WoodWorks

Big Buzz on Tall Wood

The Who, What, When, Where, Why and How on High-rise Mass Timber Buildings

Presented by

WoodWorks for Non-residential Construction

AIA Continuing Education

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

As examples of successful tall wood buildings proliferate worldwide, many U.S. architects are considering how to leverage wood's sustainability and other advantages through their own tall wood designs. Intended as a practical overview for those interested in pursuing wood's potential, this presentation will cover the "who, what, when and where" of mass timber buildings. Following a brief discussion of history and motivators, existing tall wood projects will be used to illustrate mass timber and hybrid components, high-rise structural design concepts, and lessons learned regarding cost and schedule. Topics will also include building code avenues for alternate designs, and available resources and support.

Learning Objectives

1. Review the historical context for tall timber structures, and consider the construction and sustainability motivators driving modern examples.
2. Discover the variety of structural components used in mass timber and hybrid projects and, through a series of studies, learn how they can be assembled into systems that address real architectural and structural design constraints.
3. Based on surveys done on built projects, understand what lessons have been learned and potential impacts to cost and schedule.
4. Realize the construction and sustainability motivators for pursuit of tall wood structures and become familiar with available design guidance and research.

Outline

- Who, What, When and Where
    - Historic Examples
    - Modern Built Projects
- Why
    - Motivators
    - Stakeholder Support
- How
    - Overview of Solid Wood Systems
    - High-rise Structural Design Concepts
    - Avenues for Alternate Design

1056

YINGXIAN PAGODA,
SHANXI CHINA

13TH CENTURY

HEDDAL STAVE CHURCH,
NOTODDEN, NORWAY

16TH CENTURY

KIZHI POGOST,
KIZHI, RUSSIA

Size:
7 Stories (at street)
9 stories (at waterfront)
Over 175,000 sf

1 9 0 5
T H E L A N D I N G ,
VANCOUVER, CANADA

Source: A Study on Historical Tall-Wood Buildings in Toronto and Vancouver

PROJECT SIZE:
8 buildings
Covers city block
312 K sf total

LARGEST BLDG:
6 stories
190K sf

THEN:
Carpet Factory

NOW:
Office Complex

1 8 8 9 - 1 9 2 0
TORONTO CARPET FACTORY,
TORONTO, CANADA

Source: A Study on Historical Tall-Wood Buildings in Toronto and Vancouver

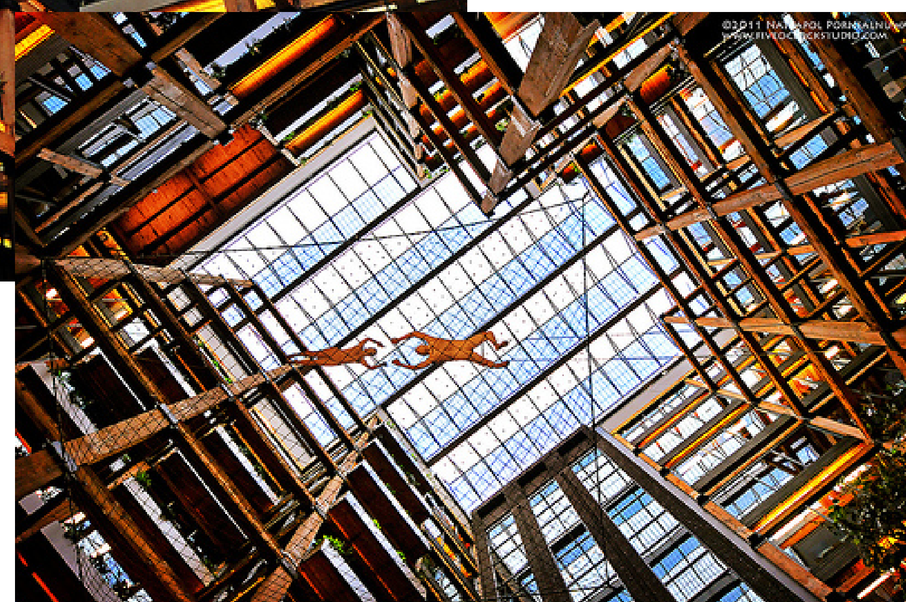
1 9 0 6

BUTLER SQUARE,
MINNEAPOLIS, MM

Size:
9 Stories
500,000 sf

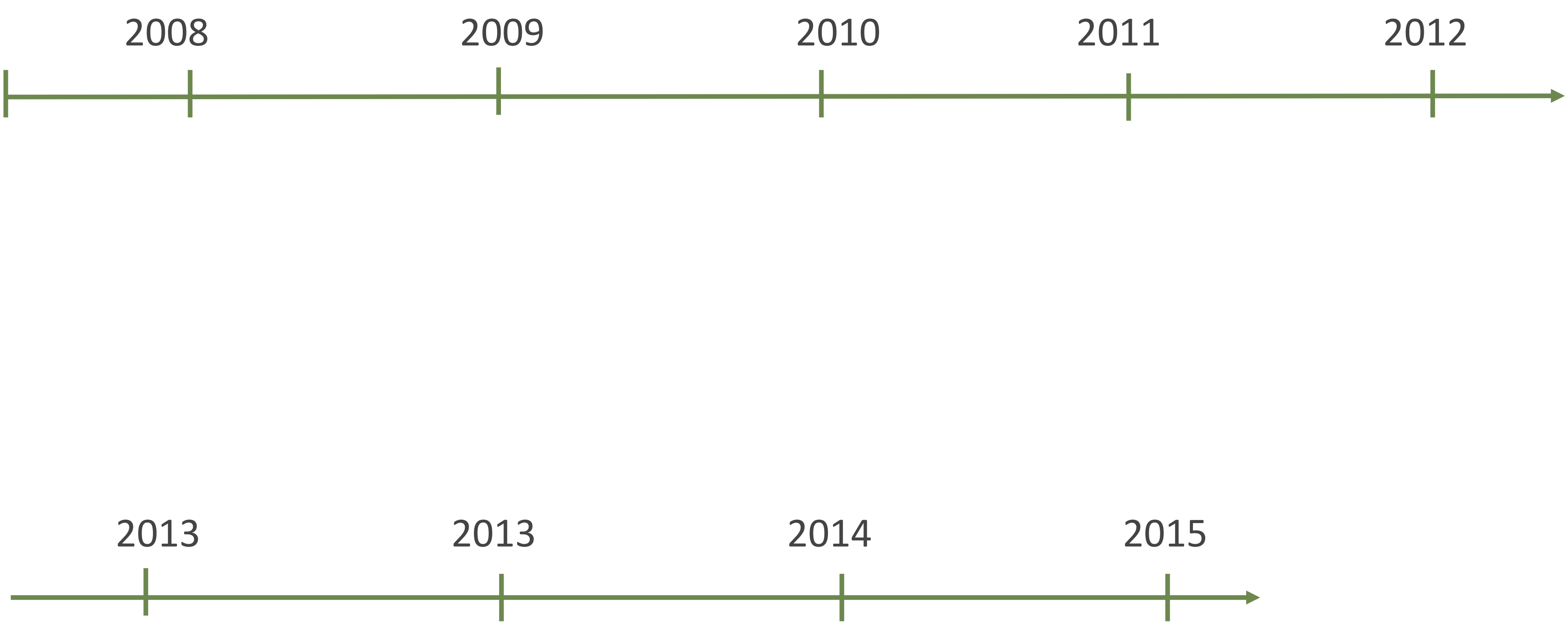
Then:
Warehouse

Now:
Office above
Retail below

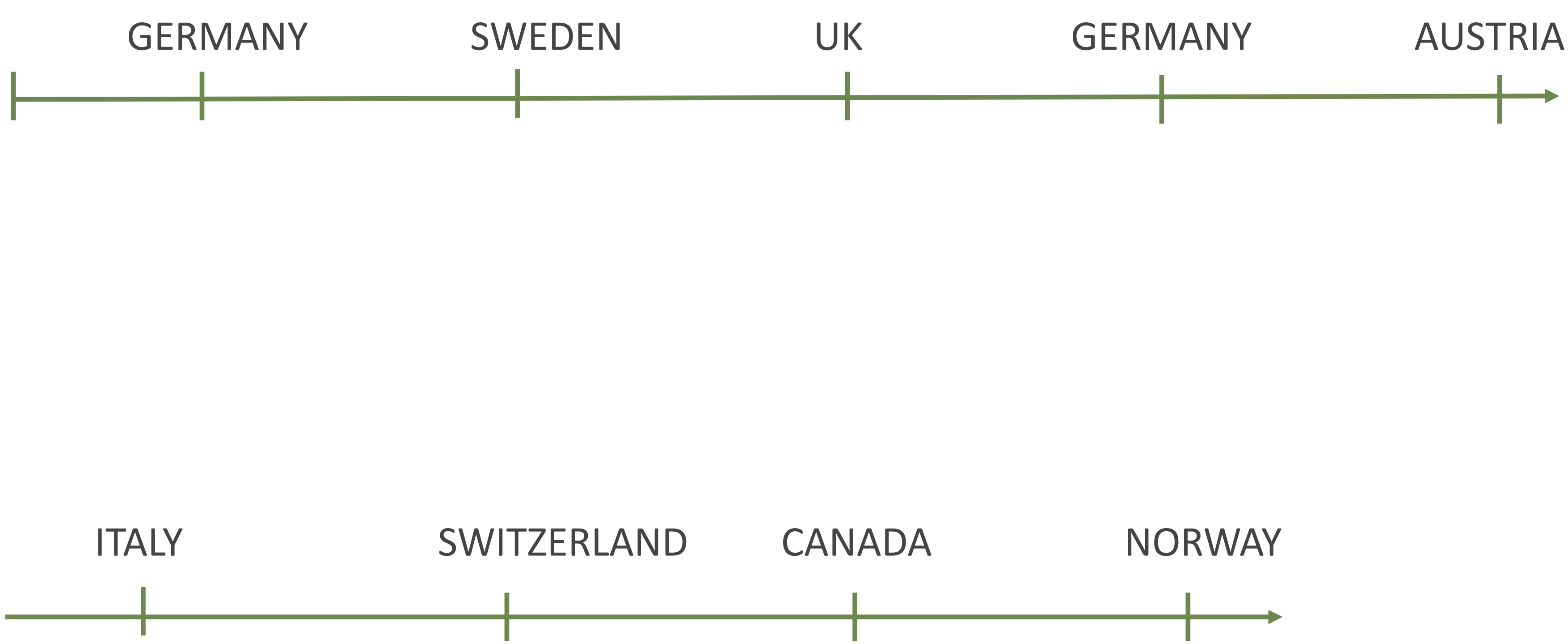


1906
BUTLER SQUARE,
MINNEAPOLIS, MM

Tall Wood Projects



Tall Wood Projects



Tall Wood Projects

7 Stories | 8 Stories/78 ft | 8 Stories/87 ft | 8 Stories/70 ft | 8 Stories/88 ft

9 Stories/92 ft | 6 Stories/75 ft | 6 Stories/96 ft | 14 Stories/163 ft

Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

2008

E3

BERLIN, GERMANY

7 STORIES

13.6K SQ.FT.

Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchar

Architect: Kaden Klingbell Architekten
Engineer: Bois Consult Natterer

Source: Survey of International Tall Wood Buildings, 2014

Photo Credit: Midroc Property Development

2009

LIMNOLOGEN

VAXJO, SWEDEN

4 BUILDINGS

8 STORIES

78 FT

115K SQ.FT.

Architect: Arkitekbolaget, Kronoberg, Martinsons
Engineer: Martinsons Byggsystem KB

Source: Survey of International Tall Wood Buildings, 2014

2009
STADTHAUS
LONDON, UK
9 STORIES

Architect:Waugh Thisleton Architects
Photo Credit:

2010

BRIDPORT HOUSE,
HACKNEY LONDON, UK
8 STORIES
87 FT
~17K SF

ARCHITECT: Karakusevic Carson
ENGINEER: Peter Brett Associates

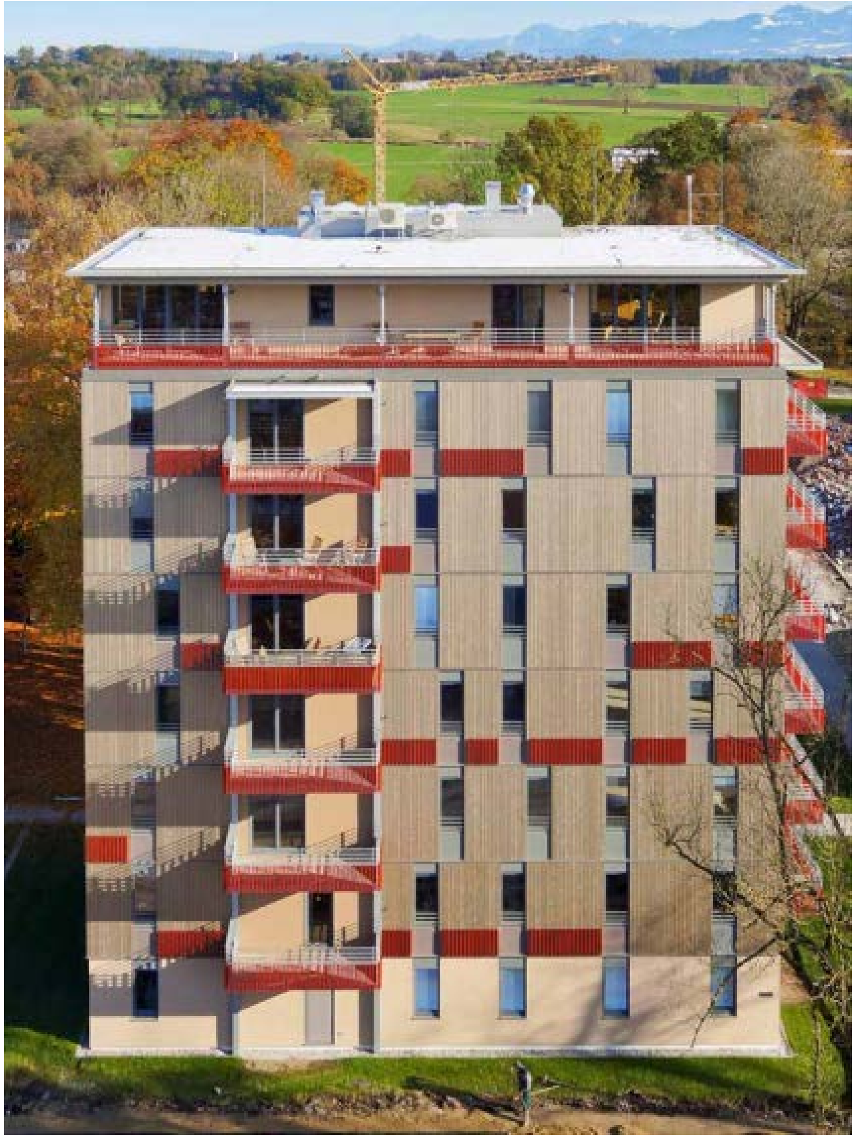


Photo credit: SCHANKULA Architekten / Photographer: Arthur Schankula

2011

HOLZ8

BAD AIBLING, GERMANY

8 STORIES

70 FT

~19K SQ.FT.

ARCHITECT: Shankula Architekten
ENGINEER: Bauart Konstruktions GmbH&Co

Source: Survey of International Tall Wood Buildings, 2014

2 0 1 2

L C T 1

DORNBIRN, AUSTRIA

8 STORIES

88.5 FT

~17 SQ.FT.

ARCHITECT: Hermann Kaufmann
ENGINEER: Merz Kley Partner

2 0 1 3

CENNI DE CAMBIAMENTO

M I L A N , I T A L Y

9 STORIES

92 FT

~183K SQ.FT.

ARCHITECT: Shankula Architekten
ENGINEER: Bauart Konstruktions GmbH&Co

Source: Survey of International Tall Wood Buildings, 2014

Photo Credit: Didier boy de la Tour

2 0 1 3

TAMEDIA HEADQUARTERS, ZURICH, SWITZERLAND

6 STORIES

75 FT

~96K SQ.FT.

ARCHITECT: Shigeru Ban & IttenBrechbuhl
ENGINEER: Creation Holz GmbH

Source: Survey of International Tall Wood Buildings, 2014

2 0 1 3

FORTE’

MELBOURNE AUSTRALIA

10 STORIES

DESIGN BUILDER: Lend Lease

Photo Credit: Lend Lease

2014

WOOD INNOVATION
DESIGN CENTRE,
PRINCE GEORGE, CANADA
6 STORIES
96 FT
~51K SF

ARCHITECT: Michael Green Architecture
ENGINEER: Equilibrium Engineering
PHOTO CREDIT: Ema Peters

2015

TREET APARTMENTS,
BERGEN, NORWAY
14 STORIES
173 FT
~63K SQ.FT.

ARCHITECT: Artec
ENGINEER: Sweco

Source: Toward Taller Wood Buildings Symposium 2014

Tall Wood Projects

?

STARTED JULY 2015

DALSTON LANE

LONDON, UK

ENGINEER: Romboll UK Limited

S T A R T E D N O V E M B E R 2 0 1 5

B R O C K C O M M O N S

BRITISH COLUMBIA, CANADA

ARCHITECT: Acton Ostry Architects
ENGINEER: Fast + Epp

2 0 1 5

REDSTONE ARESENAL CANDLEWOOD SUITES HOTEL
HUNTSVILLE, AL

DESIGN/BUILD: LendLease

UNDER CONSTRUCTION

T3 OFFICE

MINNEAPOLIS, MN

ARCHITECT: Michael Green/DLR Group
ENGINEER: Magnusson Klemencic Associates

USDA Support – Tall Wood Competition

- Originally a $2 million Project Competition
- So many high quality submissions resulted in 2 projects awarded $1.5 million each
- Funding provided by joint effort between Softwood Lumber Board, Binational Softwood Lumber Council and USDA

Framework Project Team

Portland, Oregon

Owner: The Framework Project, LLC
Land Owner: Beneficial State Bancorp
Development Team: project^
Architect: LEVER Architecture
Structural Engineer: KPFF Consulting Engineers
M/E/P: PAE Consulting Engineers
Affordable Housing/Investor: Home Forward
Fire/Timber & Environmental Engineer: Arup
General Contractor: Walsh Construction

475 West 18th Project Team

Chelsea, New York

Owner: 130-134 Holdings LLC
Development Team: 130-134 Holdings LLC and Spiritos Properties LLC
Architect: SHoP Architects
Structural Engineer: Arup
M/E/P: ICOR Consulting Engineers
Environmental Consultant: Atelier 10
Fire and Timber Engineer: Arup
General Contractor: Not yet selected

Source: reThinkWood

Tall Wood Winner – Portland, OR

Framework: An Urban + Rural Ecology

OWNER: Beneficial State Bancorp
ARCHITECT: LEVER Architecture
ENGINEER: KPFF

Framework: An Urban + Rural Ecology

- **Location**: Pearl District, Portland, OR
- **Height:** 130’ / 12 stories
- **Total Building Area:** 90,000 square feet
- **Building Uses:** Ground floor retail; 5 office floors; 5 apartment floors; Rooftop amenity
- **Materials:** Cross laminated timber floors and lateral force resisting system; Glue laminated beams and columns

Source: reThinkWood

Tall Wood Winner – New York, NY

475 West 18th: Setting the Stage for Innovation, Engineering and Architecture

- **Location**: West Chelsea, Manhattan, NY
- **Height:** 120’ / 10 stories
- **Total Building Area:** 50,000 square feet
- **Building Uses:** Residential condominium with ground floor commercial space
- **Materials**: Mass timber columns, beams, shear walls and floors

475 West 18th: Setting the Stage for Innovation, Engineering and Architecture

OWNER: Spiritos Properties
ARCHITECT: SHoP Architects
ENGINEER: ARUP

Source: reThinkWood

Outline

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- Why
  - Motivators
  - Government Support
- How
  - Overview of Solid Wood Systems
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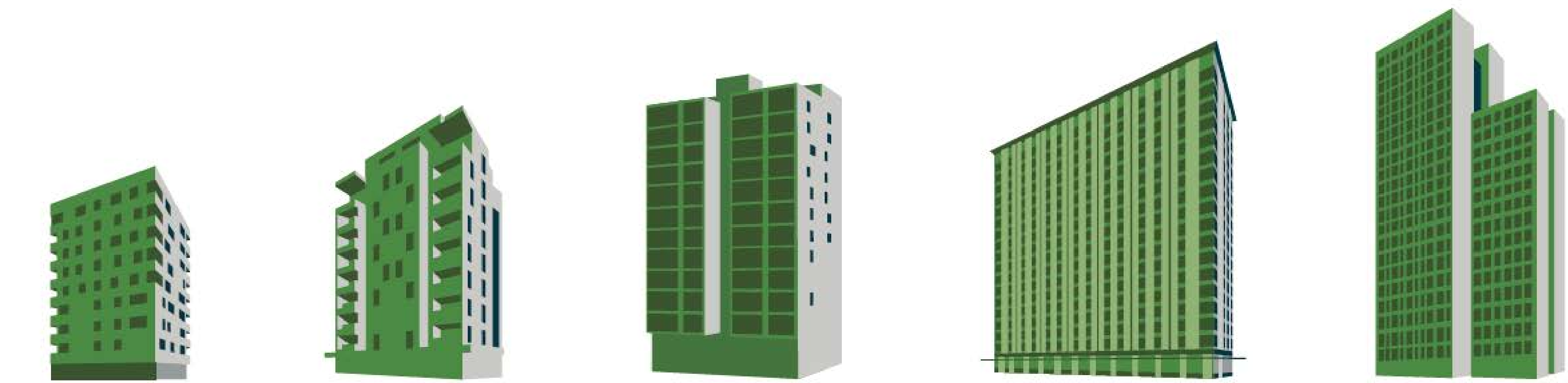
Evolution to High-rise



Murray Grove
London, United Kingdom
8 Stories
2009

Forté
Melbourne, Australia
10 Stories
2012

TREET
Bergen, Norway
14 Stories
2015

Brock Commons
Vancouver, Canada
18 Stories
2017

HoHo
Vienna, Austria
24 Stories
2017

Source: reThinkWood

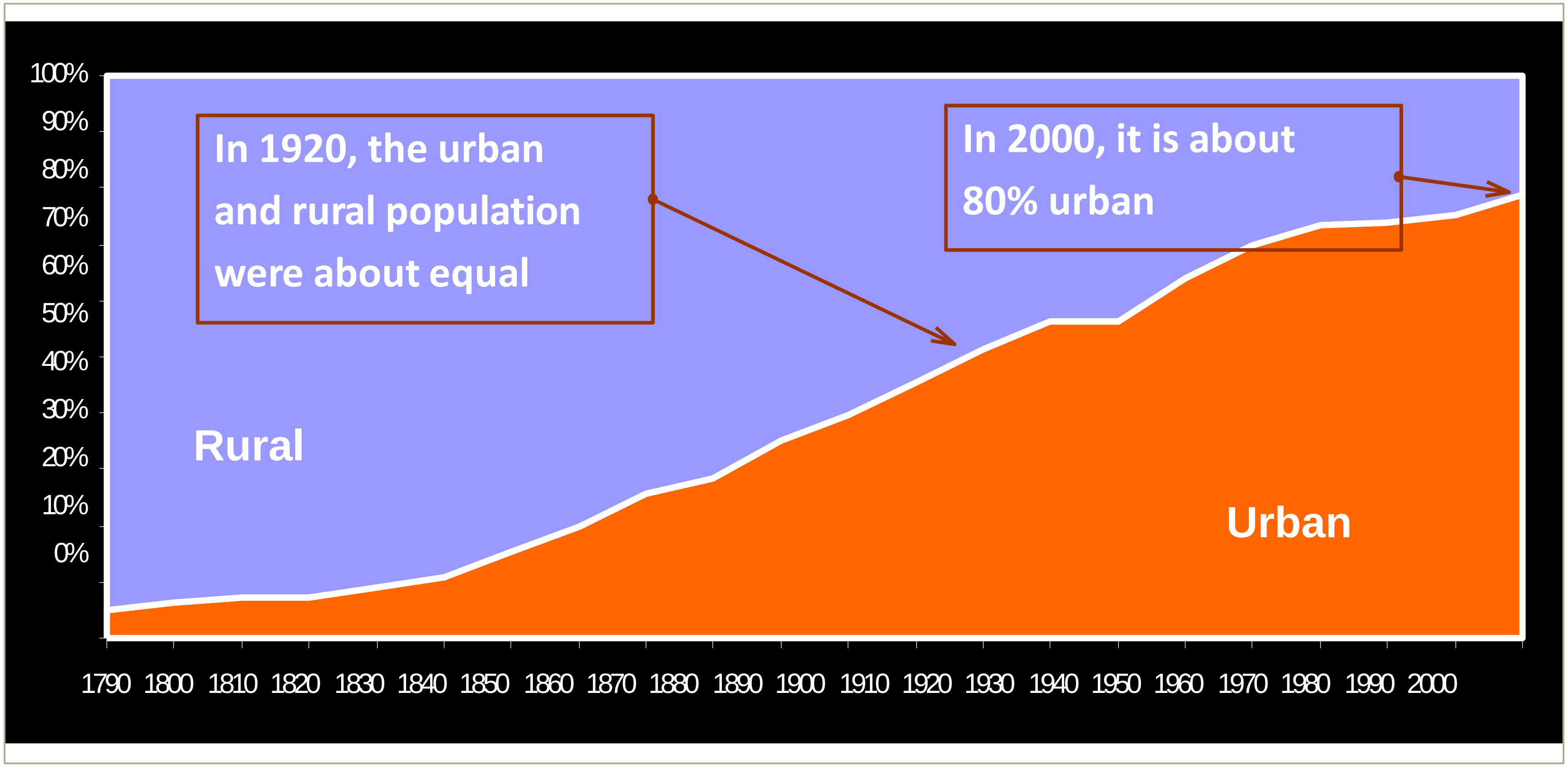
Global Population Boom

Global Population
7.3 billion now
9.7 billion by 2050
33% increase

Urban Population
6.4 billion by 2050
62% increase

Source: United Nations Department of Economic and Social Affairs

Trends in US Population



Source: US Census Bureau

Benefits of Wood Construction

Improved Sustainability

- Reduced Embodied Carbon
- Minimal waste production
- Highly Energy Efficient

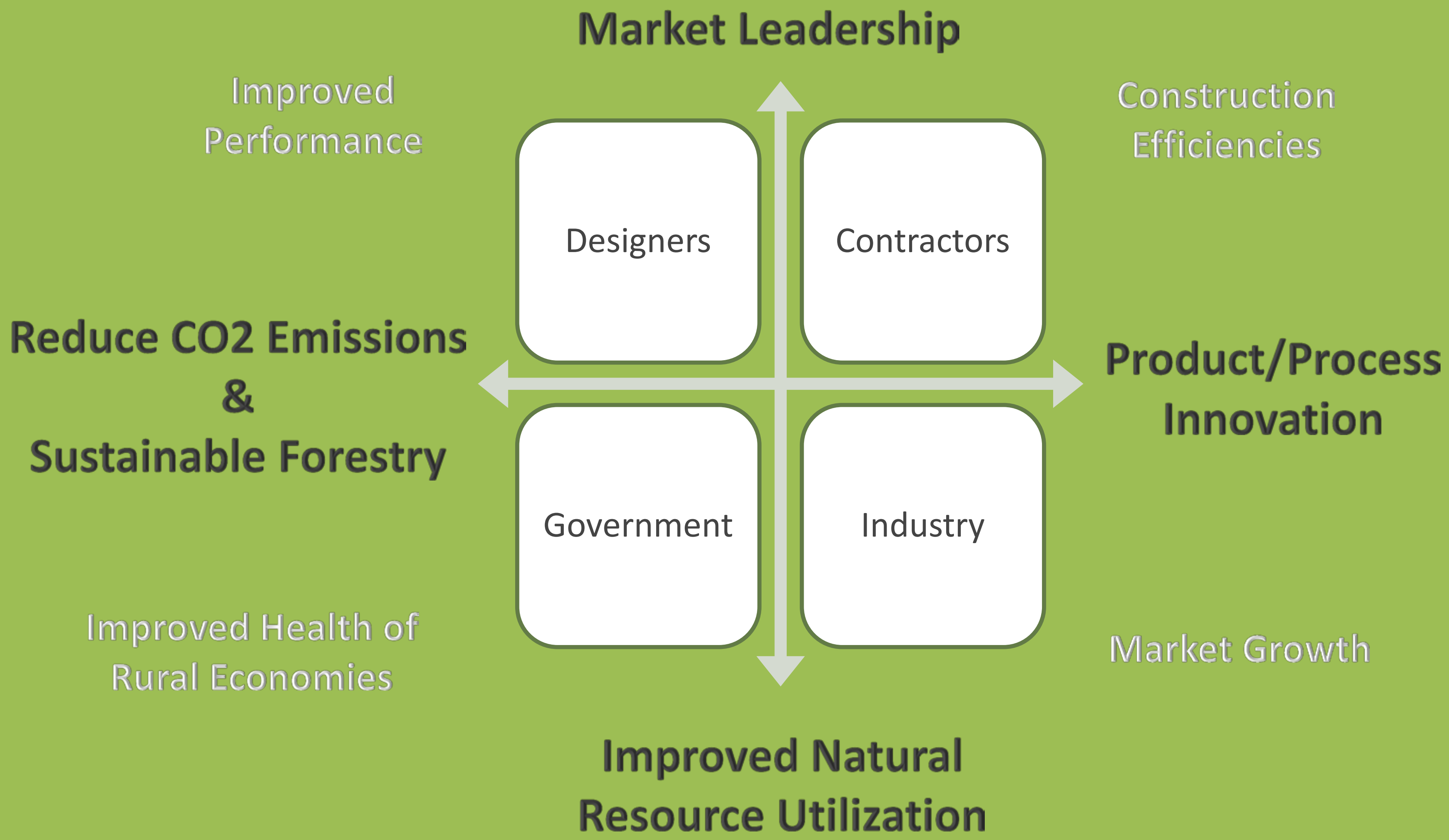
Valuable Performance

- Disaster Resilient
- Good Fire Resistance
- High performing Acoustics
- Structural Flexibility

Construction Efficiencies

- ~75% lighter than concrete
- Reduced construction time
- Pre-fabricated and Precise

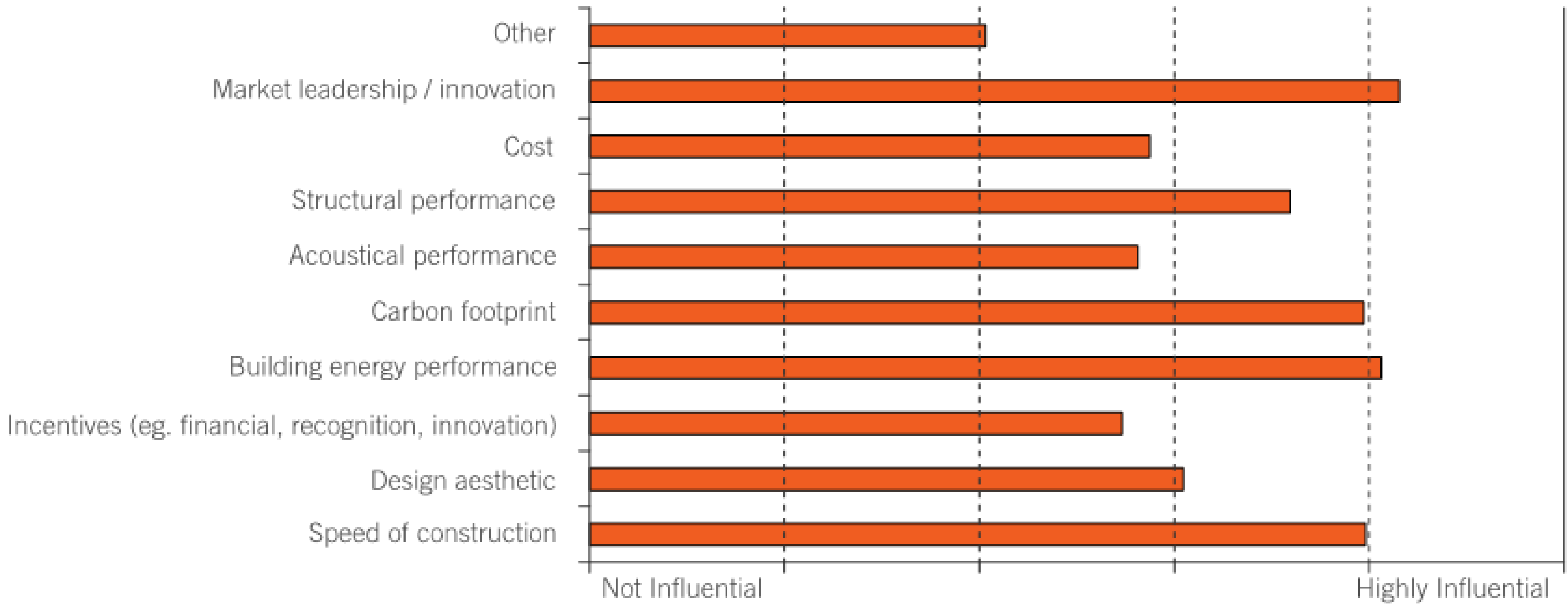
Stakeholders Supporting Tall Wood



Tall Wood Motivators – Design Team

Design Team: Online Questionnaire Participant Responses

Influential Factors on the Design Team's Decision to Use Structural Wood Technology:

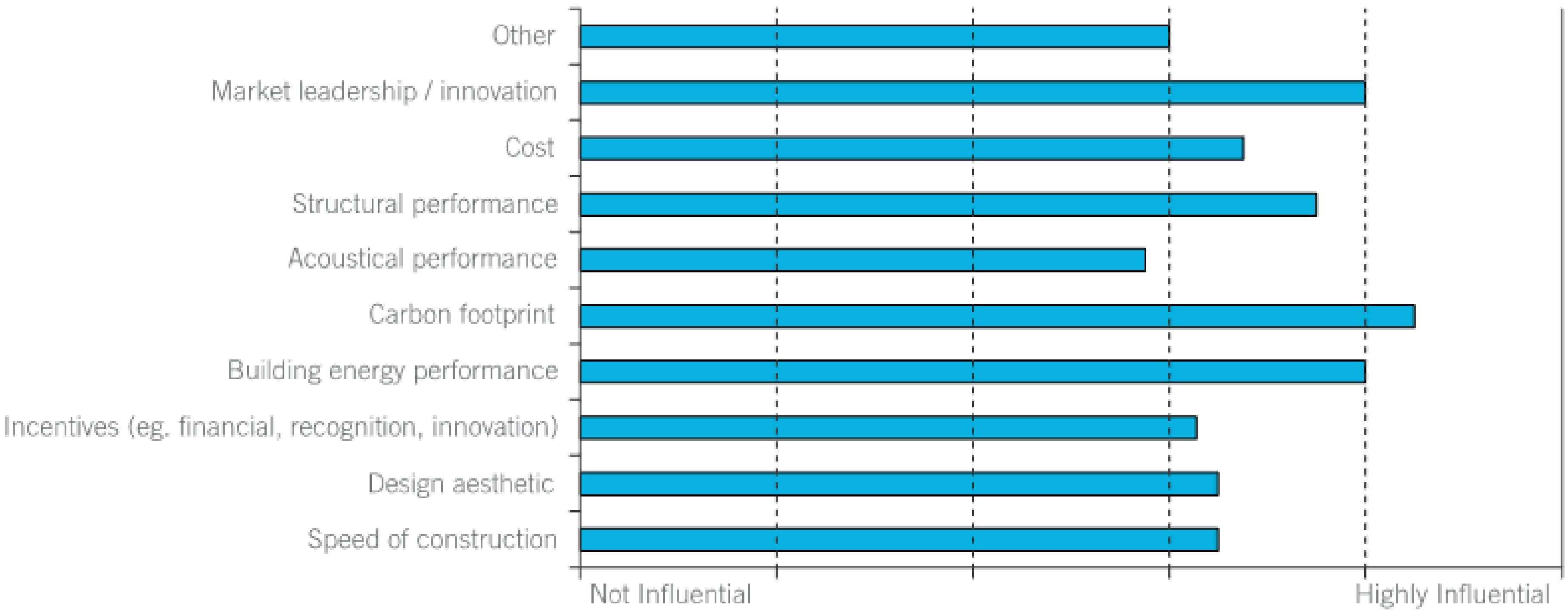


Source: Survey of International Tall Wood Buildings, 2014

Tall Wood Motivators – Owner/Developer

Owner/Developer: Online Questionnaire Participant Responses

Influential Factors on the Owner / Developer's Decision to Use Structural Wood Technology:



Source: Survey of International Tall Wood Buildings, 2014

Tall Wood Motivators

Primary Motivators

- Market Leadership
- Carbon Reduction
- Energy Performance

Secondary Motivators

- Structural Performance
  - Light weight
- Speed of Construction
- Aesthetic

Source: Survey of International Tall Wood Buildings, 2014

Market Leadership

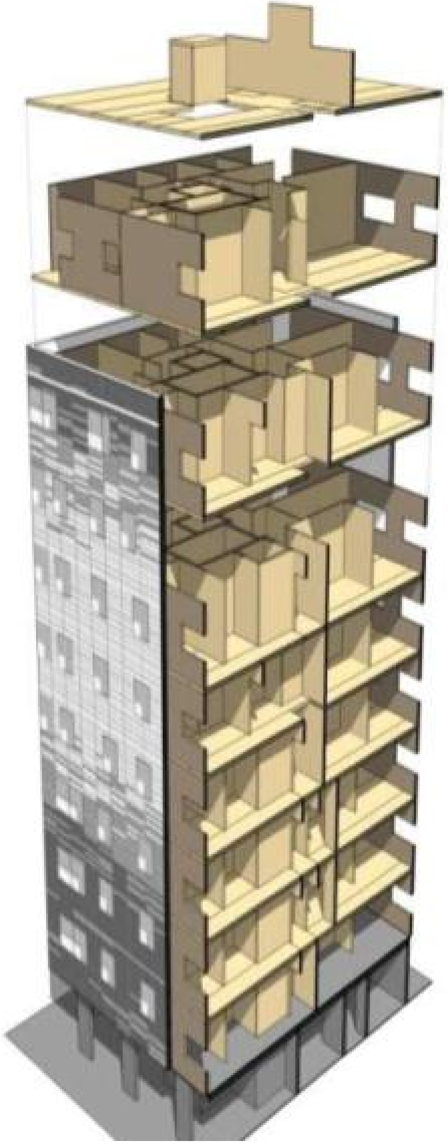
Carbon Reduction

Volume of wood used	950 m^3
Carbon sequestered and stored (CO_2e)	660 metric tons
Avoided greenhouse gases (CO_2e)	225 metric tons
Total potential carbon benefit (CO_2e)	915 metric tons

Carbon savings from the choice of wood in this one building are equivalent to:

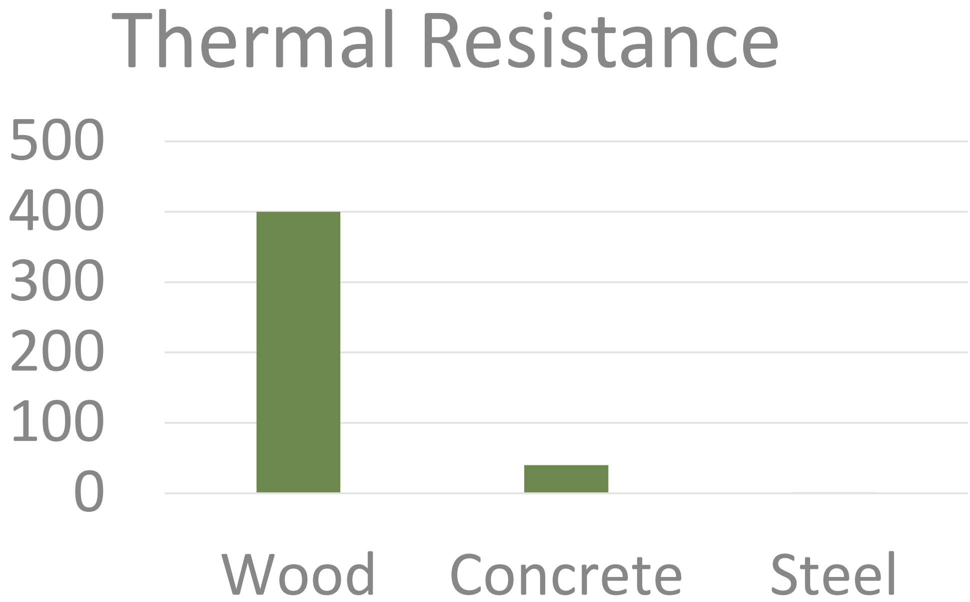
175 passenger vehicles off the road for a year

Enough energy to operate a home for 79 years



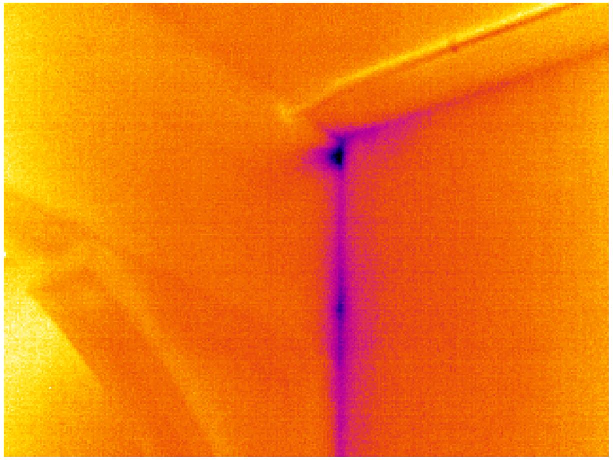
Stadhaus, London, UK
Architect: Waugh Thistleton Architects
Photo credit: Waugh Thistleton Architects

Energy Performance

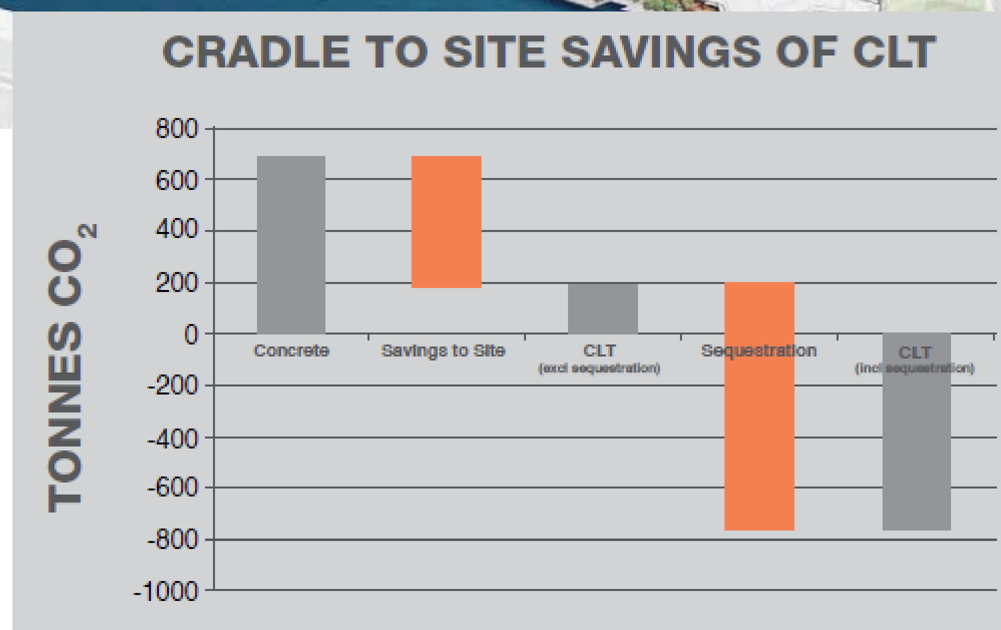


*Normalized Comparison

Source: Thermal Performance of Light framed Systems, CWC



Structural Performance



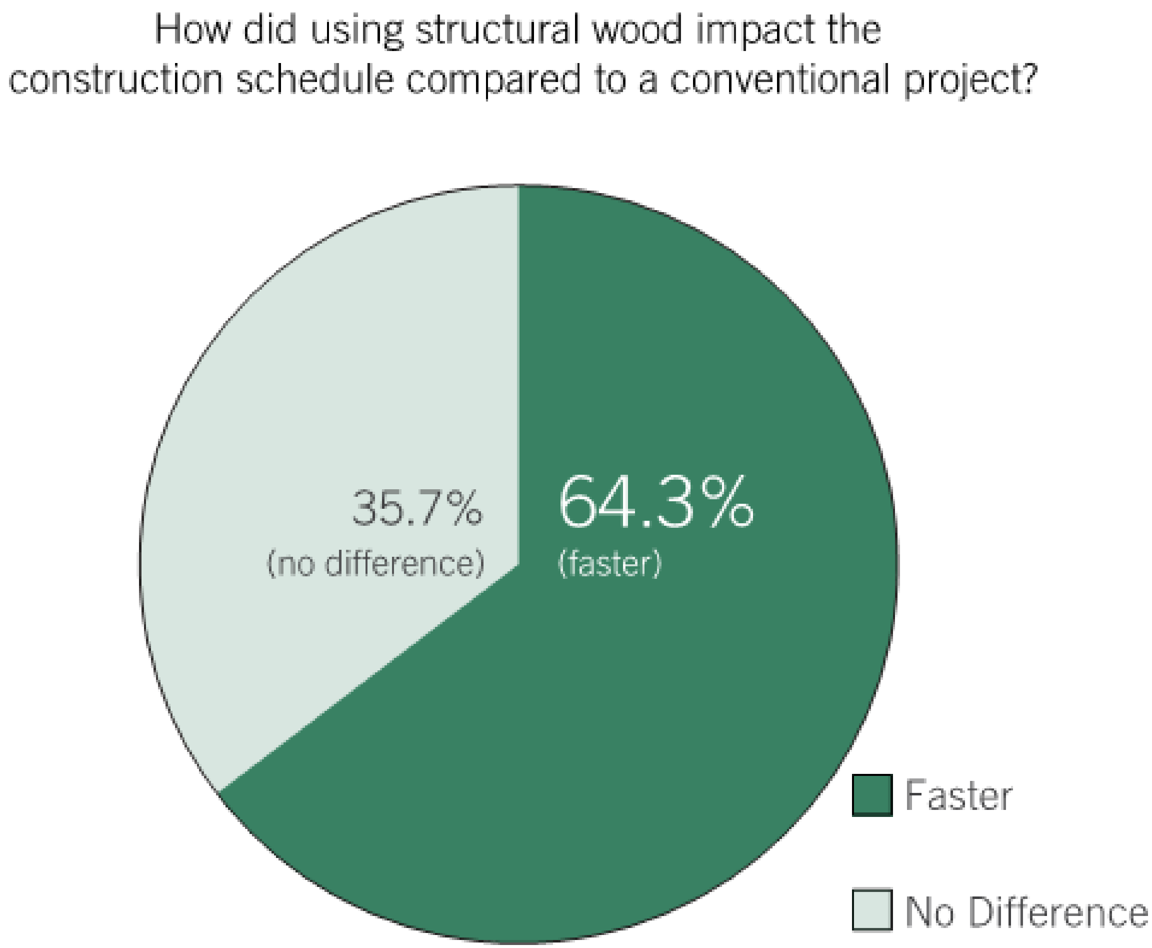
Forte', Victoria Harbor, Melbourne, Australia
Architect: Lend Lease

Speed of Construction

Stadhaus, London, UK
Architect: Waugh Thistleton Architects
Photo credit: Waugh Thistleton Architects

http://www.youtube.com/watch?v=tJHeLyFASEI

Speed of Construction



Source: Survey of International Tall Wood Buildings, 2014

Speed of Construction - Time is Money

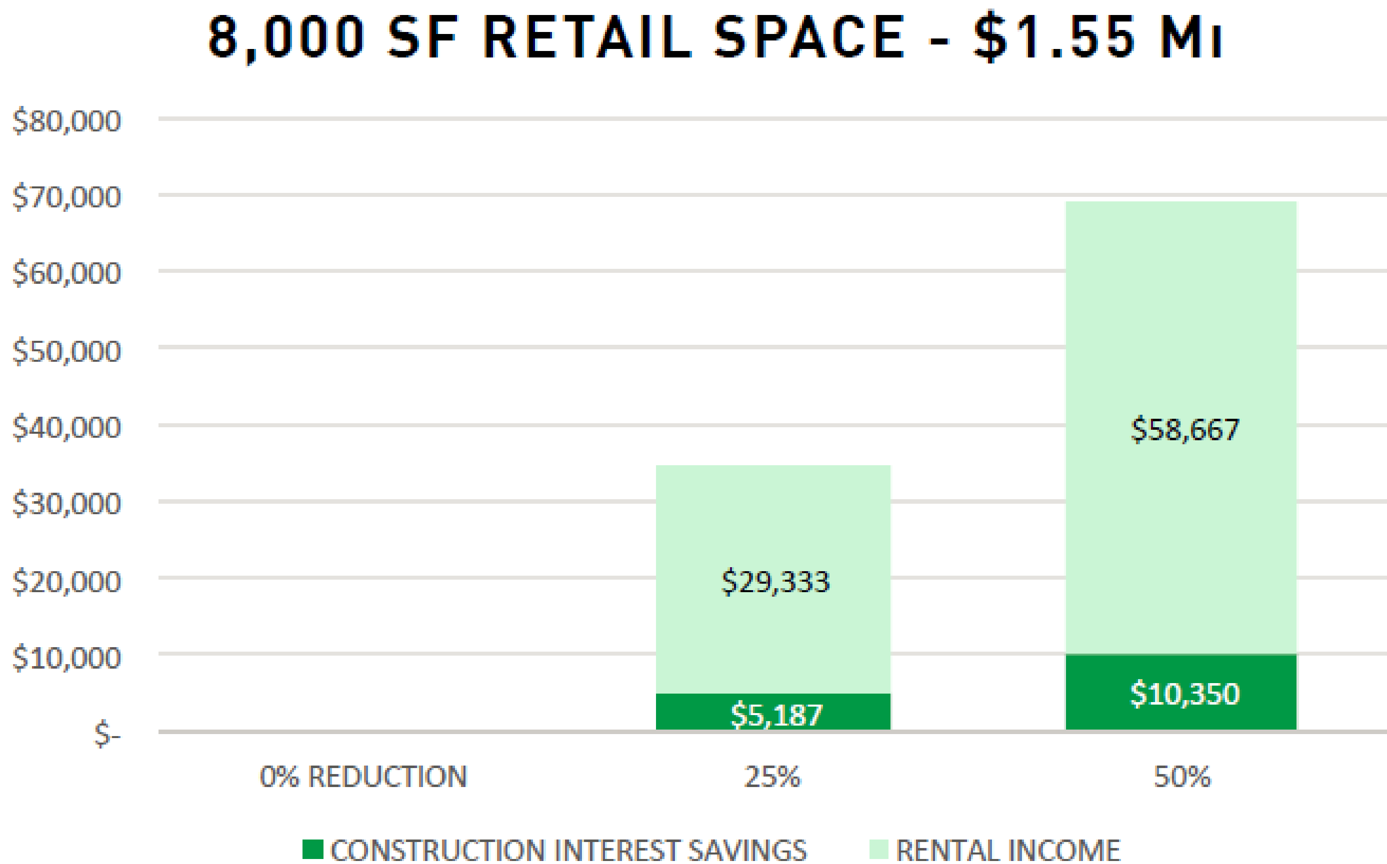


Figure 25

Pro-Formas include a cost reduction in terms of a 25% and 50% faster build time. The lease rate information assumes a 100% building occupancy to reflect the possible savings.

Source: Solid Wood Construction: Process Practice Performance, Smith, Griffin Rice, 2015

Speed of Construciton - Time is Money

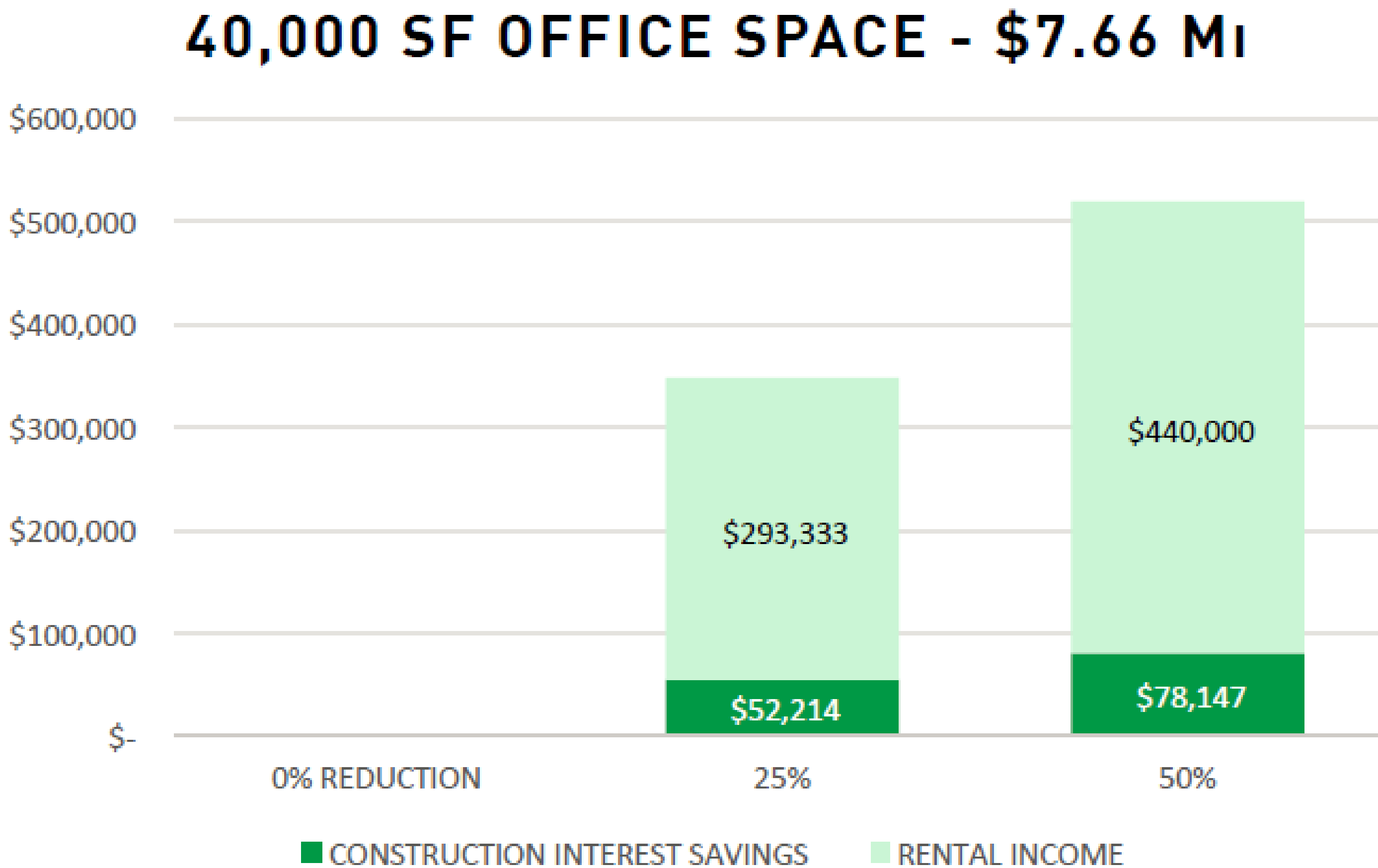


Figure 26

Pro-Formas include a cost reduction in terms of a 25% and 50% faster build time. The lease rate information assumes a 100% building occupancy to reflect the possible savings.

Source: Solid Wood Construction: Process Practice Performance, Smith, Griffin Rice, 2015

Aesthetics

ARCHITECT: Michael Green Architecture
ENGINEER: Equilibrium Engineering
PHOTO CREDIT: Ema Peter Photography

Government Support

"Building stronger markets for innovative wood products will **support sustainable forestry**, **reduce green house gas emissions**, and **put rural America at the forefront of an emerging industry**"

Tom Vilsack – Agriculture Secretary

US Forest Lands

Source: U.S. Forest Service, National Woodland Owner Survey

US/State Forest Land

LAND AREA *(in thousands of acres)*
U.S. Forest Service, 2012

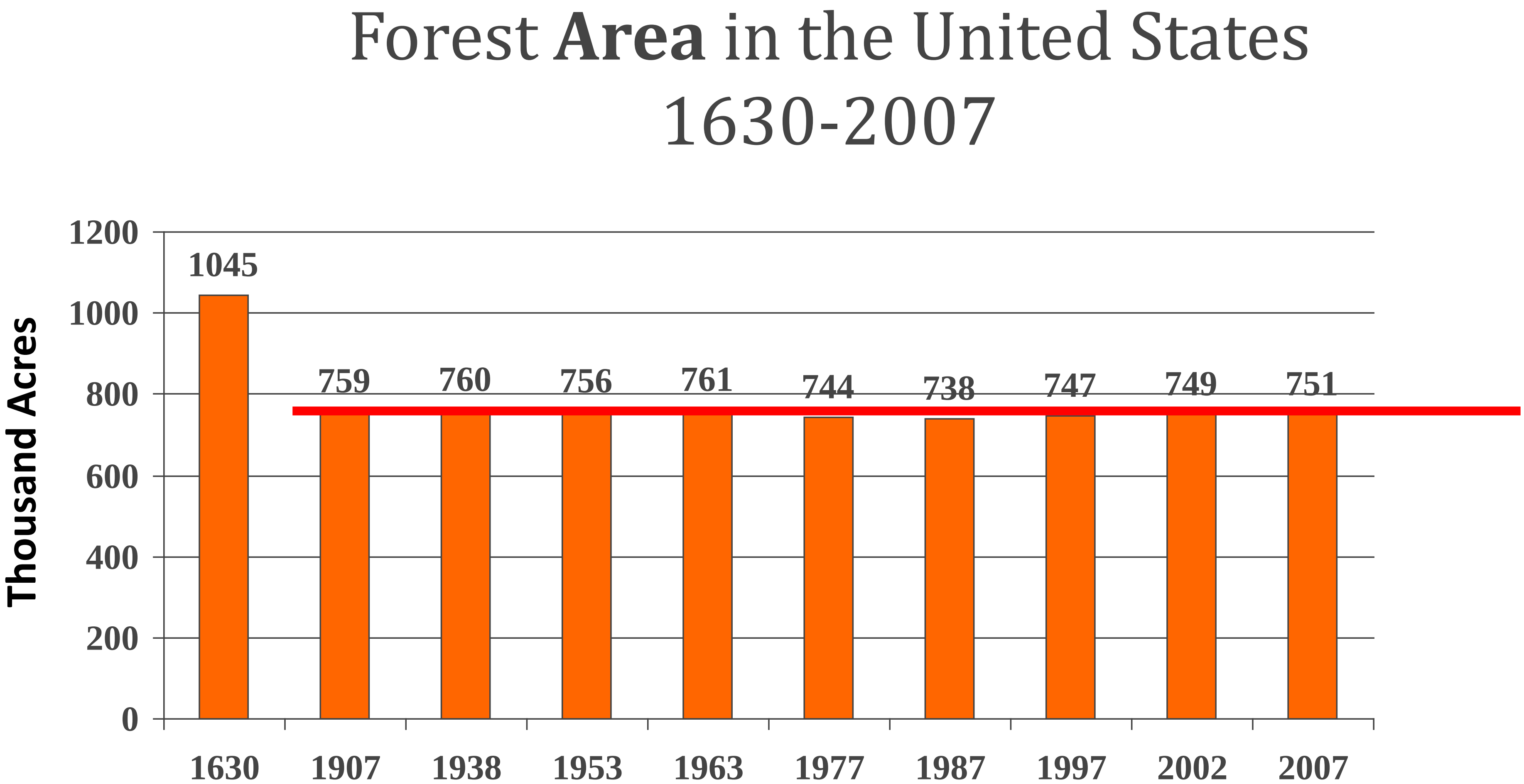
Total Land Area	**2,260,952**
Forests	776,234
Forests as Percent of Total	33.9%
Federal Lands	238,469
National Forest System	145,229

TIMBERLAND *(in thousands of acres)*
U.S. Forest Service, 2012

National Forest System	98,308
Other Federal	14,002
State, County and Municipal	48,668
Private Corporate	111,279
Private non-Corporate	248,896
Total Timberland	**521,154**

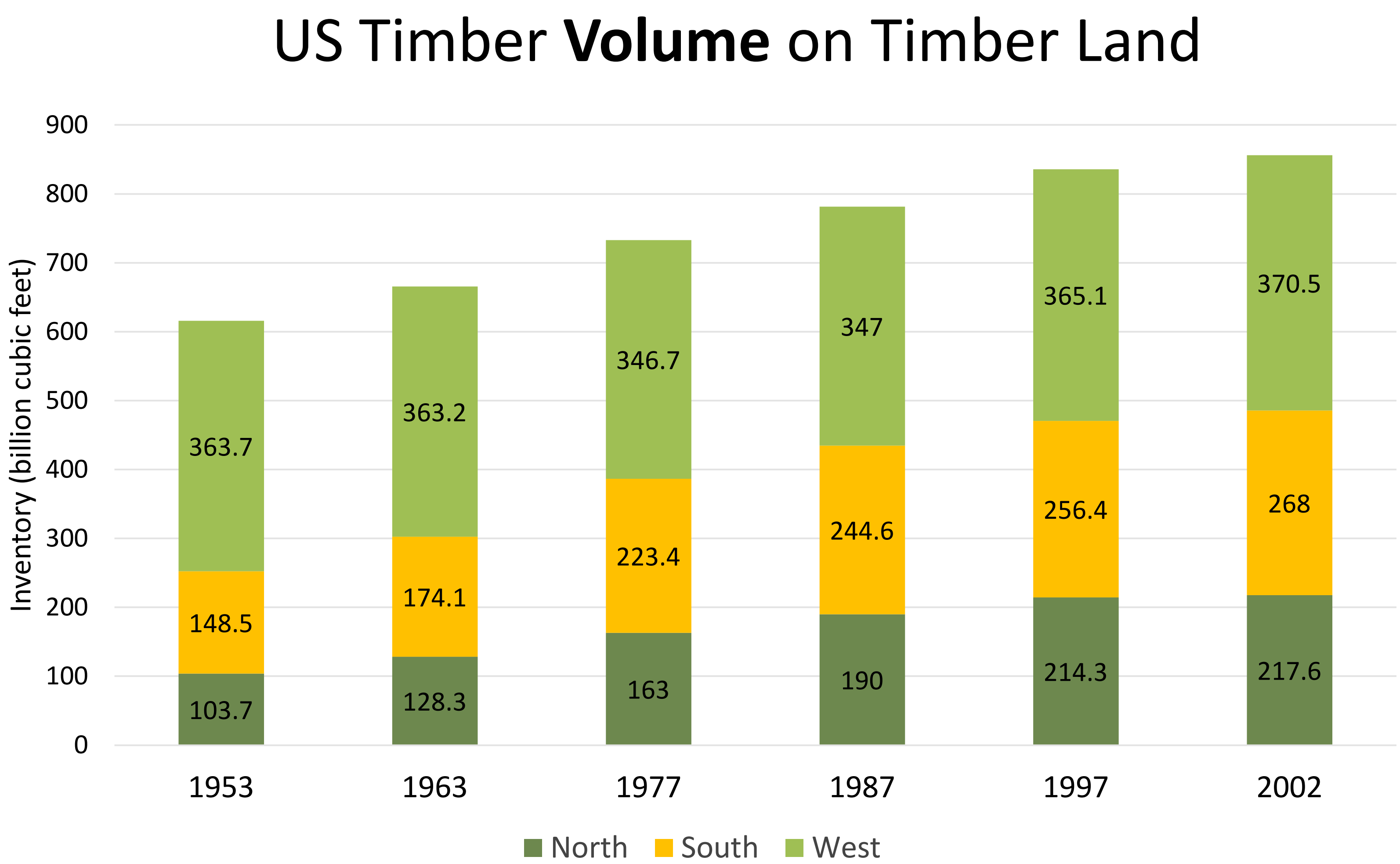
Source: http://awc.org/publicpolicy/statefactsheets

US Forest Land



Source: USDA-Forest Service, General Technical Report WO-78. (2009).

US Forest Land



Source: USDA-Forest Service, US Forest Resource Facts and Historical Trends FS-801. (2004).

Western US Wild Fire Epidemic

Source: US Forest Service –
http://www.fs.fed.us/about-agency/budget-performance/cost-fire-operations

Average US Acreage Burned in Wild Fire

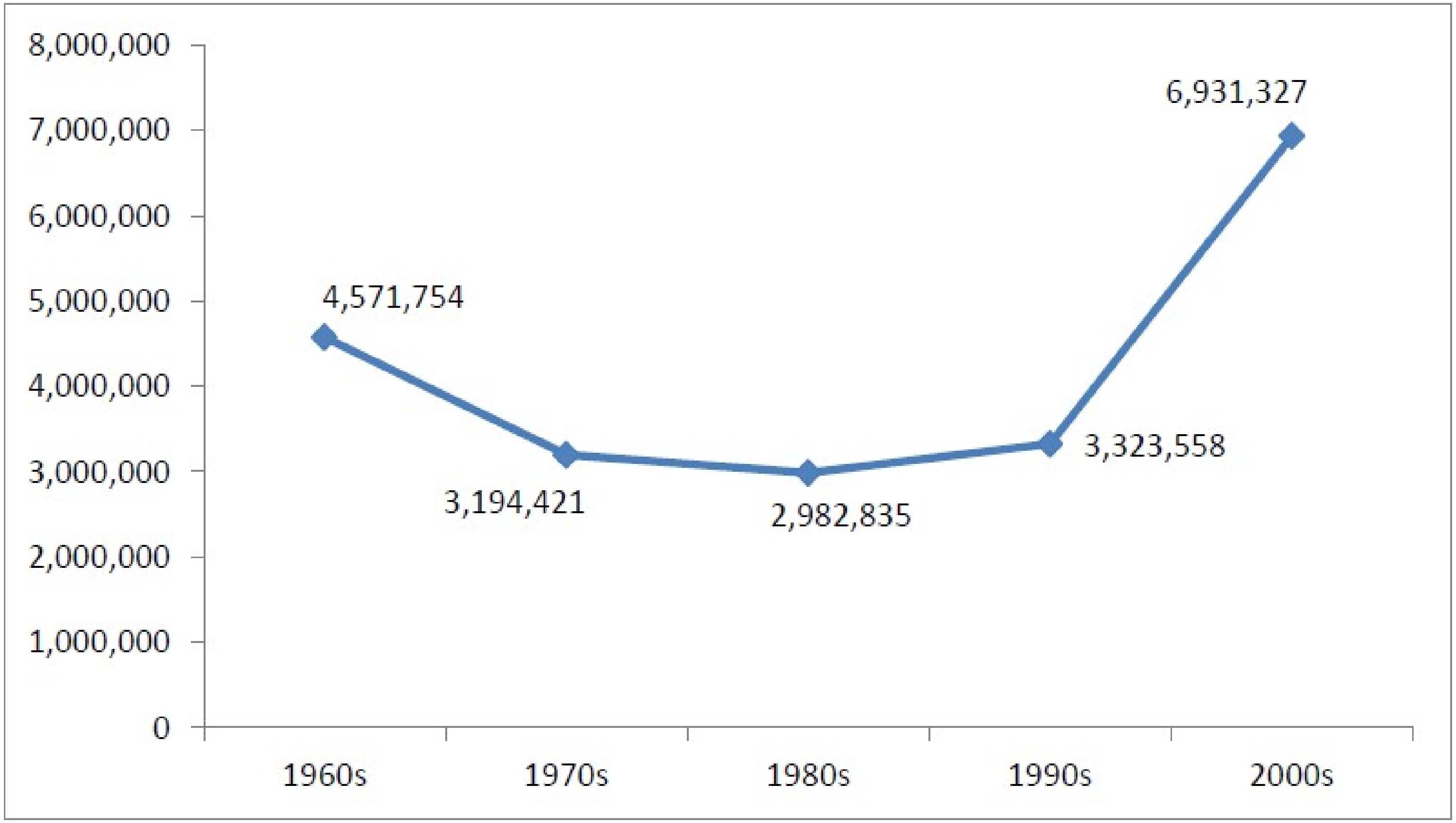
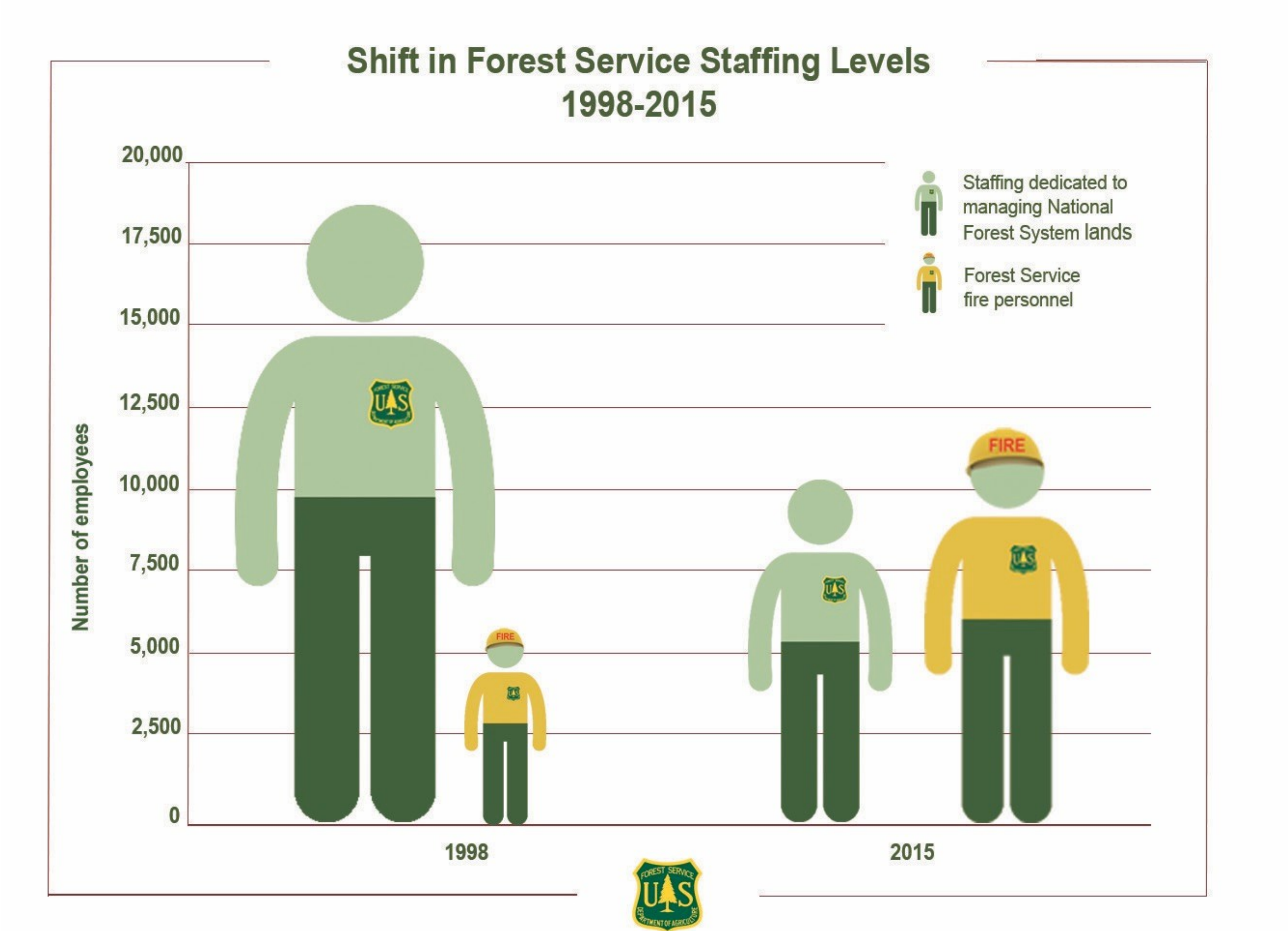


Figure 2 - Average annual acres burned, by decade. Rising firefighter effectiveness and other factors steadily lowered the number of acres burned until the 1990s, when a slight rise was followed by a sharp increase in the 2000s due to fuel buildups and worsening fire weather conditions.

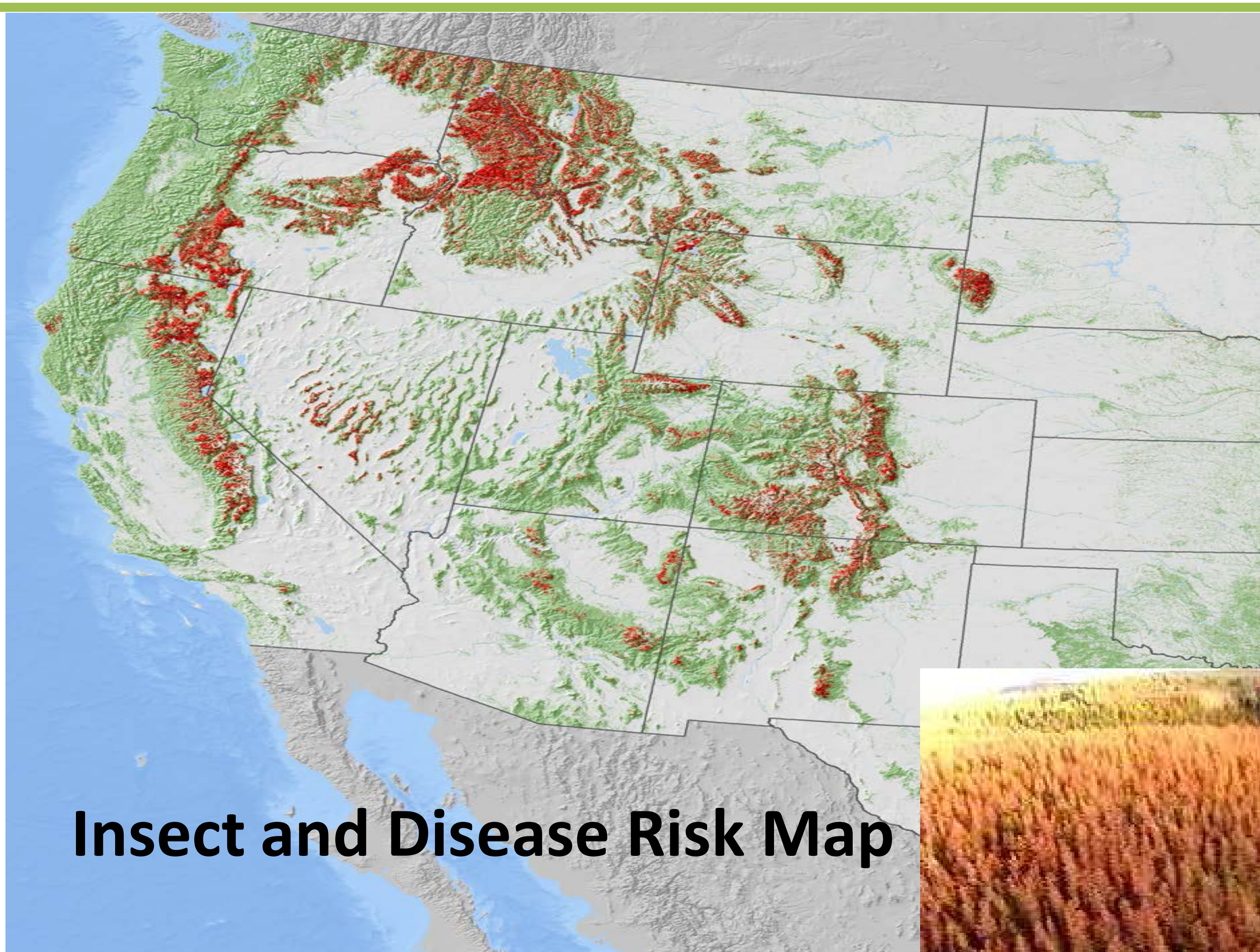
Source: US Forest Service – http://www.fs.fed.us/about-agency/budget-performance/cost-fire-operations

Shift in Forest Service Staffing



Source: US Forest Service –
http://www.fs.fed.us/about-agency/budget-performance/cost-fire-operations

Inter-Mountain West Insect Devastation



Insect and Disease Risk Map

Source: IDS- Insect and Disease Survey
USDA Forest Health Protection

Why USDA Champions Tall Wood

"Building stronger markets for innovative wood products will
support sustainable forestry,
reduce green house gas emissions, and
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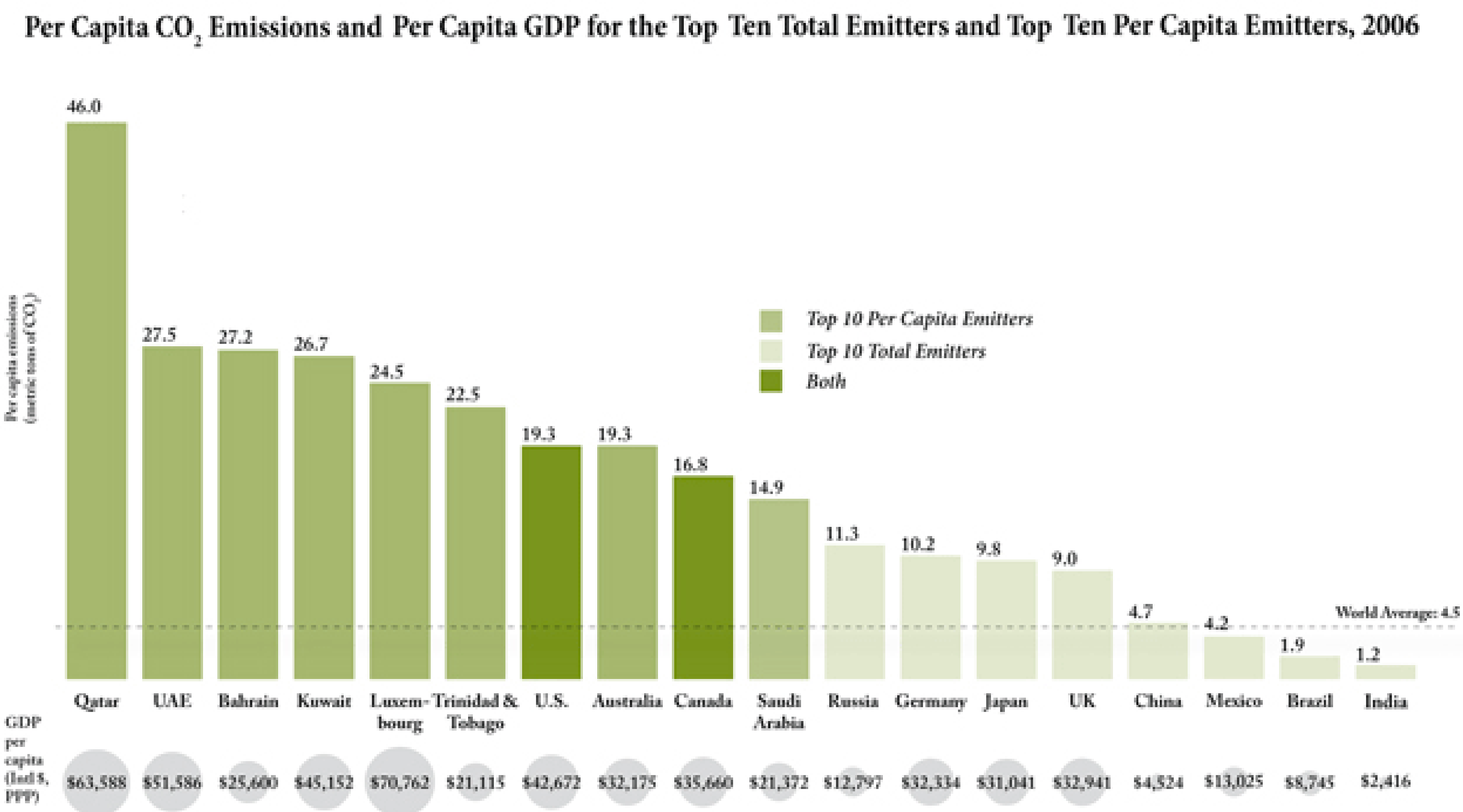
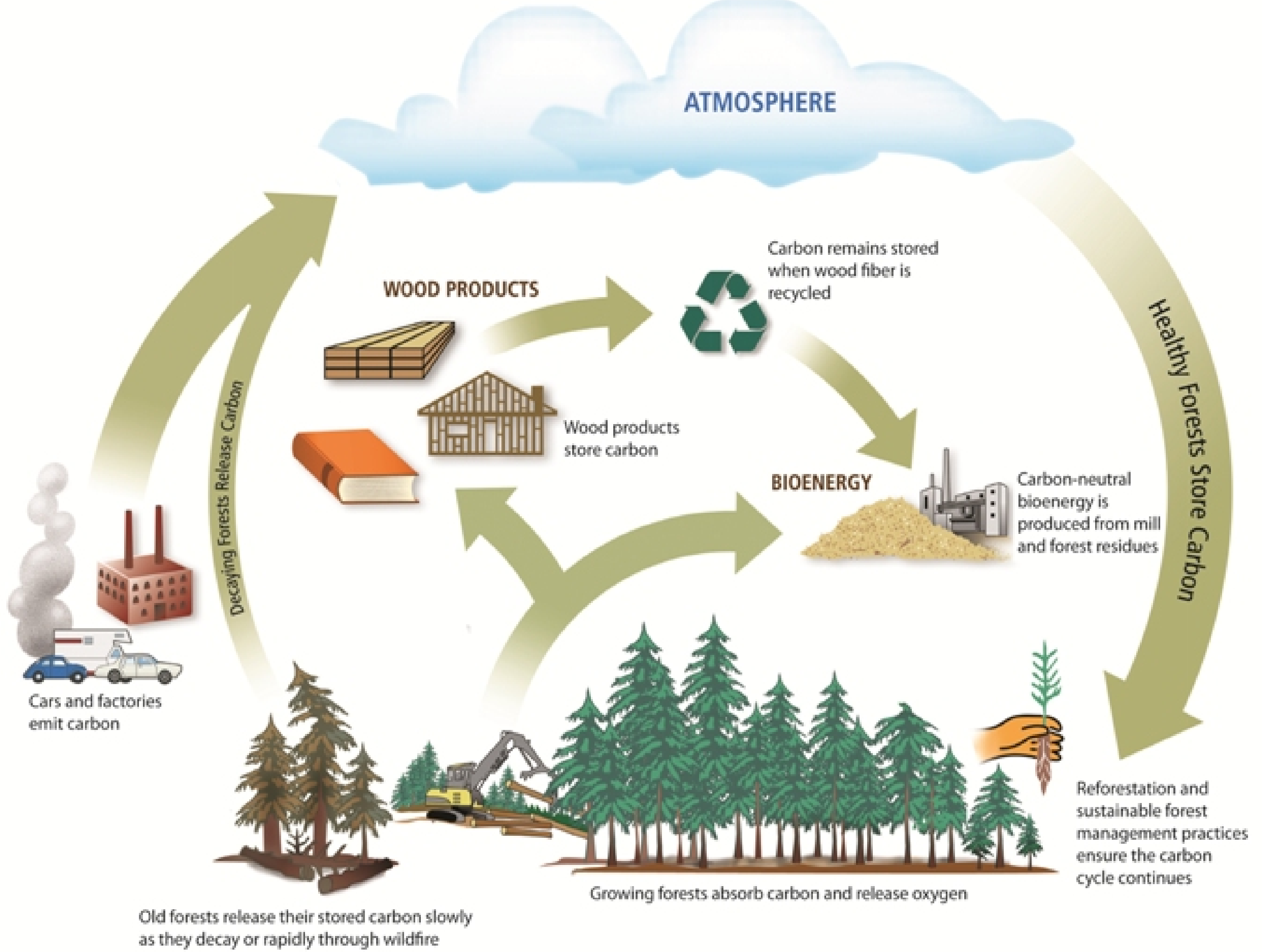
Tom Vilsack – Agriculture Secretary

US Contributes Highly to World Emissions



Data Source & Notes: WRI, CAIT (2009). Qatar GDP per capita estimate is for 2005; all other data presented are for 2006.

Sustainable Forestry Carbon Cycle



LCA of Materials: Carbon Emissions

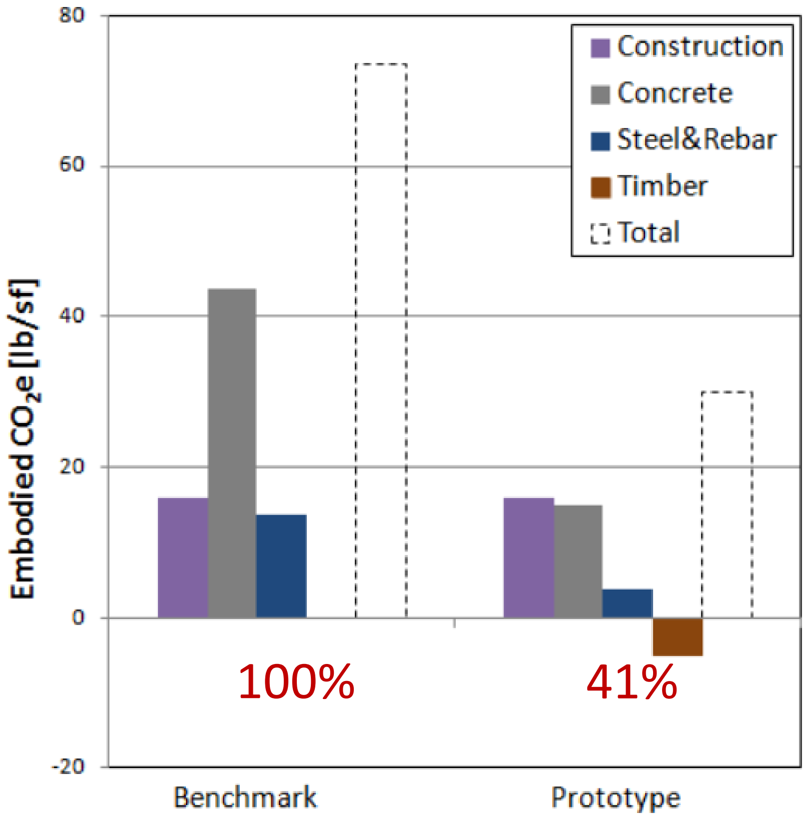
	USEPA (2006)	USEPA (2006)
Material	Process Emissions (kg CO_2e / kg of product)	Process Emissions Including Carbon Storage within Material (kg CO_2e / kg of product)
Framing lumber	0.12*	-1.68
Concrete	0.12	0.12
Concrete block	0.14	0.14
Brick	0.32	0.32
Medium density fiberboard (MDF)	0.32	-1.47
Recycled steel (avg recy content)	0.81	0.81
Glass (not including primary mfg.)	0.57	0.57
Cement (Portland, masonry)	0.97	0.97
Recycled aluminum (100% recycled content)	1.13	1.13
Vinyl	--	1.00
Steel (virgin)	2.55	2.55
Aluminum (virgin)	16.60	16.60

Carbon content of 49% assumed for wood. (measured values range from about 47-52%)

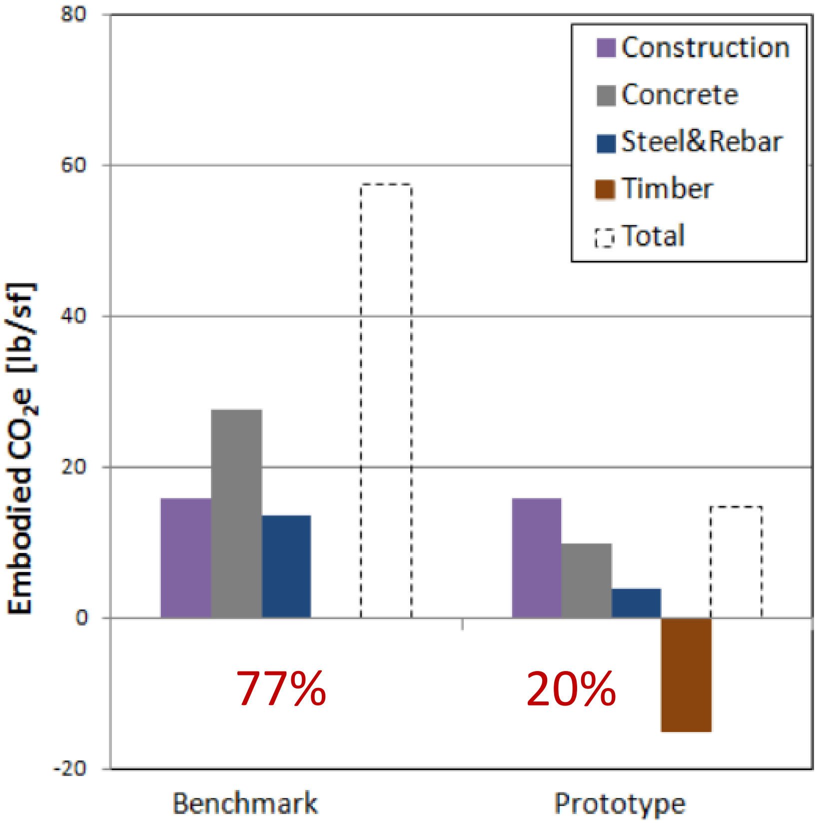
Source: 2006 US EPA Database

Dramatic Potential for Change

Standard Materials



Sustainable Materials



The Timber design has a much lower Carbon Footprint

Source: Timber Tower Research Project, Skidmore, Owings and Merrill, May 2013

Why USDA Champions Tall Wood

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US Economic Impact

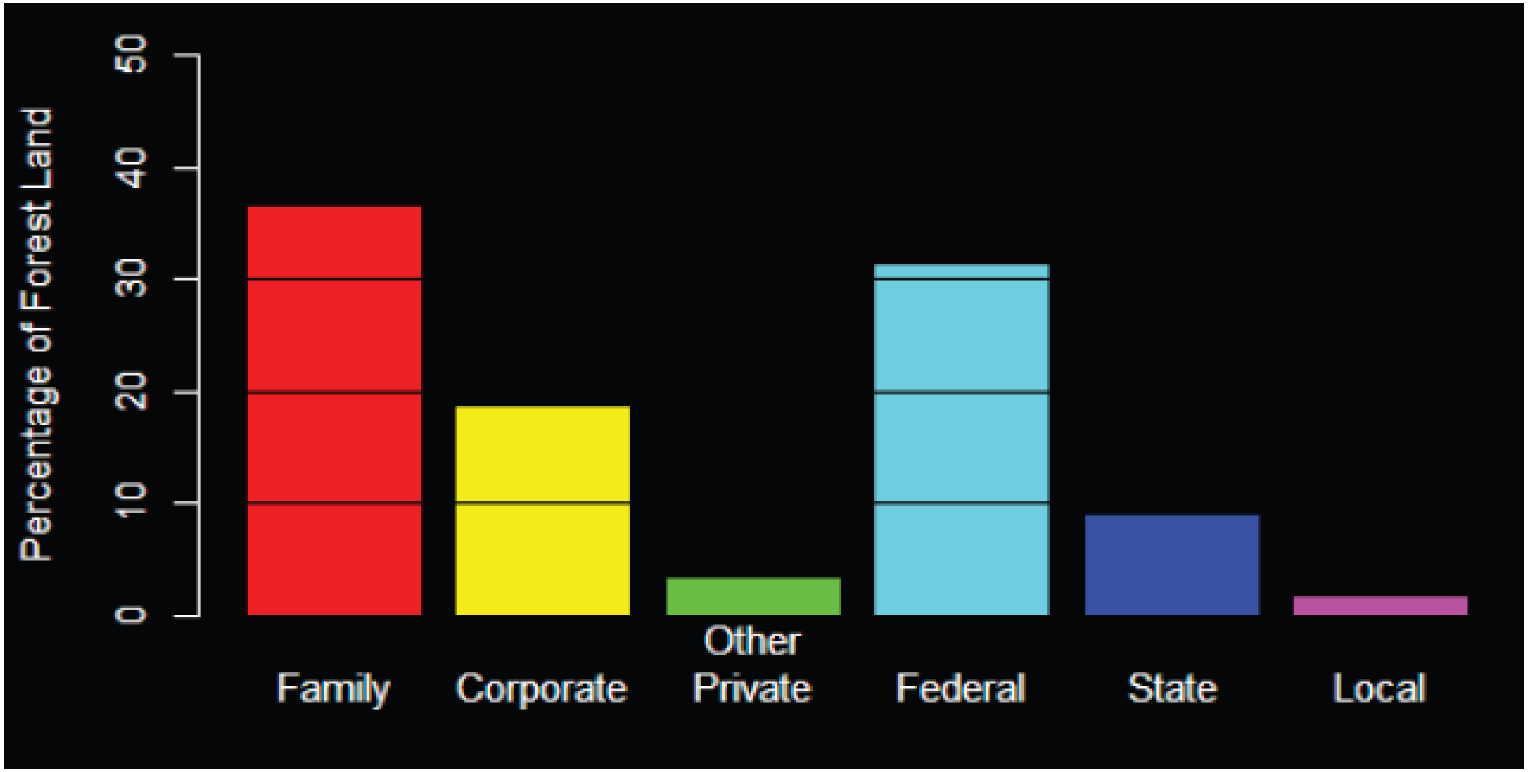

FIGURE 2-1 U.S. forestland ownership by class, 2011.
SOURCE: Available: http://www.fia.fs.fed.us/nwos [May 2014].

US/State Economic Impact

UNITED STATES, BY THE NUMBERS

EMPLOYMENT
Bureau of Economic Analysis, 2013

Wood Products	408,900
Forestry & Logging	139,000
Total Employment	**547,900**

MANUFACTURING FACILITIES
Random Lengths 2014 Big Book

Sawmills, Millwork, Treating	651
Engineered Wood and Panel	181
Other Wood Products	110
Total Facilities	**942**

Wood products data does not include paper and pulp industry

ANNUAL PAYROLL INCOME *(in thousands of dollars)*
Bureau of Economic Analysis, 2013

Wood Products	$17,728,000
Forestry & Logging	$3,147,000
Total Compensation	**$20,875,000**

VALUE OF INDUSTRY SHIPMENTS *(in thousands of dollars)*
U.S. Census Bureau Geographic Area Statistics, 2011

Wood Manufacturing	$67,365,450

TAX PAYMENTS *(in millions of dollars)*
AWC est. based on Ernst & Young (2012) and Bur. of Econ. Analysis (2012) data

Estimated State & Local Taxes	$926

Source: http://awc.org/publicpolicy/statefactsheets

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- Who, What, When and Where
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  - Modern Case Studies
- Why
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  - USDA Support
- How
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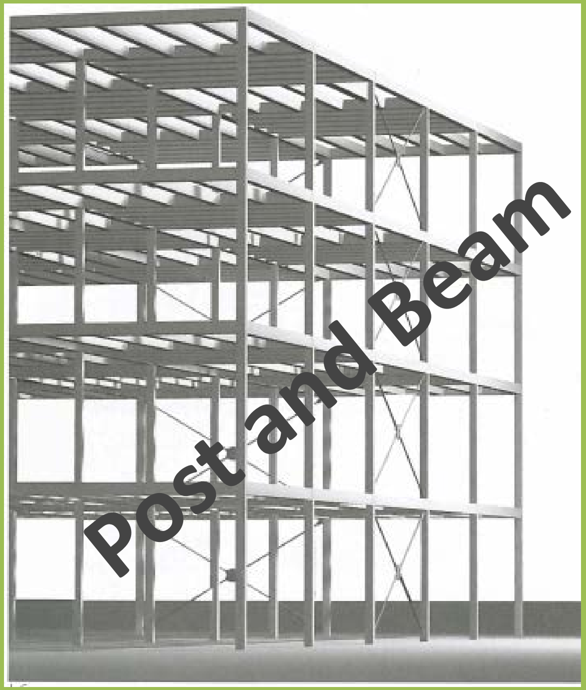
Mass Timber Building Systems



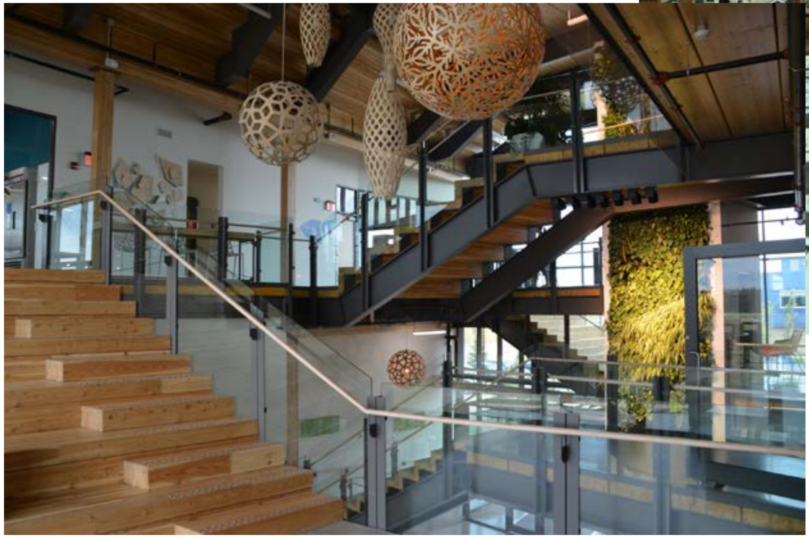
Solid Timber Panel Products

Glue Laminated Timber

Considerations:

- Gap panels for dimensional change
- Need Wood Structural Panel for diaphragm capacity
- Inconsistent lamination grades
- Manufacturers everywhere

Graphic Credit: StructureCraft



MOSAIC CENTRE
ENMONTON, AB
CANADA

Architect: Manasc Isaac
Engineer: Fast + Epp

SAUTER TIMBER PRODUCTION FACILITY
ROCKWOOD, TN
USA

Photo Credit: Andreas Sauter, Tim Clay Photography

Solid Timber Panel Products

Cross Laminated Timber

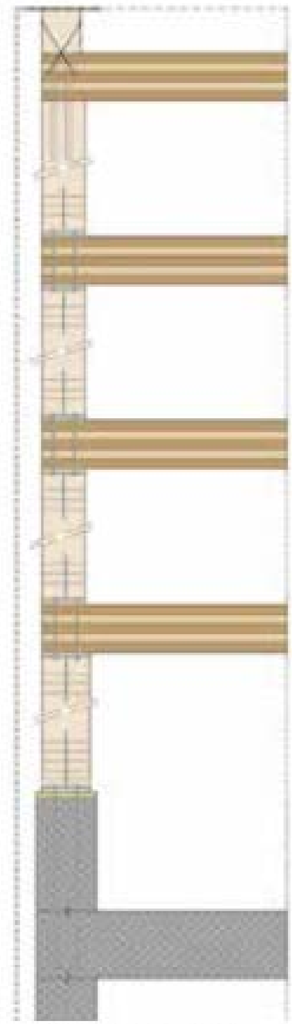
Considerations:

- Span usually governed by vibrations
- Dimensionally stable
- Recognized by 2015 codes and standards
- High in plane shear capacity
- Dual Directional span capabilities

Graphic Credit: StructureCraft

Steel plates
Photo Credit: ROSSIPRODI ASSOCIATI srl.

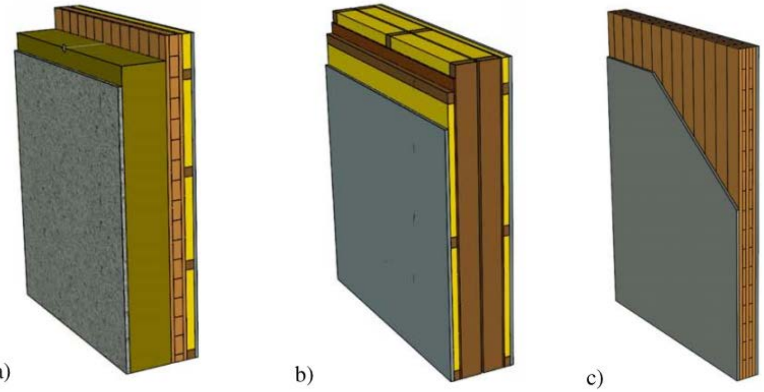
Self-tapping screws
Photo Credit: Riccardo Ronchi



Schematic of Floor and Wall panels.
Detail Credit: ROSSIPRODI ASSOCIATI srl.

ARCHITECT: Shankula Architekten
ENGINEER: Bauart Konstruktions GmbH&Co

Source: Survey of International Tall Wood Buildings, 2014



a) b) c)

Figure 5. Exemples of a) exterior wall, b) apartment separating timber framed wall and c) interior partirion wall within an apartment (also stabilising).

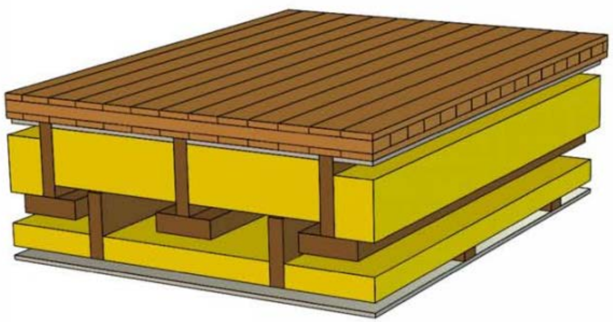


Figure 6. Floor elements used at Limnologen

Architect: Arkitekbolaget, Kronoberg, Martinsons
Engineer: Martinsons Byggsystem KB

http://www.cbbt.se/website3/1.0.3.0/28/FULLTEXT01.pdf

CLT floor panels and walls secured with custom gang nail steel plates.
Photo credit: Willmott Dixon G

Building systems are routed through a ceiling void created with gypsum board.
Photo credit: Willmott Dixon Group

Interlocking keyed edge of each floor and wall panel.
Photo credit: Willmott Dixon Group

ARCHITECT: Karakusevic Carson
ENGINEER: Peter Brett Associates

Solid Timber Panel Products

Nail Laminated Timber

Considerations:

- Requires accommodation for dimensional change
- Need wood structural panel for diaphragm capacity
- Recognized as a heavy timber floor system
- Long history of use

Graphic Credit: StructureCraft

Steel connections.
Photo Credit: Architecture by Kaden Klingbeil,
Photo by Bernd Borchardt

http://www.brettstapel.org/Brettstapel/What_is_it.html

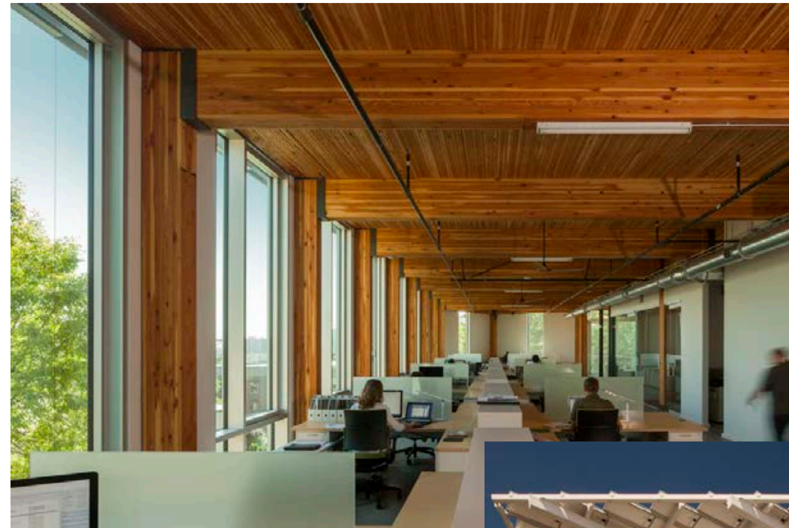
Aerial image during construction
Photo Credit: Architecture by Kaden Klingbeil, Photo by Bernd Borchardt

Architect: Kaden Klingbell Architekten
Engineer: Bois Consult Natterer

Source: Survey of International Tall Wood Buildings, 2014

Samuel Bridghouse Elemenary School,
Richmond BC, Canada
Desing Team: Perkins + Will Canada, Fast + Epp
Photo Credit: Stephan Pasche

Architect: Proscenium Architecture and Interiors
Mountain Equipment Co-op Head Office



Architect: Miller Hull Partnership
Living Building Challenge Building
Completed 2013

Solid Timber Panel Products

Laminated Veneer Lumber

Considerations:

- Established design properties
- Specially ordered but multiple domestic manufacturers
- Horizontal applications don't take advantage of the strength direction
- Relatively dimensionally stable
- Limited Thicknesses

Graphic Credit: StructureCraft

Metropol Parasol, Seville, Spain
Design Team: J. Mayer H. Architects, ARUP Consulting Engineers
Photo Credit: ARUP

Solid Timber Panel Products

Laminated Strand Lumber

Considerations:

- Established design properties
- Specially ordered but multiple domestic manufacturers
- Relatively dimensionally stable

Graphic Credit: StructureCraft

UBC Earth Science Building, Vancouver, Canada
ARCHITECT: Perkins + Will
ENGINEER: Equilibrium

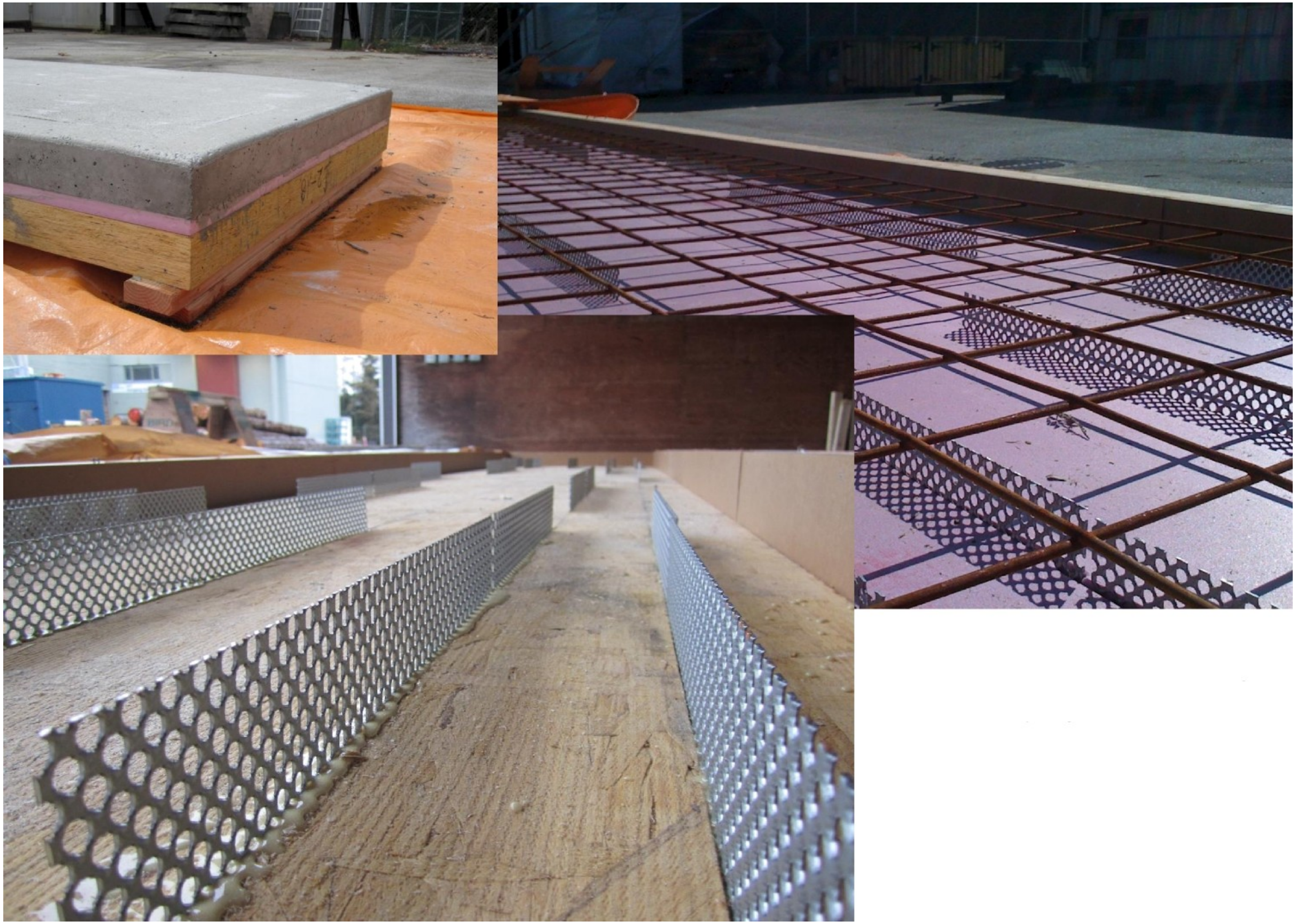
Solid Timber Panel Products

Wood/Concrete Composites

Considerations:

- Connection needs to be carefully designed
- Difficult to ensure design capacity if concrete is poured on site
- Detail needs to accommodate the moisture conflict between the materials

Graphic Credit: StructureCraft



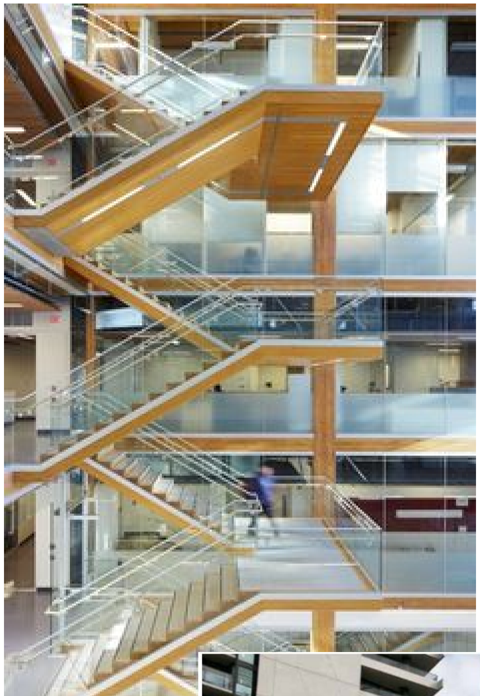
UBC Earth Science Building, Vancouver, Canada
ARCHITECT: Perkins + Will
ENGINEER: Equilibrium
Photo Credit: Structurlam

ARCHITECT: Hermann Kaufmann
ENGINEER: Merz Kley Partner
PHOTO CREDIT: CREE

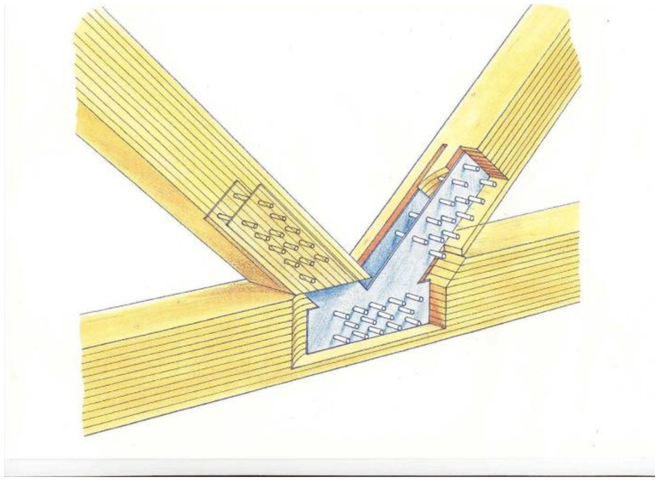
Other Mass Timber Systems

- Folded Plates
- Solid Wood Core
- Timber Braced Frames
- Timber Trusses
- Rocking Wall Systems
- Post-Tensioned Frames
- Wood/Wood Composite Systems

Other Mass Timber Systems



Installation of CLT elevator core
Photo credit: Lend Lease



ARCHITECT: Artec
ENGINEER: Sweco

Source: Toward Taller Wood Buildings Symposium 2014

ARCHITECT: Michael Green Architecture
ENGINEER: Equilibrium Engineering
PHOTO CREDIT:

Source: Toward Taller Wood Buildings Symposium 2014