WOOD 474

Engineered wood products

- Driving innovation in wood products manufacturing

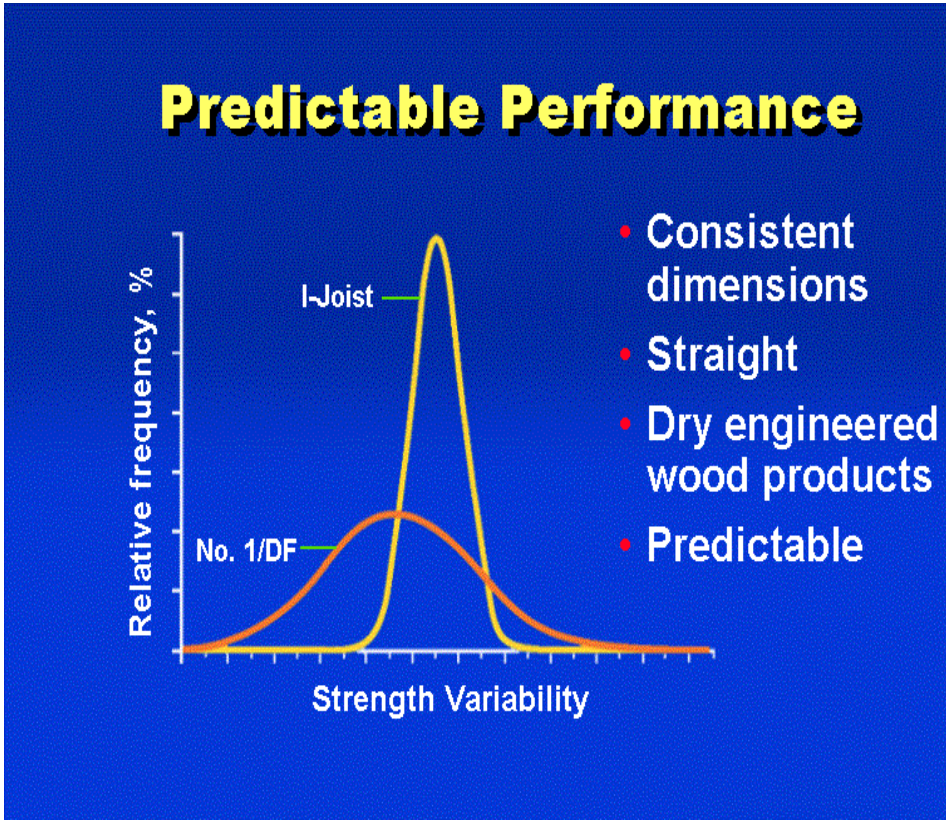
Learning objectives

- Understand what EWP are:
  - How they are manufactured
  - Categories & uses
  - Benefits and disadvantages
  - Future market expectations
  - Impacts on forestry

Ainsworth 2012

Engineered wood products (EWP)

- Definition:
  - A group of structural wood products that are *manufactured* to *specific performance standards*
- Rationale & advantages
  - Nature has optimized wood for growing trees, not for producing lumber
    - variable properties
    - solid wood is anisotropic
  - EWP provide greater uniformity, reliability and resource efficiency than lumber
  - Uniform MC, no knots
  - Available in large sizes
    - preferred by architects
  - Less wastage at construction site



Disadvantages of EWP

- Higher per-unit cost than lumber
  - On a comparative lumber size basis
  - May not be more expensive on a comparative use basis
- Thin strand-based products may have poorer thickness dimensional stability than lumber
- More complex manufacturing processes require larger initial capital investment
  - Usually offset by using lower cost fibre inputs

EWP Categories

1. Lumber-based EWP
   - 1.1.Glue-Laminated Timber (Glulam)
   - 1.2 Cross Laminated Timber (CLT)
2. Veneer-based EWP
   - 2.1 Laminated Veneer Lumber (LVL)
   - 2.2 Parallel Strand Lumber (PSL)
3. Strand-based EWP
   - 3.1 Laminated Strand Lumber (LSL)
   - 3.2 Oriented Strand Lumber (OSL)
4. Other
   - 4.1 I-Joists
   - 4.2 Finger jointed lumber

EWP markets

- EWPs compete with lumber, concrete and steel in specific market niches
  - Usually where consistent performance & ease of installation are important
- Becoming more widely used
- Three major markets
  - Residential
  - Non-residential
  - Civil engineering infrastructure

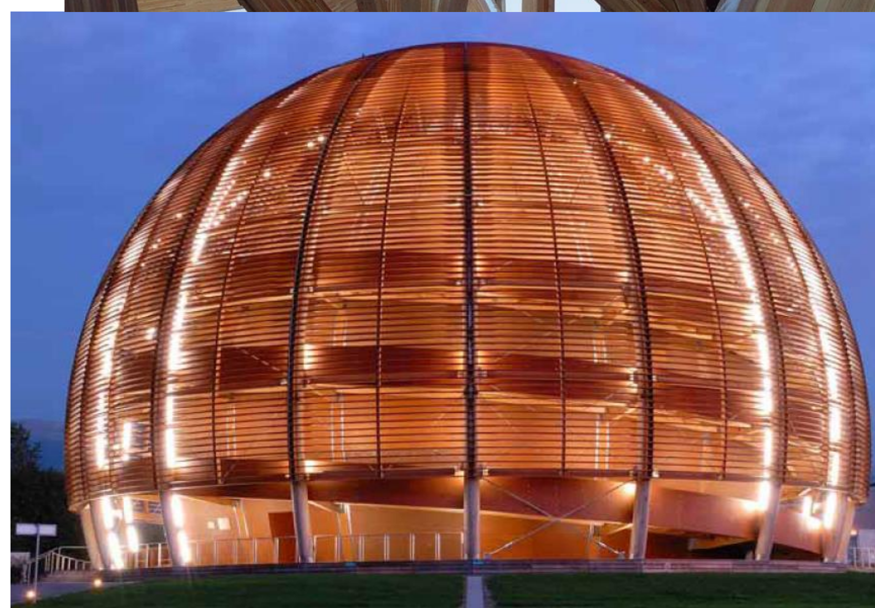


Photo: Pepke 2012

Photo source: Unalam

1: Lumber-based EWP

1.1: Glue-Laminated beams (Glulam)

Photos: http://www.timberawards.com.au/

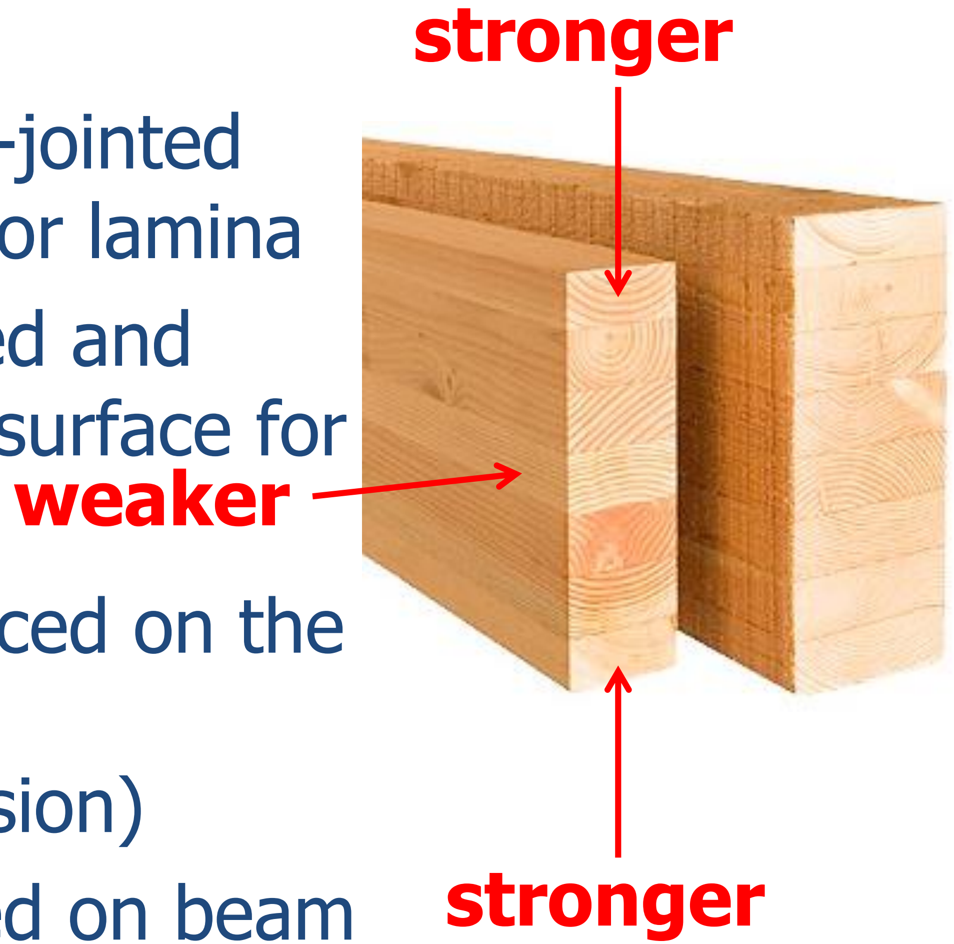
Glulam

- Oldest EWP – dates from mid 1800's
- Produced by face laminating lumber to form beams
- Individual lamina are usually 19 to 38 mm (0.75-1.5 inches) thick
- Glulam beams can be
  - larger in cross section compared to solid timber
  - curved and tapered
  - used in wide span applications
    - compete with steel or concrete beams
    - e.g. hockey arenas, swimming pools, churches, warehouses, hospitals, bridges, universities

Boise Cascade 2012

Glulam

- Production is labour intensive
  - Commodity manufacture can be automated
- Individual boards finger-jointed provide length needed for lamina
- Each lamina stress tested and planed produce a fresh surface for gluing
  - Strongest material placed on the outer faces of beam (compression and tension)
  - Weaker material placed on beam interior



Glulam manufacture

- Cold curing waterproof resin (usually PF or PRF) applied to each lamina using glue spreader
- Beams are then pressed together, placed on forms and held in place by movable clamps until the glue cures
- Finally beams are surface planed, sanded and drilled/finished to meet the design requirements
- Can be pressure treated when required with fire retardant or wood preservative
- http://www.youtube.com/watch?v=3R2s2rsp1r4&feature=player_embedded
- http://www.youtube.com/watch?NR=1&v=PnHQRhFnveM&feature=endscreen

Photo source: Unalam

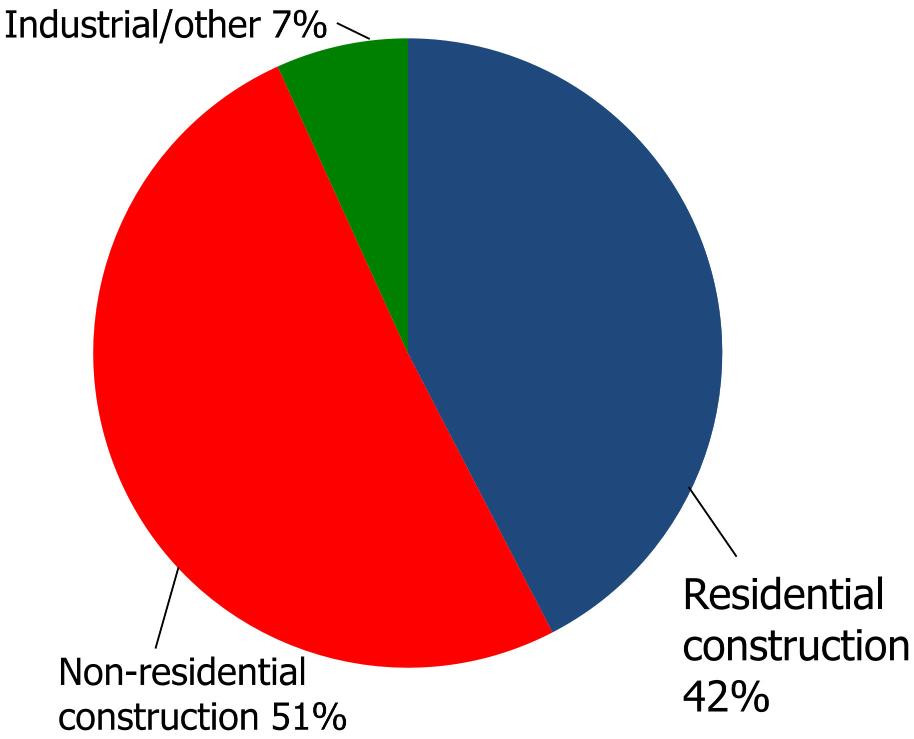

H 12'1"
W 13'2"
Weldwood

Glue-Laminated Timber

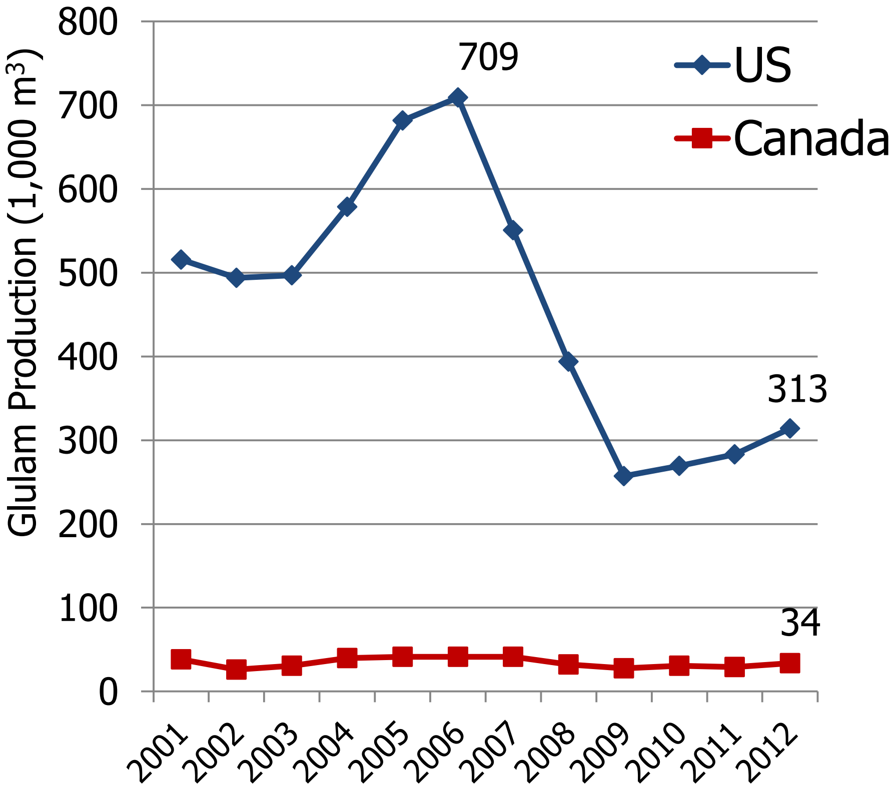
- On weight basis cost of Glulam is 2x to 3x solid wood due to:
  - High value raw material
  - Manufacturing is labor intensive
    - Only commodity-based standard beams can be automated
  - Structural adhesive is one of the most expensive in industry and high spread rates are used
    - Use 340 g/m^2, 2x that for plywood or LVL
- Greater strength & stiffness than lumber
- Stronger than steel on a weight basis

North American Glulam uses and production (UN ECE 2013)

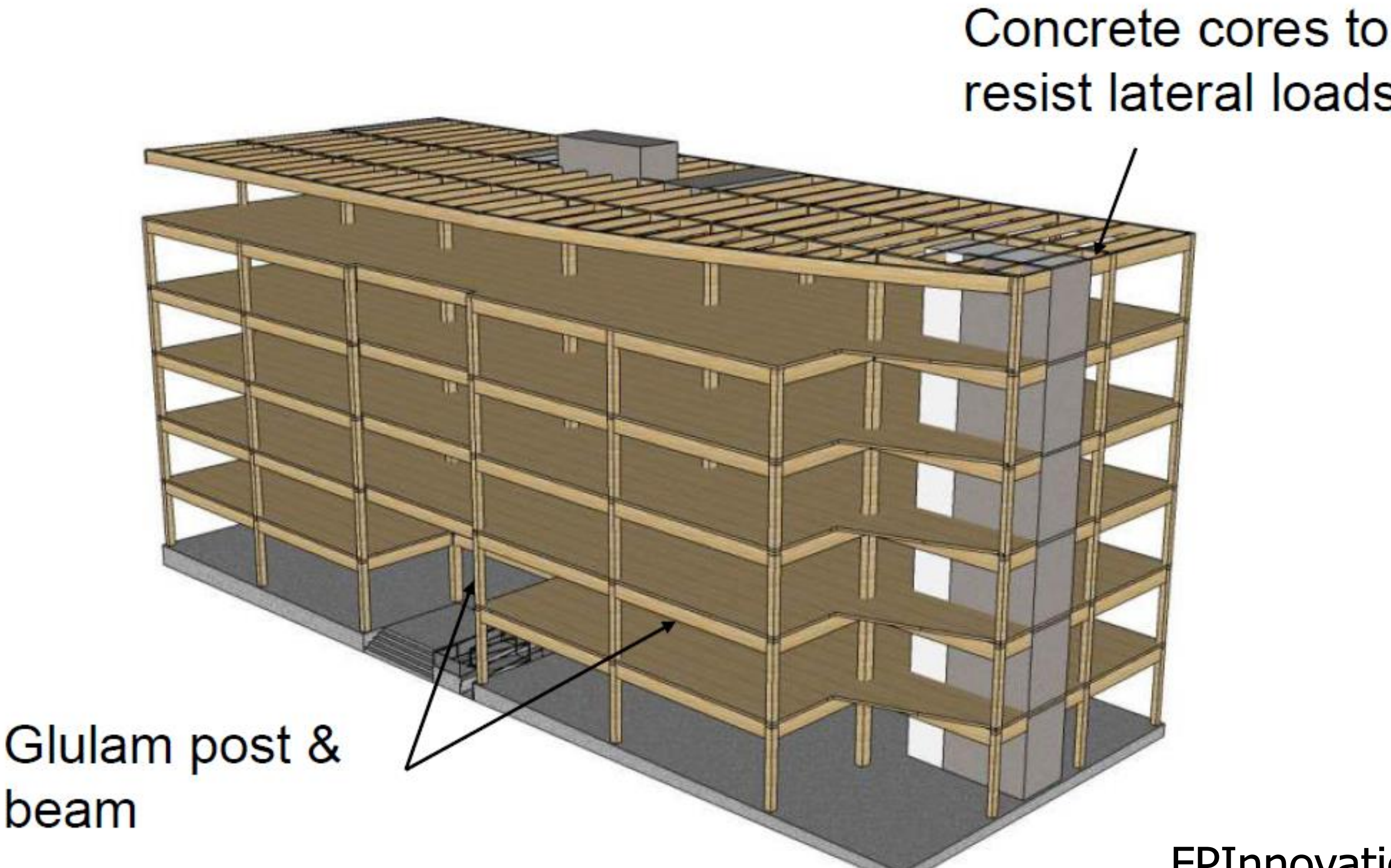
US Glulam end uses 2011



Glulam Production



Heavy frame timber using glulam beams (up to 10 stories)



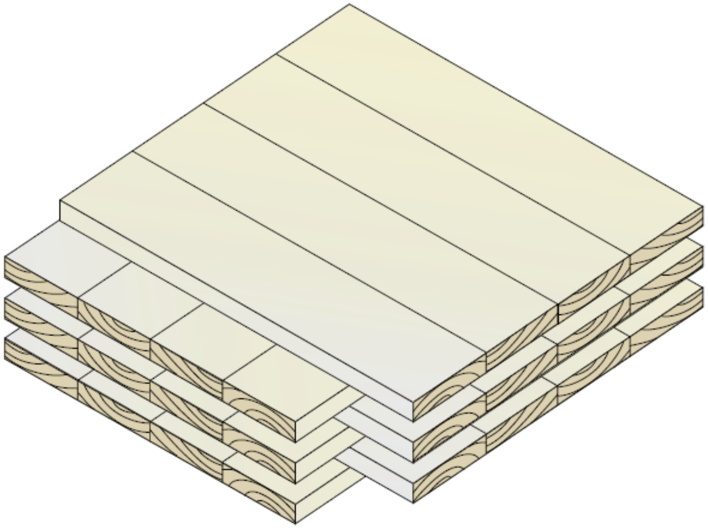
FPInnovations


Nicola
LOGWORKS
250-378-4977

1.2: Cross Laminated Timber (CLT)

Cross Laminated Timber

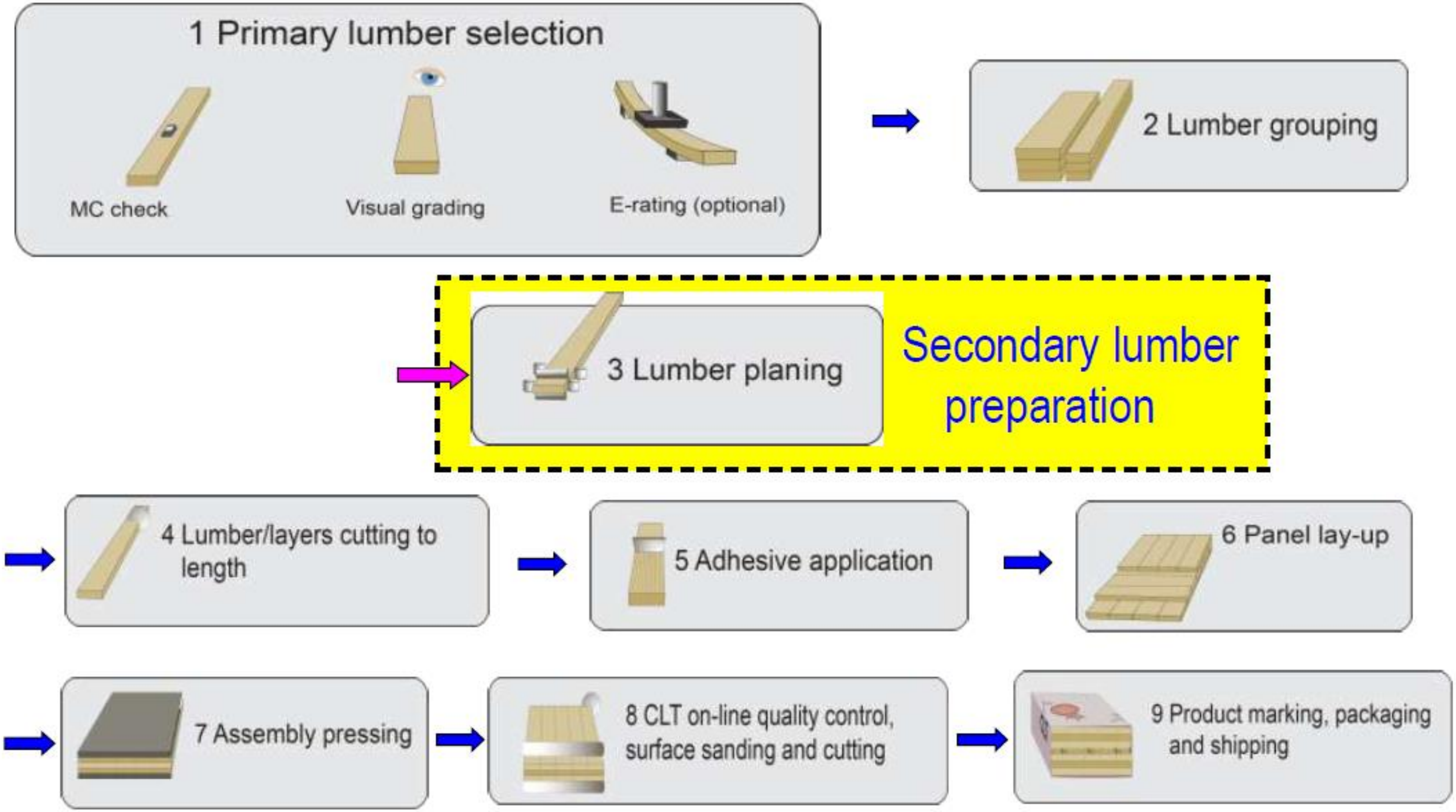
- Multi-layer panel with crosswise arrangement of lamellae (usually 3-7)
  - As for plywood but graded lumber used
  - Lamellae glued & pressed



- Common dimensions
  - Thickness: three to seven layers
    - 75 - 400 mm (3 - 16 in.)
  - Width: 600 mm to 2.4 m (2 - 8 ft.)
  - Length: up to 20 m (64 ft.)
  - Span: up to 7.5 m (24 ft.)

Source: FPInnovations

CLT manufacturing
(FPInnovations 2011)

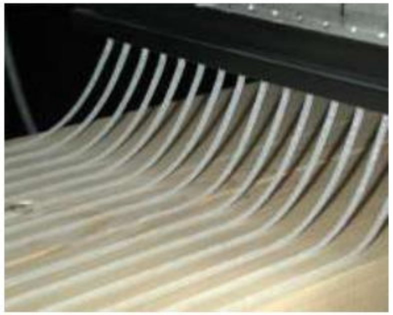


CLT adhesive application

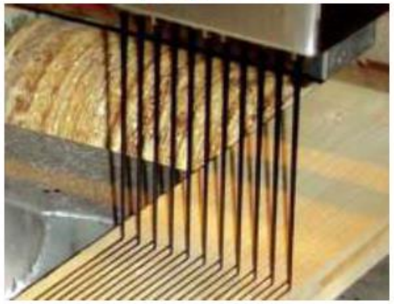
(FPInnovations 2011)

- Adhesives
  - Phenol resorcinol formaldhyde (PRF)
  - Emulsion polymer isocyanate (EPI)
  - One component polyurethane (PUR)
- Applied in parallel lines
- Application rates & press times dependent upon adhesive

Extruder heads



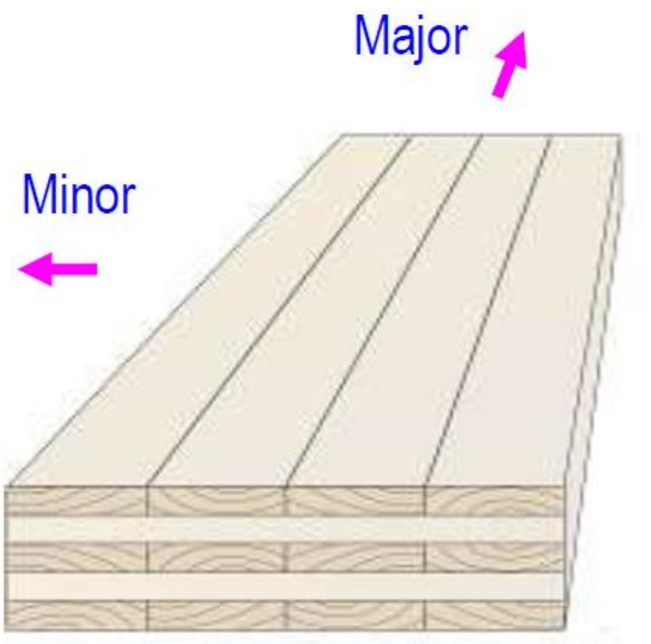
PUR, light color



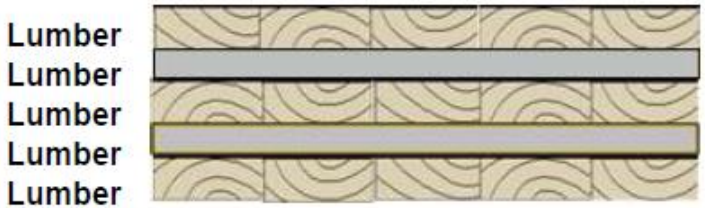
PRF, dark color

CLT panel lay up (FPInnovations 2011)

- Wood
  - Usually graded structural lumber
    - Major direction = No. 2 & better
    - Minor direction = No. 3 & better
  - May add other product in minor direction
    - OSB, LVL etc



CLT - 'Jumbo Plywood'



Generic CLT

Hybrid CLT

CLT Pressing, Grading/Sanding

CLT Machining & storage

Transport & assembly

http://www.youtube.com/watch?v=rLqiwBL28v4&feature=related

UBC Earth Sciences Building

(Photo: Structurlam)

Forte, Lend Lease Building, Melbourne, Australia

- Completed in Dec 2012
- 10 stories
  - Podium = concrete
  - Upper 9 stories CLT
  - Currently tallest wooden residential building in world
- CLT benefits (compared to steel & concrete):
  - Lighter
  - Excellent acoustic properties
  - Rapid construction
  - Low GHG footprint
  - http://www.forteliving.com.au/

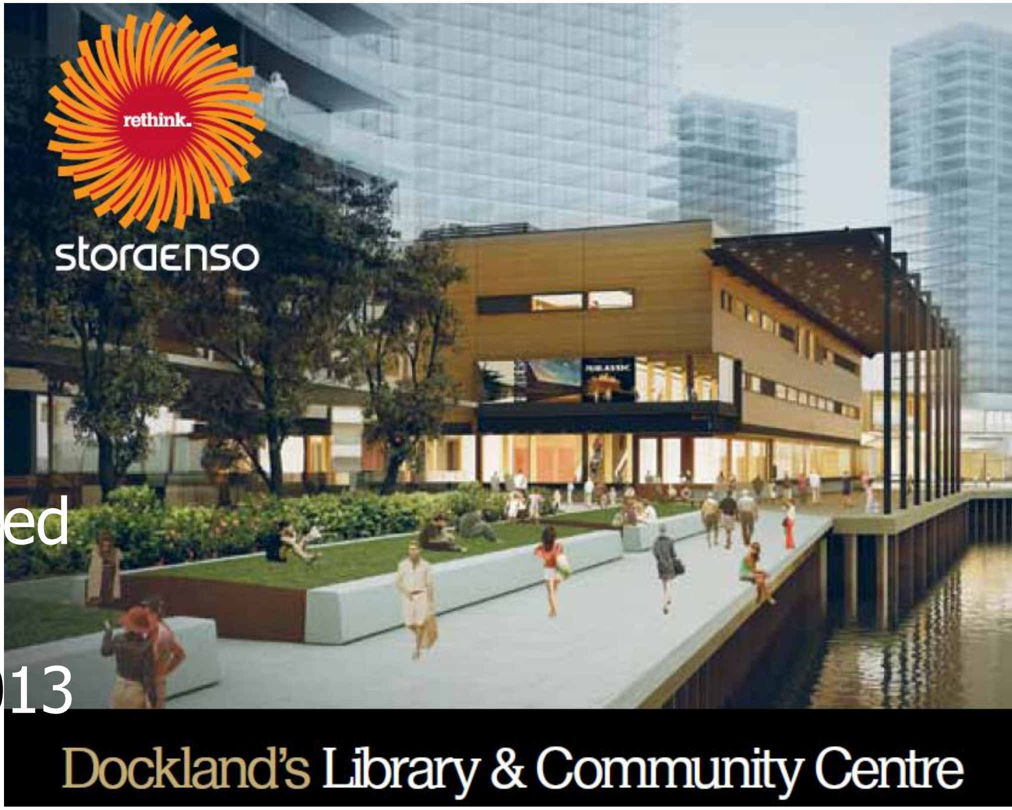
http://www.youtube.com/watch?v=cqXygHyU5ws

http://www.forteliving.com.au

Library & Community Centre, Melbourne

- Same development company as Forte
- Highest level of 'green building' in Australia
- Three-storey building 55m long x 18m wide
- CLT and Glulam beam construction
- CLT made in Austria & shipped to Australia
- Construction started April 2013
- Estimated building time 6-8 weeks
- Project completion in late 2013

Webcam of contruction: http://www.convesso-concavo.com.au/webcam.aspx?id=6



More CLT info available at: http://www.clt.info/en/news-pr/news/

2: Veneer-based EWP




2.1: Laminated veneer lumber

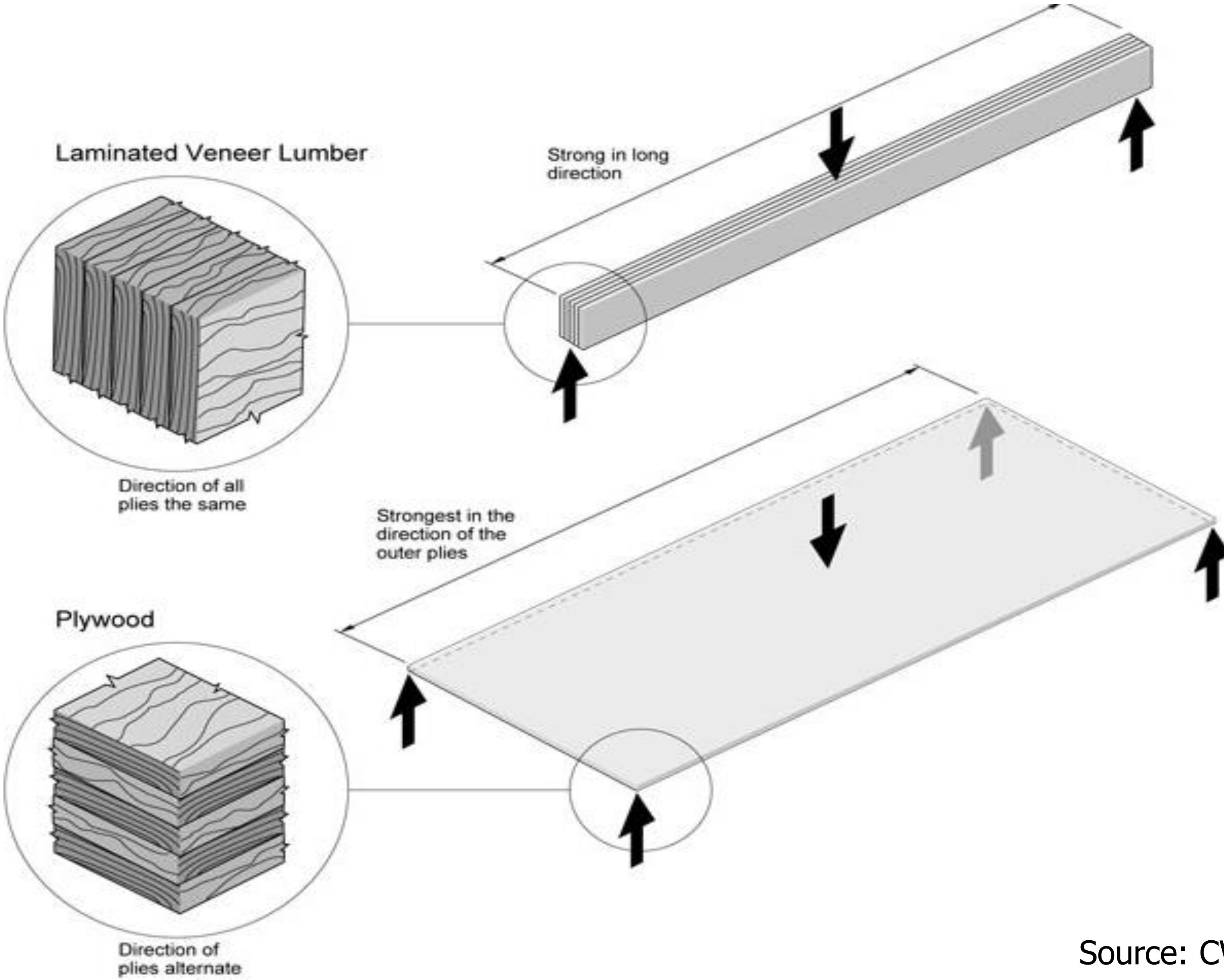
Laminated veneer lumber (LVL)

- Like Glulam, LVL uses continuous lamina
  - Lamina are sheets of veneer rather than lumber in Glulam
  - Lamina thickness = 1.5 – 6 mm (0.06-0.25 ins)
  - Density = that of its veneers
  - Dimensions = those of standard lumber
- Benefits compared to lumber:
  - Wood defects are randomized
  - Grain parallel to long direction (unlike plywood)

$\Rightarrow$ strength properties > glulam & stress graded lumber

$\Rightarrow$ also more uniform (narrower SD)

LVL compared to plywood



Source: CWC 2012

LVL production process

- http://www.youtube.com/watch?v=qASxDjoRtSo&feature=related
- Production parallels that of plywood
  - Sorting of the veneers is automated
    - ultrasound used to select for density (proportional to strength)
  - Sorting is important to give uniform products
- Large billets (1.2 m wide by 24 m long) of veneer built up on a moving belt by alternately adding veneer and glue
- Cold press before final hot press using radio frequency (RF) energy presses – reduces press times from 20 min. in regular press to 5 min.

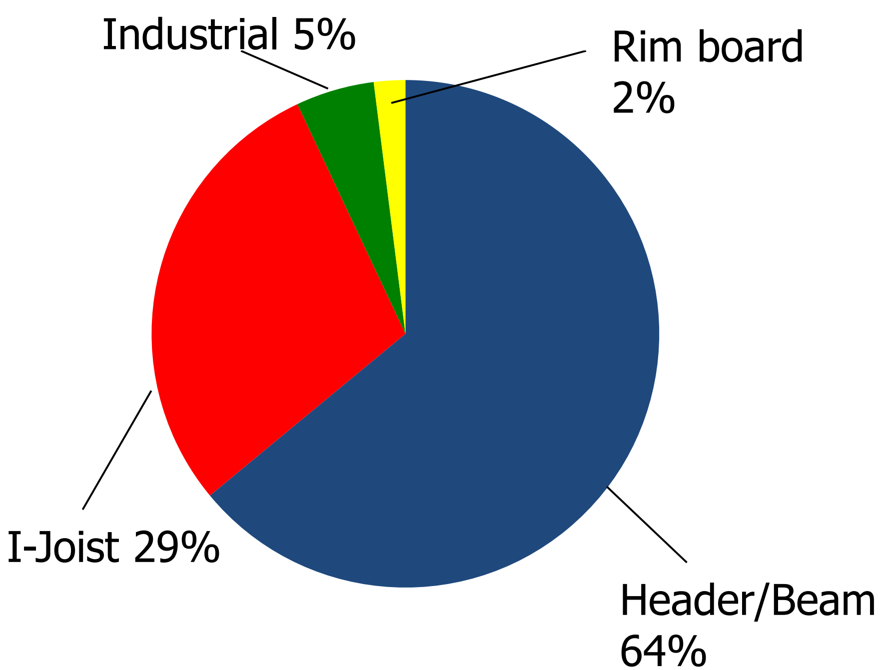
Laminated veneer lumber

- Softwood usually used (southern pine, Douglas-fir, spruce, hemlock)
- Adhesives
  - waterproof Phenol-Formaldehyde (PF) most common
  - Application rate about 180 g/m^2
- Cost: LVL >> solid wood
- Advantages:
  - Uniform MC, resistance to warp, high & uniform strength and long lengths

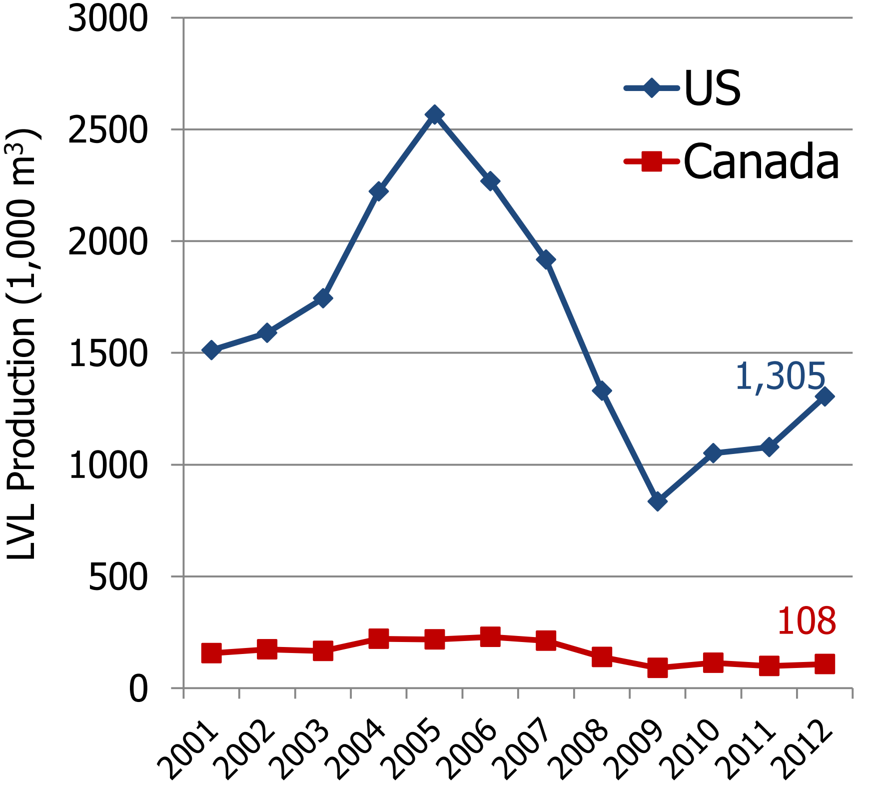
LVL header applications

North American LVL uses and production (UN ECE 2013)

LVL end uses



LVL Production



- Markets
  - ~ 80% in new homes

2.2: Parallam (or PSL)

Parallam (or PSL) manufacture

- Produced from long strands of veneer from Douglas-fir, southern pine or yellow poplar
- First veneer from logs is usually not continuous due to taper
  - PSL uses waste product from veneer, plywood and LVL mills
- Veneer put through clipper and trimmer to make long strands needed for PSL
  - Strands approx 20mm wide, 4 mm thick and up to 1 m long

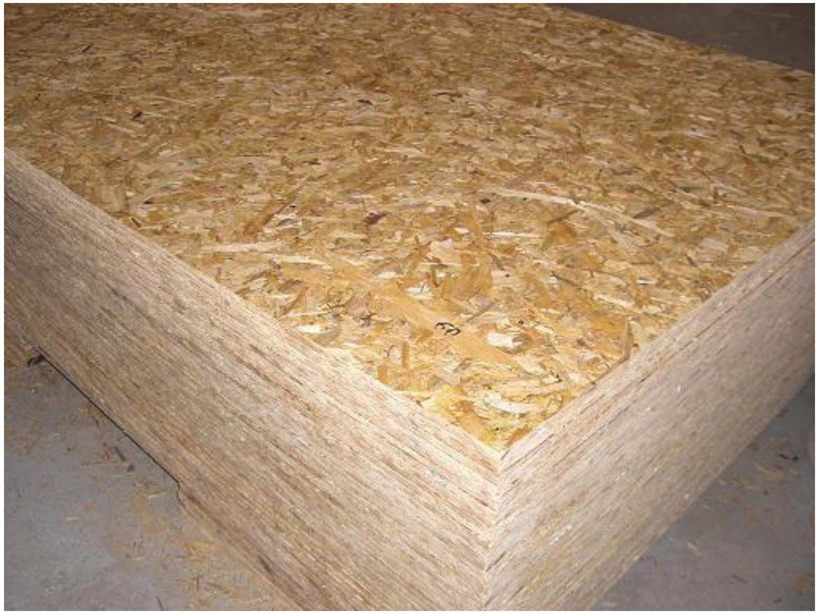
Parallam manufacture

- Strands dried to 3 – 5% MC
- PF resin applied – up to 15% by weight
- RF or microwave energy used to cure resin in a continuous "caterpillar" press
  - 25 x 25 cm billets cured in few minutes
- Billets sawn to any size - alternative to softwood timber
  - Especially larger beams
  - Also competes with LVL and shorter glulam beams

Parallam (or PSL)

- Density increased slightly by pressing so strength higher than best grades of Douglas fir or Southern pine
- Has uniform strength
  - Slightly higher bending stress than LVL
- High void volume makes preservative treatment easy
  - Enables exterior applications

3: Strand-Based EWP

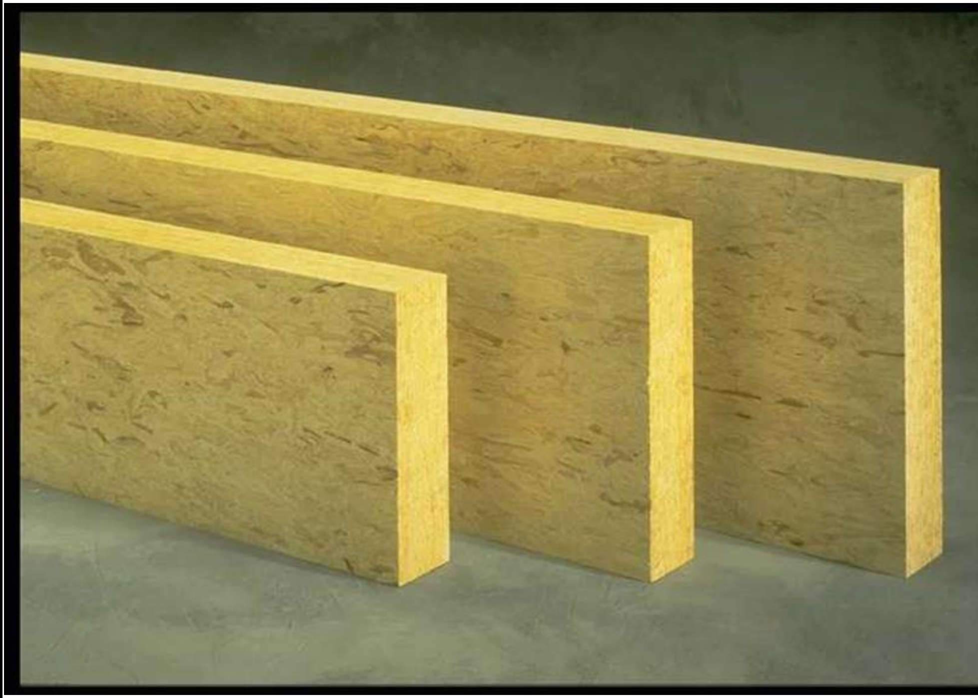


Source: Louisiana Pacific

Strand-Based Composite Lumber

- Produced by gluing and pressing wood strands or flakes into lumber substitutes
  - More consistent product attributes than lumber – strength, warp, MC
  - Allow large sizes of 'lumber' to be produced from small logs
  - Usually made from cheap, low density hardwoods (aspen, yellow poplar)
  - Higher product yield compared to a lumber mill
    - More m^3 product/m^3 roundwood
  - Takes pressure off (mature) forest resources

3.1 Laminated strand lumber (LSL)



Laminated strand lumber (LSL)

Similar to Parallam except:

- Made from strands <u>not</u> cut veneer
- Strands are thinner and wider
  - Like OSB strands but 2x as long (30 cm) & 2-5 cm wide
- Different resin is used
  - pMDI (polymeric diphenylmethane diisocyanate)
  - Used for rapid curing

LSL Manufacture

- Logs debarked (usually fast growing hardwoods)
- Strands produced by disk flaker
- Dried (to 2-5 %MC)
- Screened to remove broken & fine strands
- Blended with pMDI resin
- Can add wax for water repellency
- Formed into mat – strands not fully aligned
- Billets (25-150 mm thick) cured in steam press
  - Cured in minutes
- Cut to desired dimensions

LSL applications

- Competes with solid wood in high grade structural applications
  - beams, headers, rim boards and structural framing lumber
- straighter, stronger and can handle longer spans.
- more consistent moisture content than lumber
  - minimizes twisting, warping and shrinking

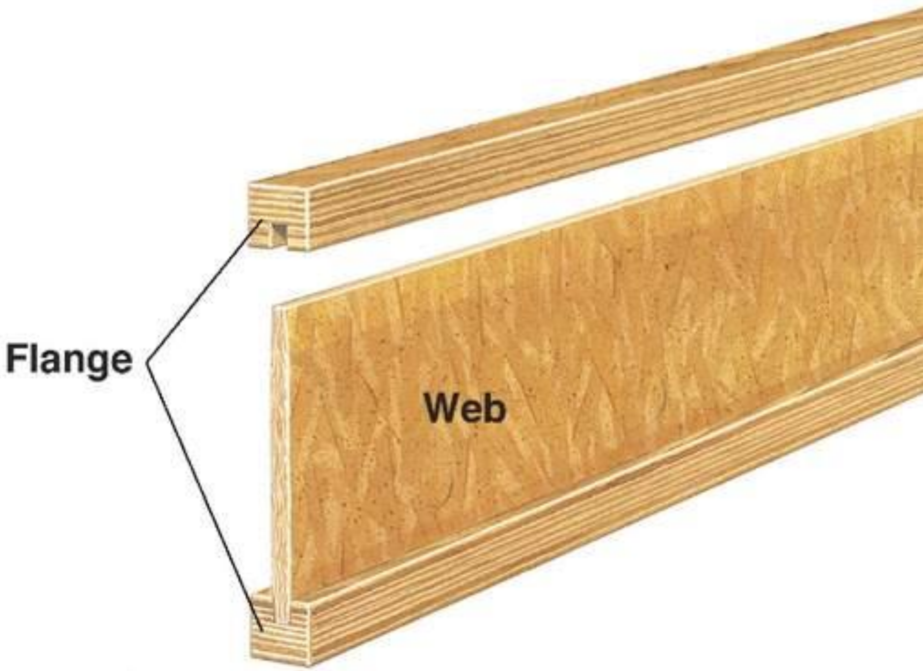
Photos: Louisiana Pacific

Oriented strand lumber (OSL)

- Newest of the composite products
- Made from oriented flakes
  - like LSL/OSB but strands all aligned along billet
- Flakes are shorter (by 50%) than LSL
  - ~ 15 cm same as OSB
- Competes with LVL, LSL and large lumber
  - headers for windows, doors

OSL applications (Ainsworth 2011)

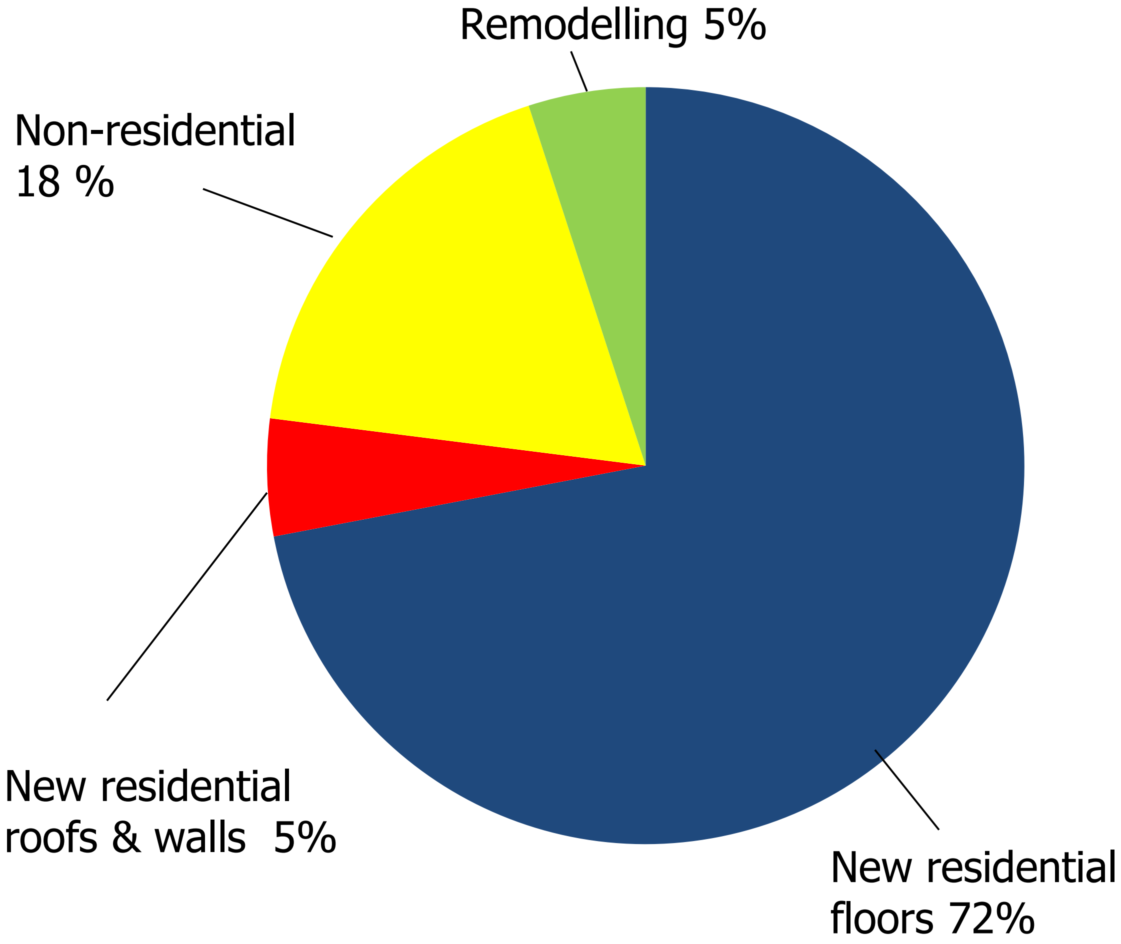
4:Other EWP



4.1: I-Joists (aka I-beams)

- Early I-joists used solid wood and plywood for web
- Plywood now replaced by OSB
- LVL now used in place of solid wood
- Very long joists possible but handling generally limits length to 25 m
- Web can be made fire-resistant by layer of gypsum
    - http://www.youtube.com/watch?v=R4-orETdkgA

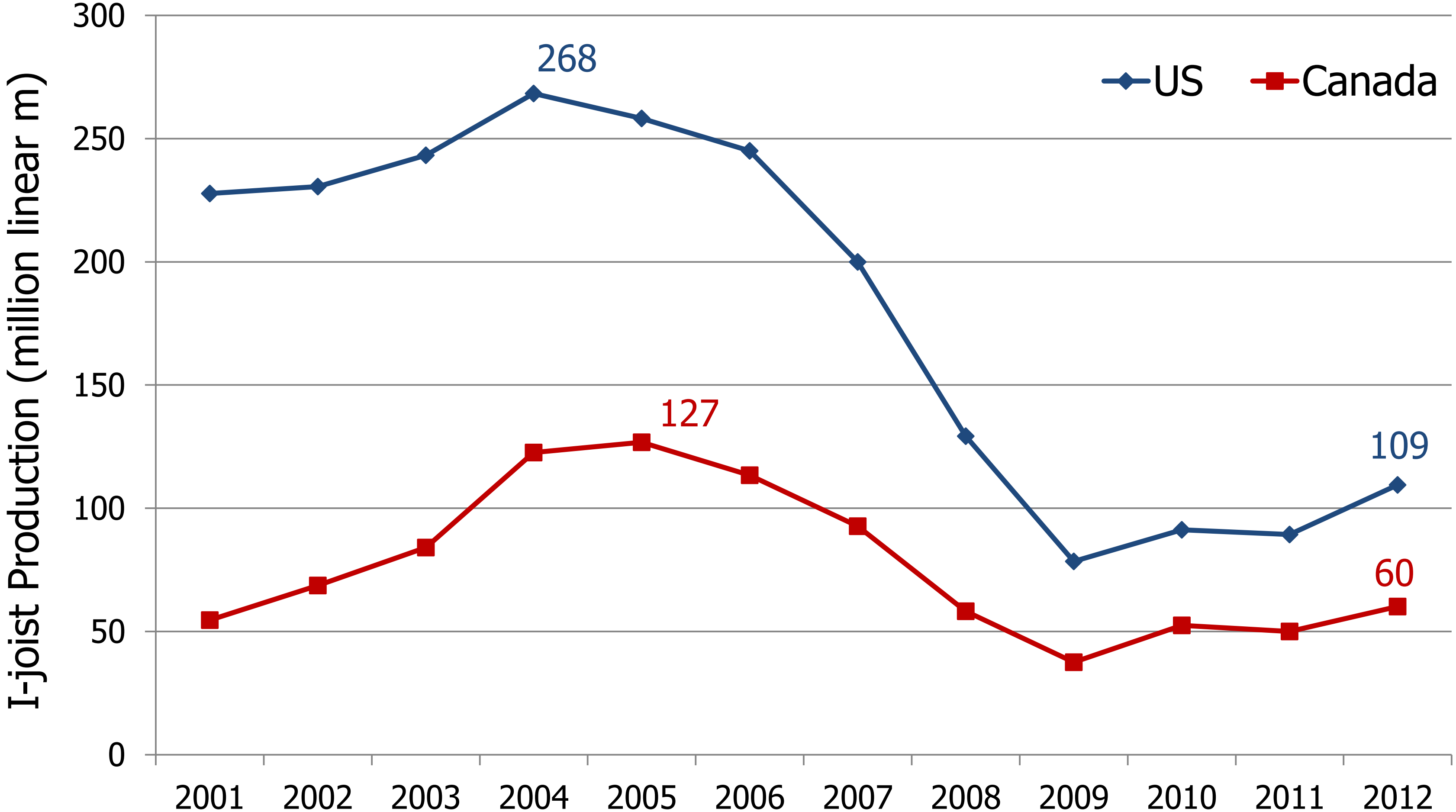
I-Joist markets
(UN ECE 2011)



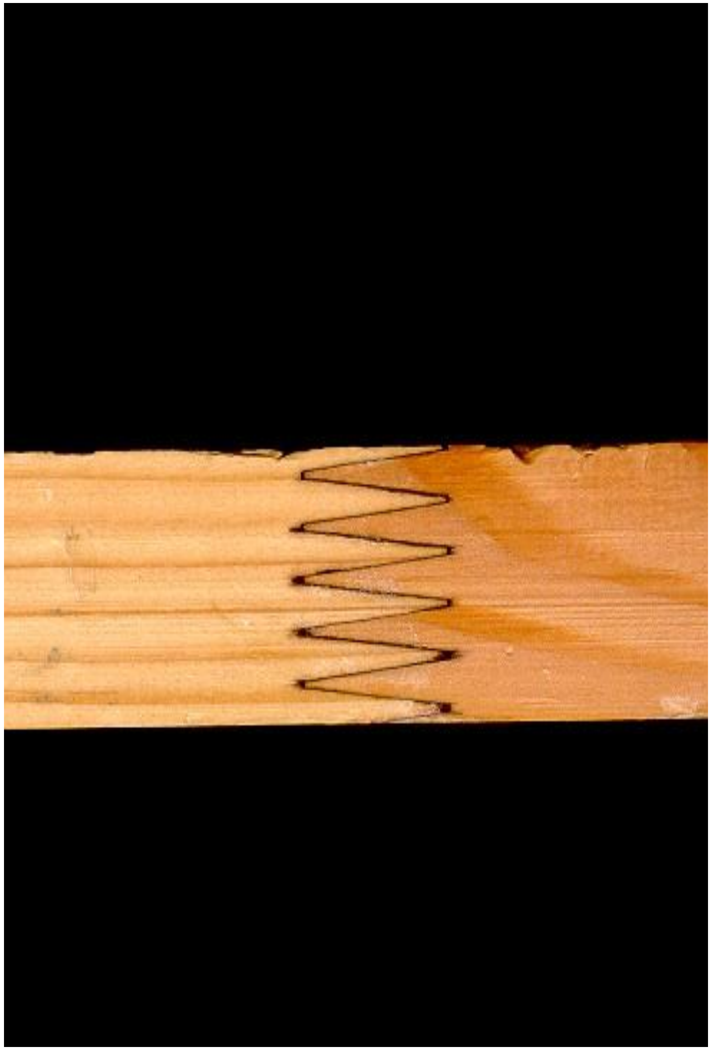
Markets

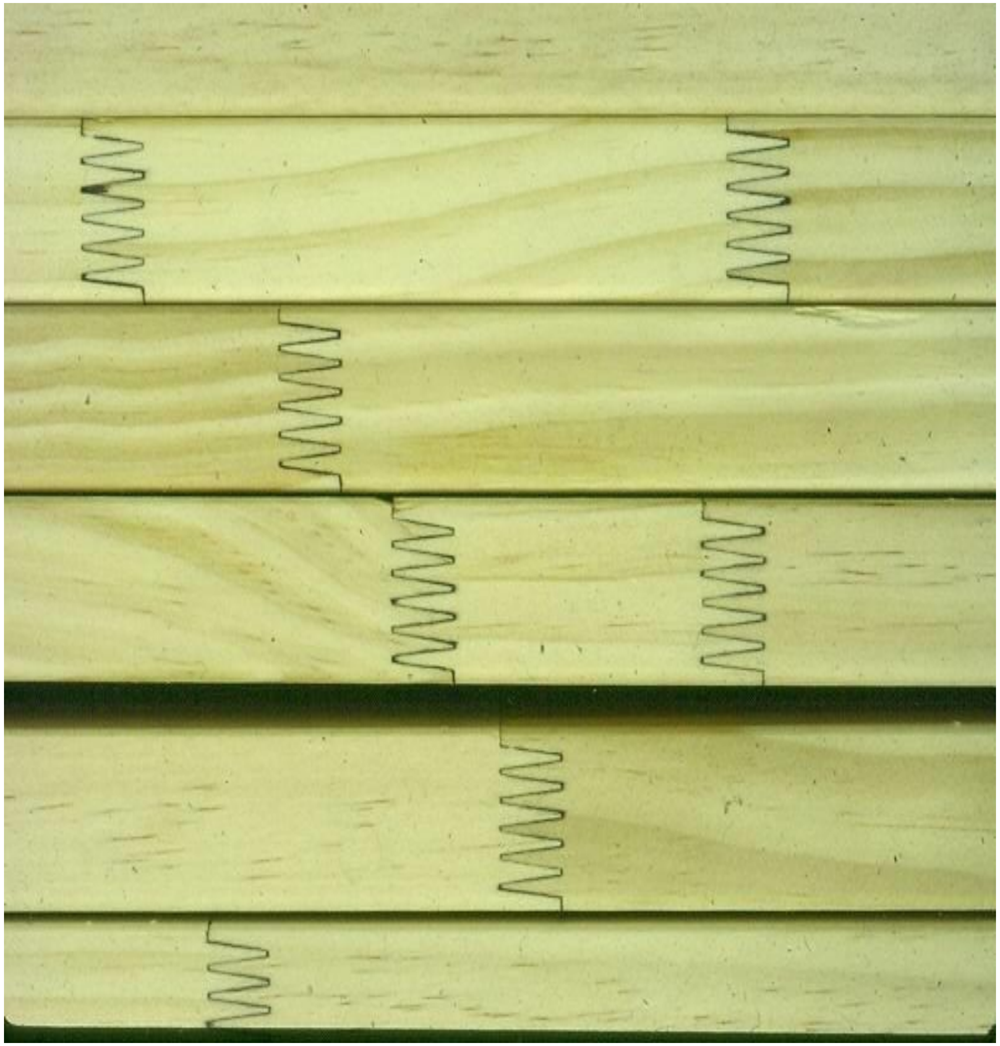
- New single & multi-family homes
  - Raised floors
- 2011: 52% share of SF home raised flooring market
- 1998: share = 31%
- 1992: share = 16%

North American I-joist production (UN ECE 2013)



4.2: Finger-jointed lumber





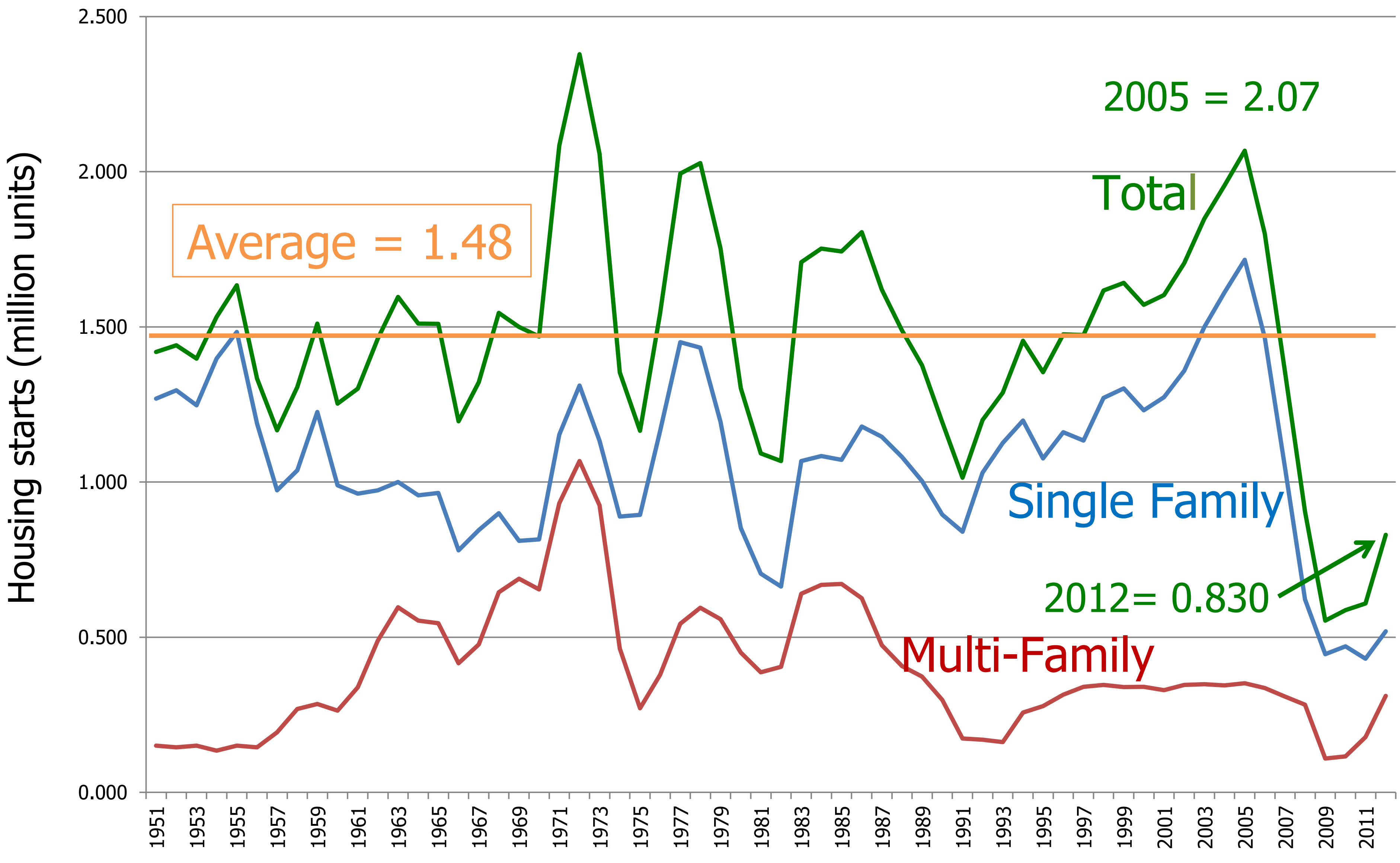
Finger-jointing

- Used to join to pieces of wood by their ends
- Often used to remove defects from wood or to provide an "endless ribbon" of sawn wood for products such as Glulam, CLT
- Strength of joint depends on length and pitch of fingers and adhesive used

Market developments - EWP

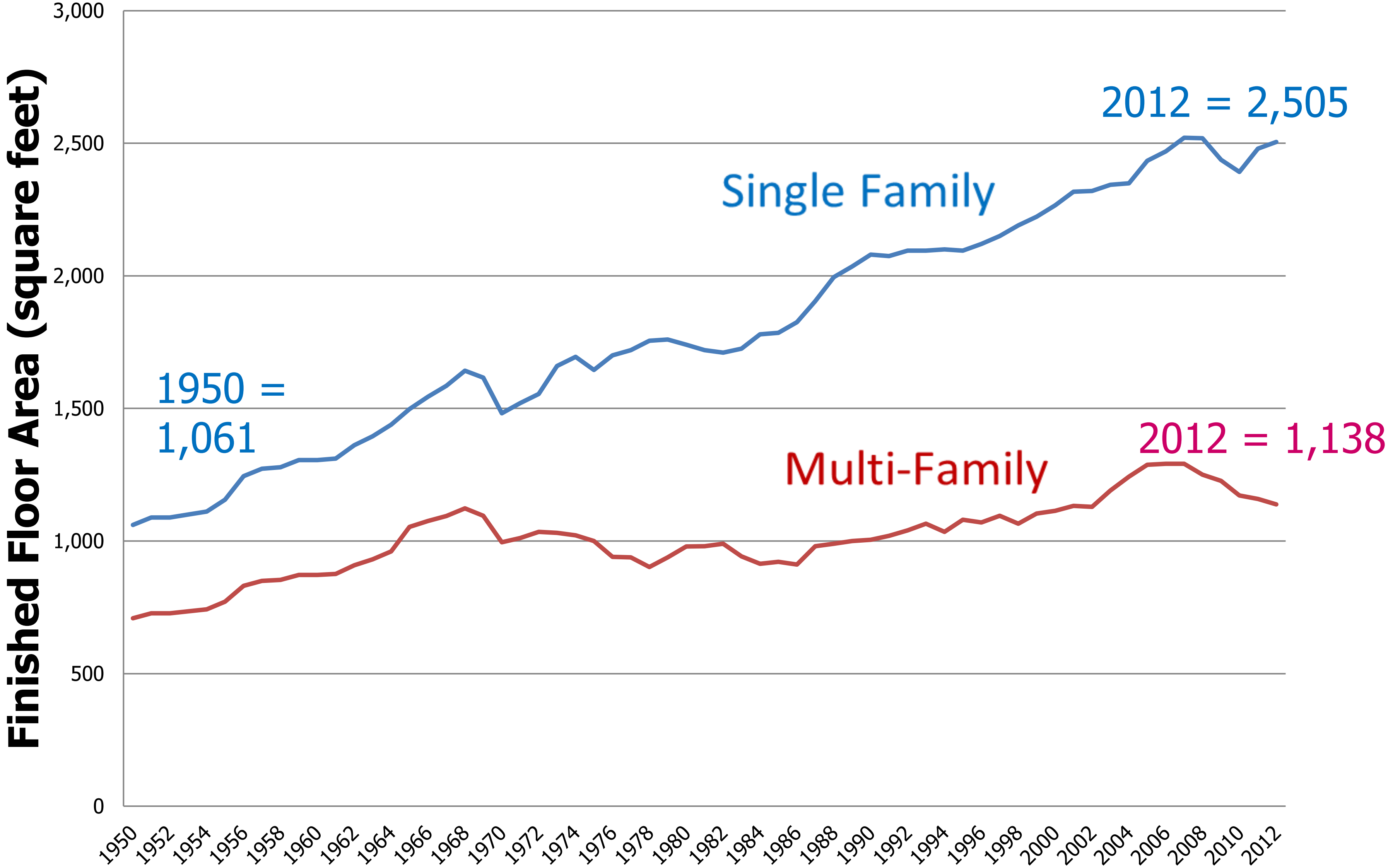
- North American residential housing market is most important for all EWP categories except 1
  - ??
- What has been happening in this market

US housing starts
(US Census Bureau 2013)



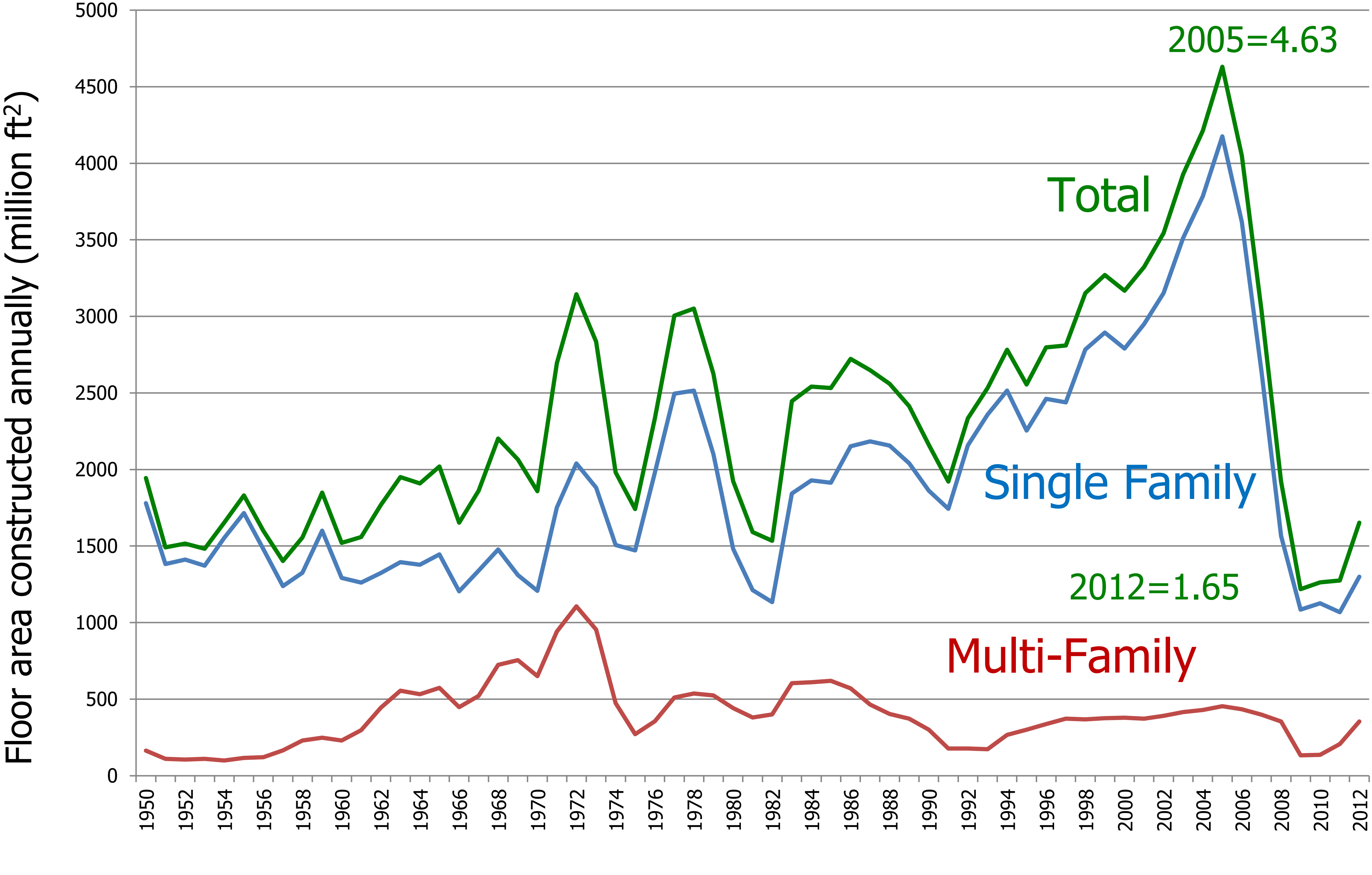
Average area of US houses

(US Census Bureau 2013)



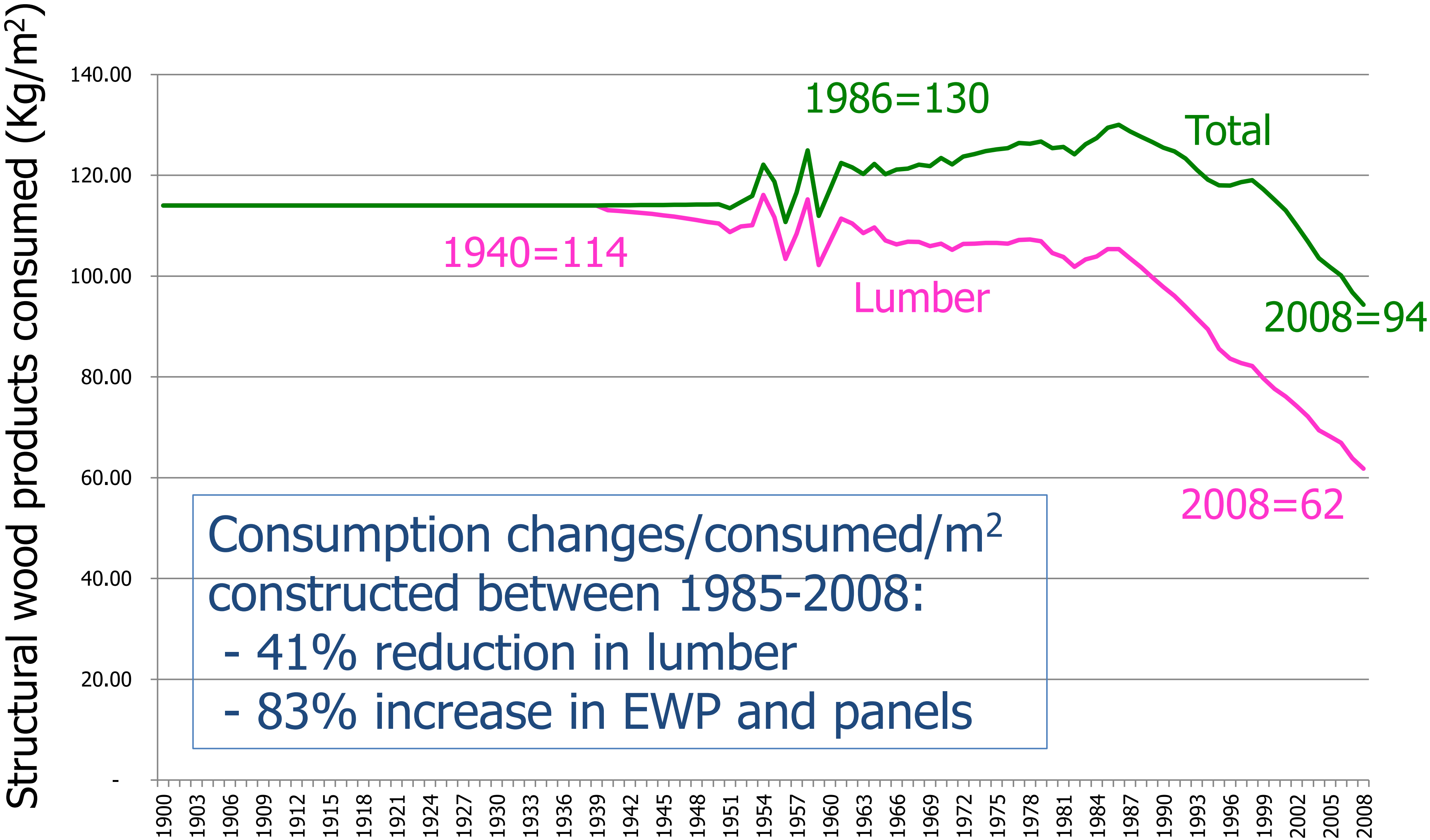
US house area constructed annually

(US Census Bureau 2013)



Structural Wood Products Consumed/m² of Single Family Homes Constructed in the US

(Sianchuk & McFarlane 2012)

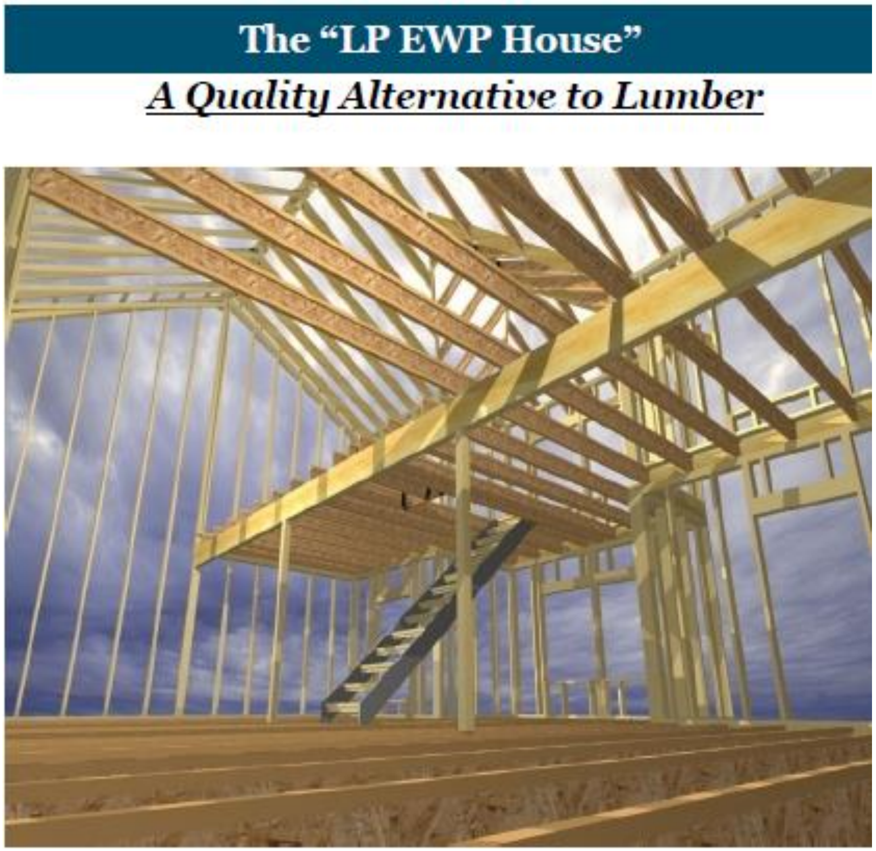


Consumption changes/consumed/m² constructed between 1985-2008:

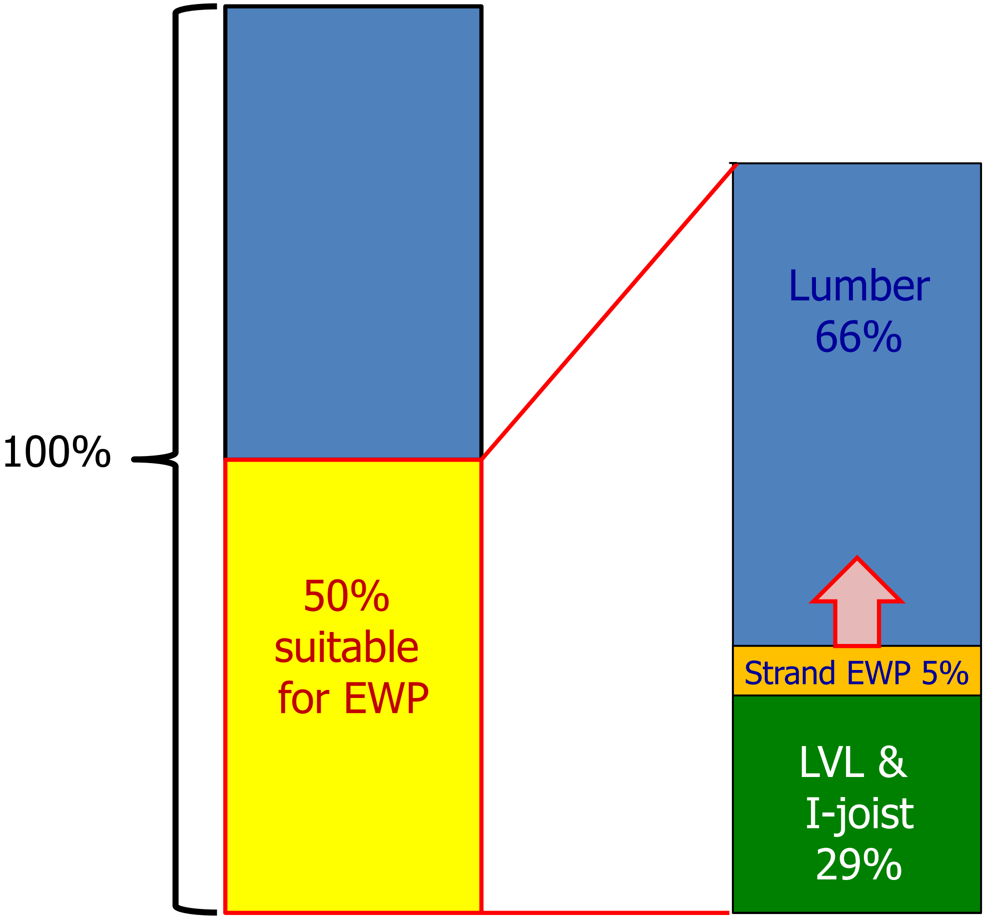
- 41% reduction in lumber
- 83% increase in EWP and panels

Growth Potential for EWP

(adapted from APA 2012, LP 2013)

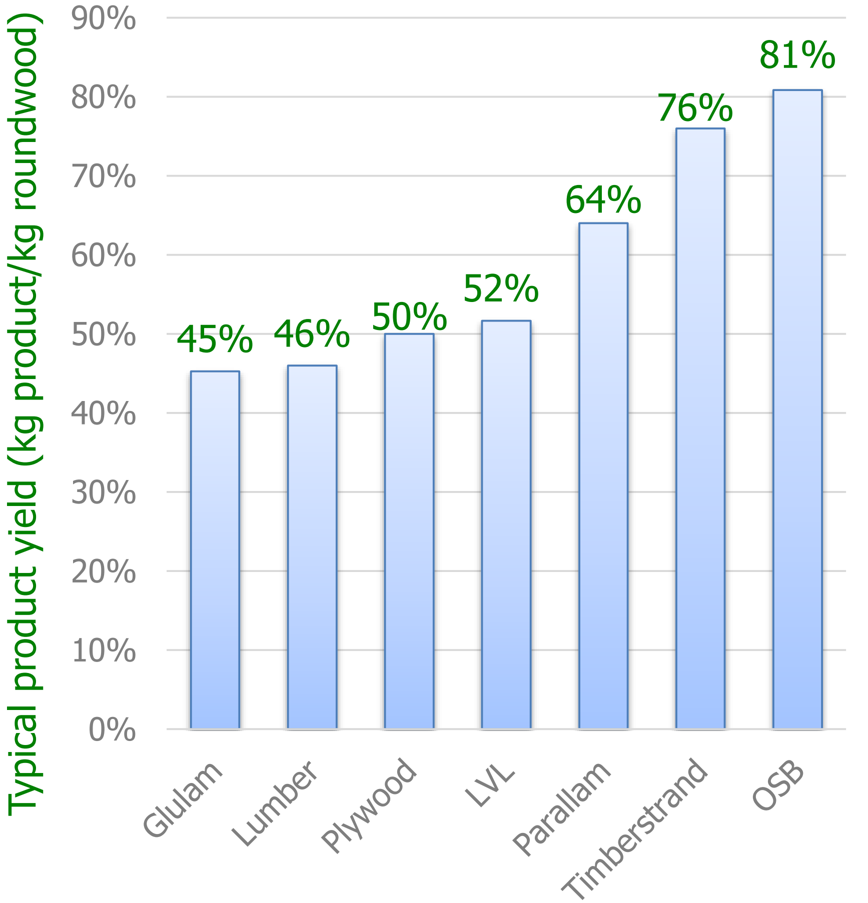


North American framing market 2012



EWP often have higher yields and use lower quality species

- We can increasingly engineer in product attributes rather than having to grow great fibre
- Compare by use:
  - Lumber: Lumber, LVL & Timberstrand (LSL/OSL)
  - Panels: Plywood & OSB
  - Beams: Glulam & Parallam (PSL)
- Implications for forestry
  - See homework



Impact of EWP on harvest volume and roundwood quality?

1. Process yield affects RW required to meet market demand
2. Fibre quality affects RW type and cost

Category	Product	Volume	Quality
Lumber	Lumber		
	2.1 LVL		
	3.1 LSL/3.2 OSL		
	1.2 CLT		
Panel	Plywood		
	OSB		
Beam	1.1 Glulam		
	2.2 PSL		

EWP often require less use of wood fibre in construction (Schuler 2004)

- Conventional flooring system
  - 85 2x10's; 133 pieces total
  - 2700 bd ft/house
  - 1.3 million single family houses consume 3.5 BBF/yr
- I joist system
  - 26 I joists; 80 pieces total
  - Overall 50% savings in wood fibre
  - Reduce consumption by 1.75 BBF timber/yr
  - Roundwood harvest reduction: 8.3 million m^3 .

Bamfield Marine Center Bamfield, British Columbia

StructureCraft
Fast + Epp

Take home concepts

- EWP driving innovation in manufacturing & construction
- EWP produce more from less
  - High performance products from reduced volumes of lower quality inputs
  - Can engineer product attributes rather than depending on natural fibre quality
    - Less dependent upon natural resource attributes
    - Require cheaper fibre inputs due to higher manufacturing costs
- EWP taking market share from lumber
  - Lumber will dominate SF/MF home construction for foreseeable future
- Large CLT potential in high rises

Homework:

1. EWP and innovation in construction

1. Michael Green: Ted talk - Wooden High Rises
   - http://video.ted.com/talk/podcast/2013/None/MichaelGreen_2013.mp4
2. Leander Bathon: Earth Sciences Building at UBC
   - http://www.youtube.com/watch?v=9Z95EhBo9ZY
3. Hubert Rhomberg: CREE buildings, Austria
   - http://www.youtube.com/watch?v=ZpBfXZ5tKdk&list=PL85Gt5s9miEfwC5kV-WChZx70GQCOdNG3

2. Assignment: Impact of technological developments on roundwood demand