WASHINGTON STATE UNIVERSITY

Cross-Laminated Timber: Potential & Challenges for the Construction Industry

Don Bender
Weyerhaeuser Professor and Director,
Composite Materials & Engineering Center

October 30, 2018
NW Construction Consumer Council
Annual Conference
Lynnwood Convention Center

WASHINGTON STATE UNIVERSITY

Composite Materials & Engineering Center

70-year track record in wood composites R&D

Core Competencies:

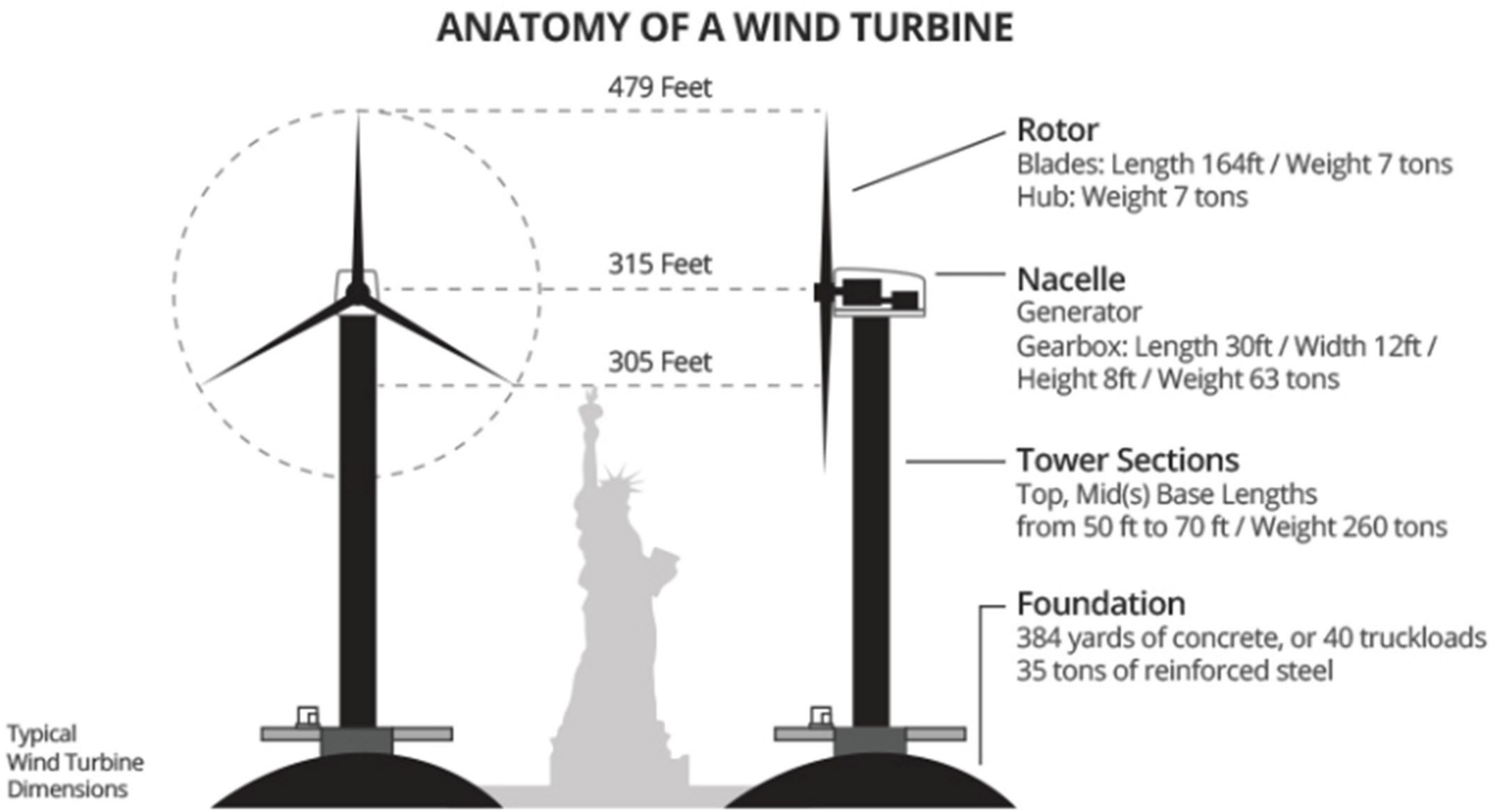
- Wood composite materials development and manufacturing
- Testing (IAS accredited)
- Design codes and standards

Research & Commercialization

Nondestructive testing, lumber and veneer grading, decay detection

Research & Commercialization

Wood composites – product and process development

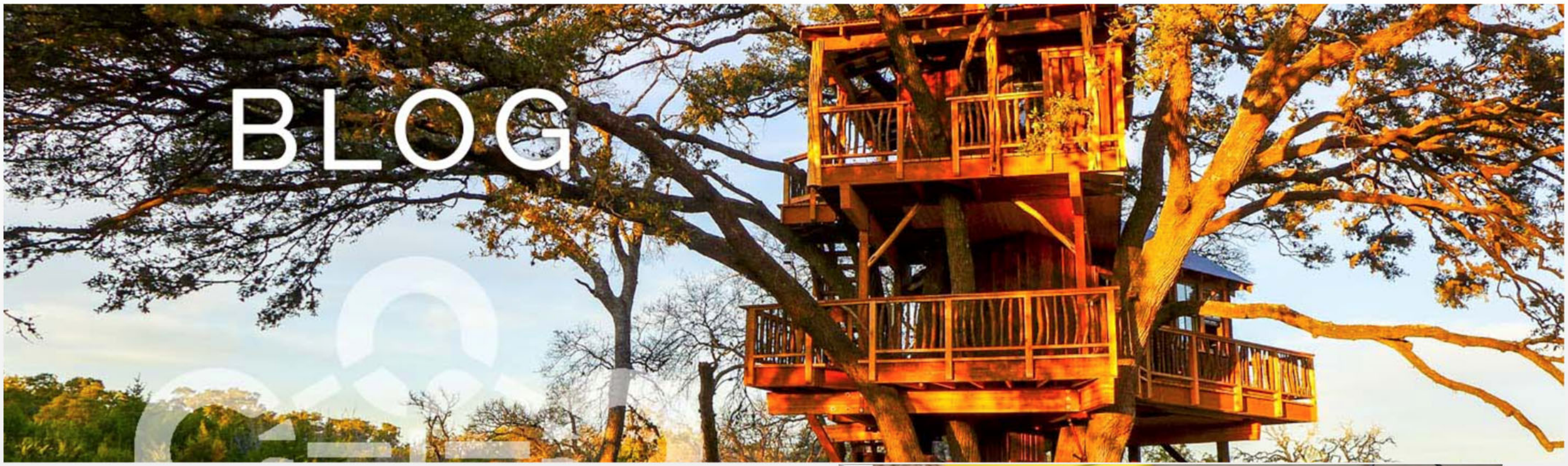


100m diameter turbine at 15 rpm = 175 mph!

WASHINGTON STATE UNIVERSITY

Research & Commercialization

Nelson Treehouse - Animal Planet's *Treehouse Masters*



Cross-Laminated Timber

What is it and why the excitement?

Cross-Laminated Timber (CLT) is an engineered wood composite made from lumber that forms large plates. The plates can be made quite thick (7 laminations or more), which make it viable for buildings of 10 stories or higher.

Source: Structurlam Products Ltd.

Uses of CLT

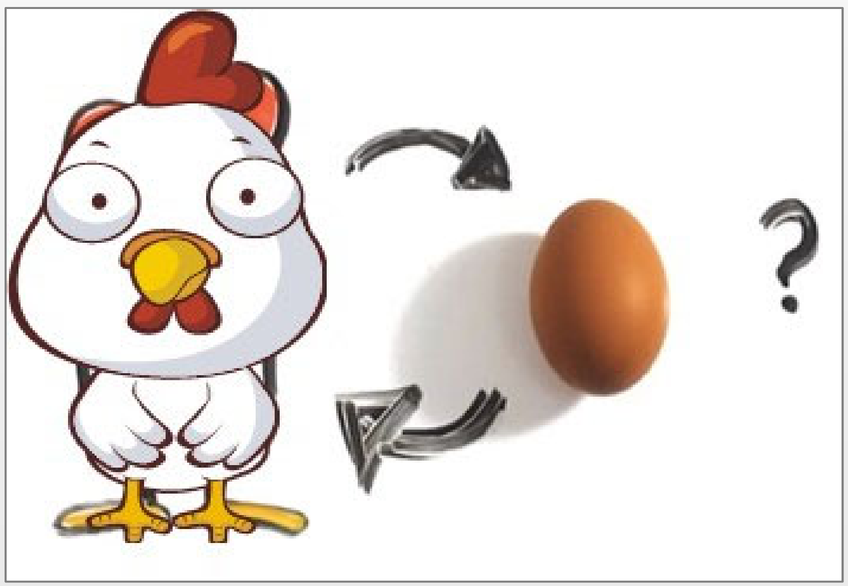
- ✓ Walls
- ✓ Floors
- ✓ Roofs
- ✓ Mats

Opportunities

- ✓ Mid-rise construction
- ✓ Schools (rapid construction over summer)
- ✓ Modular (can withstand handling and transportation loads)

Evolution

- Europe led the way approximately 3 decades ago
- In North America, Canada was the first to adopt
- Progress in US is a bit slower



Who manufactures CLT in North America?

- Structurlam Products Ltd., Penticton, BC CANADA
- Nordic Structures, Quebec CANADA
- StructureCraft Builders, Abbotsford, BC CANADA
- DR Johnson, Riddle, OR
- Smartlam Technology Group, Columbia Falls, MT
- Katerra, Spokane, WA (opens 2019)
- Vaagen Timbers, Colville, WA (opens 2019)

Albina Yard (Portland, OR)

First building in US made from domestically-produced CLT.

Brock Commons Tallwood House, UBC

Great illustration of hybrid construction – 17 stories of mass timber above concrete podium, two concrete stair cores and steel roof

WSU Brelsford Visitor Center

WSU Brelsford Visitor Center

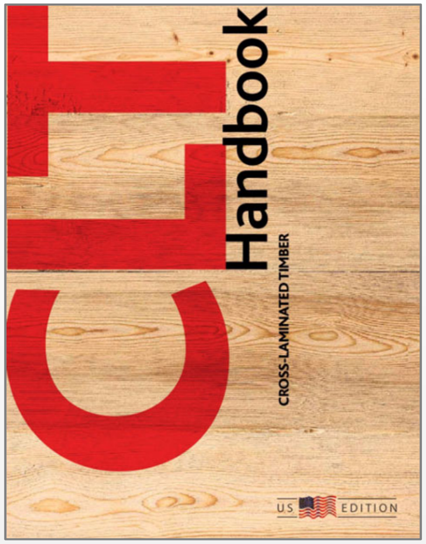
WASHINGTON STATE UNIVERSITY

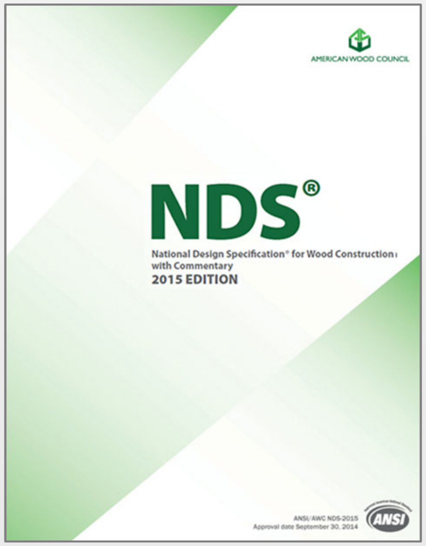
WSU PACCAR Environmental Technology Building

WSU PACCAR Environmental Technology Building

Code Acceptance

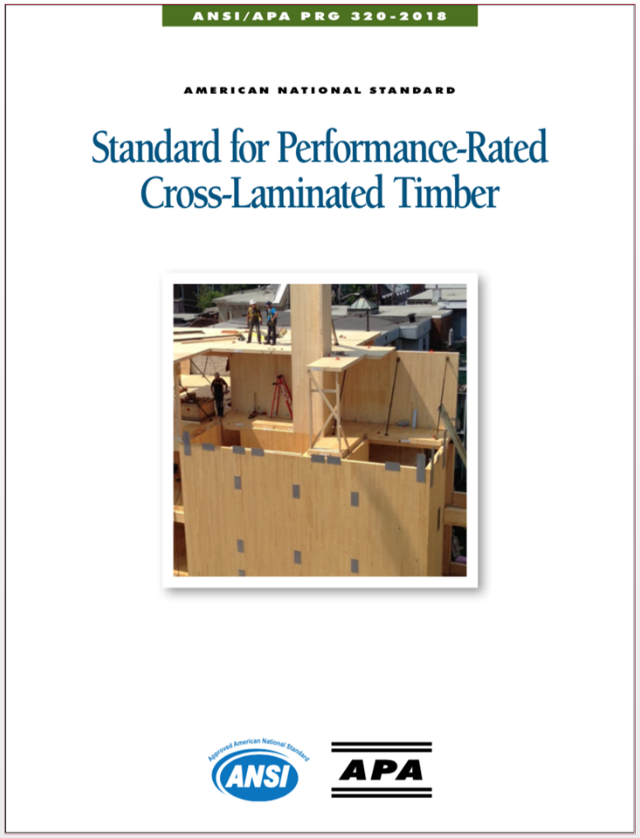
- ❑ Progress
  - ✓ CLT Handbook (joint effort with Canadians)
  - ✓ 2015 National timber design standard (NDS)
    - CLT member
    - Connections
    - Fire
- ❑ Challenges
  - ✓ Seismic design coefficients (FEMA 695 study)
  - ✓ Prescriptive fire design provisions (ICC Ad Hoc Committee)
  - ✓ Floor vibration and acoustics





Manufacturing

- ❑ Progress
  - ✓ Voluntary Product Standard ANSI/APA PRG 320
  - ✓ Research and testing facilities
  - ✓ New plant start-ups in US
- ❑ Challenges
  - ✓ Evolving supply chain
  - ✓ Limited availability/competition within 500 miles of metro markets
  - ✓ Linking engineering design software with digital manufacturing software



Professional Practice

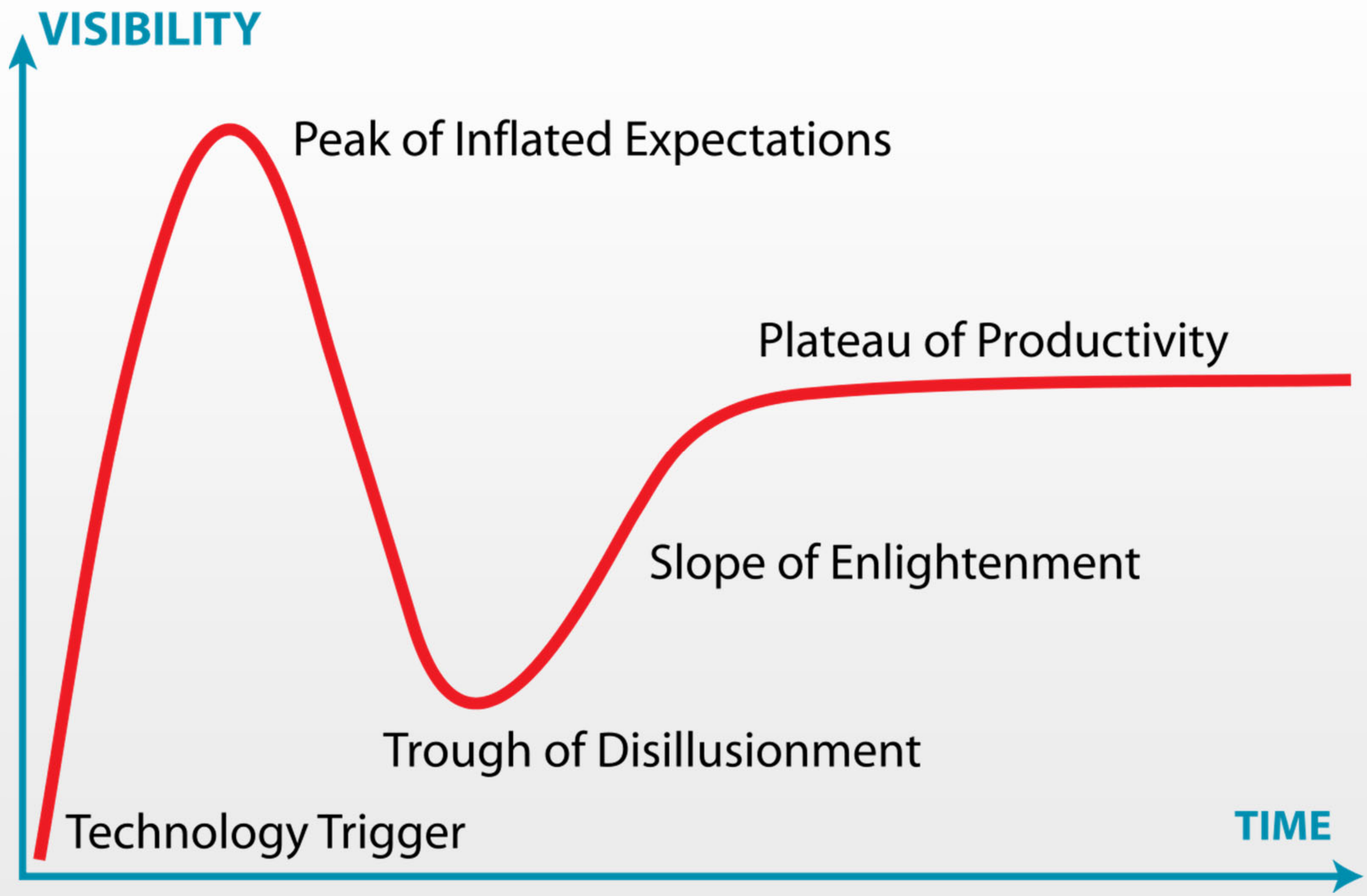
- ❑ Progress
  - ✓ Low-rise and mid-rise design and engineering methods
  - ✓ Potential for rapid construction times

- ❑ Challenges
  - ✓ Time to permit
  - ✓ Cost estimation
  - ✓ Construction workforce training
  - ✓ Education: detailing for durability; field modification; protecting CLT from weather during construction

Summary

Pro	Con
Low carbon footprint	Availability (and initial purchase price)
Potential savings in construction time and cost	Extra design and permitting costs (in short term)
Biophilic response (people respond well to it)	Design issues need to be resolved before digital manufacturing
Beauty and aesthetics	Potential issues with labor unions
Reduced onsite wastes	Supply chain not fully developed
Potential for modular construction	Seismic and fire design issues need to be resolved

Mass timber



Source: Gartner hype cycle

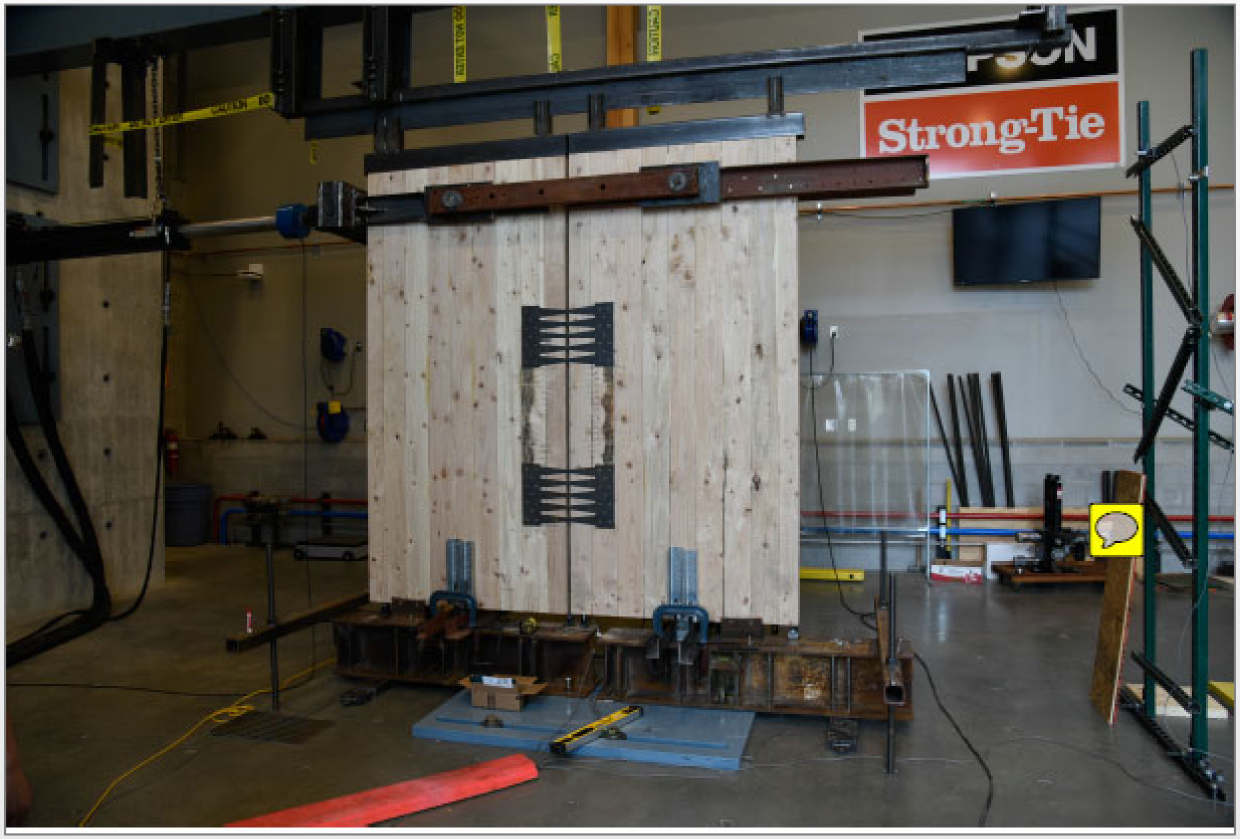
CLT Research & Education at WSU

Self-Centering Rocking Walls

- NSF-sponsored collaboration with Colorado School of Mines, Colorado State Univ, Univ of Washington, Washington State University, Lehigh University, Univ of Nevada
- Initial concepts tested at WSU
- 2-story building tested at shake table at UC San Diego

Inter-Panel Fuses for Shear Walls

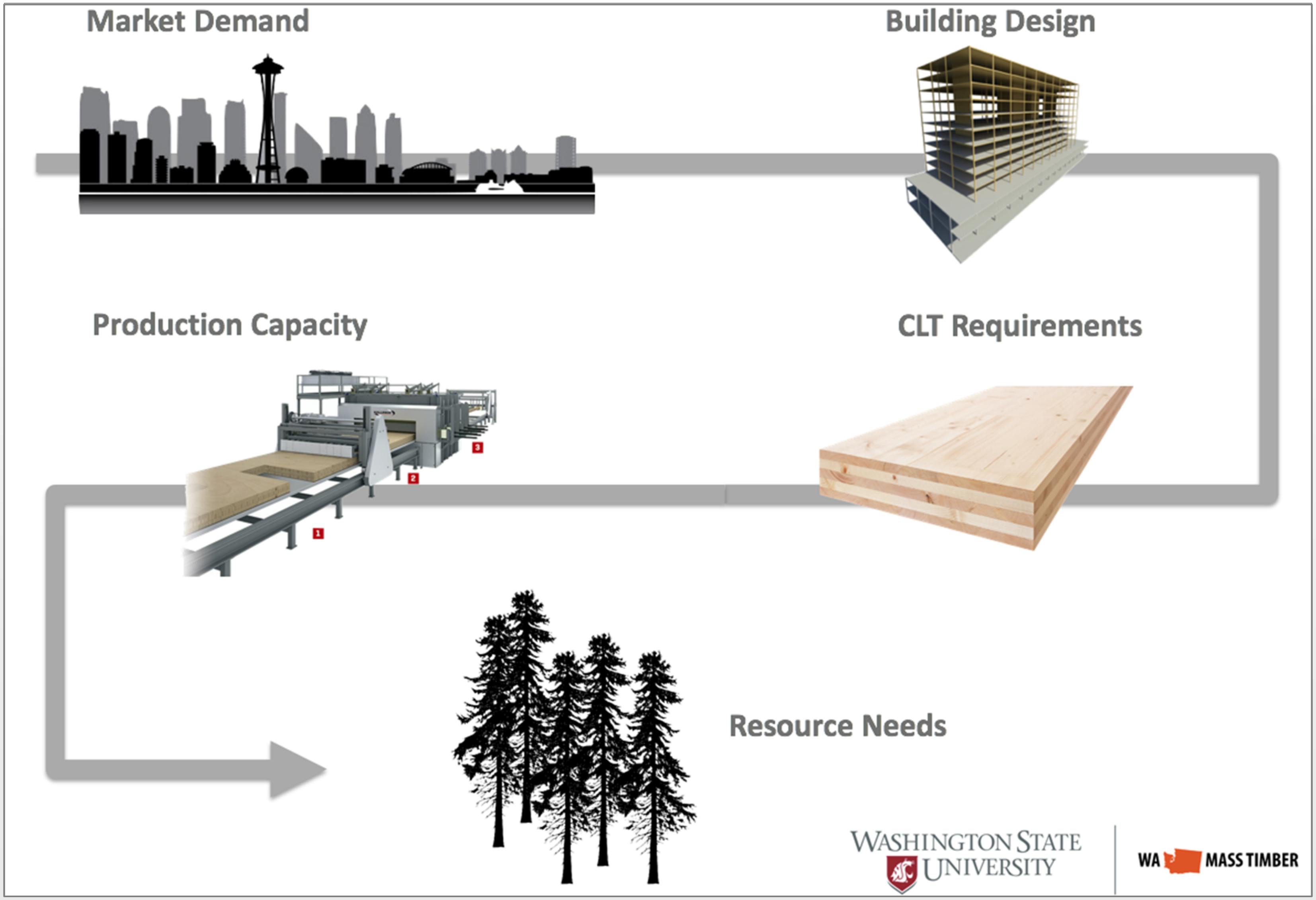
- Collaboration with Katerra and WSU
- Fuse dissipates seismic energy
- Concept tested in laboratory and at UC San Diego



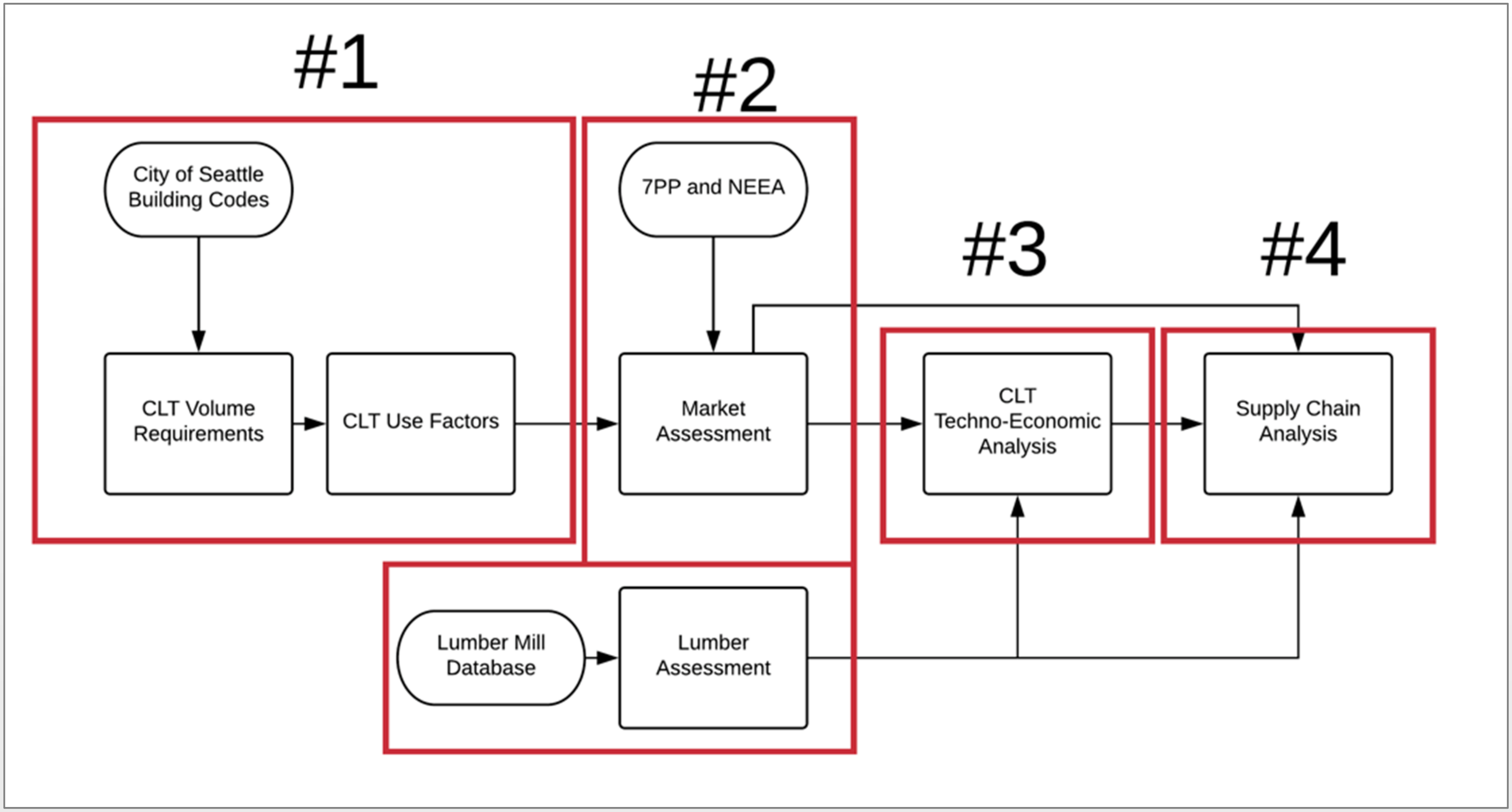
Design Methodologies for Seismic and PBD

- Design methodology and performance of tall CLT buildings – development of modeling and acceptance procedures for *performance based design (PBD)*.
- New performance based design guidelines for CLT – justification for reducing PBD acceptance criteria for buildings under 6 stories and do not have torsional irregularity.

CLT Supply Chain Analysis



Project Components



Building Archetypes

Building Archetype Details

Building Height (stories)	Low-Rise (1-6)	Mid-Rise (7-12)	High-Rise (13-20)
Construction Type	platform	balloon frame	hybrid system
Lateral Loads	CLT	CLT	concrete core
Gravity System	CLT	CLT	CLT

Average CLT Use Factor (ft^3/ft^2)			
Footprint Range (ft^2)	Low-Rise (1-6)	Mid-Rise (7-12)	High-Rise (13-20)
1,000 – 10,000	0.71	0.88	0.57
20,000 – 50,000	0.69	0.88	0.57
60,000 – 100,000	0.69	0.88	0.57

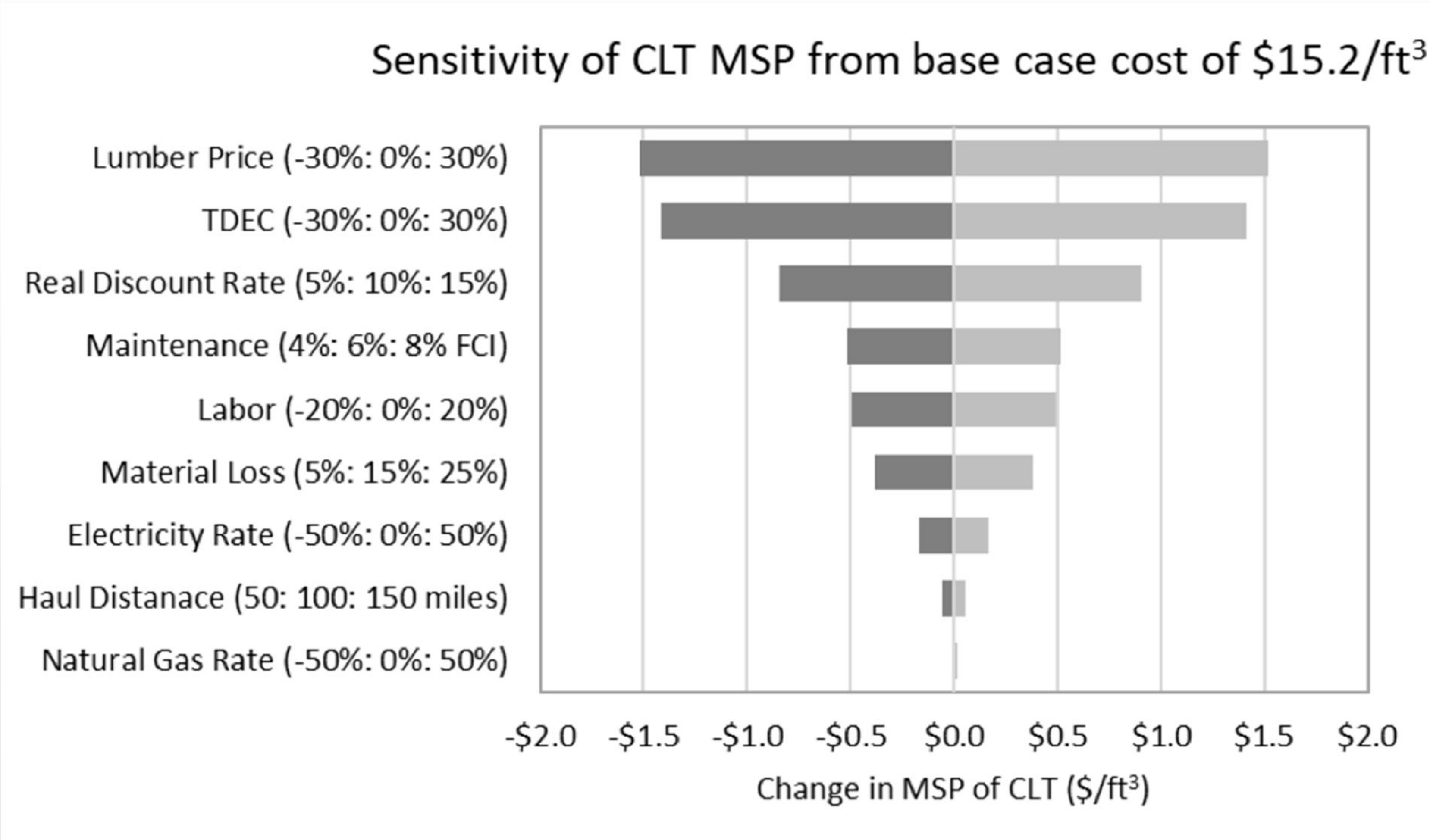
- Design of each archetype was reduced into a CLT use factor
- CLT Use Factor = **ft^3 of CLT /ft^2 of building**
- For a each footprint, CLT use factor increases with increasing building height up to 12 stories from lateral load demands
- CLT use factor is smallest for high-rise buildings; CLT is assumed to carry no lateral load
- Low-rise CLT use factor range = 0.62 to 0.88
- Mid-rise CLT use factor range = 0.80 to 0.96

Capital Costs

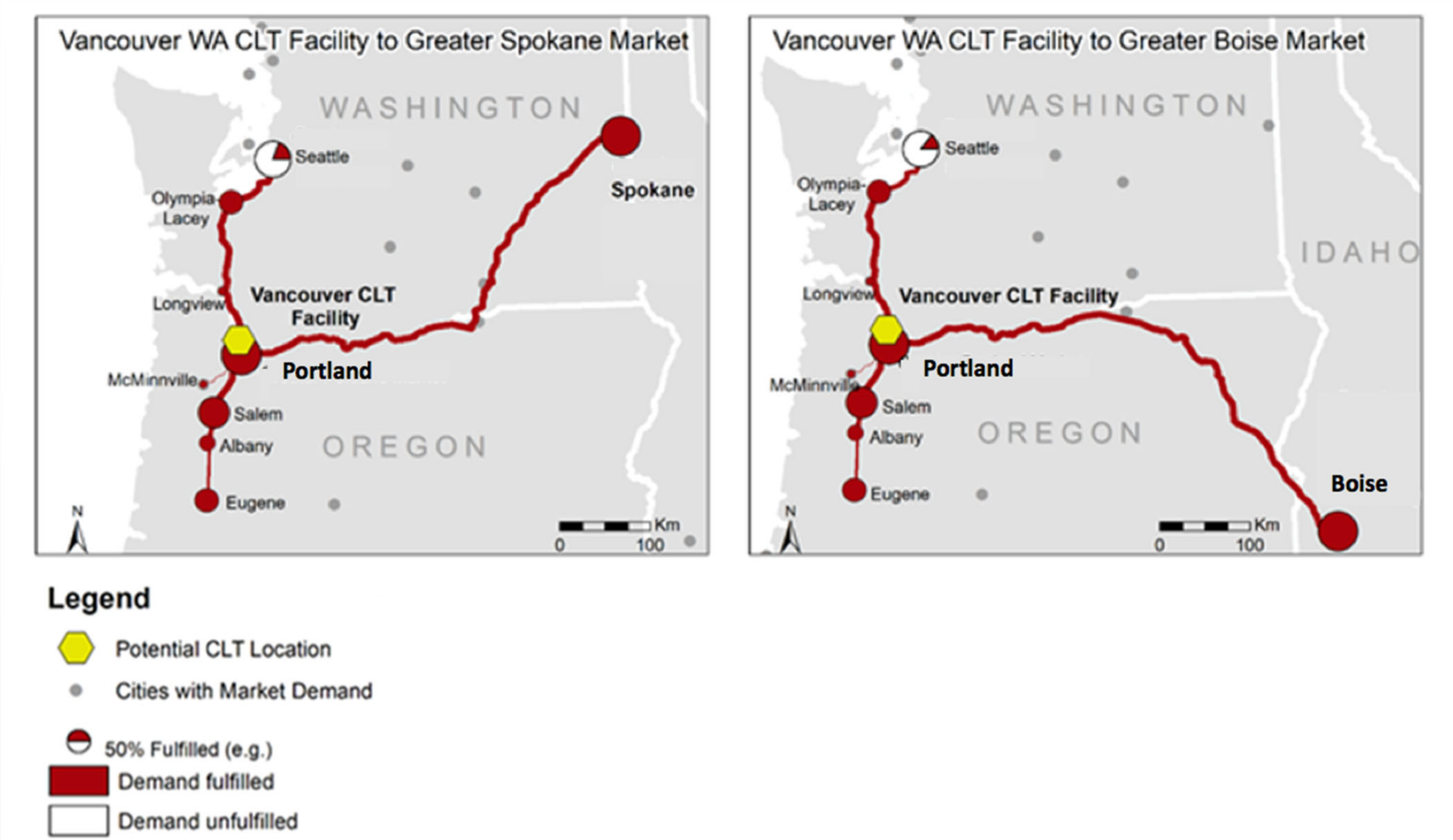
Department	Large Scale Cost (MM$)	Small Scale (MM$)
Lumber Preparation	$3.0	$2.1
Finger Jointing	$2.7	$2.7
Lay Up/Resin Application	$1.9	$1.4
Press	$2.4	$1.5
Panel Finishing	$6.6	$5.8
Total Direct Costs	**$51.9**	**$42.1**
Total Capital Investment	**$80.6**	**$64.6**

- Large Scale = 3.1 MM ft^3/year
- Small Scale = 1.8 MM ft^3/year

Estimated Production Costs



Example CLT Facility to Spokane and Boise Markets



R&D and Testing Services for New CLT Plants

KATERRA
BREAK NEW GROUND

Vaagen Timbers

Education

- Teach over 170 students per year in civil engr, const mgmt, architecture
- Timber design textbook used by over 70 colleges
- Partner with Simpson Strong-Tie on education symposium

Building Connections

Saturday, October 7, 2017
PACCAR Environmental Technology Building
2nd Floor – Town Square
9am – 3pm

How do universities figure into your value propositions?

Universities can…

- Educate future design and construction professionals
- Provide R&D services (leverage your resources)
- Participate in relevant codes and standards development

How to activate industry/university collaborations:

- Identify universities that have design and construction programs
- Offer guest lectures and teaching samples
- Sponsor research
- Offer scholarships and internships
- Sponsor student design competitions


Questions?
cmec.wsu.edu