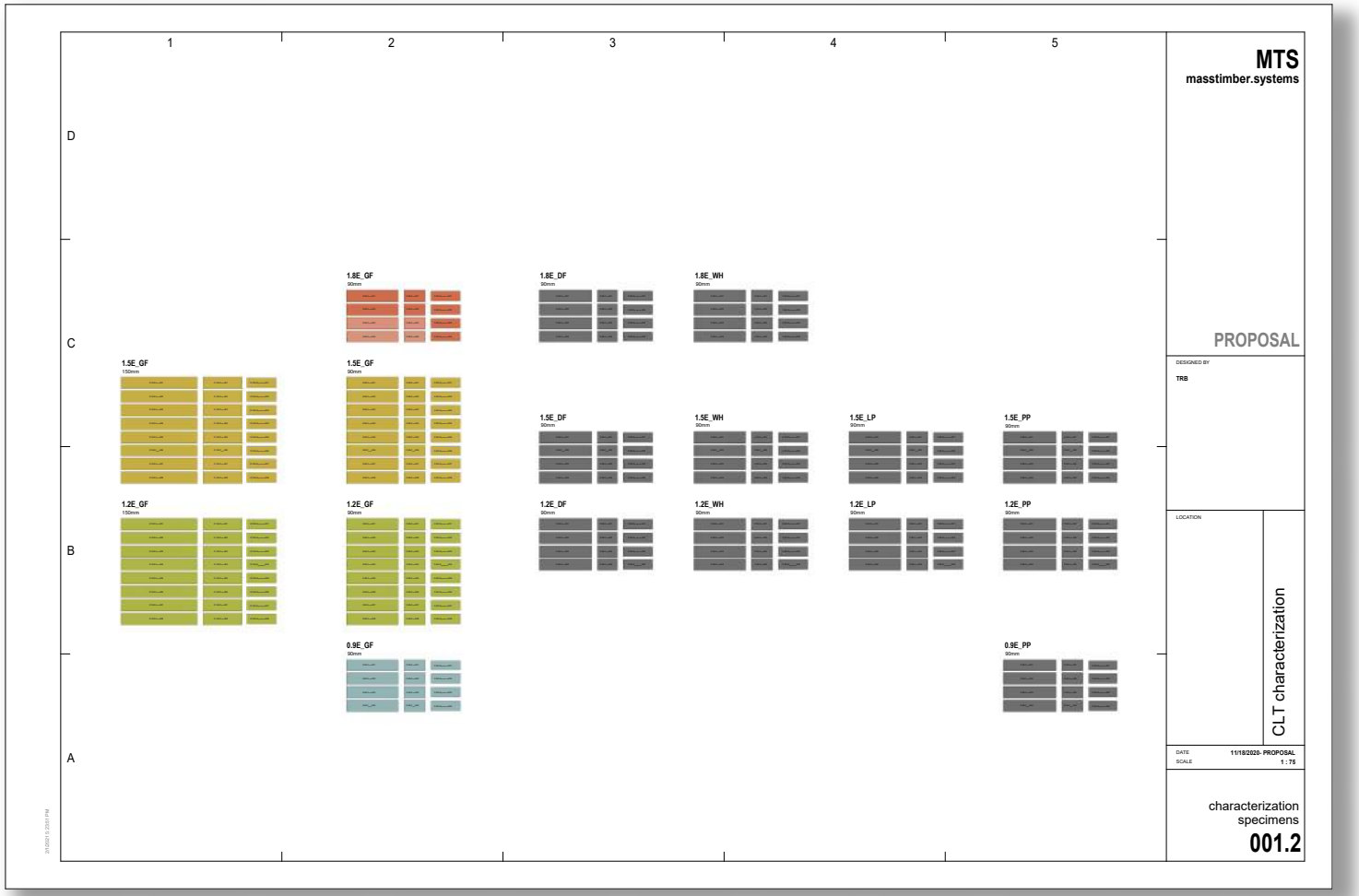
CLT characterization

out-of-plane BENDING strength and stiffness

out-of-plane SHEAR strength and stiffness

in-plane SHEAR strength and stiffness

WASHINGTON STATE UNIVERSITY



CLT characterization

out-of-plane BENDING strength and stiffness

out-of-plane SHEAR strength and stiffness

in-plane SHEAR strength and stiffness

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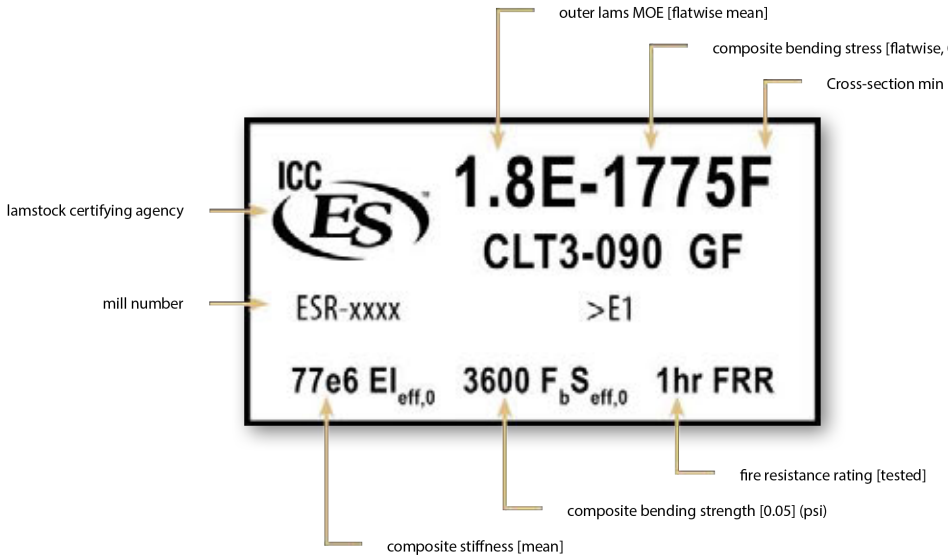
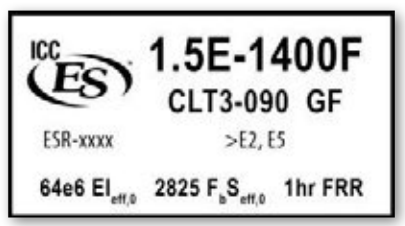
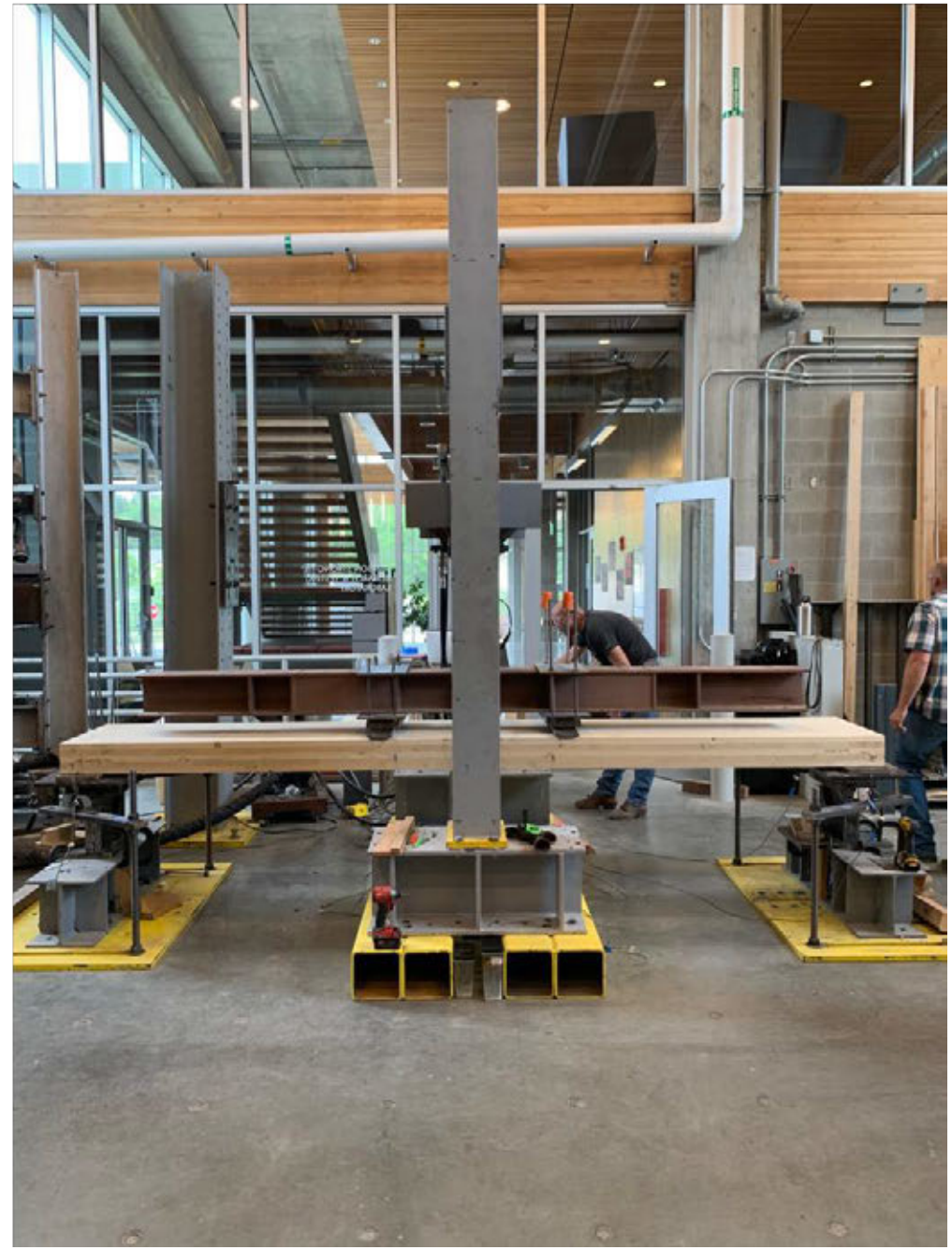
1.6 CLT strength and stiffness certifications



Like lamstock, stiffness and strength classes can be established for composite sections of CLT and GLT. This normalization is similar to prescriptive glulam grades in published standards and allows normalization of material performance parameters. Design values for each section and species combinations are clearly noted at the bottom of the grade stamp. The complexity of the multiple agency and standards pathways is captured in the overarching ICC-ES product report.



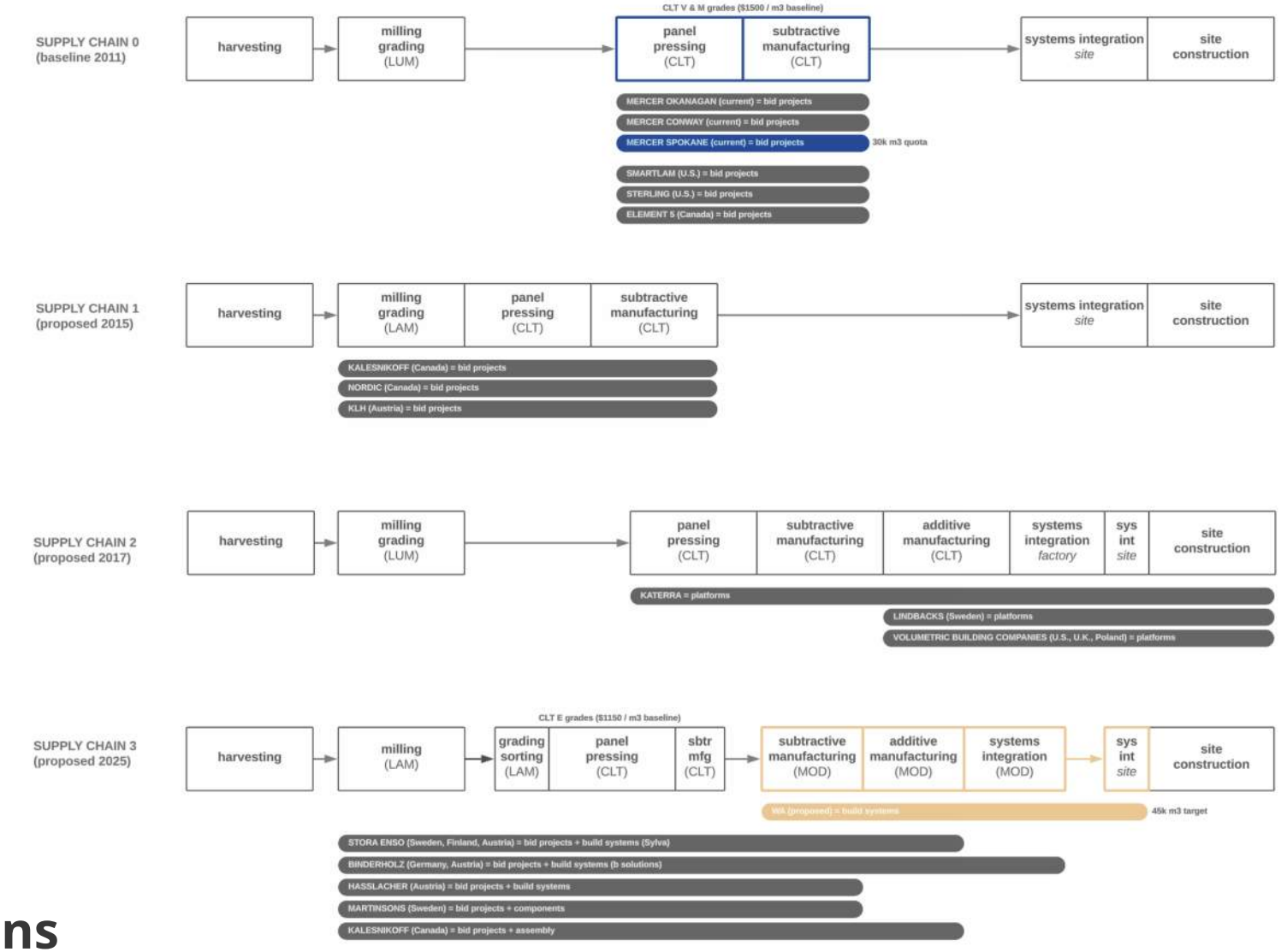


Technoeconomics of **value chains**

Strategic Intent: Add CLT production dedicated to modular.

1. Existing CLT production serves BID project growth
2. New CLT production serves MOD project growth

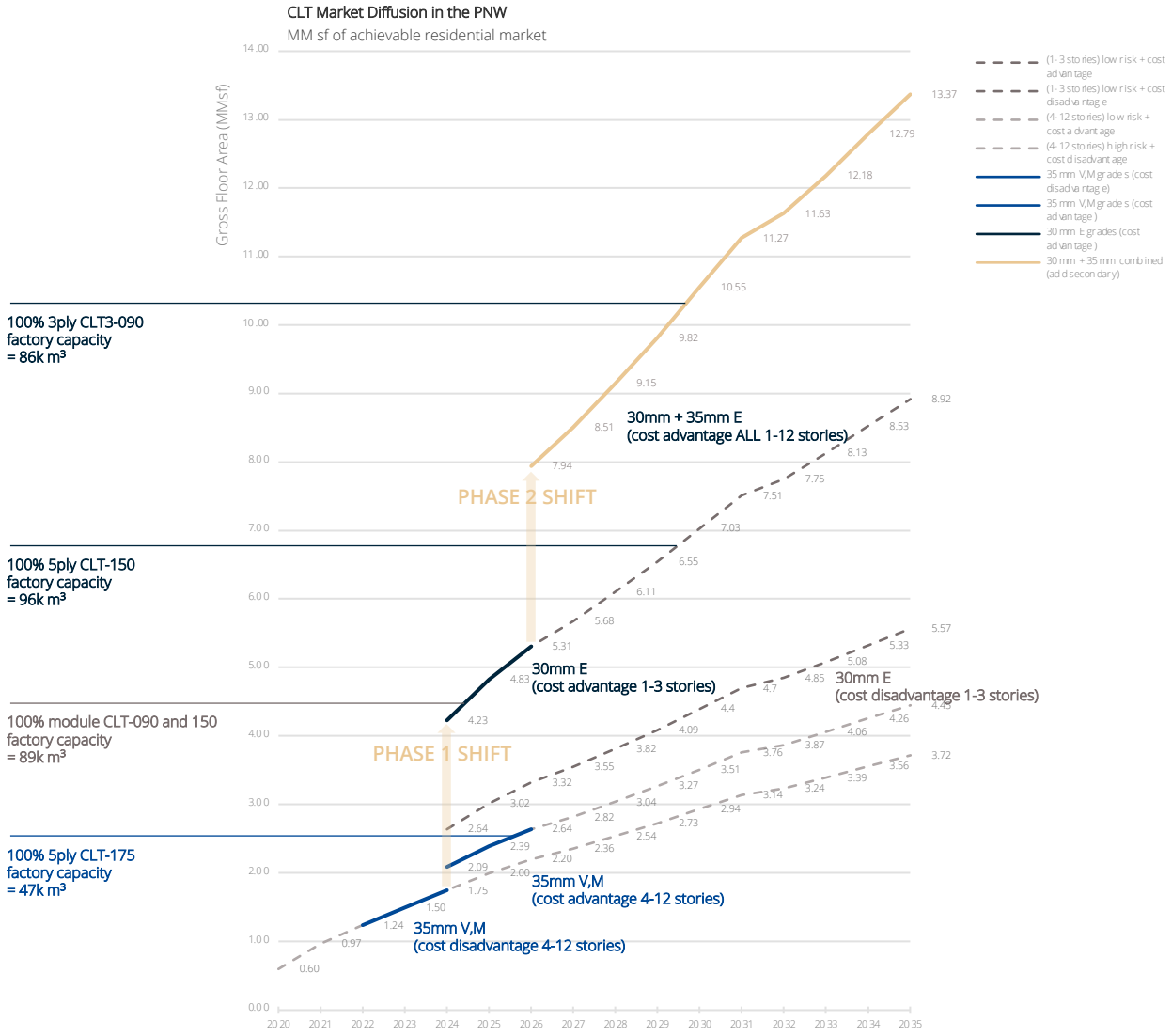
Key Takeaway: Modular (MOD) projects are a market expansion strategy to complement existing design-bid-build (BID) projects.



Strategic Intent: Increase CLT production from ~25k m^3 to ~75k m^3.

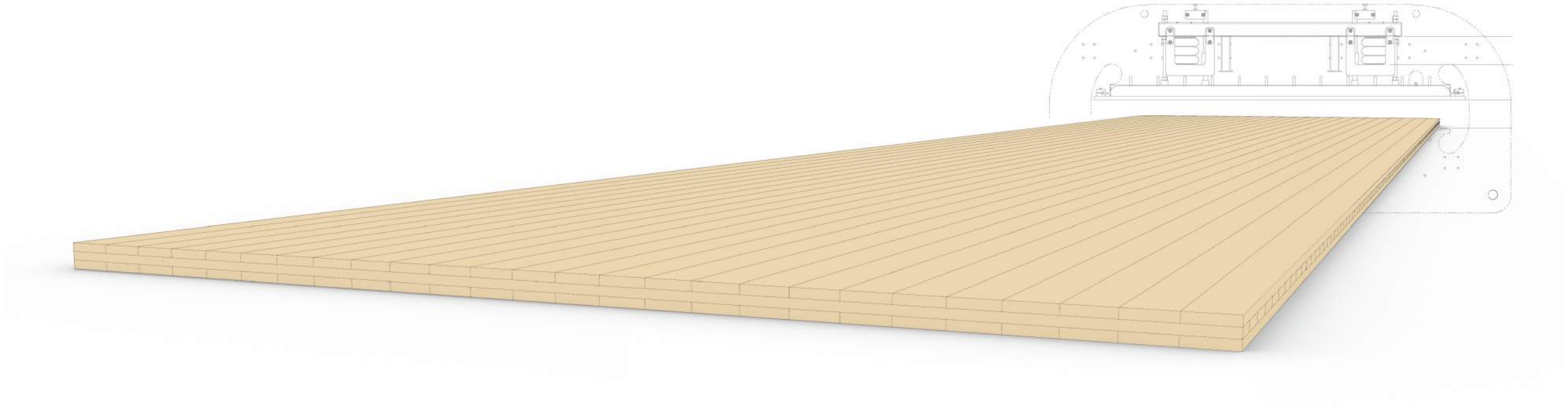
1. PHASE 1 SHIFT (2025) capitalizes existing primary manufacturing assets
2. PHASE 2 SHIFT (2026) capitalizes proposed secondary manufacturing assets

- PNW market diffusion models by Beyreuther, Ganguly 2016-2020 model



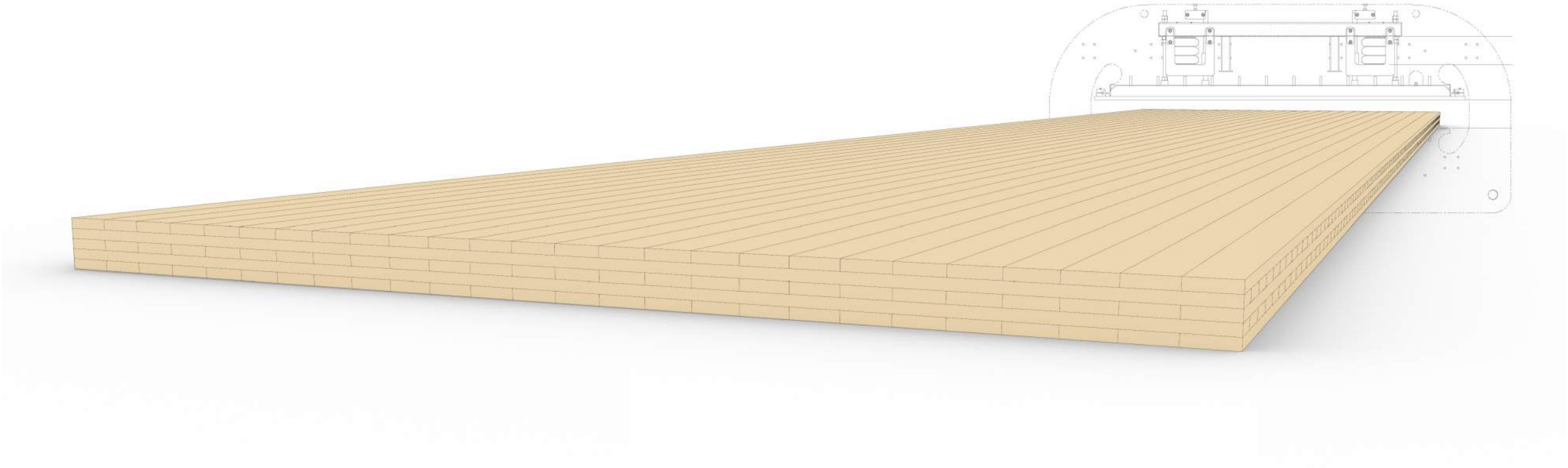
Technoeconomics of **scale**

Key Takeaway: MOD projects on 30mm basis complement BID projects on 35mm basis.



Technoeconomics of **manufacture**

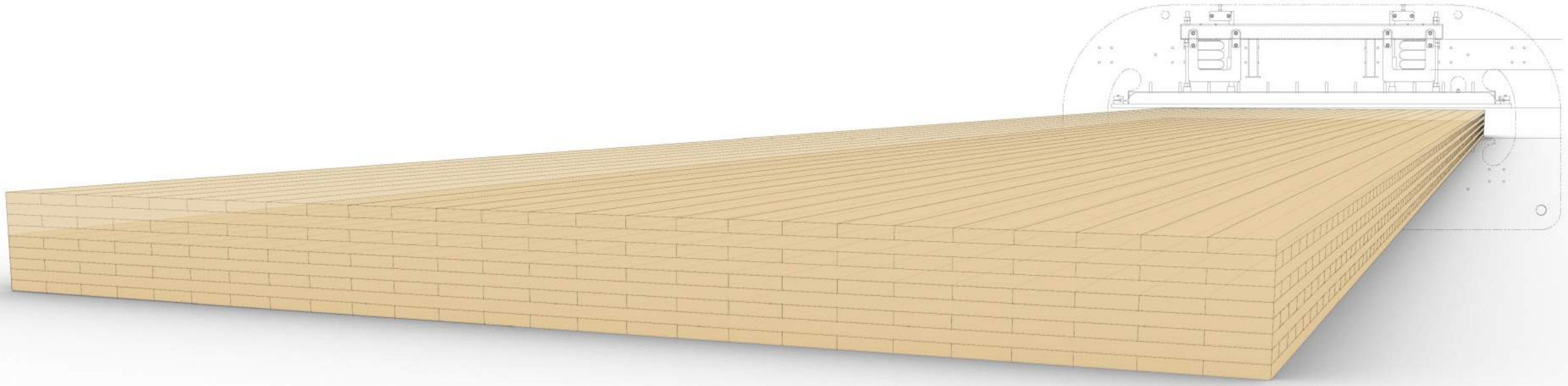
Strategic Intent: Increase utilization in CLT production processes



Technoeconomics of **manufacture**

Strategic Intent: Increase utilization in CLT production processes

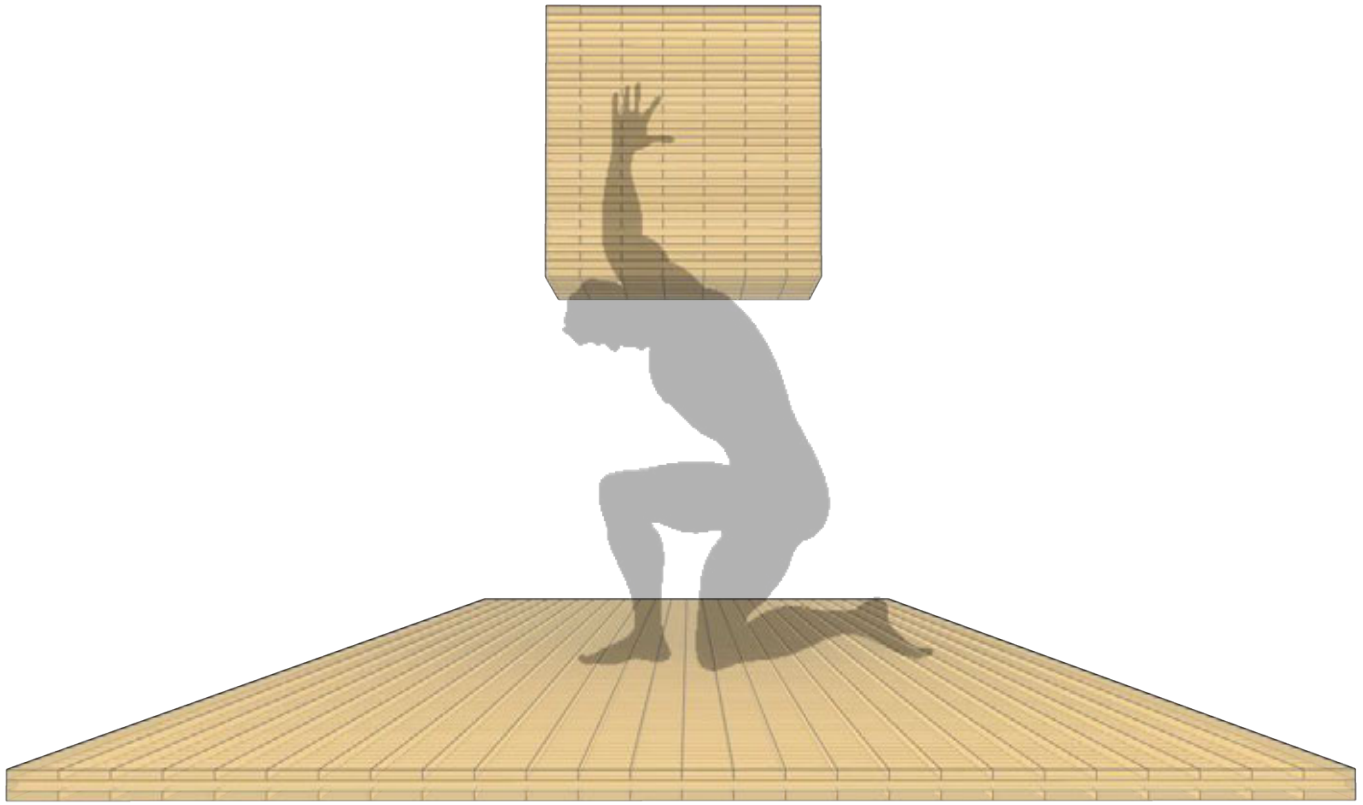

DANGE



Technoeconomics of **manufacture**

Strategic Intent: Increase utilization in CLT production processes

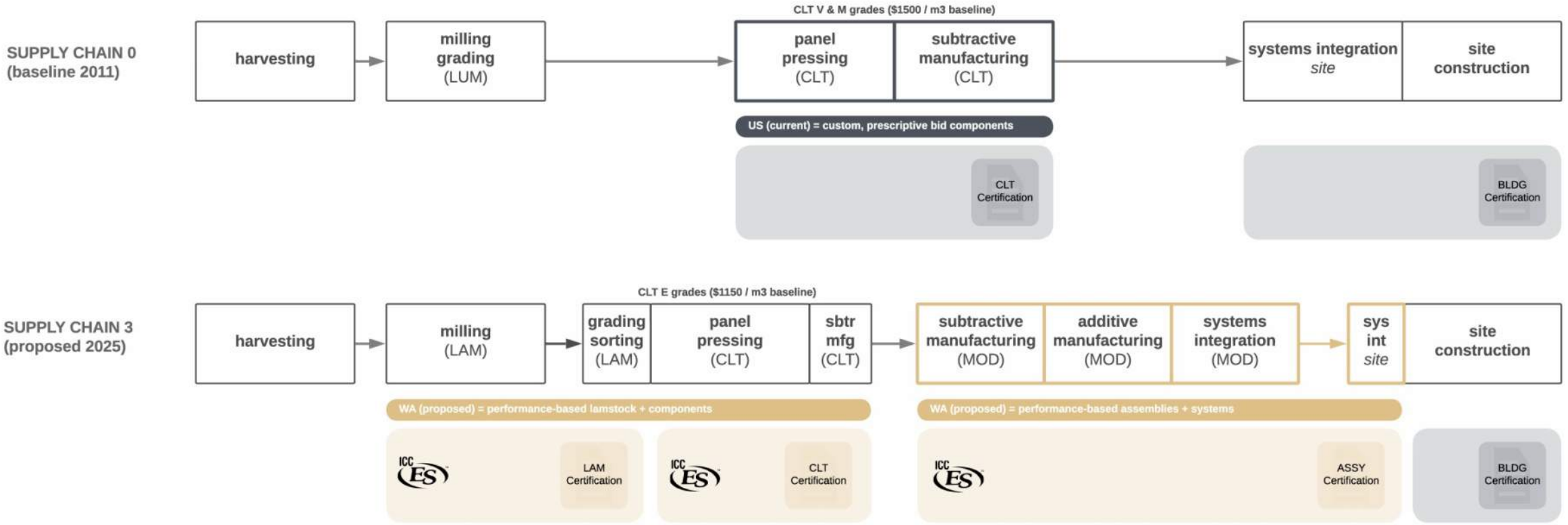
1m x 1m x 1m = (1) timber**blok**



(1) 18.3m x 3.6m x CLT3_090mm billet approximately = (6) timber**bloks**

Technoeconomics of **manufacture**

Strategic Intent: Increase utilization in CLT production processes



Key Takeaway: Modular (MOD) projects are a market expansion strategy to complement existing design-bid-build (BID) projects.

POST and BEAM

GLT columns, beams, purlins

CLT one-way floor plates

POST and BEAM

GLT columns, beams, purlins

CLT one-way floor composite ribbed plates

POST and BEAM

GLT columns, beams, purlins

CLT one-way floor plates

BEARING WALL

CLT walls

CLT floor plates

POST and PANEL

GLT columns

CLT floor plates (two-way)

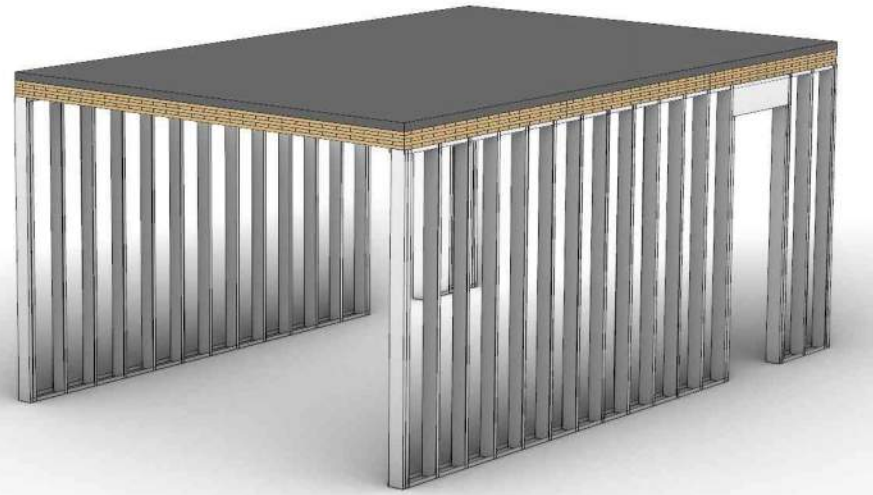
CFS non-structural infill

POST and BEAM

STEEL columns, beams

CLT floor plates

CFS non-structural infill



BEARING WALL

CFS structural walls

CLT floor plates

POST and BEAM

GLT columns, beams

CLT floor plates

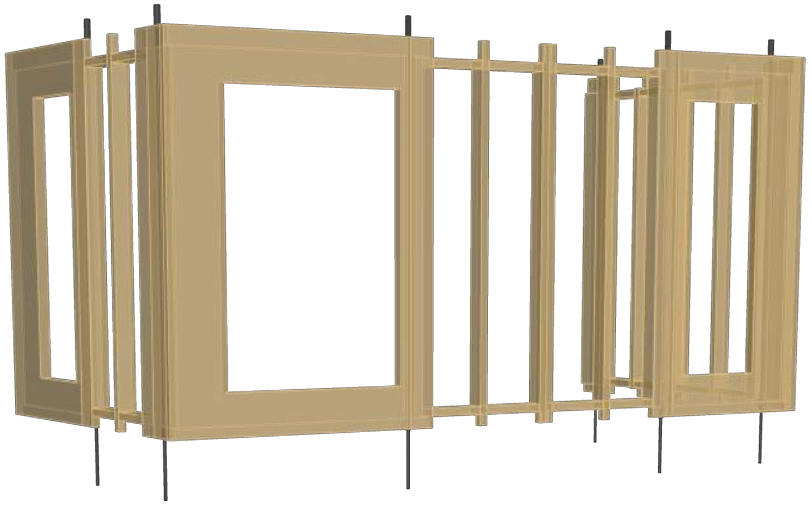
CFS non-structural infill

MOD ASSEMBLIES

CLT floor plates

CLT framing components

CLT non-structural infill



MOD ASSEMBLIES

CLT floor plates

CLT framing components

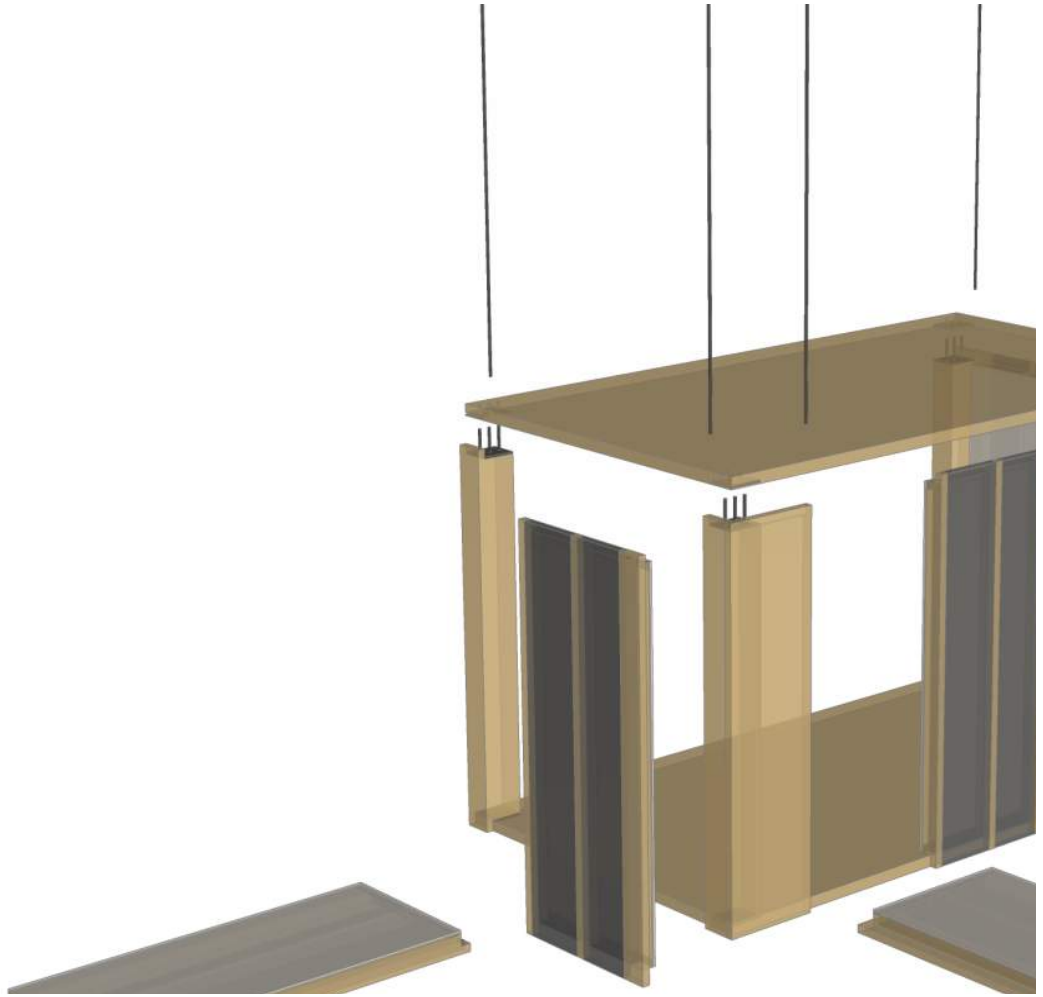
CLT non-structural infill

MOD ASSEMBLIES

CLT floor plates

CLT framing components

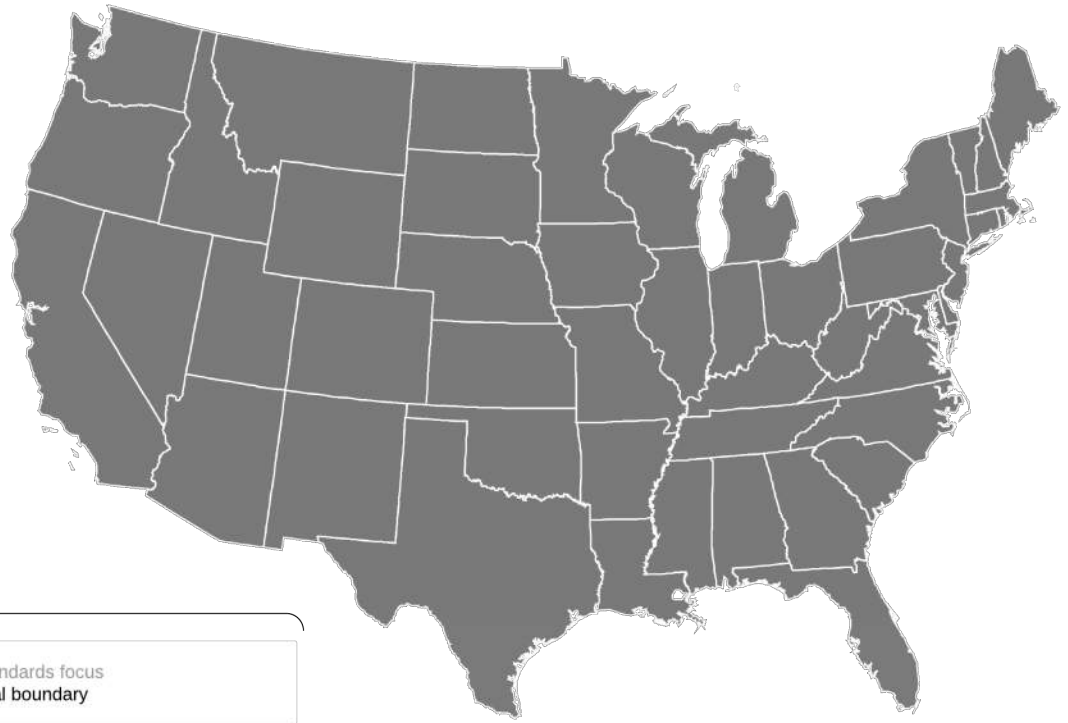
CLT non-structural infill



WA
local ecologies and economies focus
state political boundary

WA, OR, ID, MT
supply chain focus
regional resource boundary

WA, OR, CA, (BC)
market focus
regional policy boundary

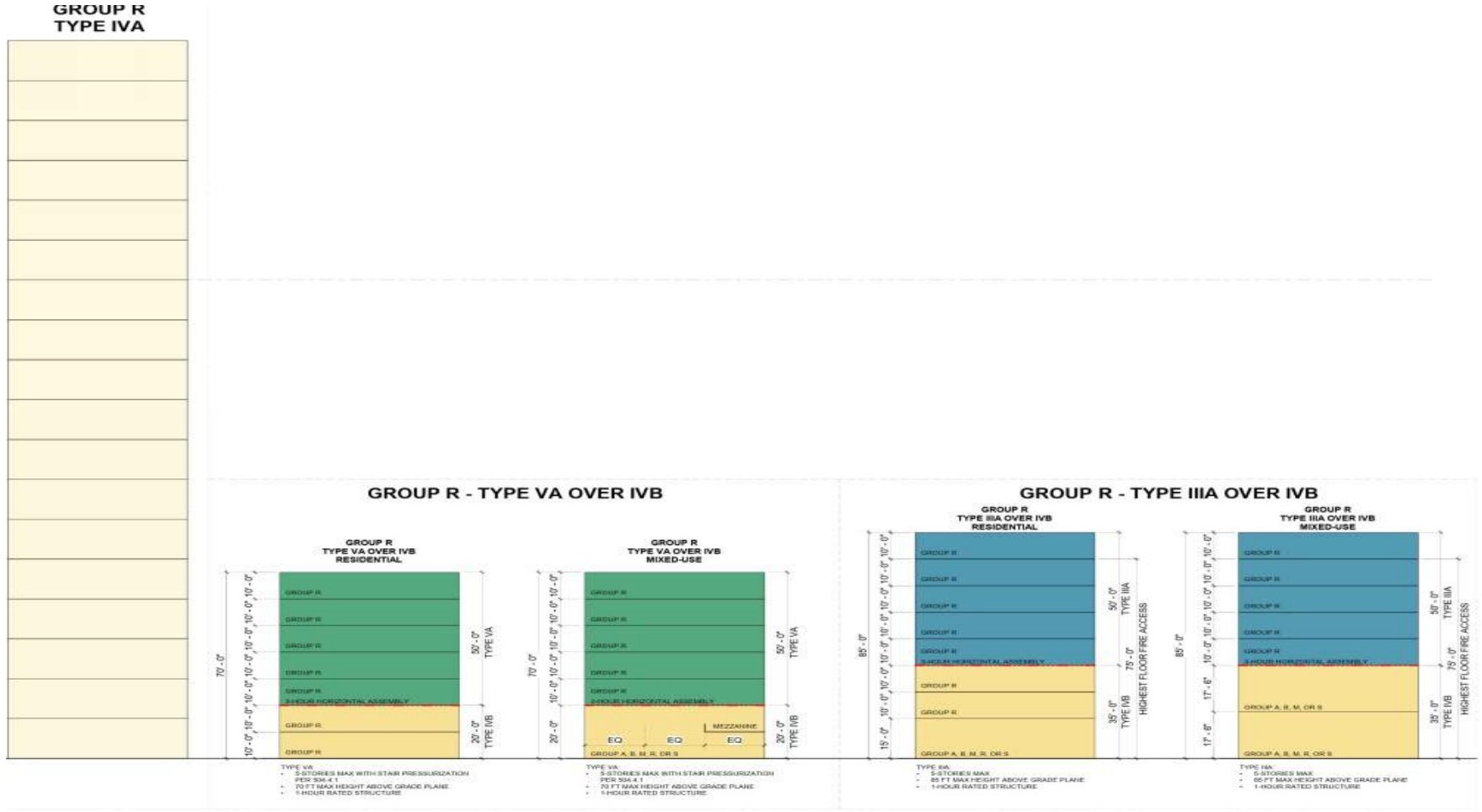


US
codes and standards focus
federal political boundary

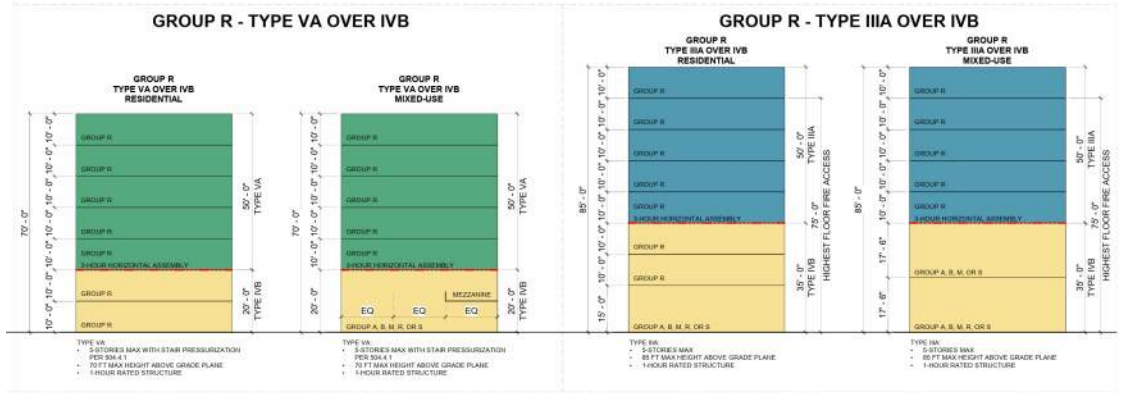
Technoeconomics of **regions**

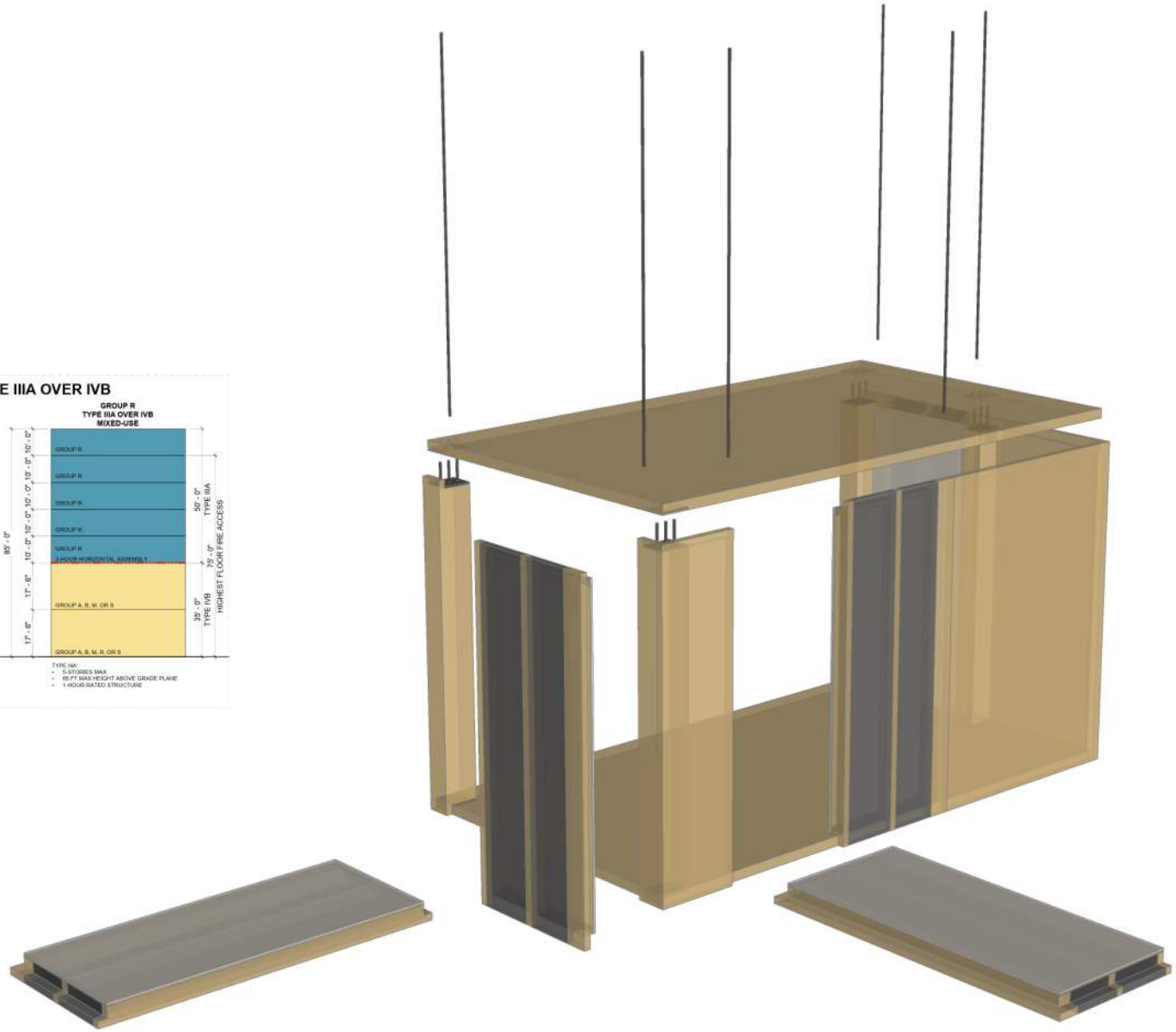
Strategic Intent: drive codes and policy at regional scales

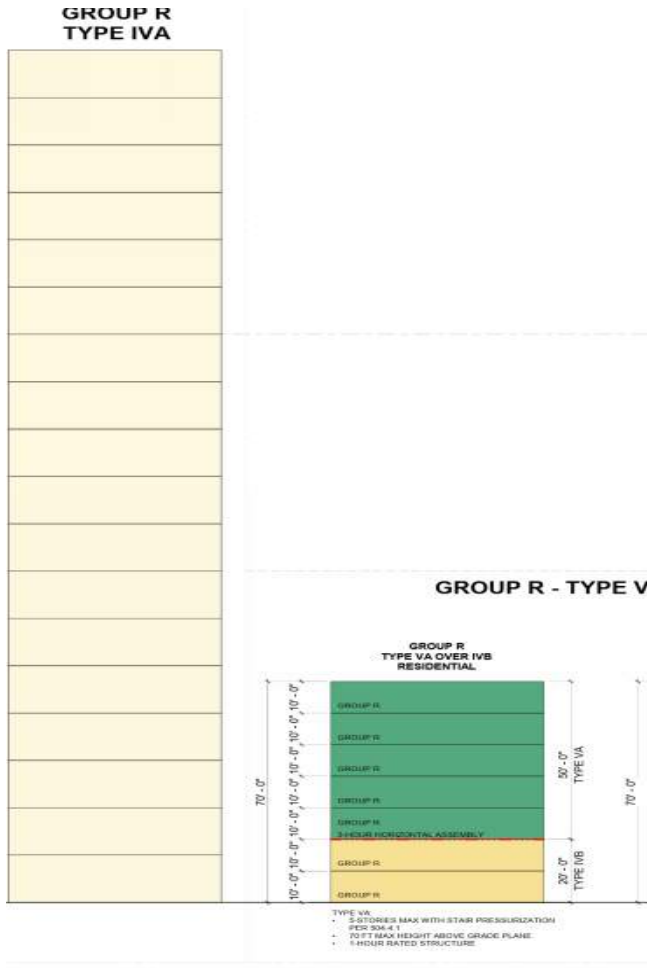
Mass Timber Code and Policy Development

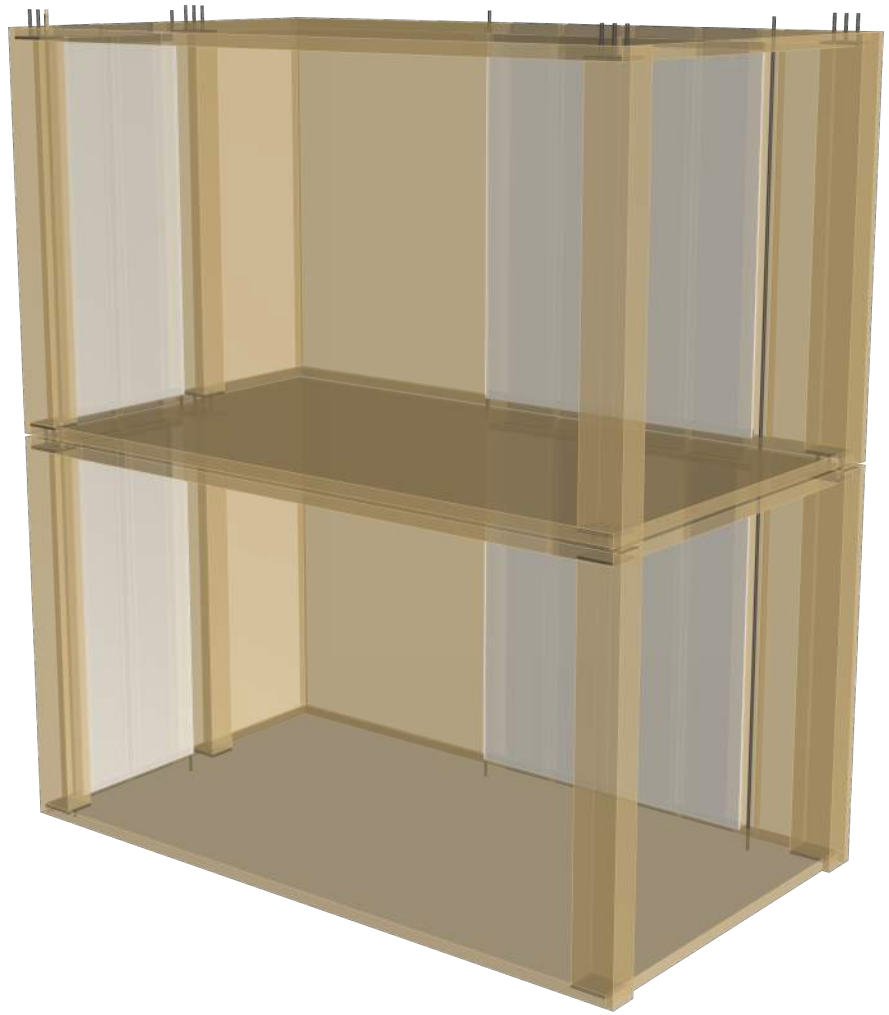


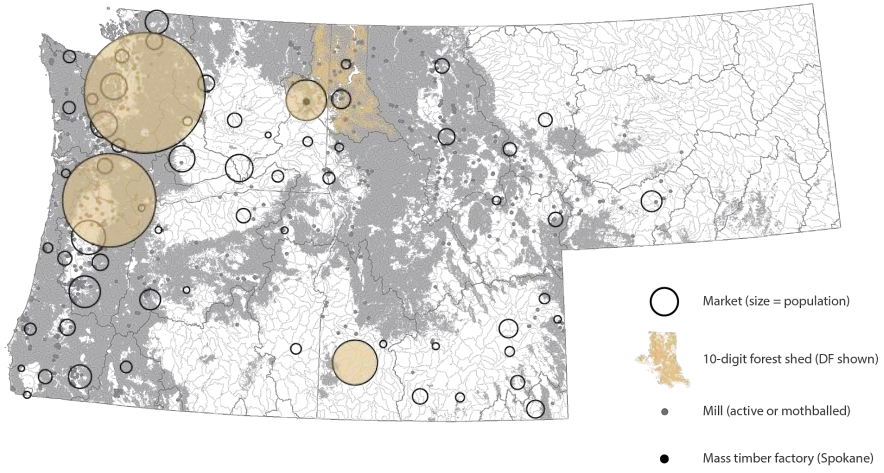
LAM – CLT – MOD

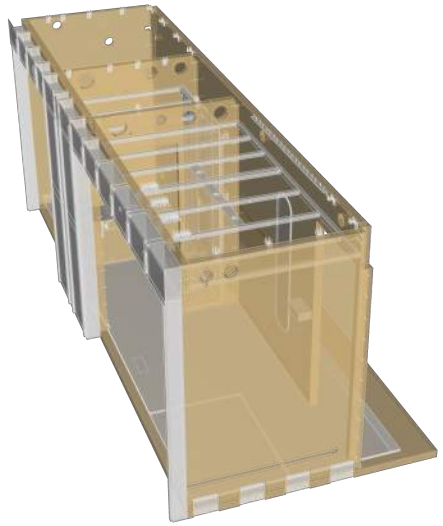

GROUP R - TYPE VA OVER IVB
GROUP R
TYPE VA OVER IVB
RESIDENTIAL
GROUP R
TYPE VA OVER IVB
MIXED-USE
GROUP R
3-HOUR HORIZONTAL ASSEMBLY
MEZZANINE
EQ
EQ
EQ
50' - 0"
TYPE VA
20' - 0"
TYPE IVB
GROUP R - TYPE IIIA OVER IVB
GROUP R
TYPE IIIA OVER IVB
RESIDENTIAL
GROUP R
TYPE IIIA OVER IVB
MIXED-USE
50' - 0"
TYPE IIIA
35' - 0"
TYPE IVB
75' - 0"
HIGHEST FLOOR FIRE ACCESS

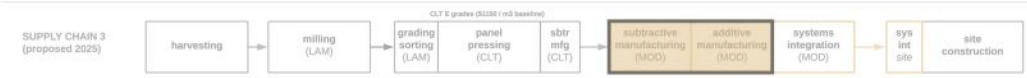



GROUP R
TYPE IVA
GROUP R - TYPE V
GROUP R
TYPE VA OVER IVB
RESIDENTIAL
GROUP R
GROUP R
GROUP R
GROUP R
GROUP R
3-HOUR HORIZONTAL ASSEMBLY
GROUP R
GROUP R
70' - 0"
10' - 0"
10' - 0"
10' - 0"
10' - 0"
10' - 0"
10' - 0"
10' - 0"
10' - 0"
50' - 0"
TYPE VA
20' - 0"
TYPE IVB
70' - 0"
TYPE VA
5-STORIES MAX WITH STAIR PRESSURIZATION
PER 504.4.1
70'-T MAX HEIGHT ABOVE GRADE PLANE
1-HOUR RATED STRUCTURE




Market (size = population)
10-digit forest shed (DF shown)
Mill (active or mothballed)
Mass timber factory (Spokane)




SUPPLY CHAIN 3
(proposed 2025)
harvesting
milling
(LAM)
grading
sorting
(LAM)
panel
pressing
(CLT)
sbtr
mfg
(CLT)
subtractive
manufacturing
(MOD)
additive
manufacturing
(MOD)
systems
integration
(MOD)
sys
int
site
site
construction


SUPPLY CHAIN 3
(proposed 2025)
harvesting
milling
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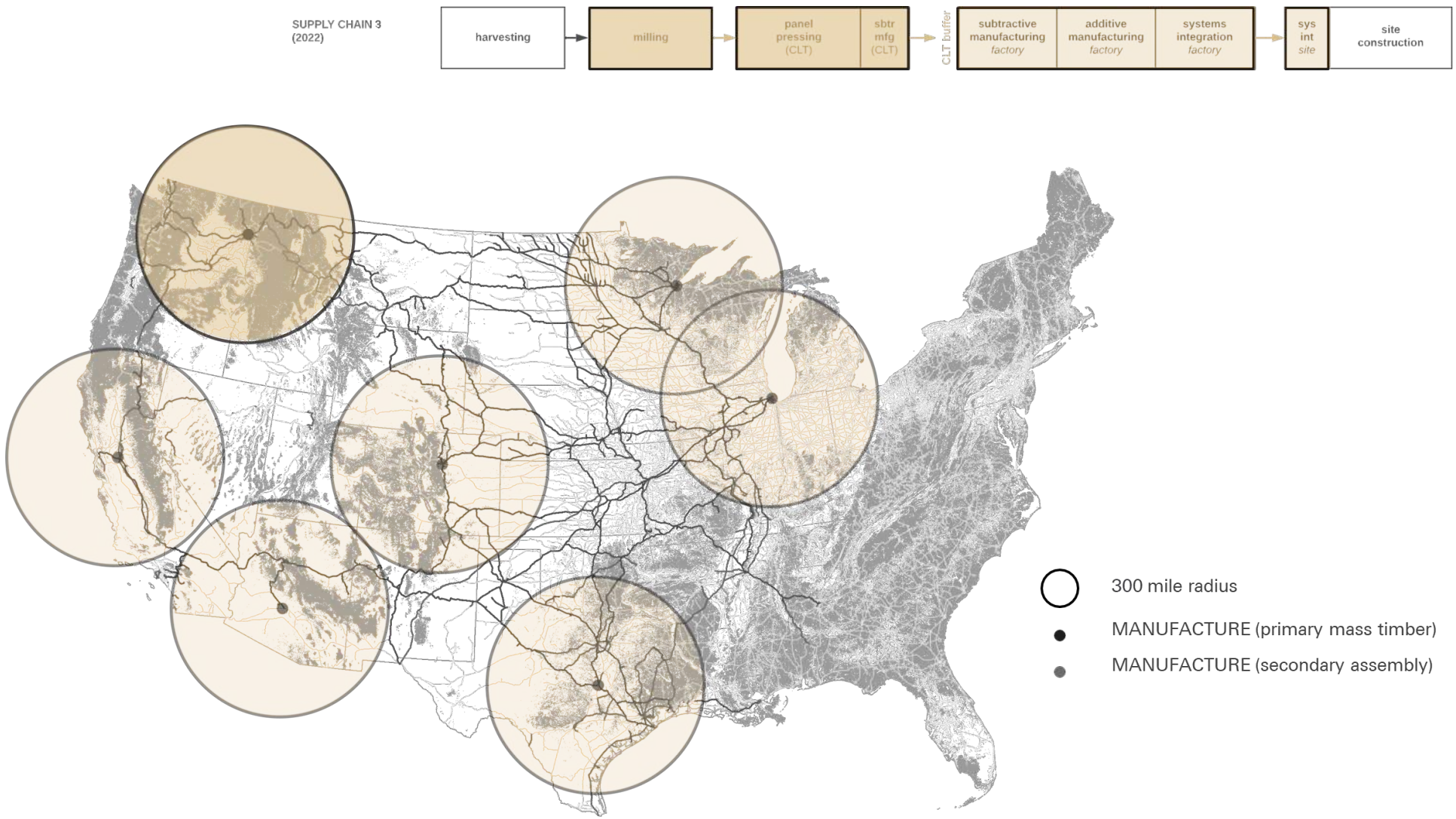
(MOD)
additive
manufacturing
(MOD)
systems
integration
(MOD)
sys
int
site
site
construction

Technoeconomics of **manufacture**

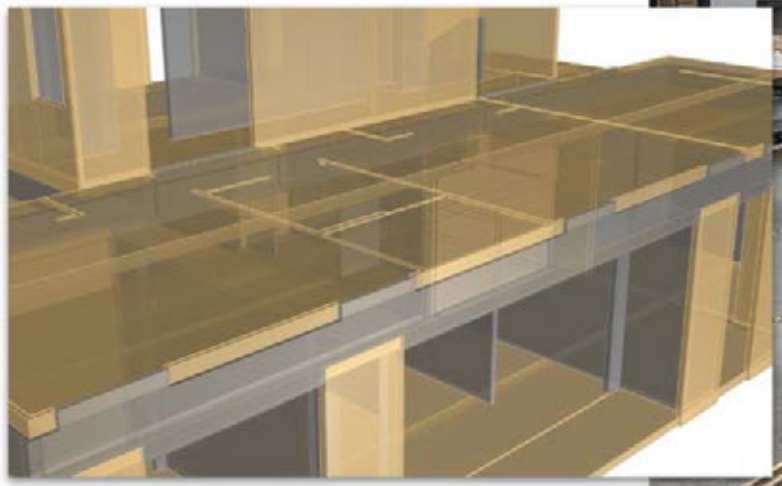


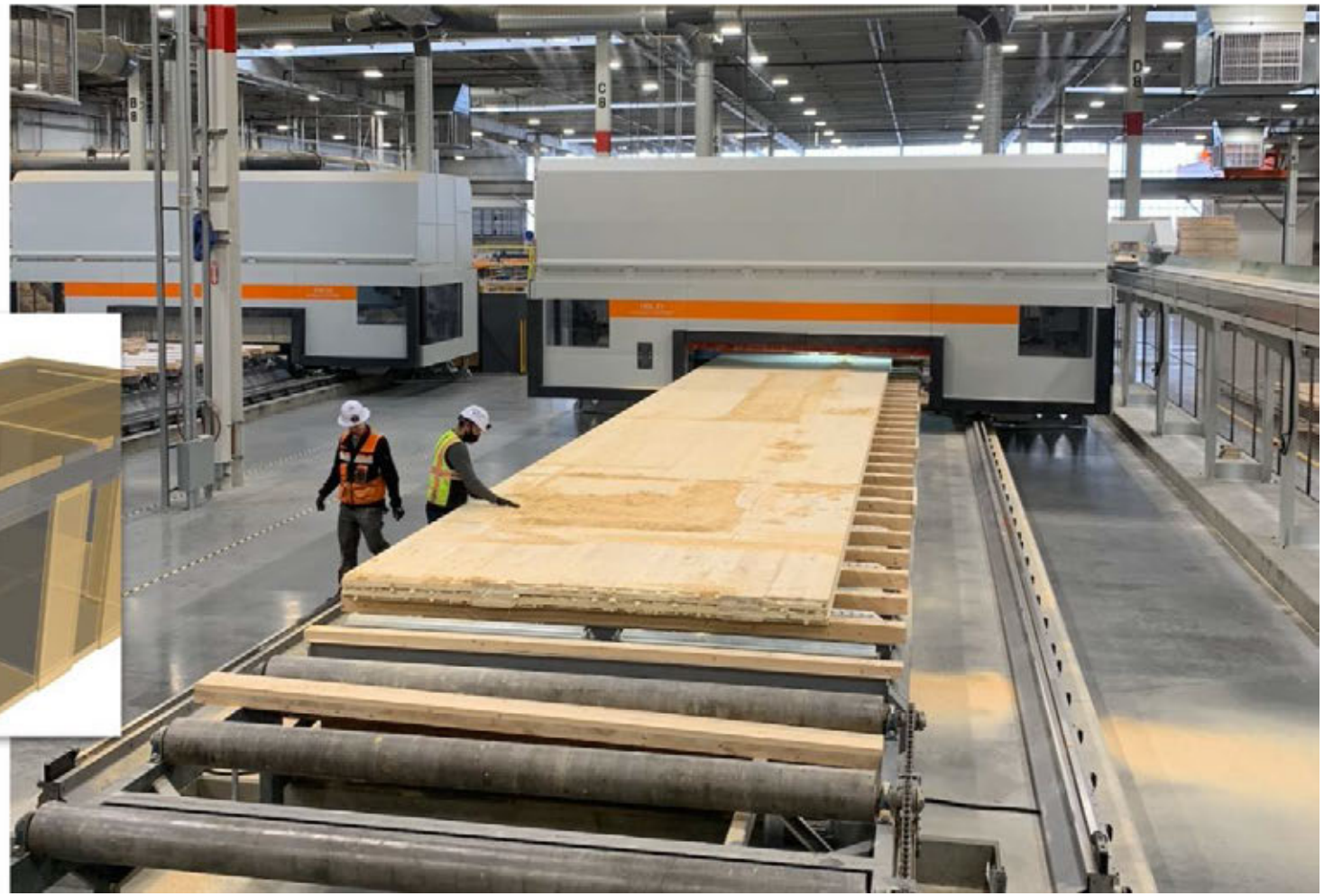
Technoeconomics of **manufacture**

'Boolean' methods

Tectonic detailing derived from linear scripting of processes.

(image: Beyreuther, 2022)





Technoeconomics of **manufacture**

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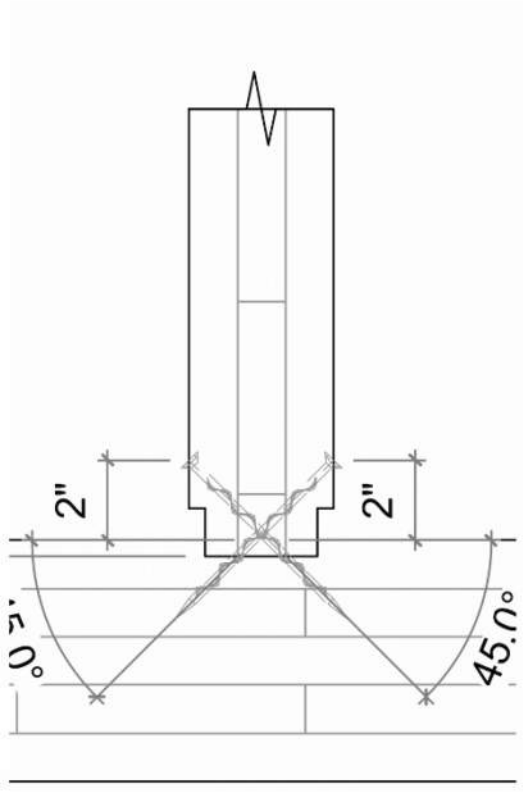
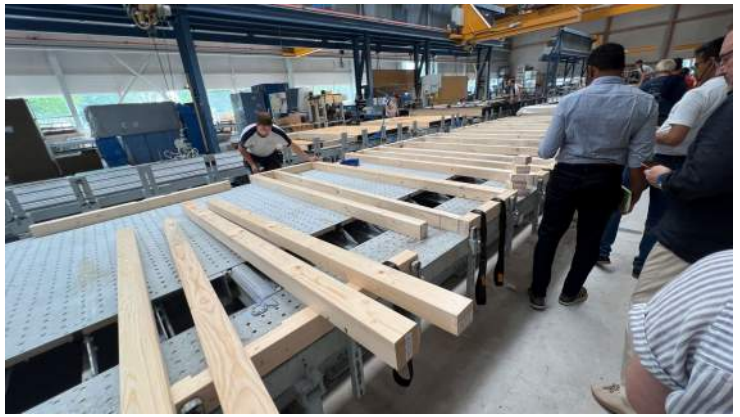


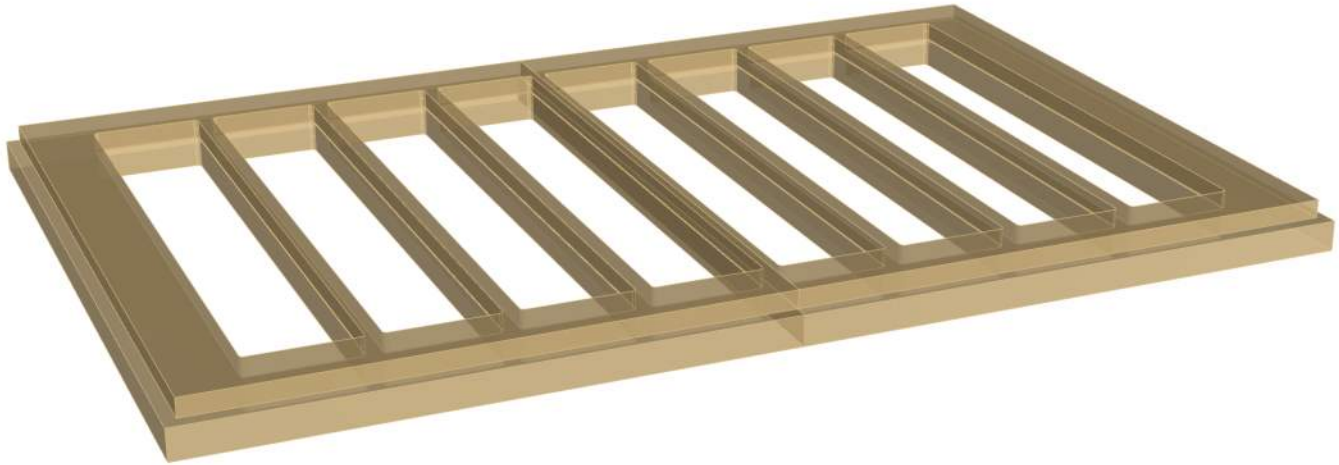
Technoeconomics of **manufacture**

MOD volumetric assemblies

MOD assemblies

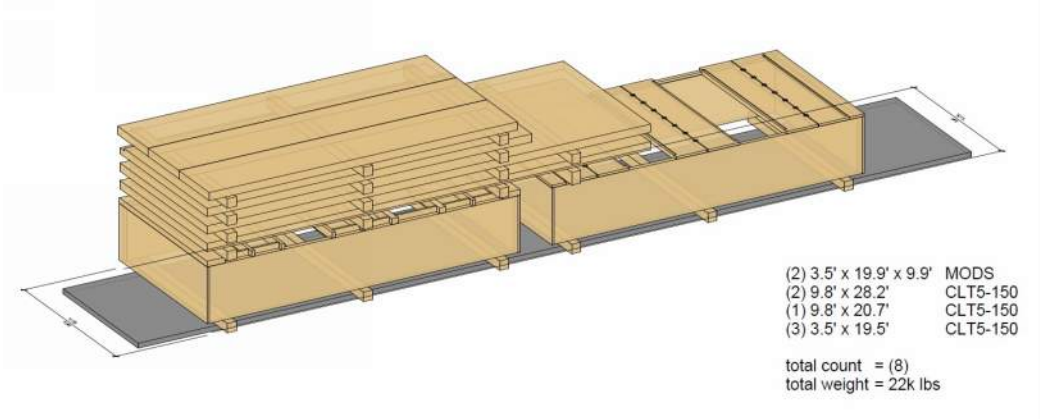
European precedents demonstrate durable assemblies and advanced manufacturing processes integrating ‘light’ mass timber components (Renggli AG, Schötz, Switzerland)





MOD hybrid framing

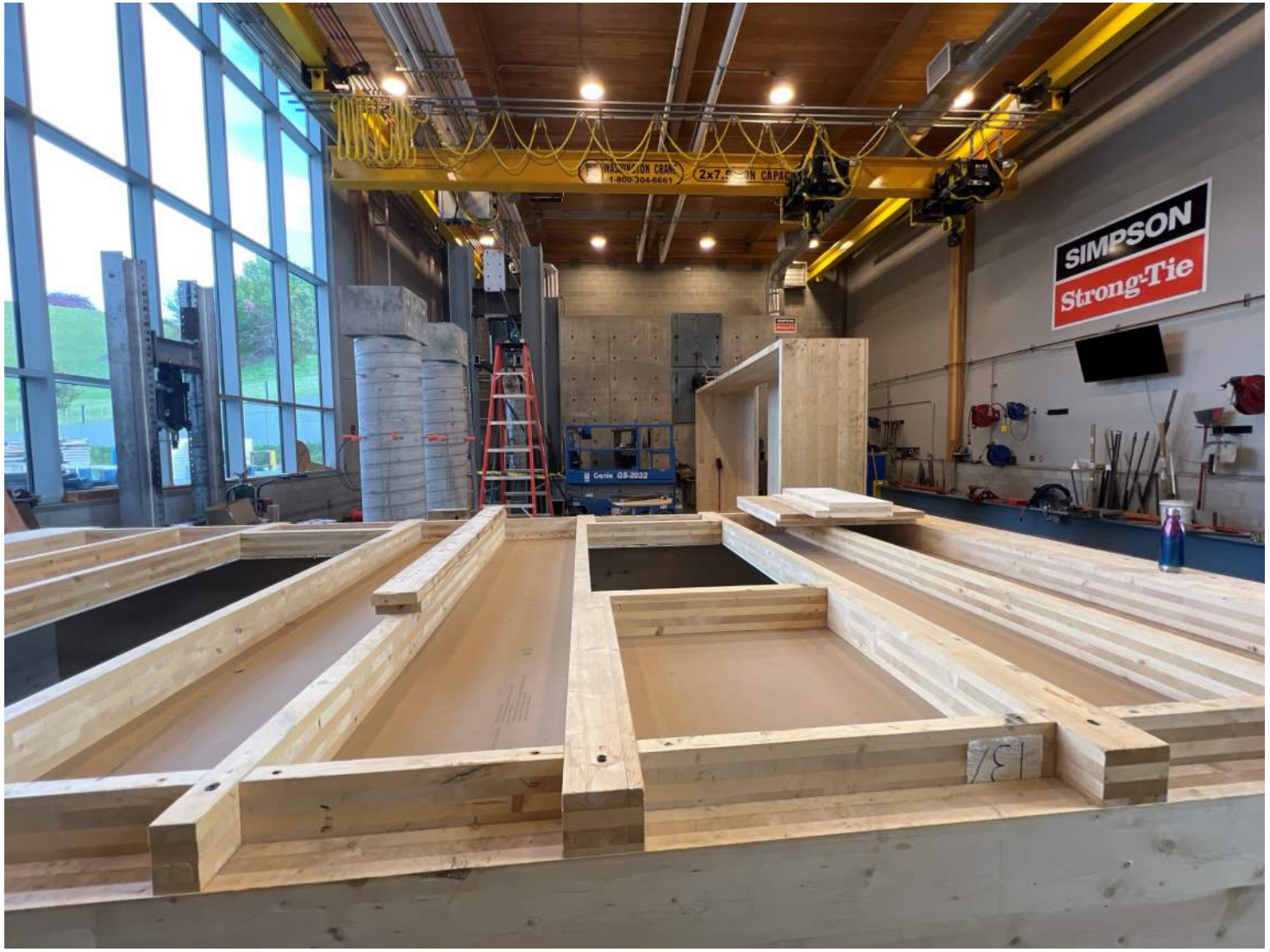
Targeting prefabrication assembly lines, MOD framing components with both cross-laminated timber (CLT) and glued-laminated timber (GLT) material offers custom solutions for assembly lines.

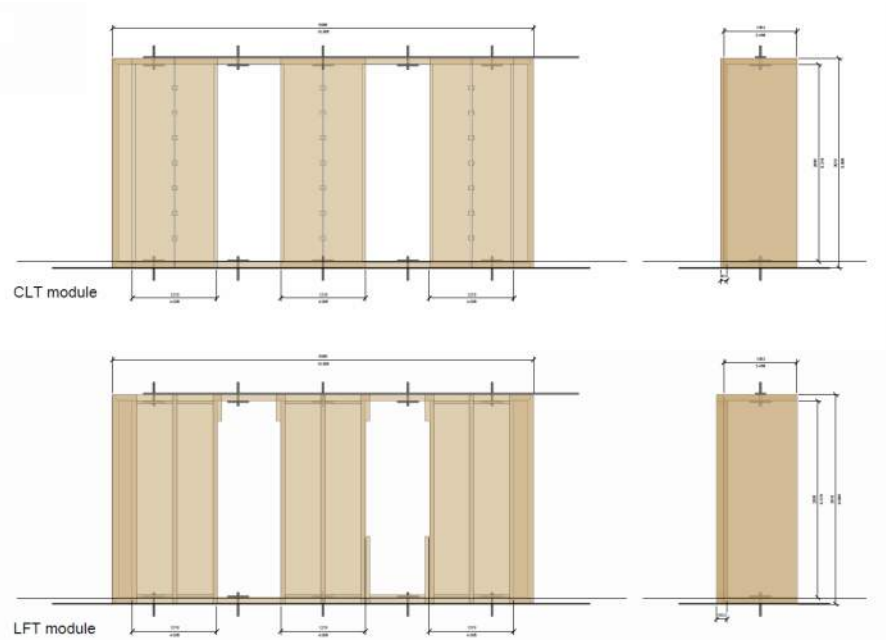


MOD hybrid framing

Targeting prefabrication assembly lines, MOD framing components with both cross-laminated timber (CLT) and glued-laminated timber (GLT) material offers custom solutions for assembly lines.

Grades:	1.2E, 1.5E
Layups:	CLT3-090, CLT5-150, GLT3-090, GLT5-150
Species:	DF, GF, WH, SPF





MOD hybrid framing

Grades:	1.2E, 1.5E
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MOD seismic detailing

Assemblies with mass timber components require new ways of detailing to demonstrate seismic equivalency with existing, mature systems (e.g. light wood frame).

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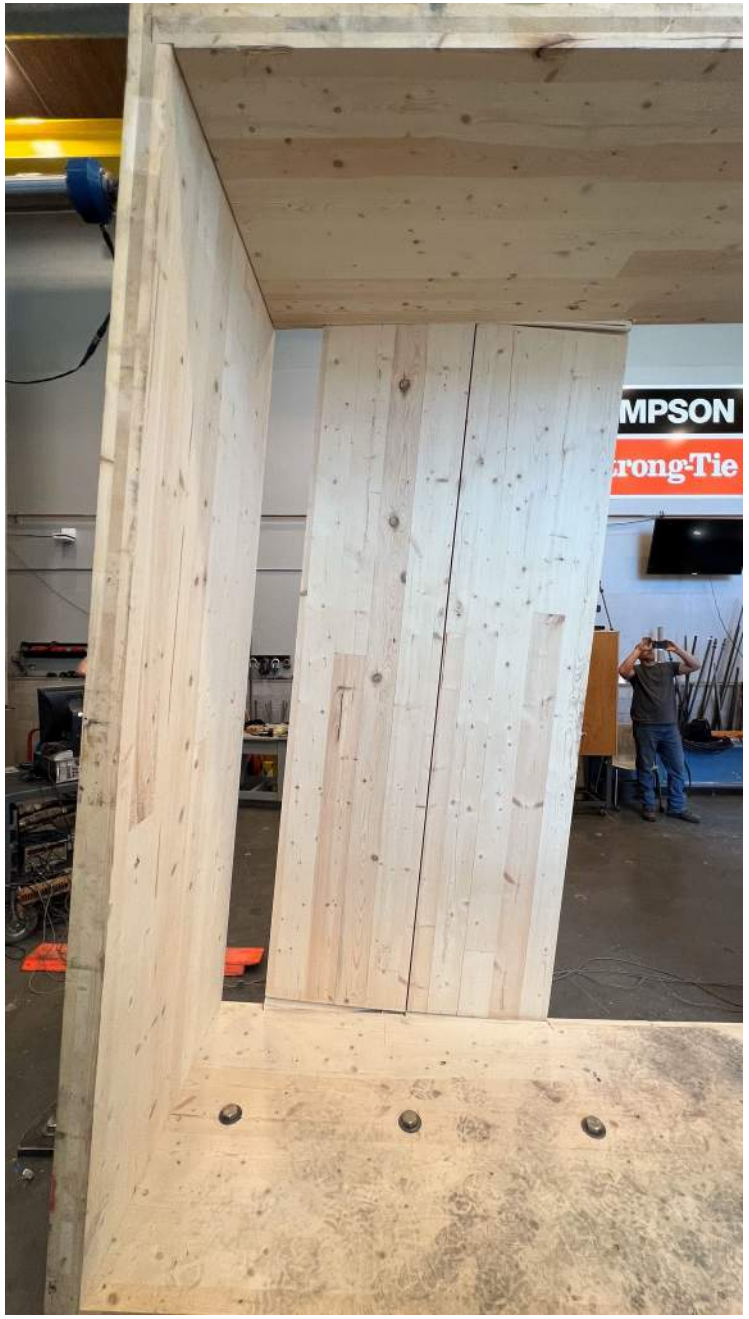

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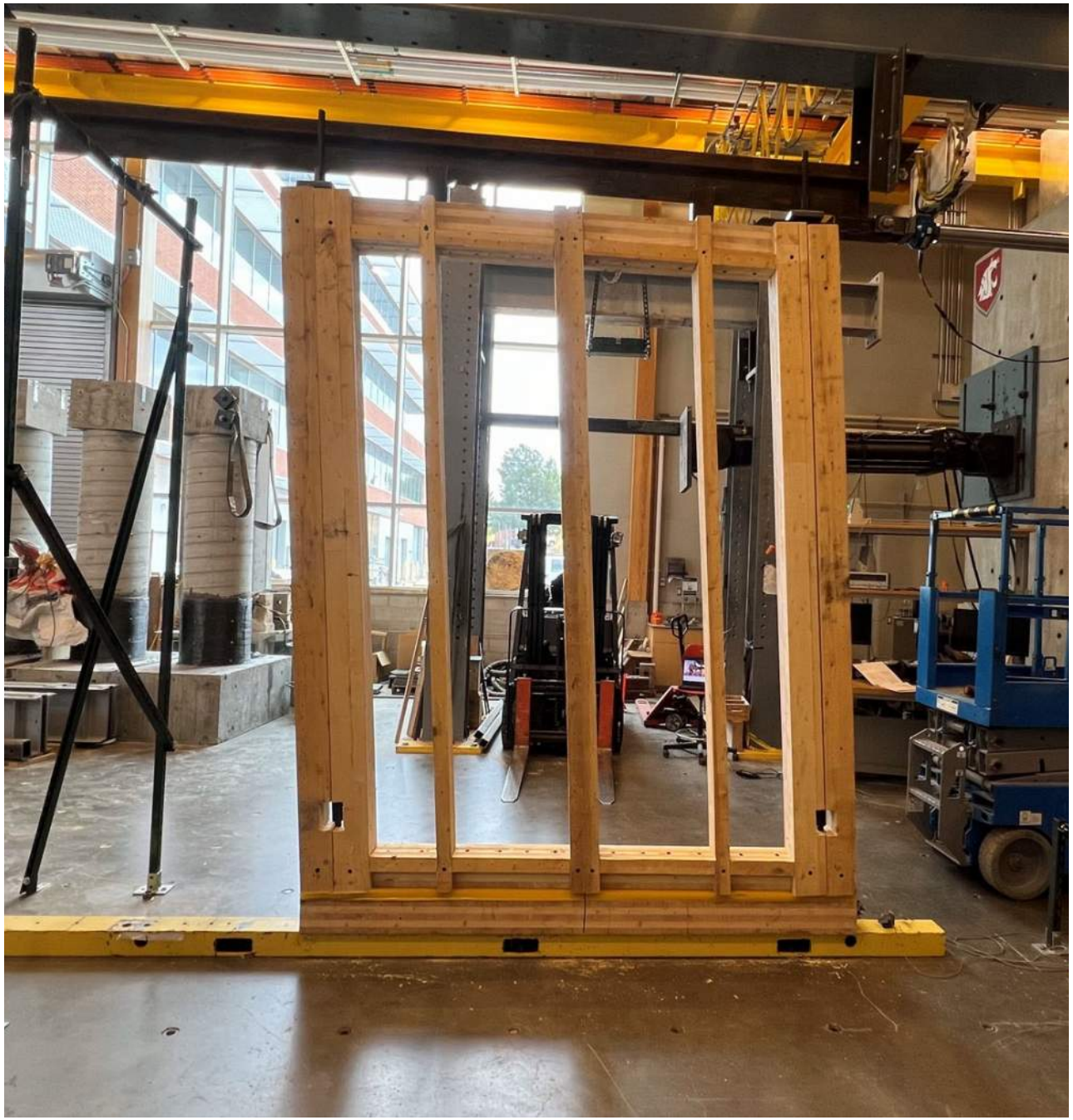
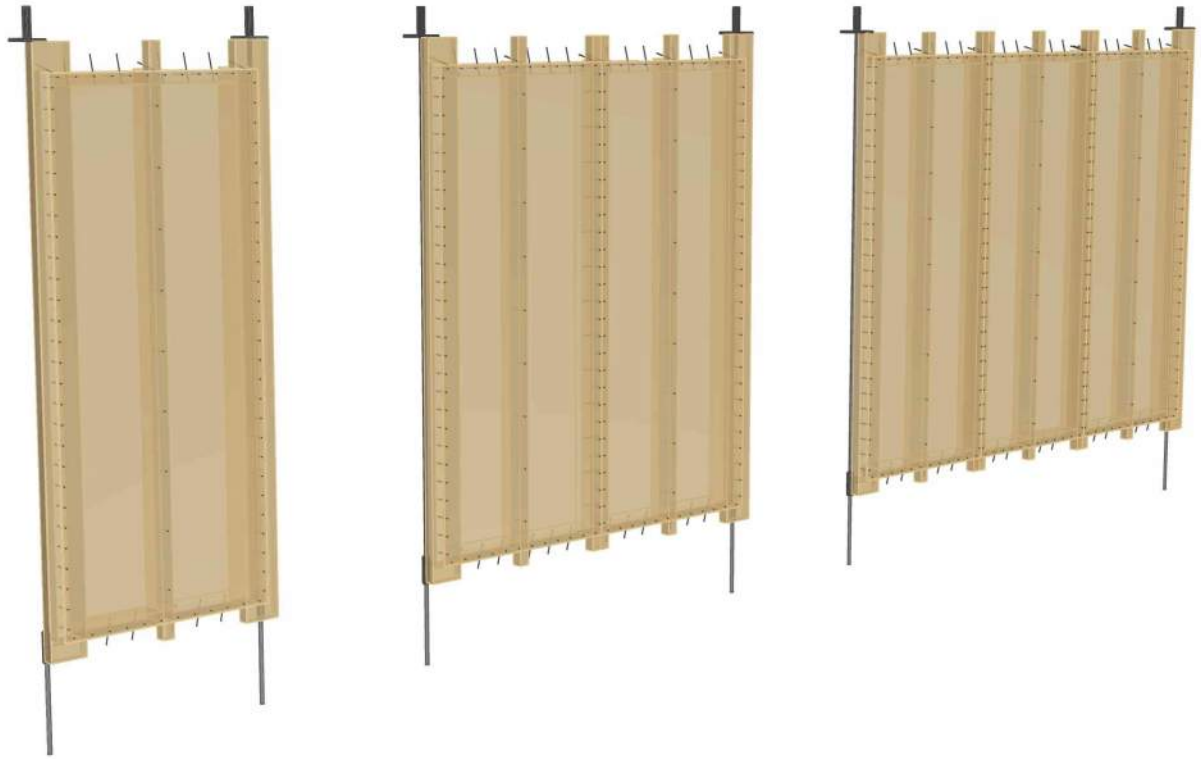
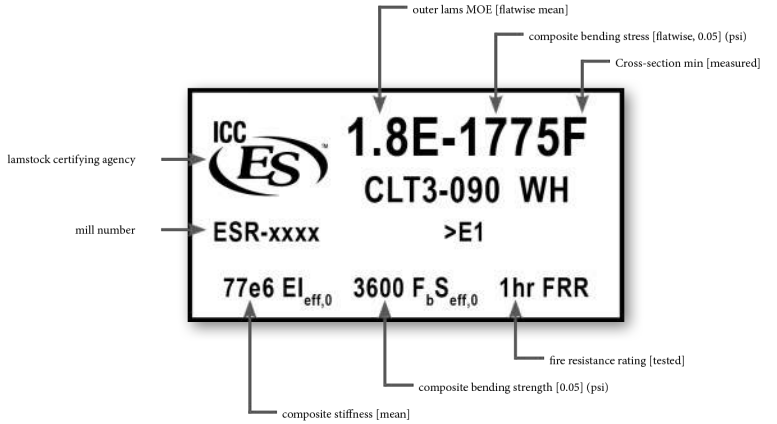
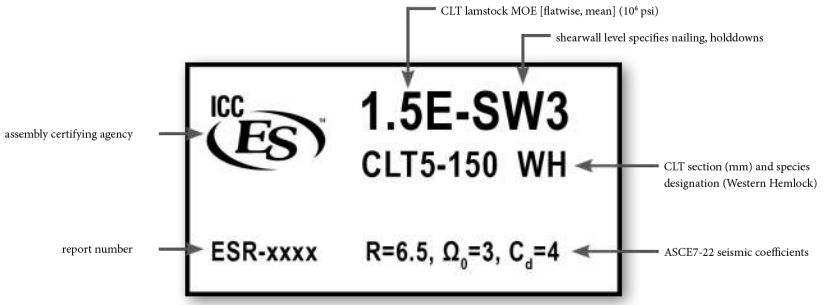


MOD seismic certification

Assemblies with mass timber components require new ways of detailing to demonstrate seismic equivalency with existing, mature systems (e.g. light wood frame).



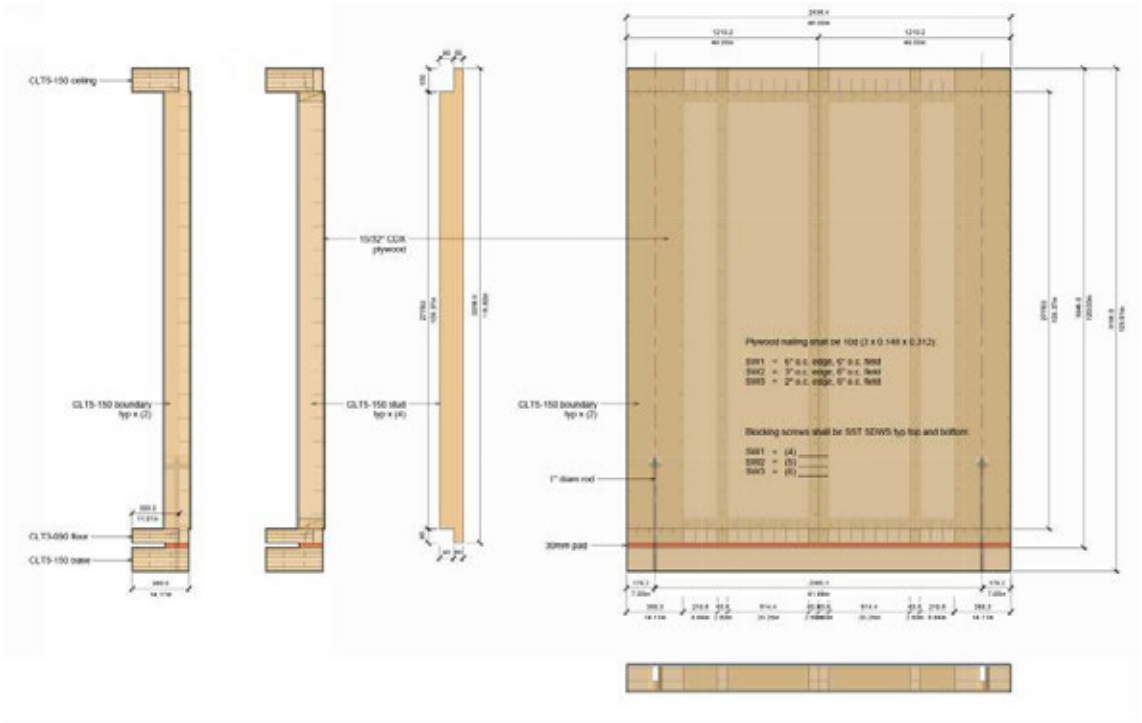


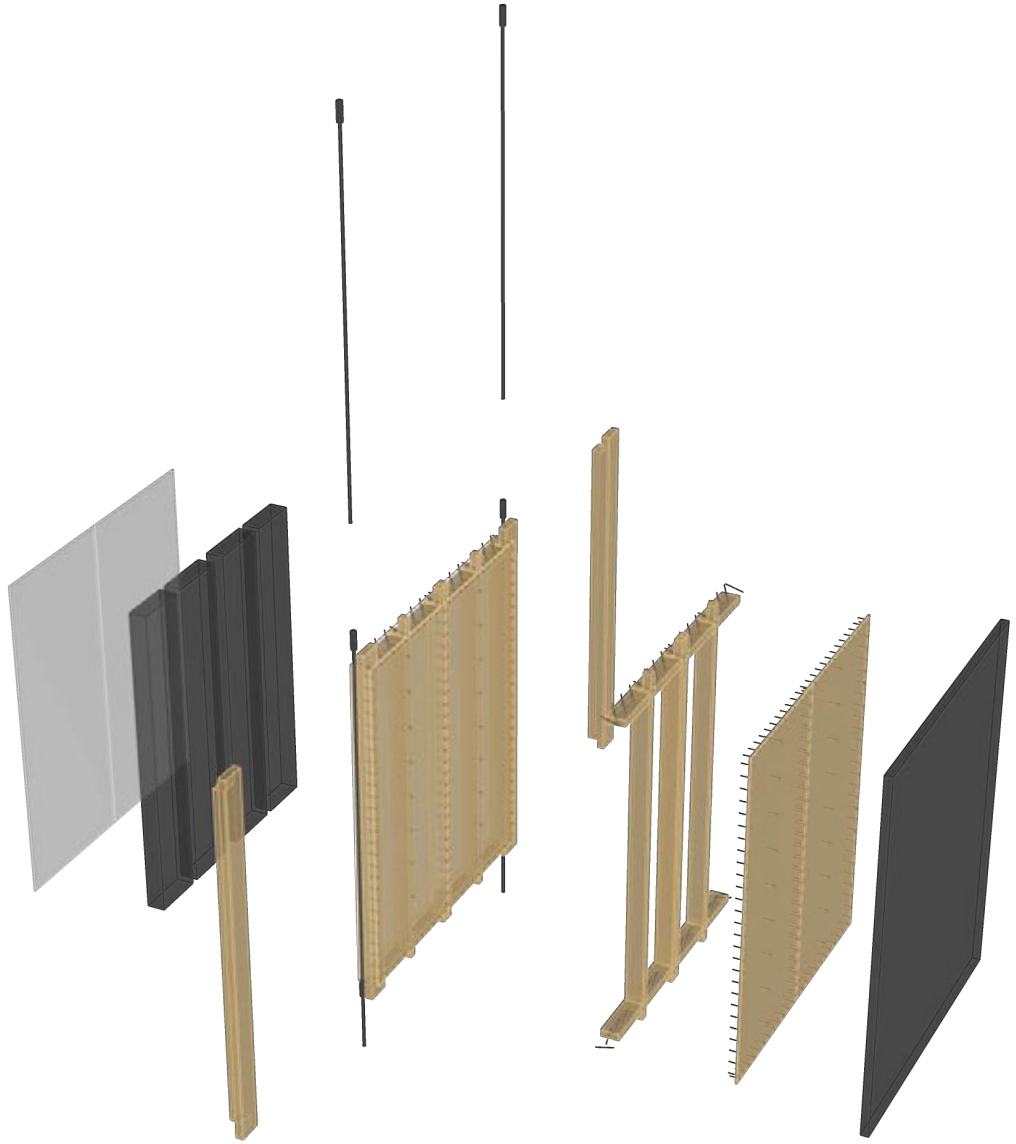


System	Standards	Seismic Design Coefficients			IBC Construction Type
		R	Ω_0	C_d	
Ordinary CLT SW	SDPWS 2021	1.5	2.5	1.5	Type III, IV, V
SDPWS Appendix B CLT SW	SDPWS 2021 ASCE 7-22	3 (2:1) 4 (4:1)	3 3	3 4	Type III, IV, V
Oregon Alternative CLT SW	Oregon SAM 15-01	2	2.5	2	Type III, IV, V
STRIATE LFW equivalency CLT SW	ASCE 7-22 ASTM D7989-21	6.5	3	4	Type III, V

MOD seismic certification

Assemblies with mass timber components require new ways of detailing to demonstrate seismic equivalency with existing, mature systems (e.g. light wood frame).



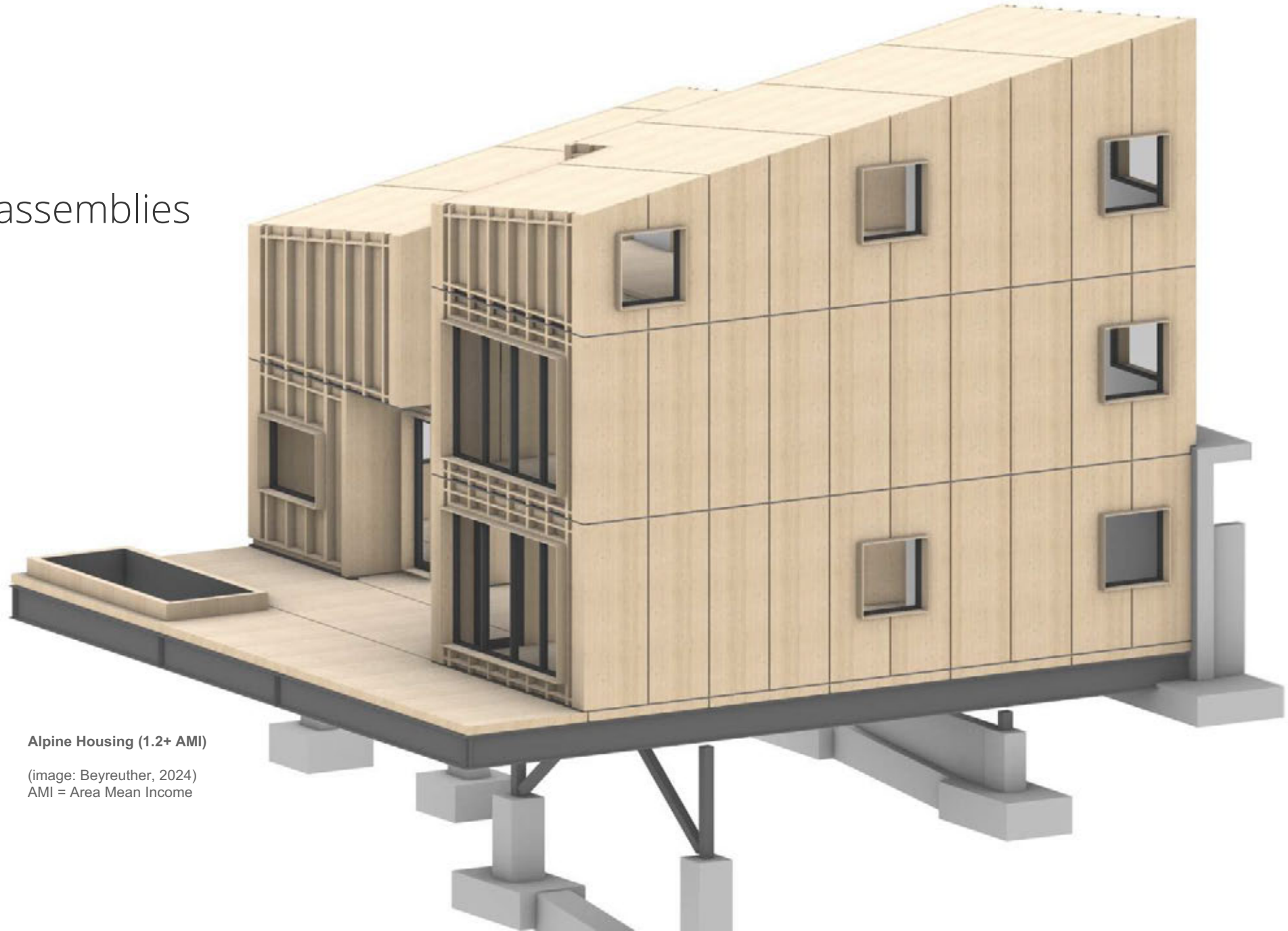


MOD volumetric assemblies

Grades:	1.2E, 1.5E, 1.8E, 1.4V
Layups: GLT3-090	CLT3-090, CLT5-150,
Species:	SPF, DF, GF, WH

MOD volumetric assemblies

Grades:	1.2E, 1.5E, 1.8E
Layups:	CLT3-090, CLT5-150 GLT3-090
Species:	GF



Alpine Housing (1.2+ AMI)

(image: Beyreuther, 2024)
AMI = Area Mean Income

MOD volumetric assemblies

Grades:	1.2E, 1.5E, 1.8E
Layups:	CLT3-090, CLT5-150 GLT3-090
Species:	GF

Alpine Housing (1.2+ AMI)

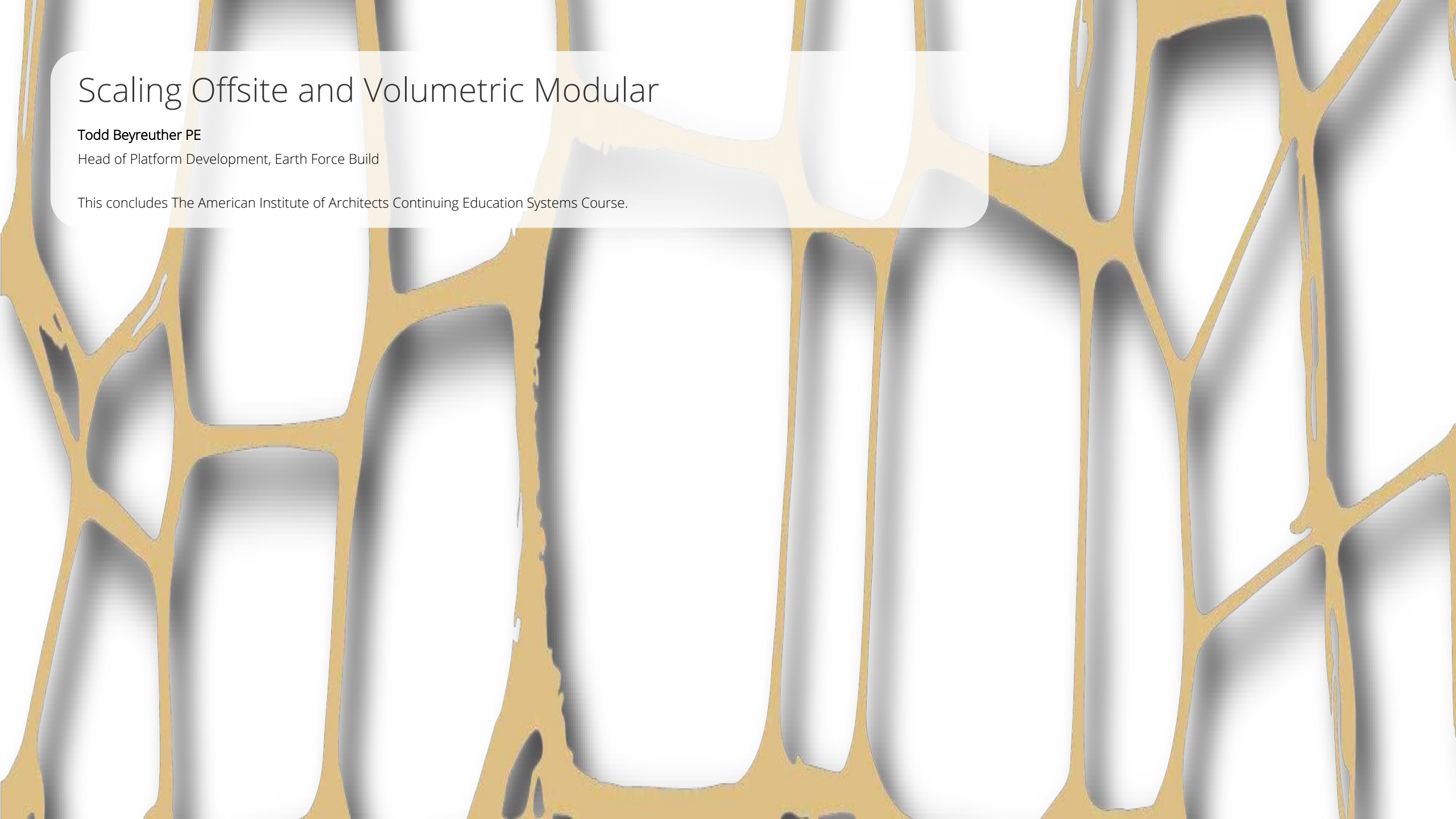
(image: Beyreuther, 2024)
AMI = Area Mean Income

Scaling Offsite and Volumetric Modular

Todd Beyreuther PE

Head of Platform Development, Earth Force Build

This concludes The American Institute of Architects Continuing Education Systems Course.



MODULAR MASS TIMBER

Bringing construction into the digital / robotic era

INTEGRATED DESIGN CUBED
MODULAR MASS TIMBER

Peter Rose + Partners | NKBAK | Kaufmann Bausysteme

Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.

MODULAR MASS TIMBER KEY ELEMENTS

Mass Timber

MODULAR MASS TIMBER KEY ELEMENTS

Mass Timber – Robotically Fabricated

MODULAR MASS TIMBER KEY ELEMENTS

Mass Timber Modules

MODULAR MASS TIMBER **KEY ELEMENTS**

Mass Timber Modules

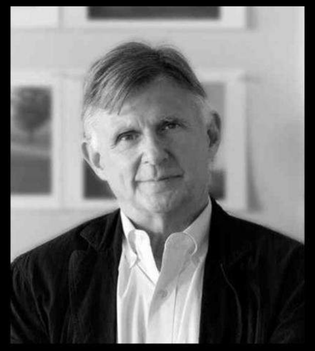
MODULAR MASS TIMBER KEY ELEMENTS

Modular Mass Timber Buildings

MODULAR MASS TIMBER KEY ELEMENTS

An Integrated Team

IDCUBED



Peter Rose, AIA, FRAIC
IDCUBED Co-Founder
Peter Rose + Partners
Founding Principal
Harvard GSD
Professor

Andreas Krawczyk
IDCUBED Co-Founder
NKBAK
Founding Principal

Christian Kaufmann
IDCUBED Partner
Kaufmann Bausysteme (KBS)
Founding Principal

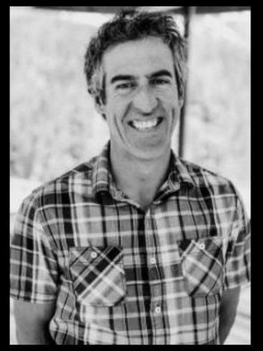
Stani Iordanova
IDCUBED Senior Director
Peter Rose + Partners
Principal

Christopher Flass
IDCUBED Project Director
Peter Rose + Partners
Principal

Justin Cook
IDCUBED Co-founder
RISD Center for Complexity
Founding Director

FABRICATORS

Todd Thesing
Fabrication Partner
Highline Partners
Co-Founder

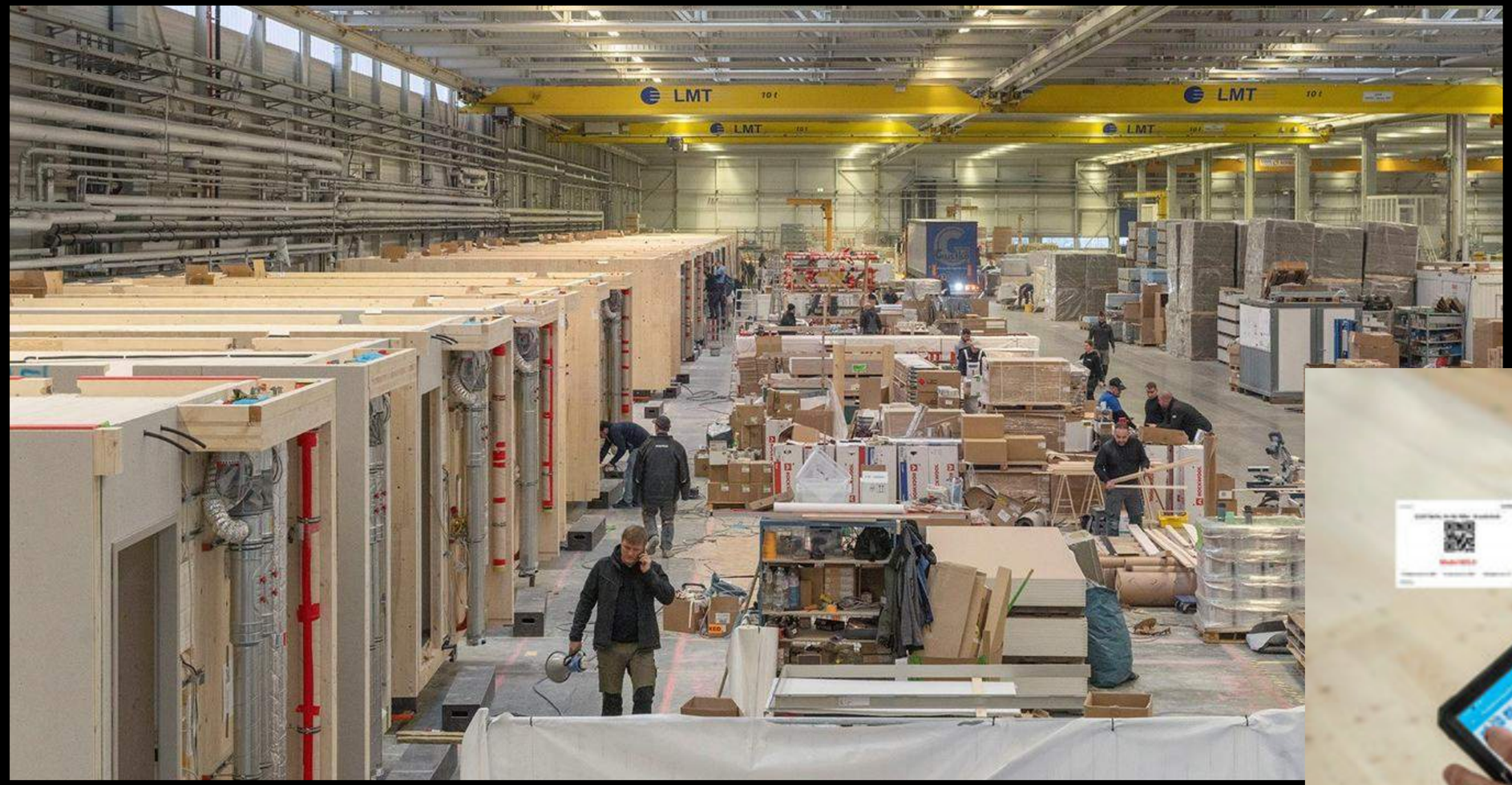


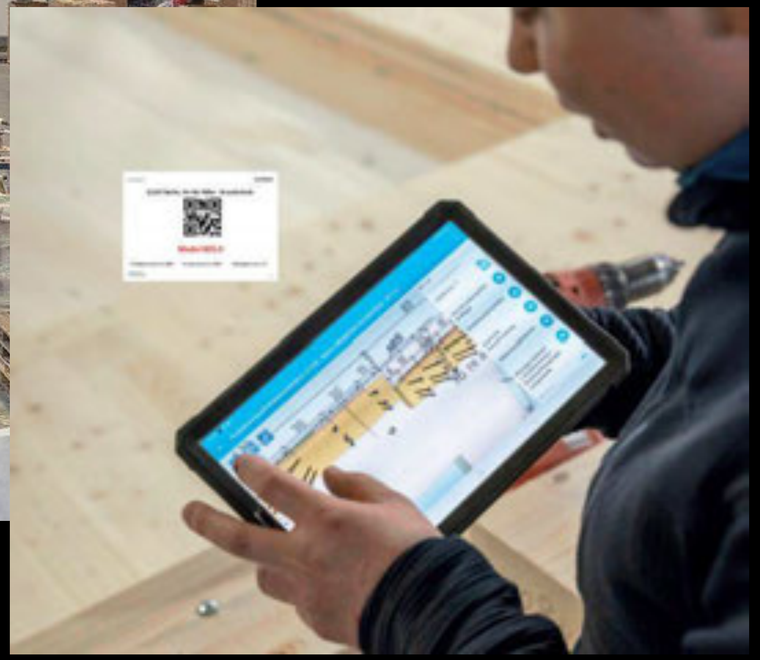
Rob McRae
Fabrication Partner
Highline Partners
Co-Founder

An integrated team of highly skilled architects and fabricators, *in constant communication*, designing and directing every aspect of the process.

MODULAR MASS TIMBER KEY ELEMENTS

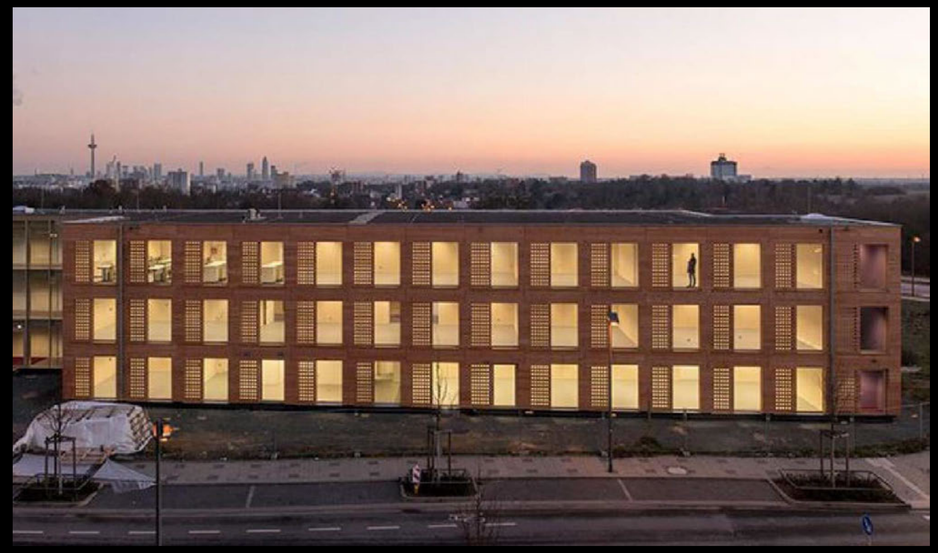
Software





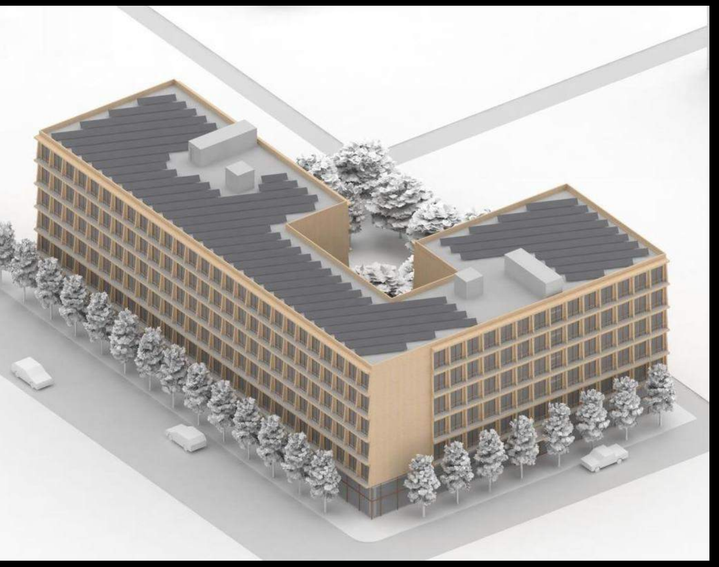
Supply chain and local module assembly managed remotely by our software.

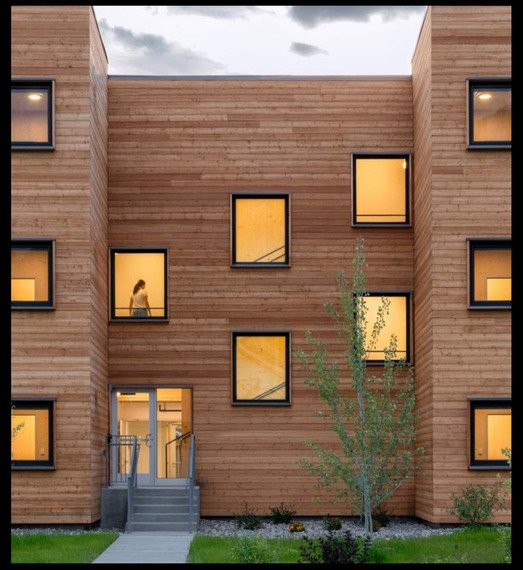
MODULAR MASS TIMBER PROJECTS



Exceptional buildings for users and owners.

MODULAR MASS TIMBER PROJECTS





Every project:
on time, on budget.

MODULAR MASS TIMBER PROJECTS

A wide range of programs, scales, and contexts.

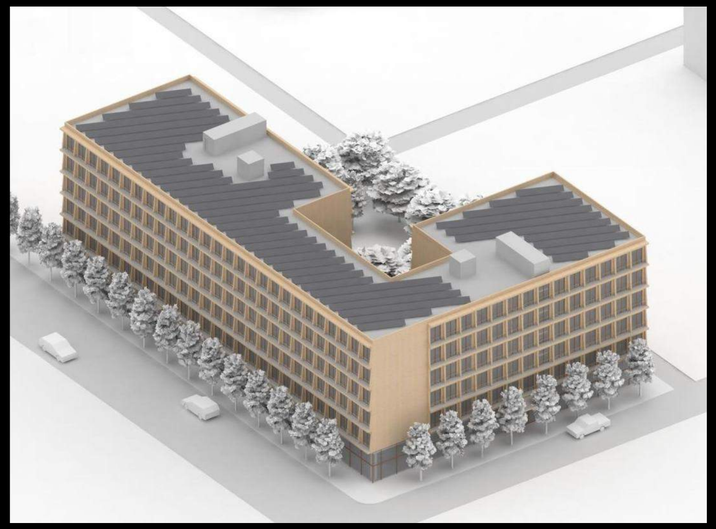
MODULAR MASS TIMBER **PROCESS** (3 STAGES)

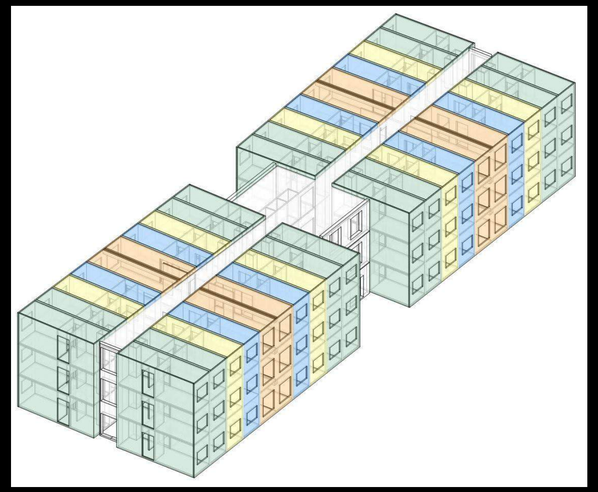
Stage 1. Integrated Design Of Everything

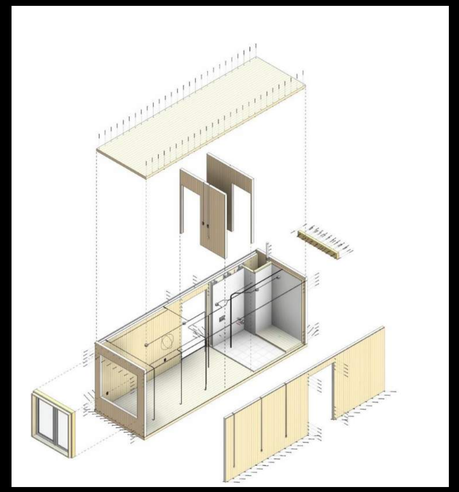
Buildings
Modules
Timber and Other Components
Supply Chain
Assembly Process

KEY OBJECTIVES:

very good buildings
modules - very easy to assemble
buildings - very easy to assemble
constant improvement

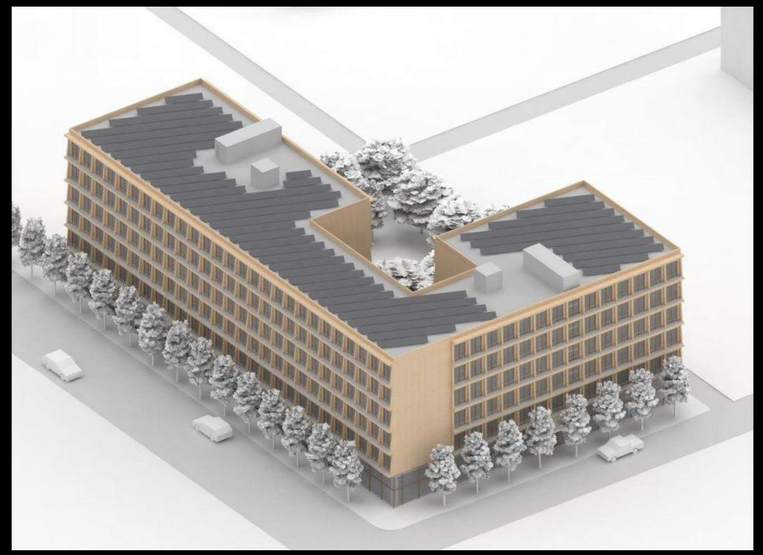






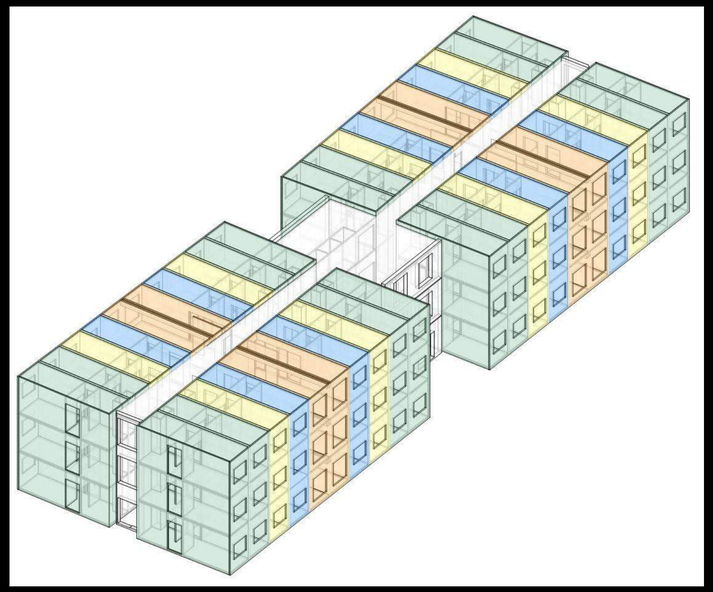
MODULAR MASS TIMBER **PROCESS** (3 STAGES)

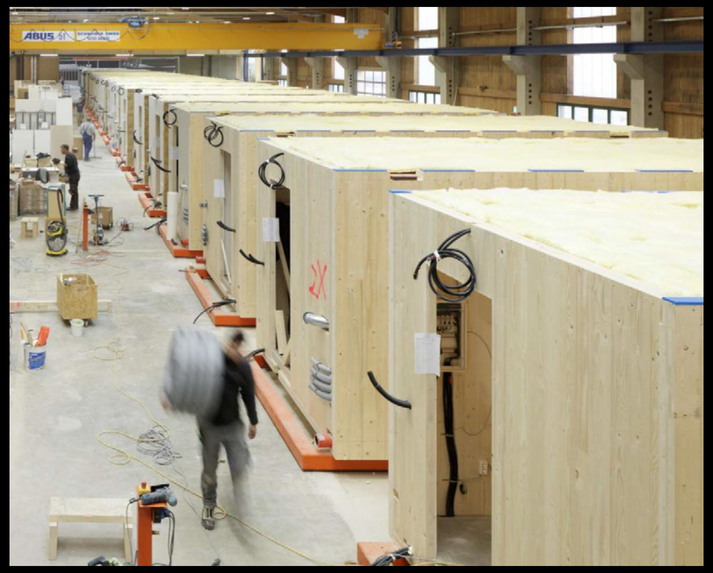
Stage 1: Integrated Design of Everything - Buildings



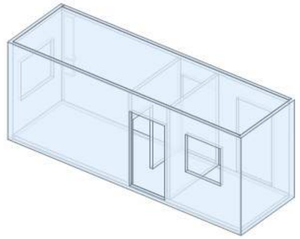
MODULAR MASS TIMBER **PROCESS** (3 STAGES)

Stage 1: Integrated Design of Everything: Modules





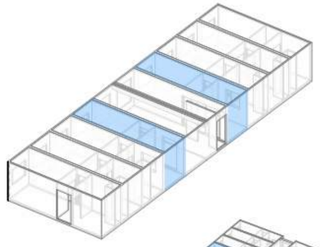
MODULE C : Bedroom + Pantry/Mudroom



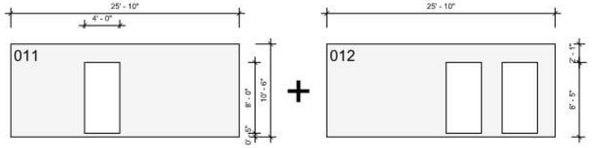
FLOOR/ CEILING
3 lam / 0.3' thick

x 2

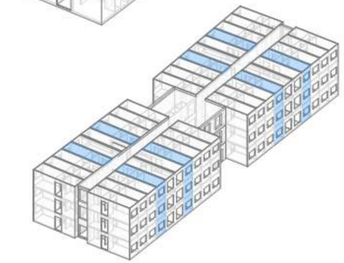
3.2



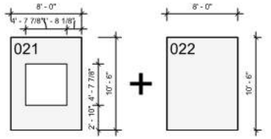
LONG WALLS
3 lam / 0.3' thick



4.6

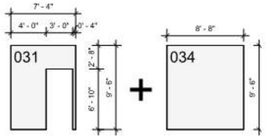


END WALLS
4 lam / 0.4' thick



1.9

INTERIOR WALLS
3 lam / 0.3' thick



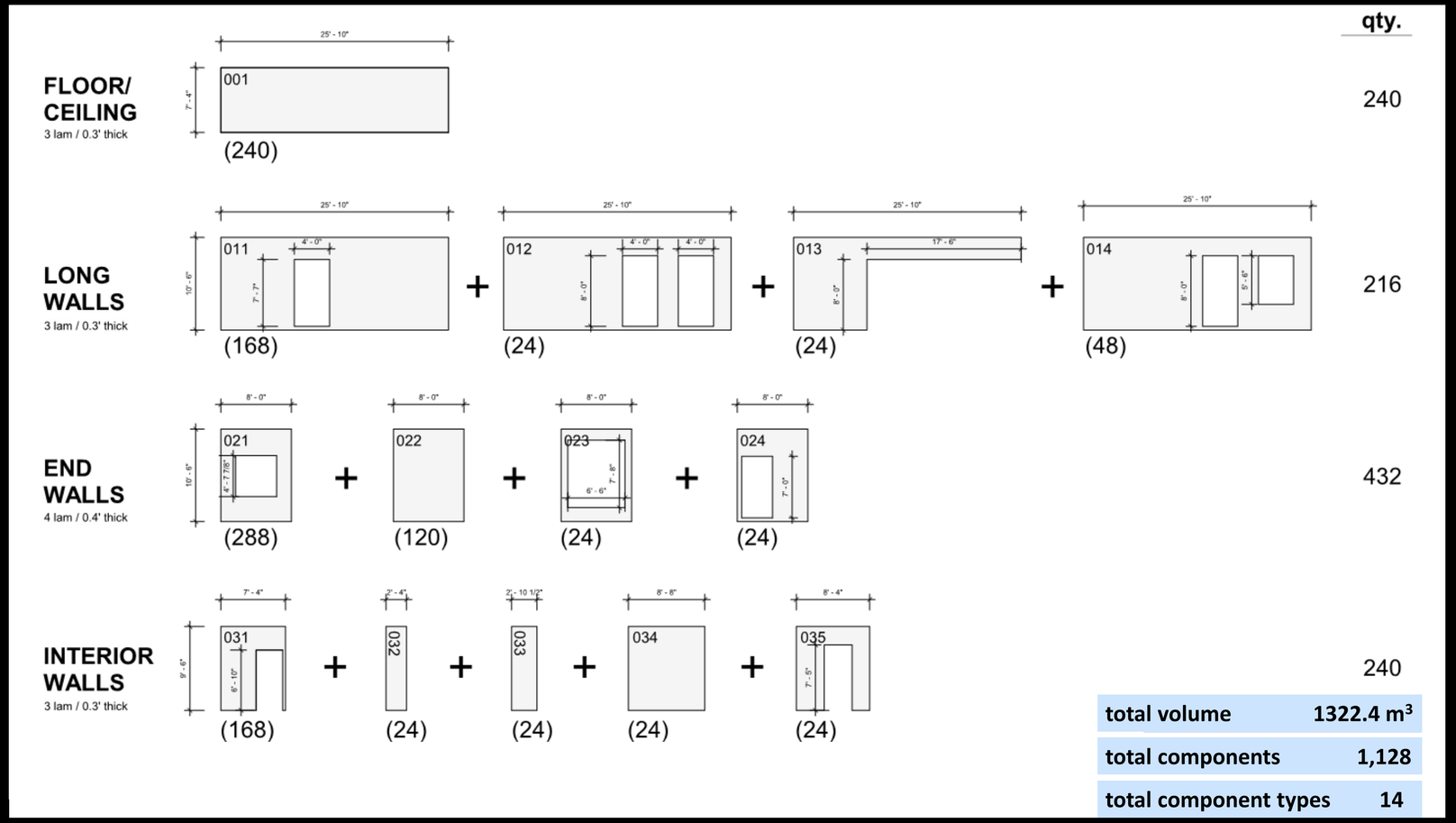
1.29

	m³
total volume	11.02 m³
total components	7

Modules designed to meet the specific needs of each project. A wide range of sizes, configurations, shapes is possible.

MODULAR MASS TIMBER **PROCESS** (3 STAGES)

Stage 1: Integrated Design of Everything: Timber Components



Robotically Fabricated **By Multiple Suppliers**

MODULAR MASS TIMBER **PROCESS** (3 STAGES)

Stage 1. INTEGRATED DESIGN OF EVERYTHING

Stage 2. MODULE ASSEMBLY

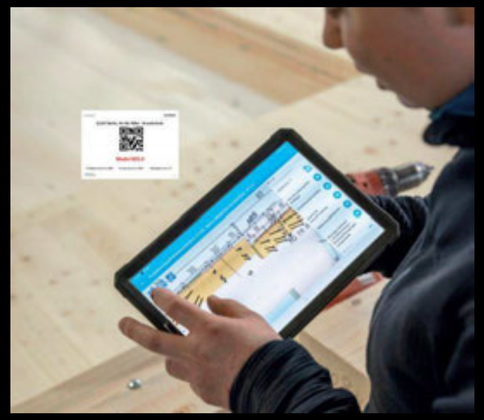
Directed – on tablets – by proprietary software.

Supply chain also managed by proprietary software.

Supply chain and module assembly are **managed remotely**.

MODULAR MASS TIMBER **PROCESS** (3 STAGES)

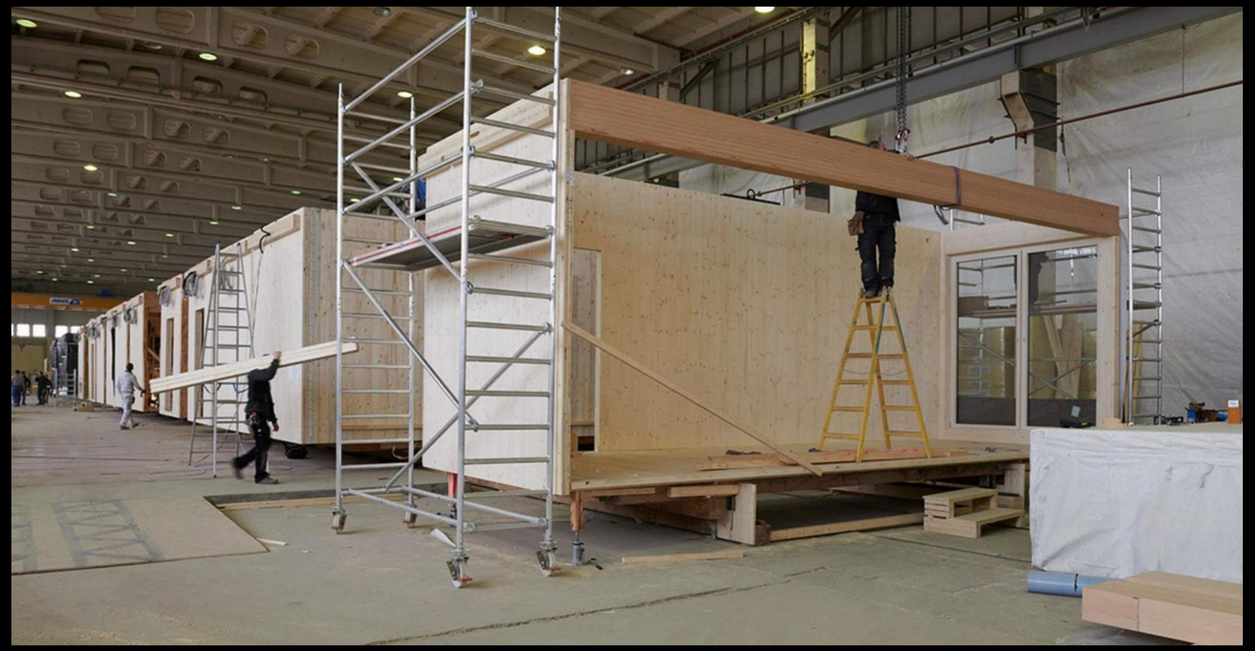
Stage 2: Module Assembly: Software-directed

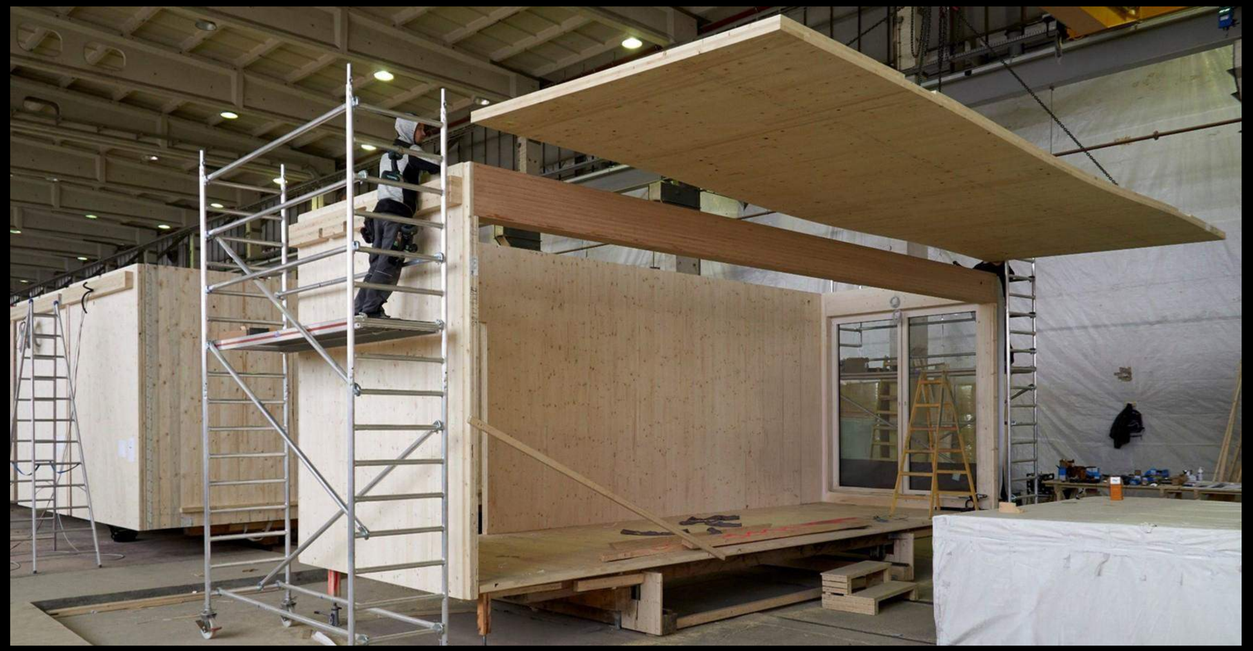


Instructions For Every Task **On A Tablet** **At Every Module Station**

MODULAR MASS TIMBER **PROCESS** (3 STAGES)

Stage 2: Module Assembly





Assembly Hall, not a Factory **Rented, not Owned** **A Crane, no Robots**

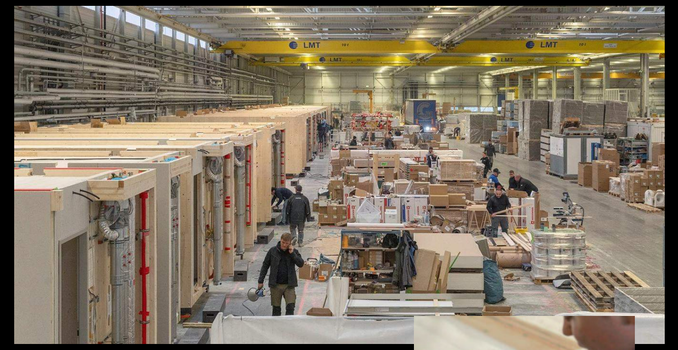
MODULAR MASS TIMBER **PROCESS** (3 STAGES)

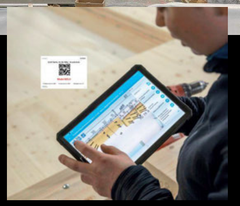
Stage 2: Module Assembly

Worker Friendly **Builder Friendly**

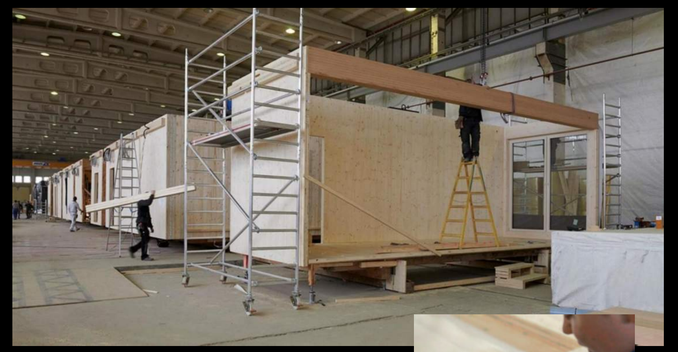
MODULAR MASS TIMBER PROCESS (3 STAGES)

Stage 2: Module Assembly: Software-directed, remotely



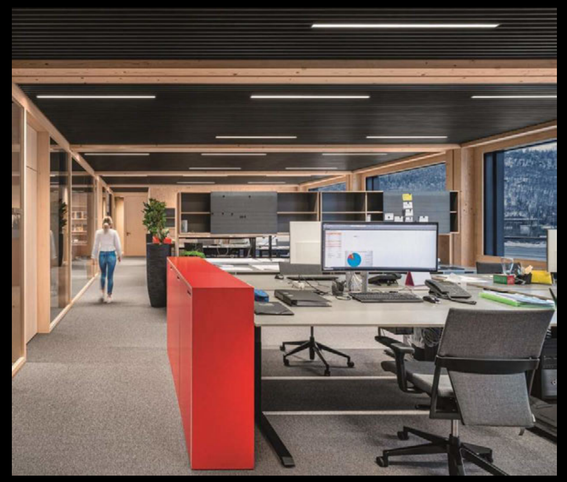


Assembly Hall 2
Rostock



Assembly Hall 1
Berlin

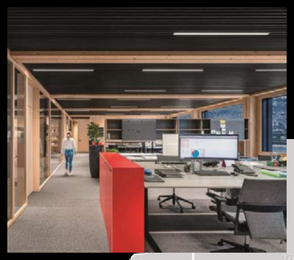
KBS Headquarters
Reuthe, Austria



Module Assembly **Remotely Managed** **From KBS HQ**

MODULAR MASS TIMBER **PROCESS** (3 STAGES)

Stage 2: Module Assembly: Software-directed, remotely



KBS Headquarters
Reuthe, Austria

IDCUBED and Assembly Halls
Anywhere in North America

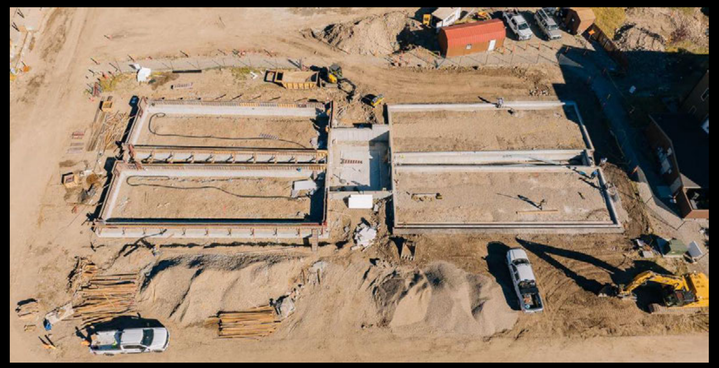
MODULAR MASS TIMBER **PROCESS** (3 STAGES)

Stage 1. INTEGRATED DESIGN OF EVERYTHING

Stage 2. MODULE ASSEMBLY

Stage 3. BUILDING ASSEMBLY

- Sitework
- Setting of modules
- Facade / Roof
- Hook-ups

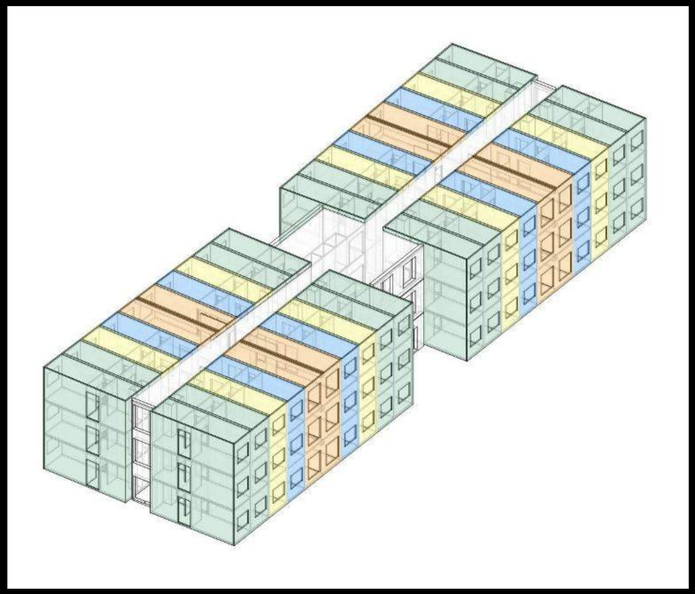


MODULAR MASS TIMBER IN NORTH AMERICA

Knight Building, Big Sky, MT

MODULAR MASS TIMBER IN NORTH AMERICA

Knight Building, Big Sky, MT



120 modules
Set at a max rate of 20 per day

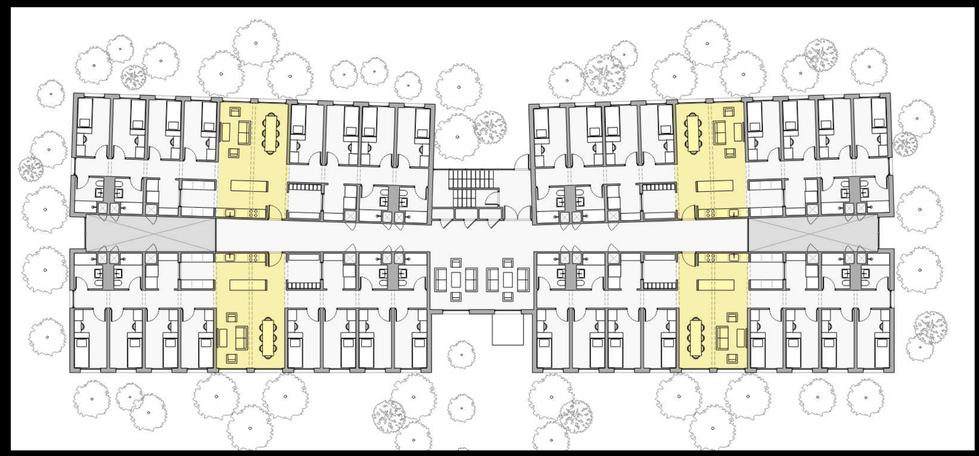
96 occupants
12 suites
8 bedrooms per suite

MODULAR MASS TIMBER IN NORTH AMERICA

Knight Building, Big Sky, MT

BEDROOM

LIVING ROOM



MODULAR MASS TIMBER IN NORTH AMERICA

Knight Building, Big Sky, MT

Workforce housing for 95 employees

31,000 GSF

11 months on-site construction

On time

Under budget

Sustainable, all electric, solar array

Stores 1,200 tons of carbon

MODULAR MASS TIMBER KEY ELEMENTS

Mass Timber

A game-changing innovative material.

Precise, strong, beautiful.

CLT panels available in very large sizes.

(up to 12’ x 60’ x 11”)

MODULAR MASS TIMBER KEY ELEMENTS

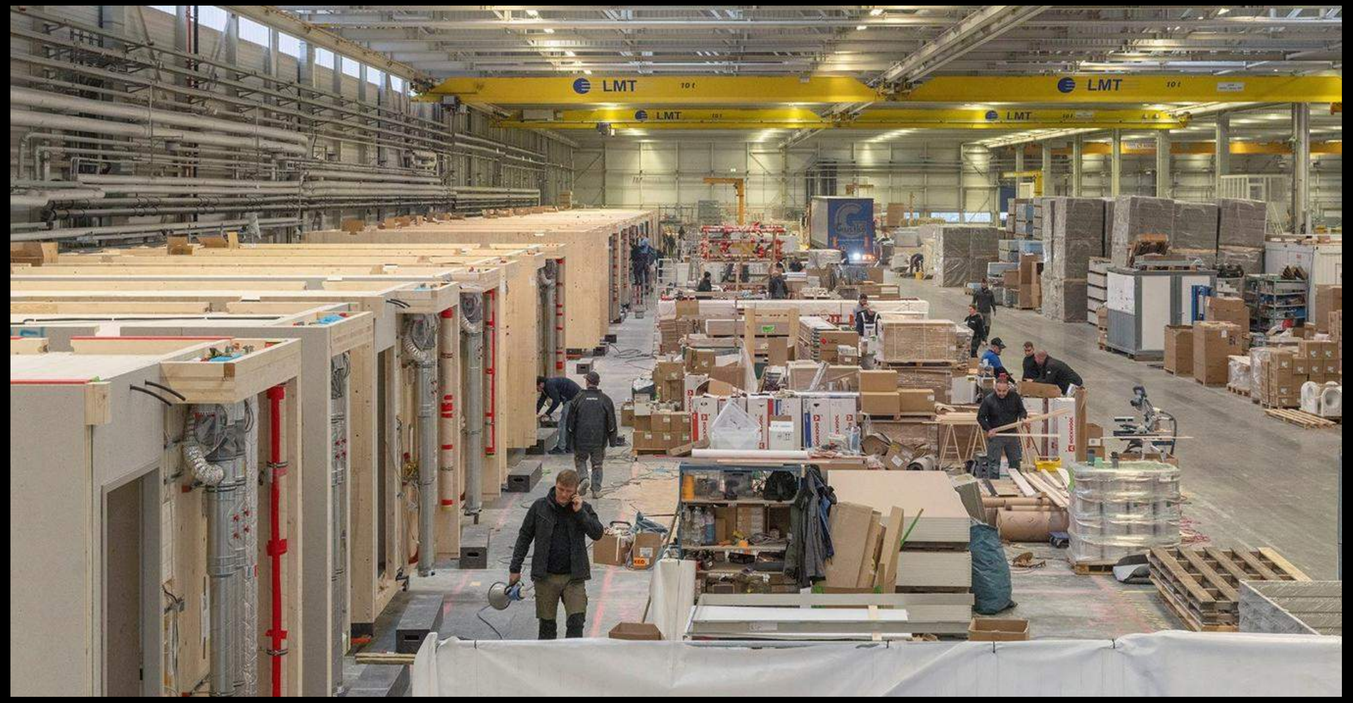
Mass Timber Components

Components fabricated robotically with extreme precision to our specifications **by others**.

Available **from a wide range of mass timber suppliers** in North America and Europe.

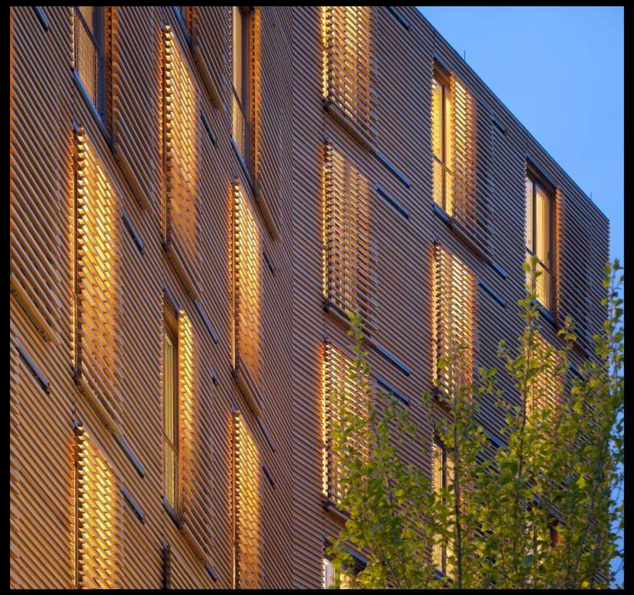
MODULAR MASS TIMBER KEY ELEMENTS

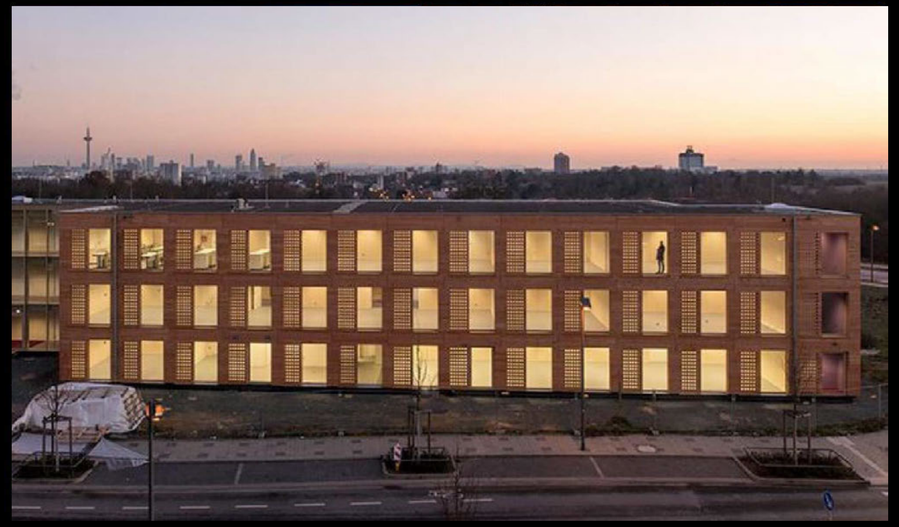
Mass Timber Modules

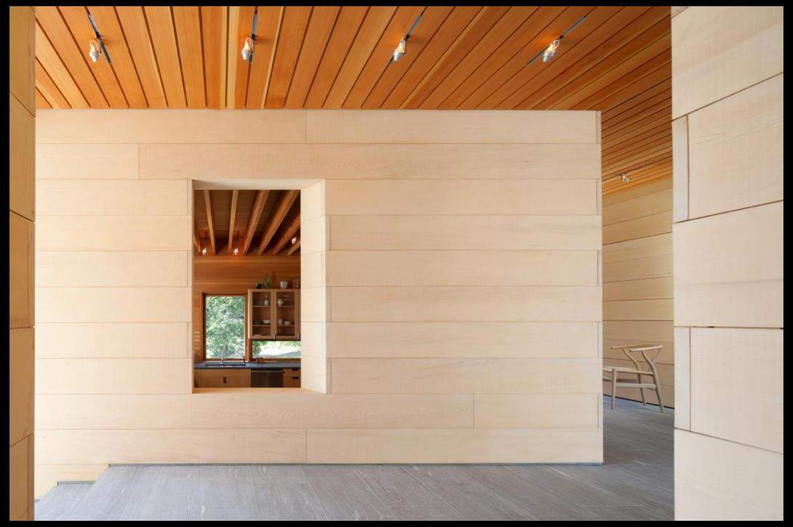


Modules designed strategically with the goals of:

1. **Easy and quick assembly** by small teams of relatively low-skilled laborers in local assembly halls.
2. **Easy and quick setting** on site
3. **Exceptional buildings**







INTEGRATED DESIGN CUBED

MODULAR MASS TIMBER

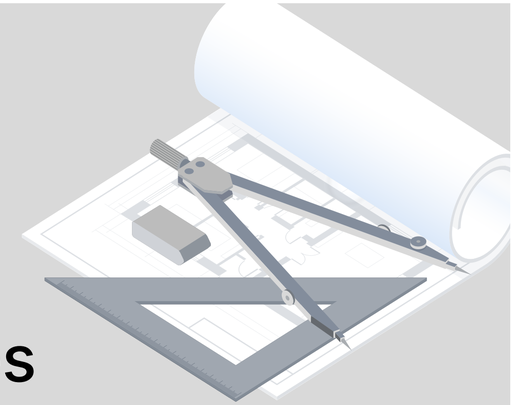
Reframe
SYSTEMS

Resilient Homes

**Disclaimer: this presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board*

Manual Design

Paper Processes

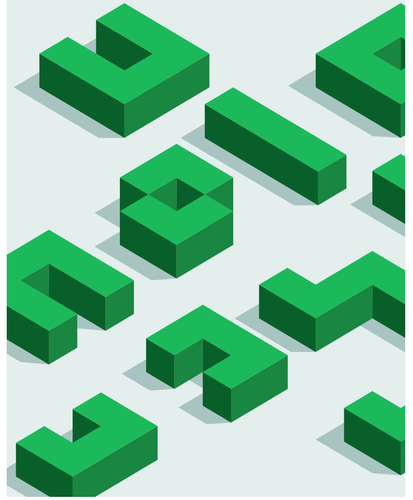


High Capital Cost

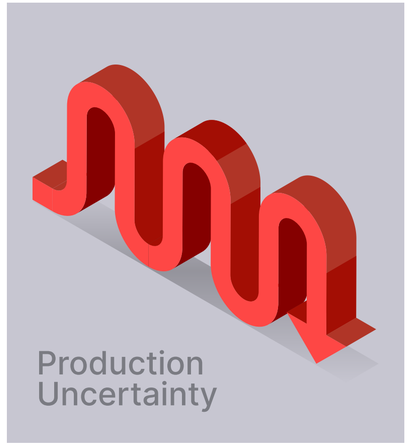
550,000+ Skilled Worker Shortage

Long Tail Problem

7 Climate Zones
50 States
~30k Zoning Jurisdictions



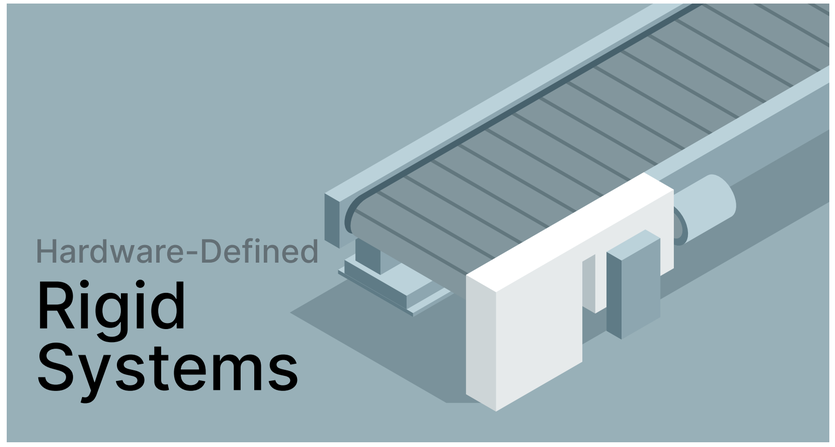
Pipeline Adaptability Challenge



Production Uncertainty

Construction needs a paradigm shift

No Volumetric Approach



Hardware-Defined Rigid Systems

Reframe Systems

3 years old, founding team from Kiva Systems and Amazon Robotics.

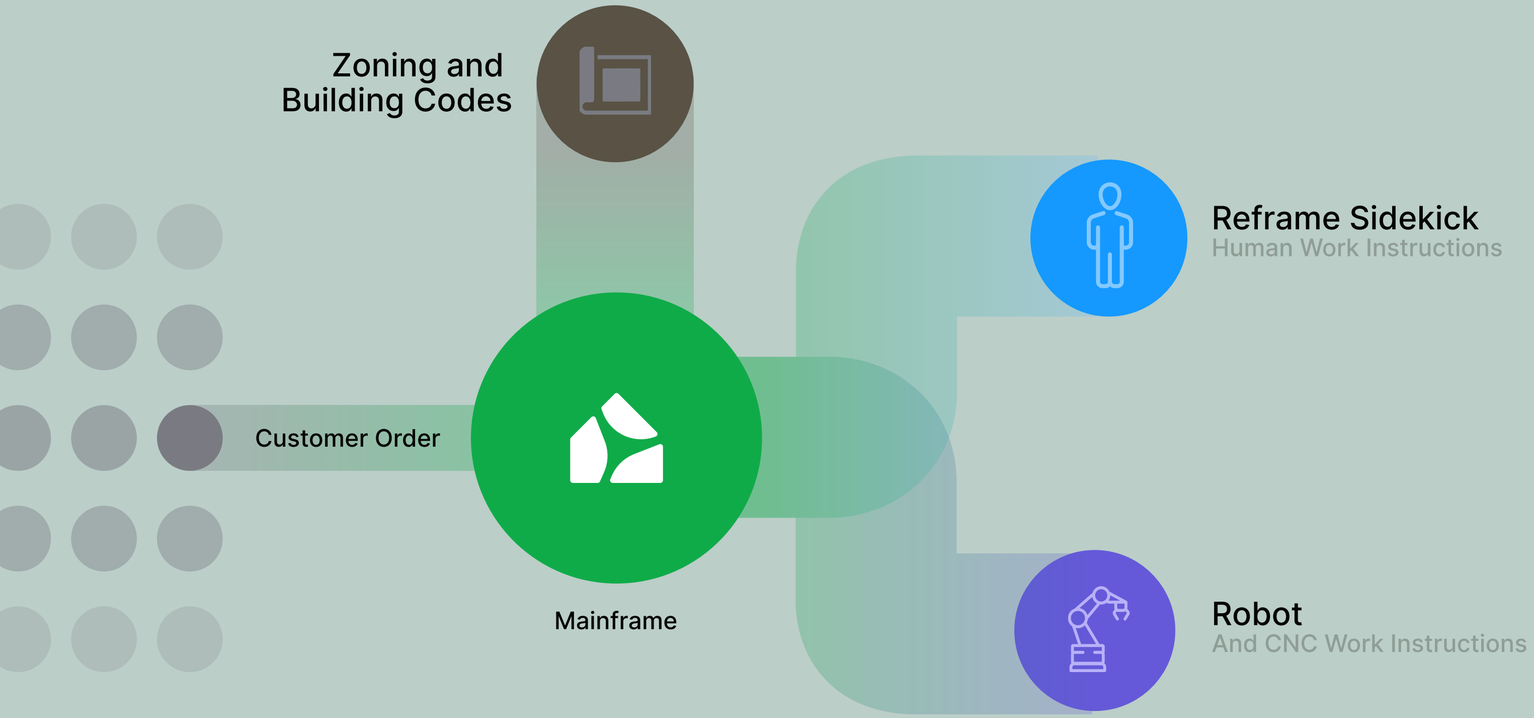
Delivering homes to paying customers. Vertically integrated. 40X production growth in 2025


Microfactory #1 operational in Andover, MA

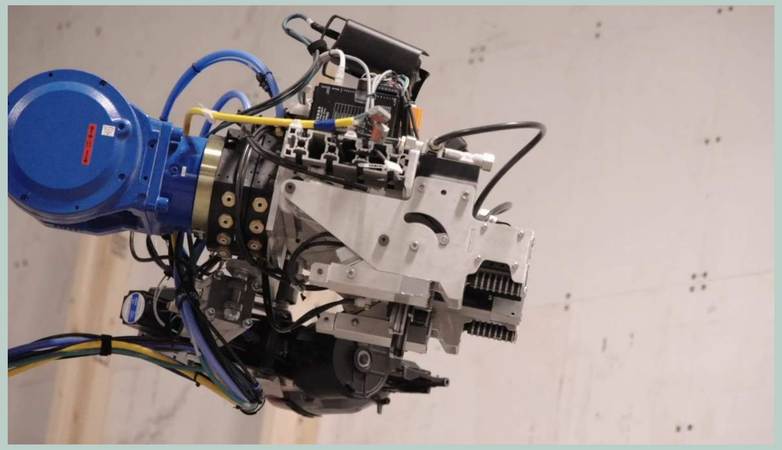
Microfactory #2 in Los Angeles EOY 2026

Reframe is building climate-resilient homes using robotics, algorithms, and a microfactory network. We’re turning construction into computation to unlock housing abundance.

We're reframing construction into a software and AI problem

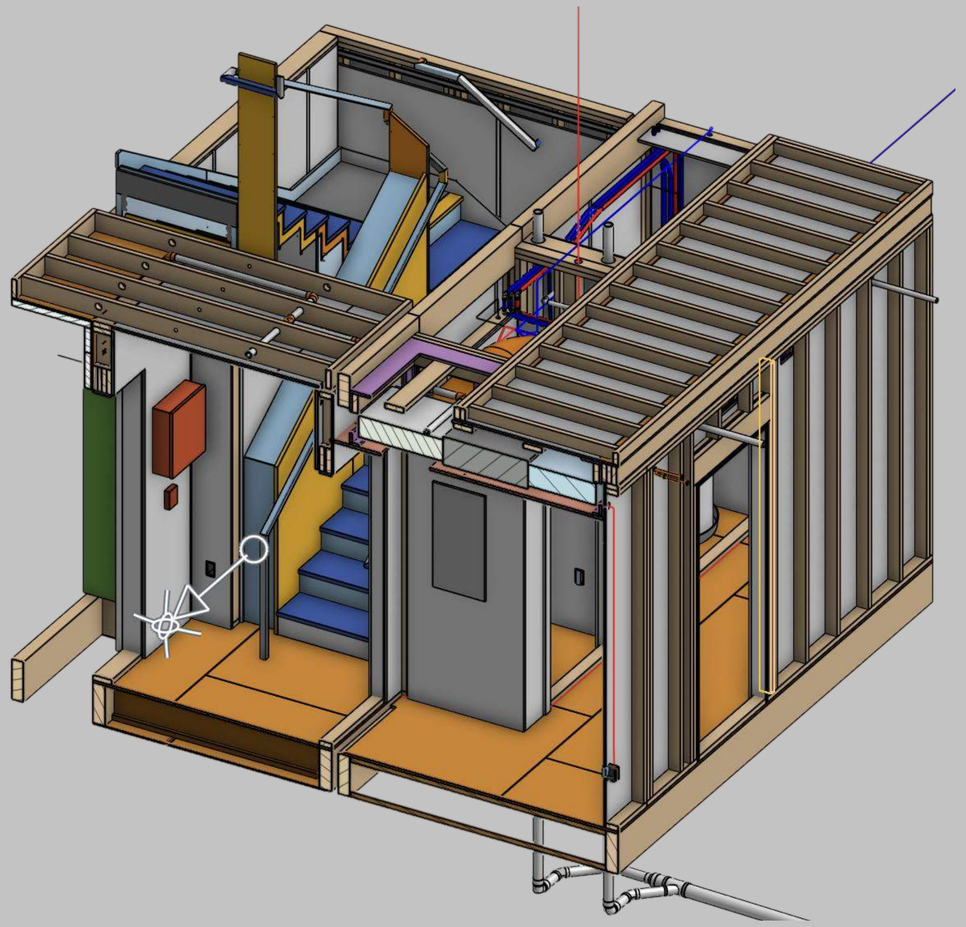


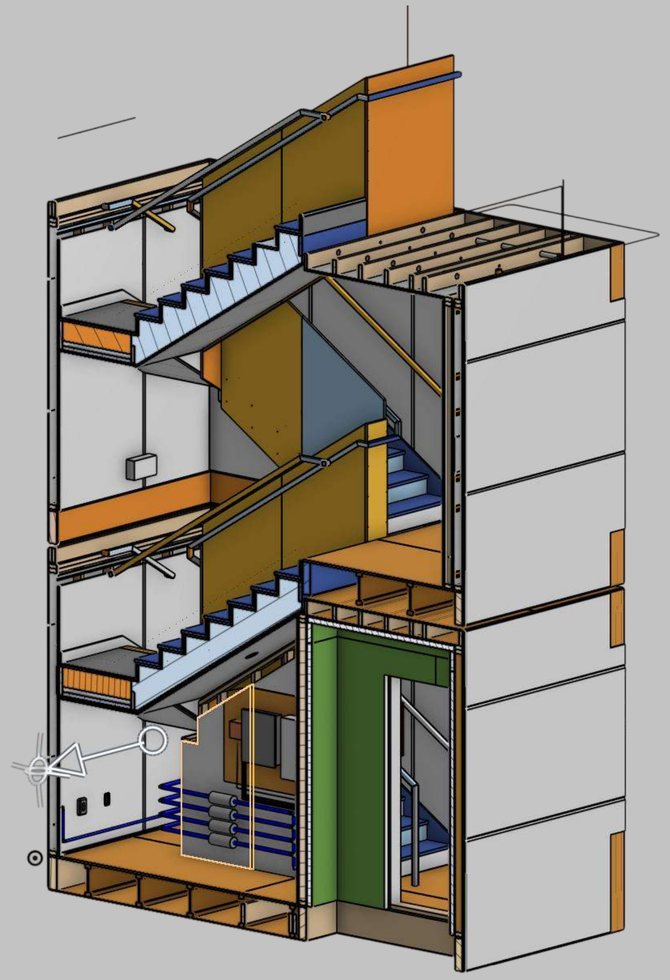
Augmented Workcells
Supercharges Apprentice Builders

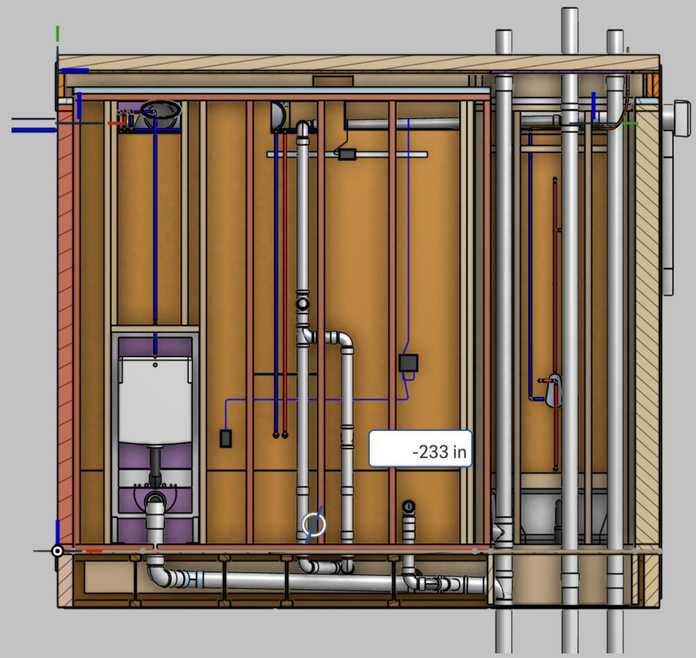


Low-Cost Flexible Robots
Physical World API

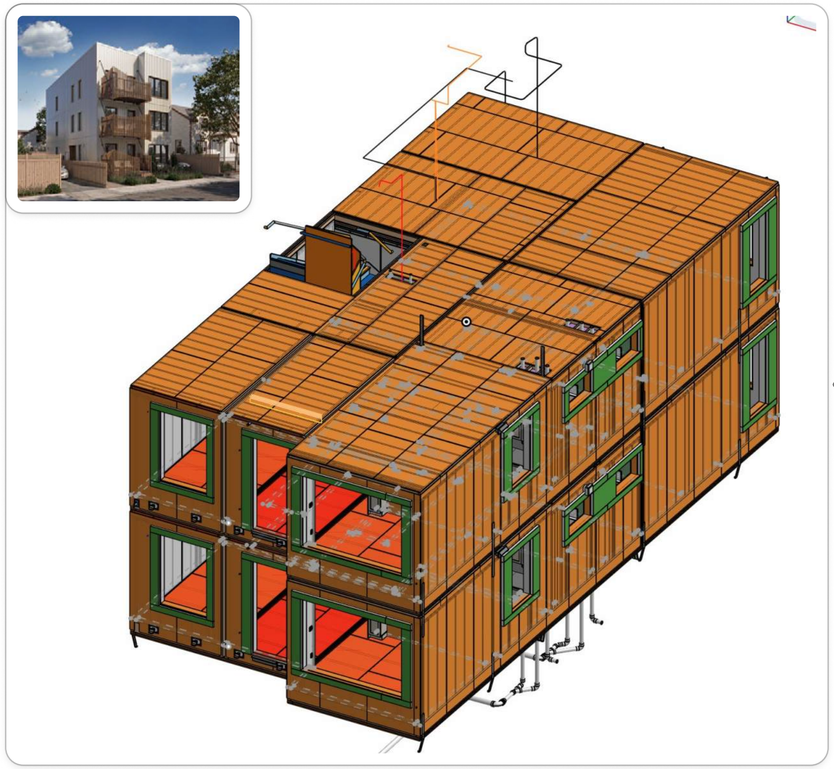
Highly detailed parametric CAD

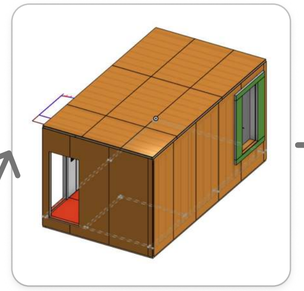


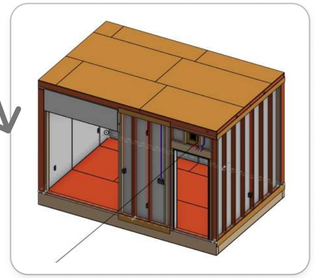


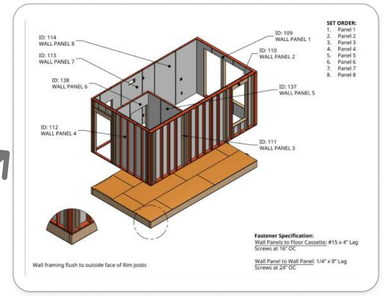


Work instructions drive shop floor efficiency

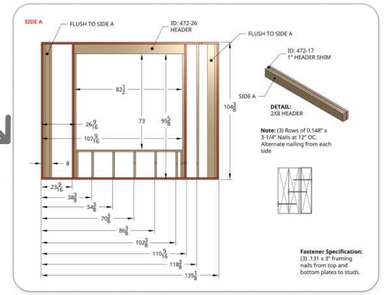




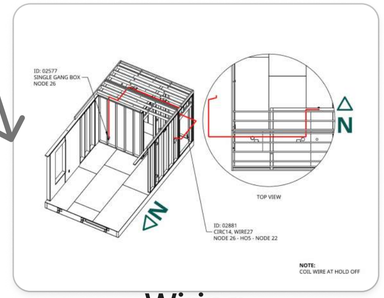




Integration



Panel



Wiring

1 Triple Decker ⇒ 24 Modules + 6 Roof Cassettes X ~200 Work Instructions/Module (100 Annotated Views/Module)

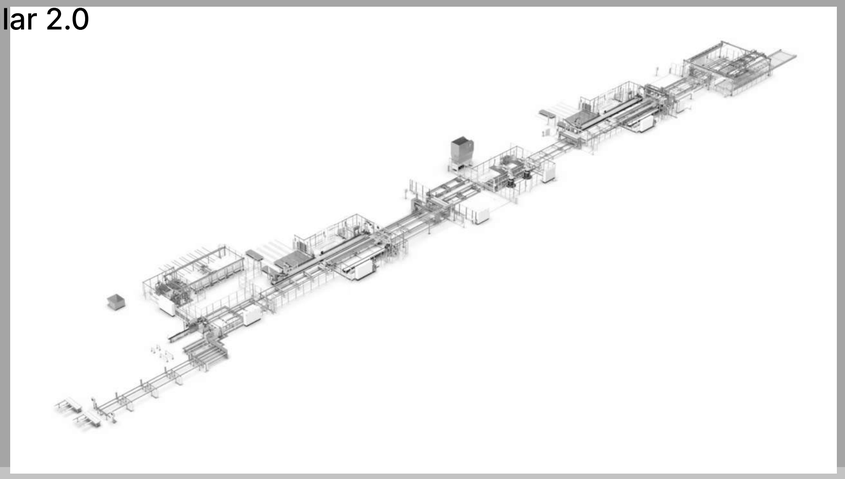
= ~3500 Work Instructions (800 unique annotated views) per project

Reframe Robotic Paneling

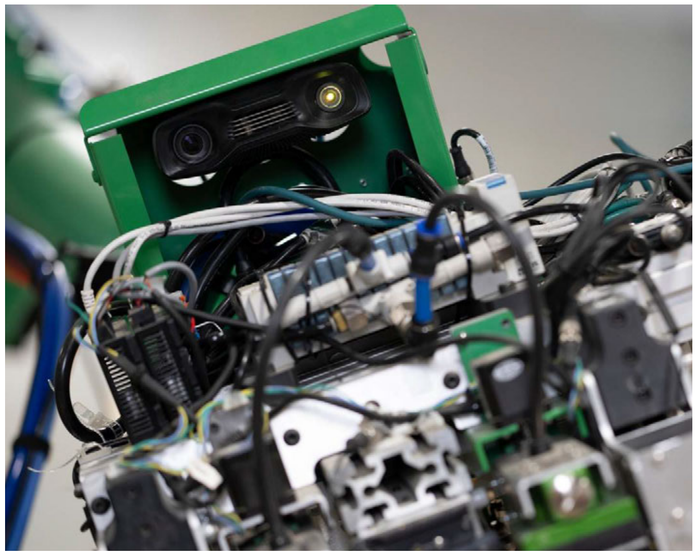
50x smaller, 25x cheaper

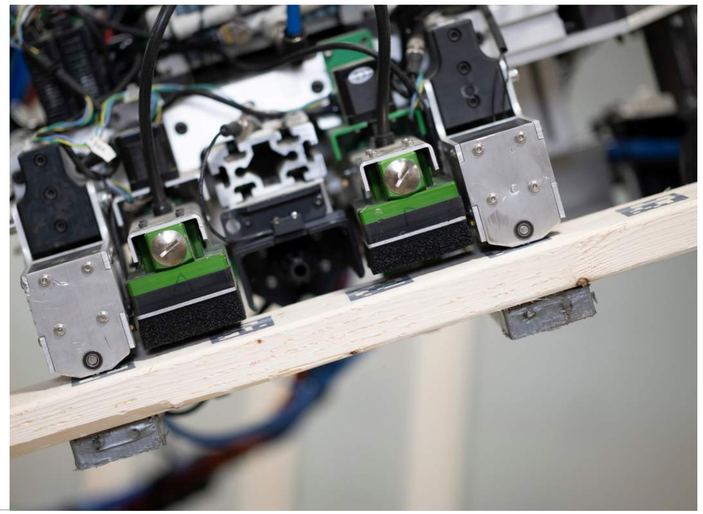
	Modular 2.0	**Modular 3.0** (Reframe Systems)
CAPEX	High (>$5M)	Low ($200k)
Installation Time	800 days	100 days
Flexibility	Very Low	Very High
Scaling/Utilization	None/Low	Yes/High
Throughput	150 linear ft/hr	36 linear ft/hr
Footprint	26,000 sqft	500 sqft
Min Factory Footprint	200k sqft	20k sqft

Modular 2.0



From #2 Lumber - High performance buildings





Software is material agnostic

Delivered our first climate-resilient home in 48 days

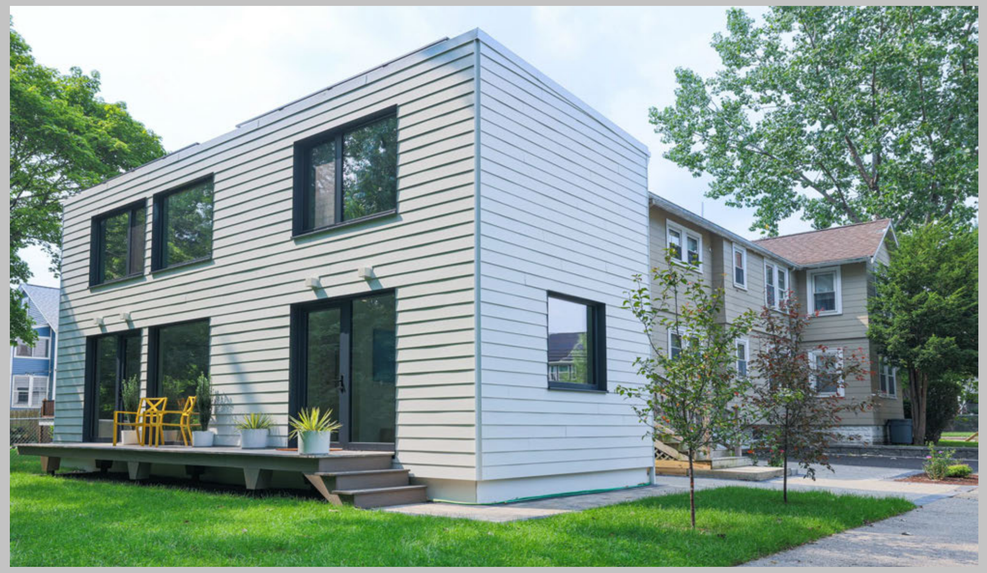
2.5X
Faster
48 days vs. 120 days
Foundation to Substantial
Competition

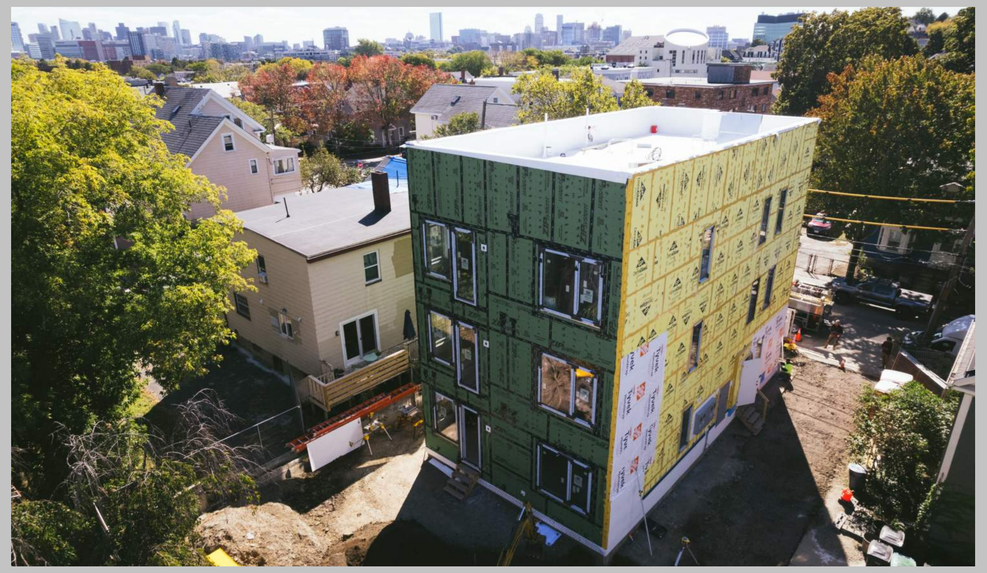
20%
Tighter
0.47ACH50 vs.
0.6ACH50

85%
Less Carbon
Compared to non-Passive
two-story home

Reframe Living

PORTFOLIO





Source: houseplans.com

Reframe
SYSTEMS

This concludes The American Institute of Architects Continuing Education Systems Course.