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Whole building life cycle assessment (LCA)

Exploring the GHG mitigation opportunity from multistory wood buildings

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Overview

1. Introduce common building LCA terminology
2. Segue: low energy building LCAs
3. Review: comparative multistory building LCAs - wood as a low carbon structural material
4. Scaling the findings: how big of a mitigation wedge are we talking about from wood construction?
5. Expanding the scope

Building life cycle terminology (EN 15978: 2011)

Building Life Cycle														Supplementary Information
Product Manufacturing			Construction Stage		Building Use Stage					End-of-Life Stage				Outside the System Boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D
Raw Material Production	Transport	Product Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Demolition	Transport	Waste Processing	Disposal	Reuse, Recovery, Recycling Potential

B6	Operational Energy Use
B7	Operational Water Use

EeBGuide requirements for “screening” LCA

EeBGuide requirements for “simplified” LCA

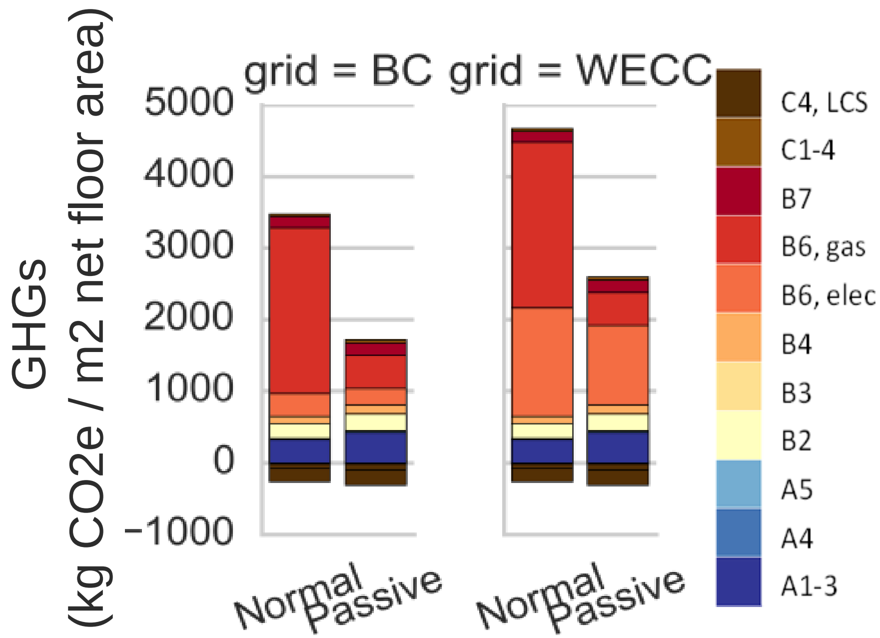
EeBGuide requirements for “complete” LCA

Low building LCA case studies

Passive house triplex, Nelson BC

- Building characteristics
  - Triplex, ~200 m^2 (2150 ft^2) net floor area
  - Double stud, light-frame wood envelope
  - Propane heat and hot water
  - Unheated basement with concrete walls
  - Metal roof
  - Wood decks
  - Wood siding
  - Cellulose insulation

Passive House LCA Results (Grann, 2015)

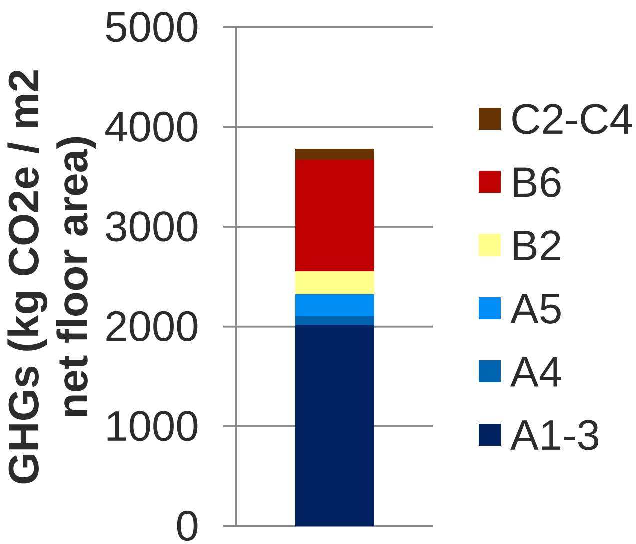


- Scenarios:
  - Design
    - Passive: passive building design, Nelson BC
    - Normal: code compliant building design
  - Electricity supply
    - BC: British Columbia
    - WECC: Western Electricity Coordinating Council

Results assume 60 year building lifetime

LCS: landfill carbon storage

"Nearly zero-energy building" with high footprint materials (Paleari et al. 2016)



- Building Description
  - 4040 m^2 (43,500 sqft) net floor area
  - Concrete/brick structure with wood framed roof
  - 2-3 stories plus underground parkade
  - Tile finishes
  - Photovoltaic (PV), mechanical, and electrical systems included in LCA
- Electricity supply
  - Solar PV & Italian electricity grid (mostly gas, also oil, coal, hydro)

*Assumes 100 year building lifetime

Figure based on data reported in Paleari et al. (2016)

Review: Comparative multi-story building LCAs - wood as a low GHG structural material

Building life cycle (EN 15978: 2011)

Building Life Cycle															Supplementary Information
Product Manufacturing			Construction Stage		Building Use Stage					End-of-Life Stage					Outside the System Boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4		D
Raw Material Production	Transport	Product Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Demolition	Transport	Waste Processing	Disposal		Reuse, Recovery, Recycling Potential

B6	Operational Energy Use
B7	Operational Water Use

EeBGuide requirements for “screening” LCA

Overview of case studies

- 12 comparative building LCA studies (**17 building comparisons**)
- Building **locations**:
  - Scandinavia, Australia, New Zealand, Canada, China ,US
- **Building characteristics**
  - Floors: 3-6 stories and one 8 story buildings
  - Floor area: ~1000-6000 m^2
  - Building types: residential apartments + 2 university buildings

Overview of case studies, continued

- Based on **equivalent system boundaries** within studies
  - i.e. same life cycle stages, building elements
- Buildings labelled wood, steel and concrete based on structural system, but **buildings are composites containing many materials**

- Wood/concrete building comparisons
  - 7 light-frame wood buildings
  - 5 mass timber buildings

- Wood/steel building comparisons
  - 2 light-frame wood / light gauge steel
  - 1 light-frame wood / heavy steel
  - 2 mass timber / heavy steel comparisons

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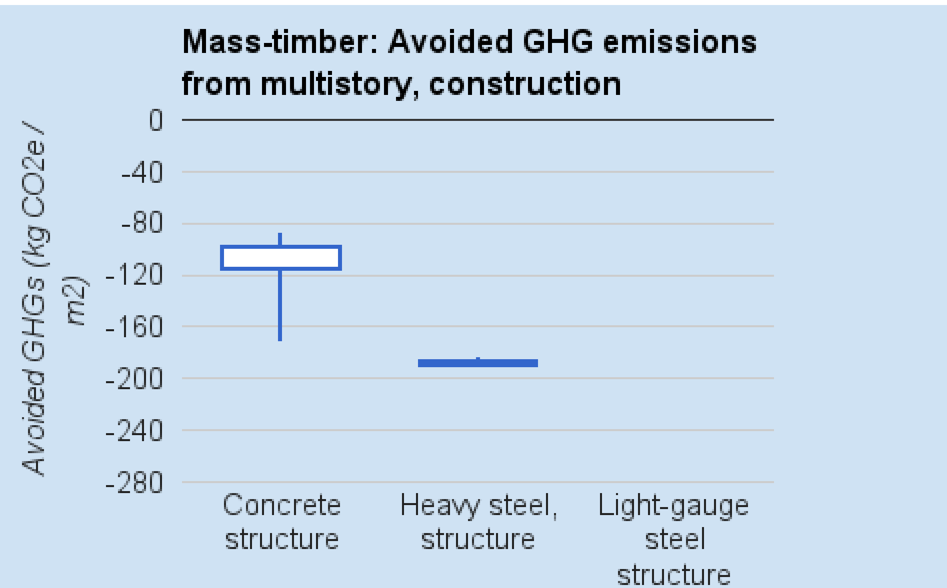
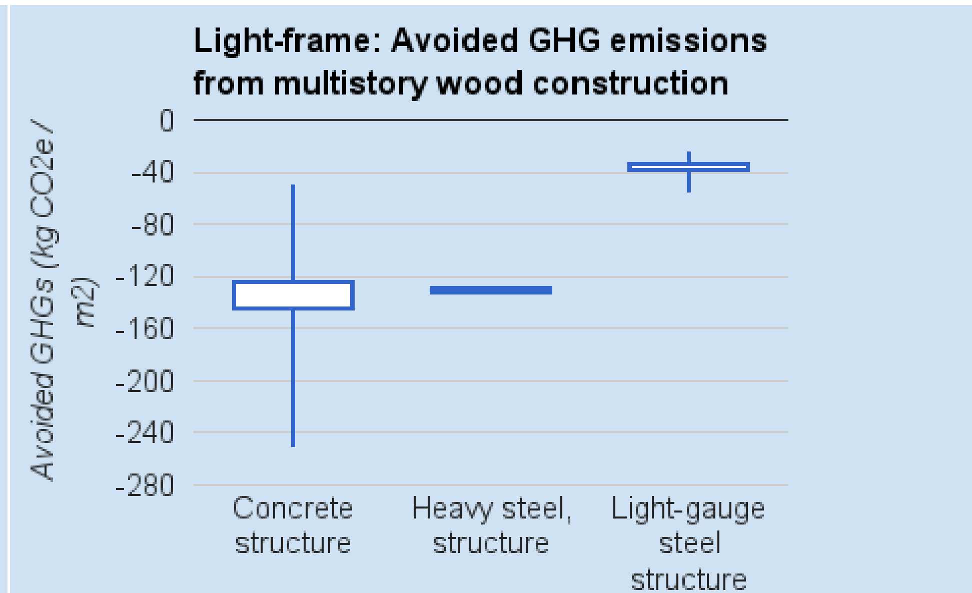
Avoided GHG emissions: aggregated results

- Mass timber comparisons
- Light-frame wood comparisons





#	5	2	0	7	1	2

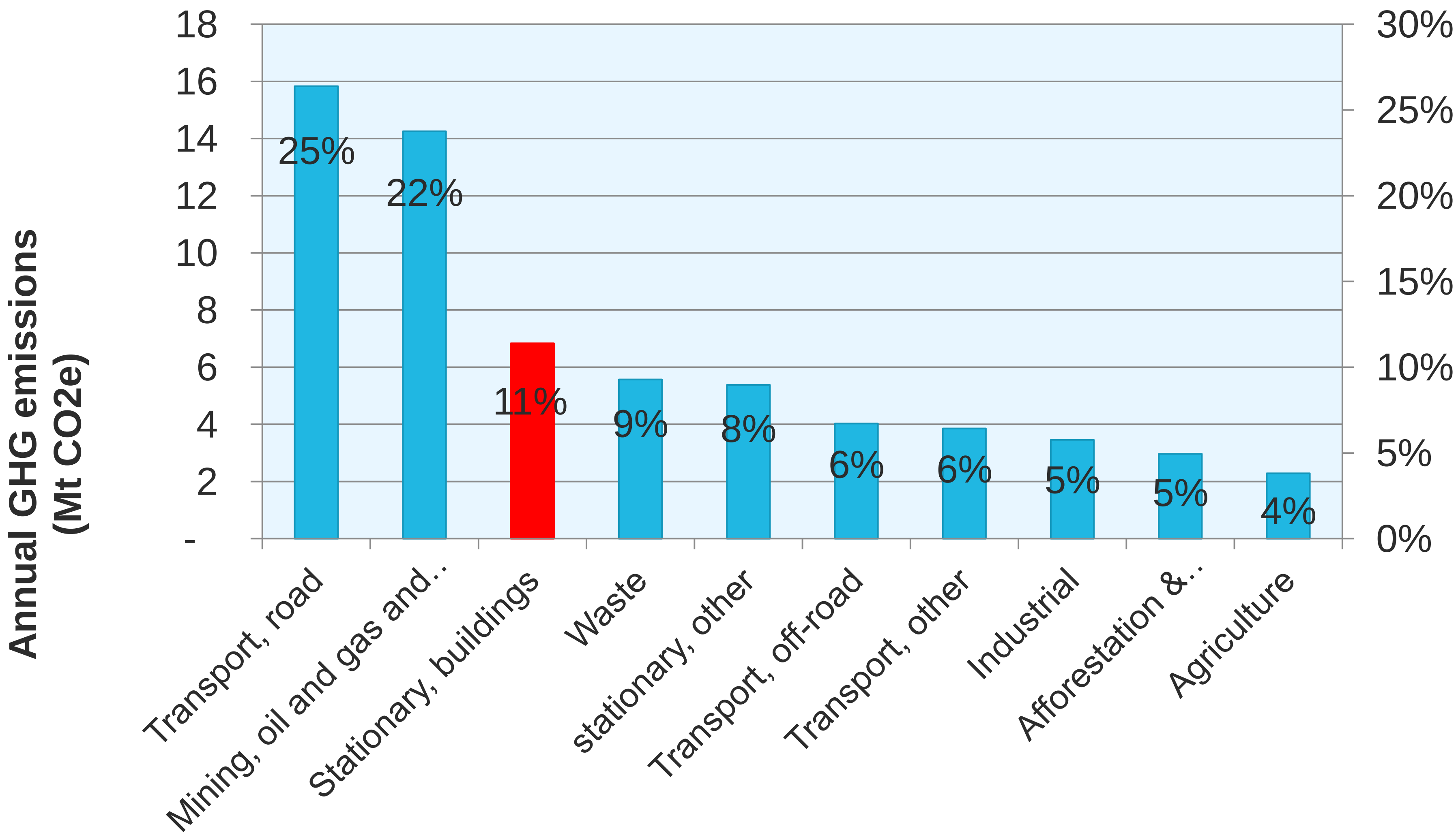
Note: comparisons limited to GHGs from material extraction and manufacturing (A1-3)

Scaling the findings: how big of a mitigation wedge are we talking about?

Scaling the findings

- What is the potential order of magnitude of GHG mitigation from wood construction?

Context: BCs 2014 GHG emissions



Data Source: BC Ministry of Environment

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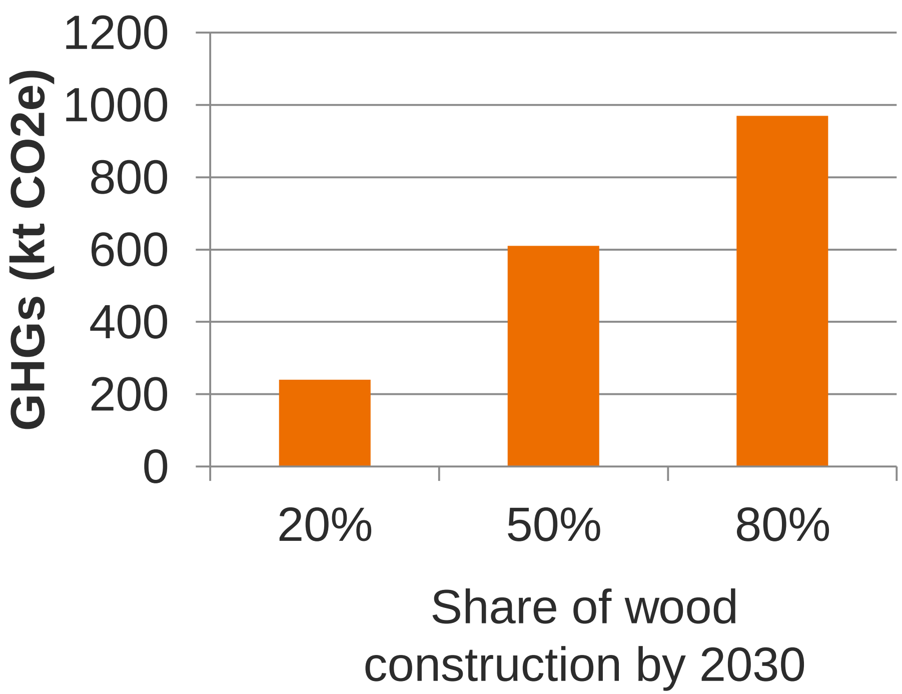
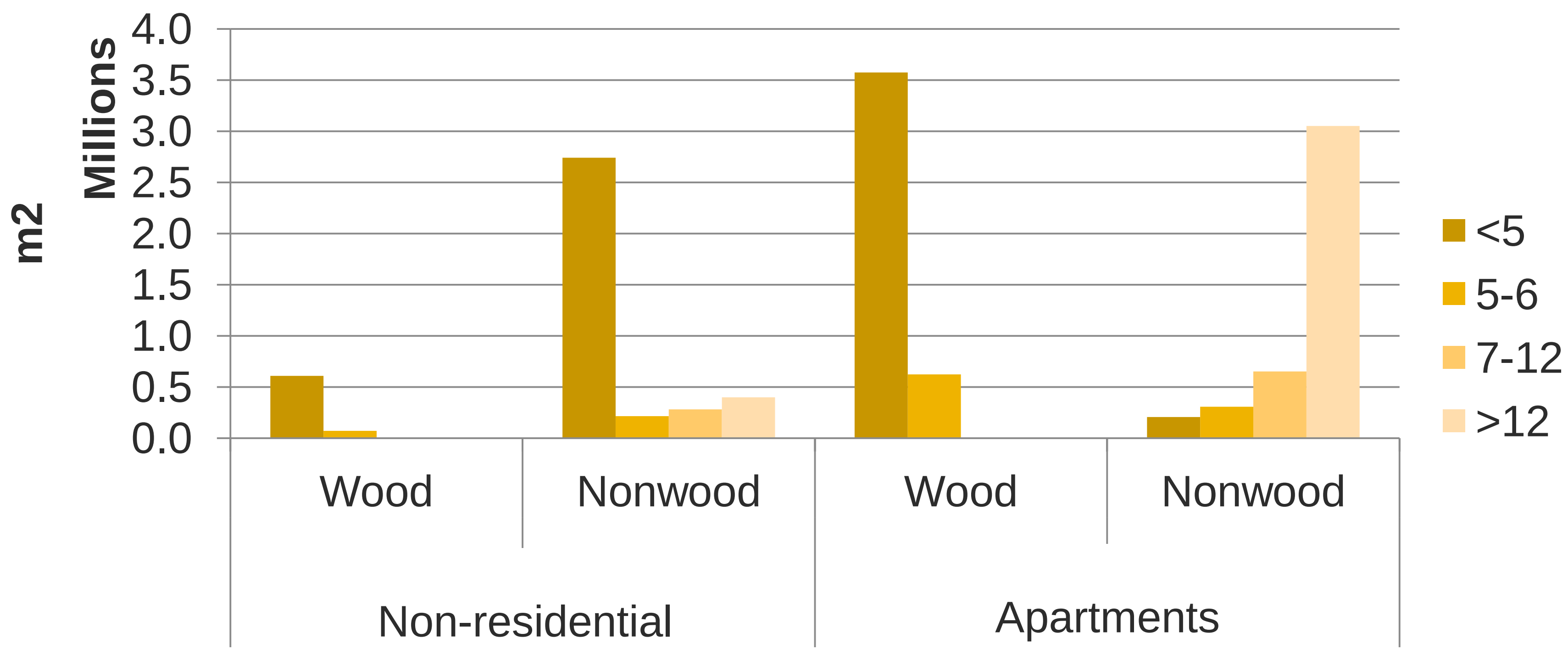
Scaling Findings

- Ruuska & Hakkinen (2012)
  - Situation in Finland
    - 1,035,000 m^2 multistory residential construction per year
      - 2% of multistory residential buildings have wood structure
  - Consider 3 scenarios:
    - Linear increase in multistory wood construction from 2008-2030
      - 20%, 50%, 80% wood by 2030
- Cumulative GHG Savings (2008-2030)



Annual construction starts in BC: 5 year average



GHG mitigation opportunity based on wood penetration assumptions by 2030

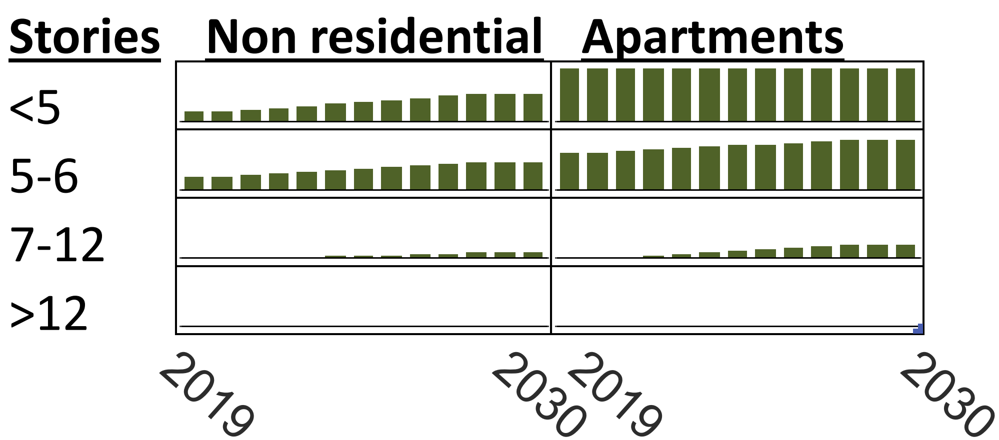
% wood construction

Non residential

Stories	Initial	Final
<5	18%	50%
5-6	25%	50%
7-12	0%	10%
>12	0%	0%

Apartments

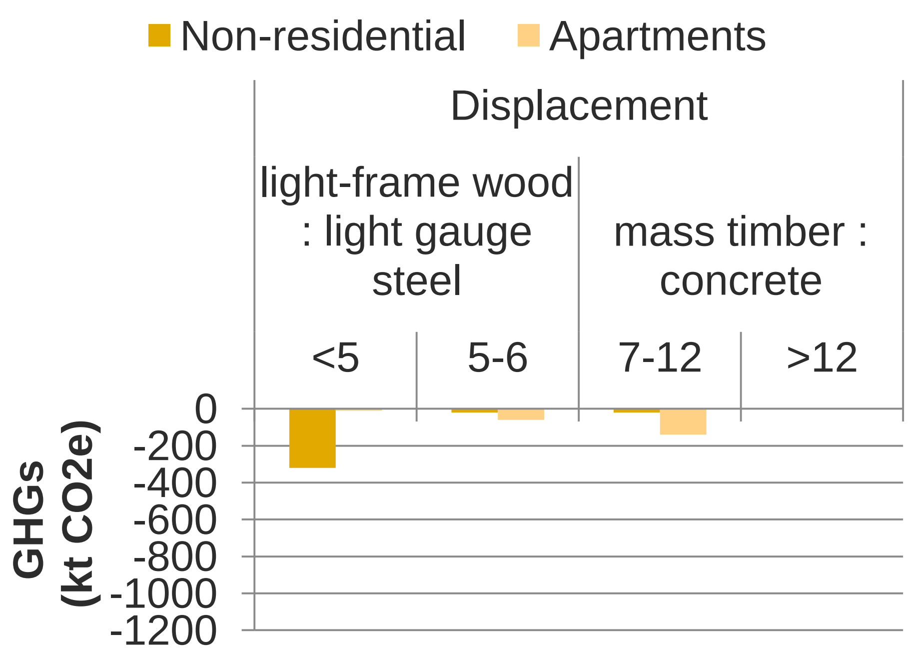
Stories	Initial	Final
<5	95%	95%
5-6	67%	90%
7-12	0%	25%
>12	0%	0%



Scenario results for expanding wood use: potential cumulative GHG savings by 2030

- Assuming all concrete displacement
  - High estimate
    - 1700 kt CO2e

- Assuming light gauge steel (<7 stories) and concrete (>7 stories) displacement
  - Low estimate
    - 570 kt CO2e



*Assumes no change in carbon footprint from material production over time

Some caveats...

- Annual GHGs from cement production in BC
  - Calcination: 975 kt CO2e in 2014
  - Energy: ~625 kt CO2e
- No steel produced in BC

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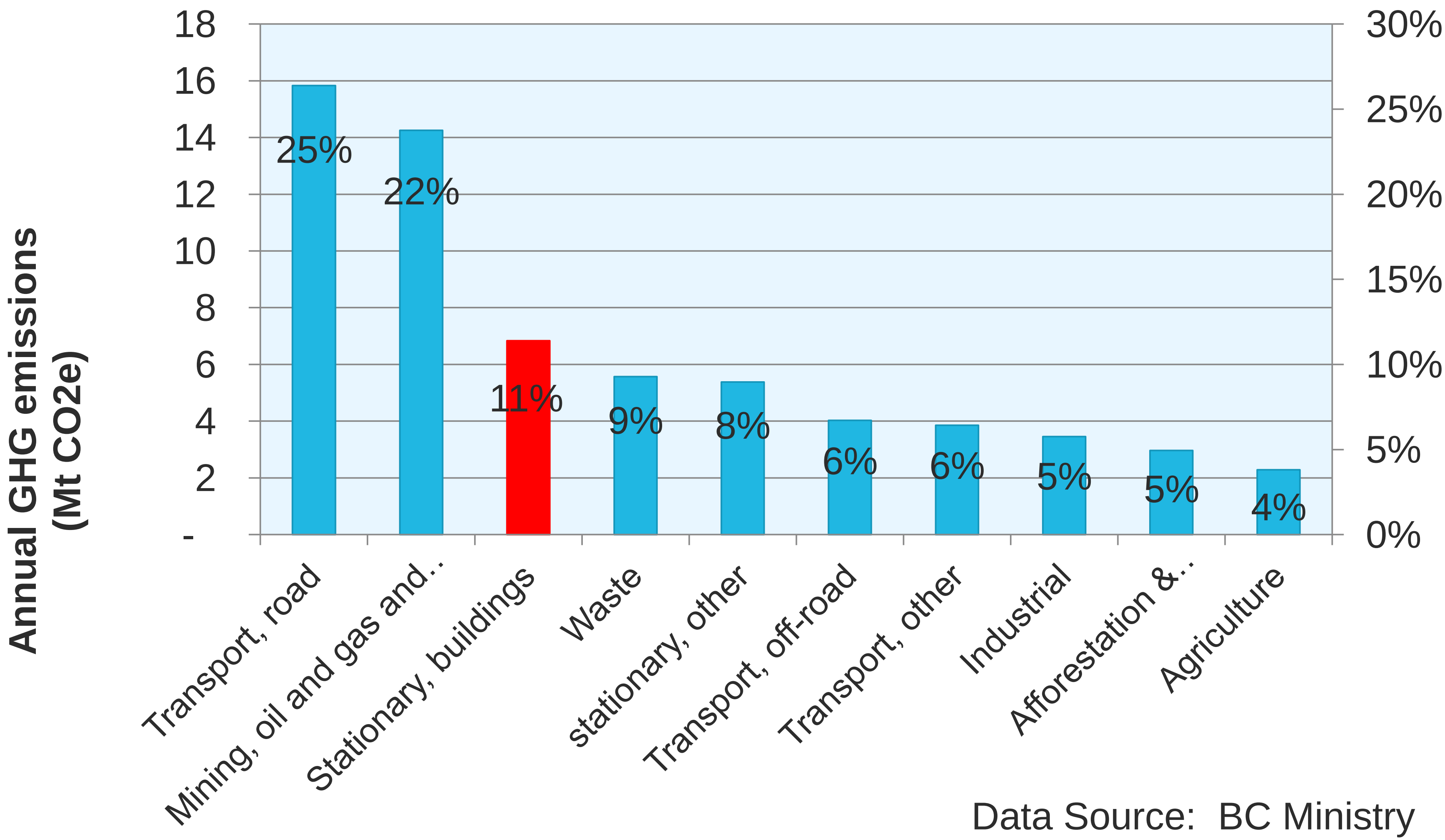
Expanding the scope

2014 GHG emissions in BC: First Lens



Data Source: BC Ministry of Environment

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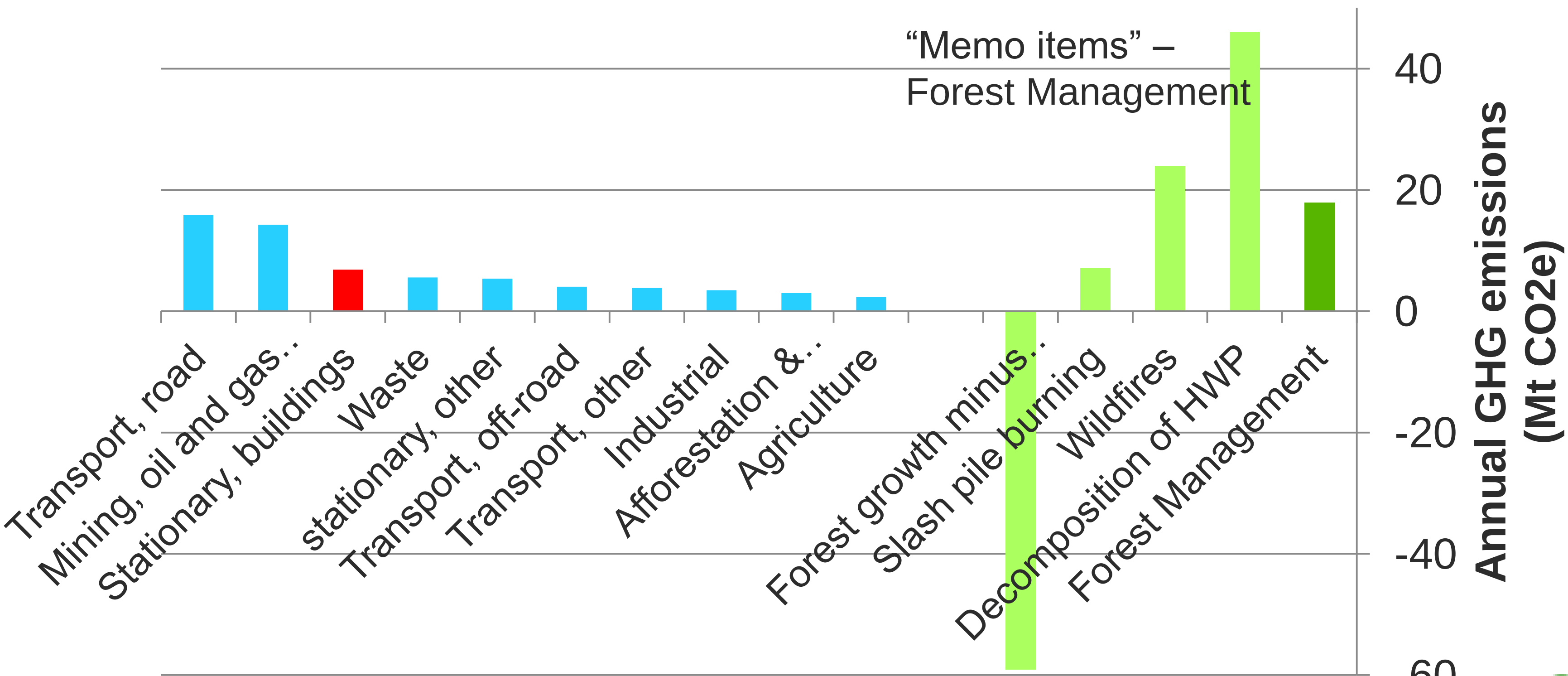
2014 GHG emissions in BC: including "memo items"

- National GHG inventory report
  - "Upon being retired from the inventory pool, all C [in harvested wood products] is assumed to be instantly oxidized" NRCan (2016, p. 146)
  - Waste chapter assumes 50% of C in landfilled wood products is released



Conclusions

- Materials contribute to the carbon footprint of buildings
  - ~10-15% based on current energy codes
  - ~40%+ for low energy buildings
- Wood construction has the potential to contribute as a climate mitigation strategy by expanding into new buildings types
  - 500-1,500 kt CO_2e cumulatively by 2030
    - Cumulatively ~1-2% of BCs 2014 GHGs

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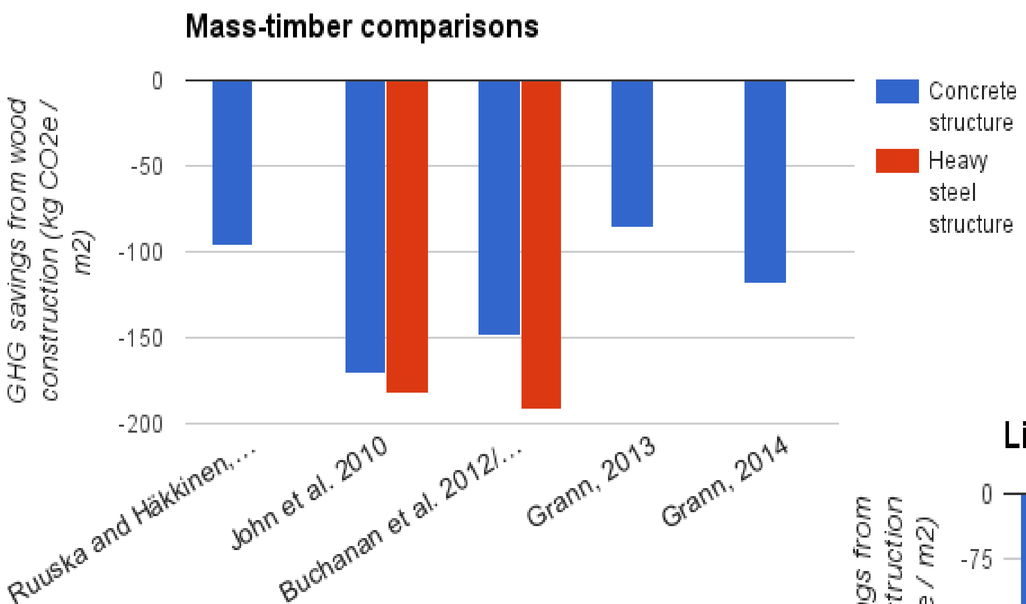
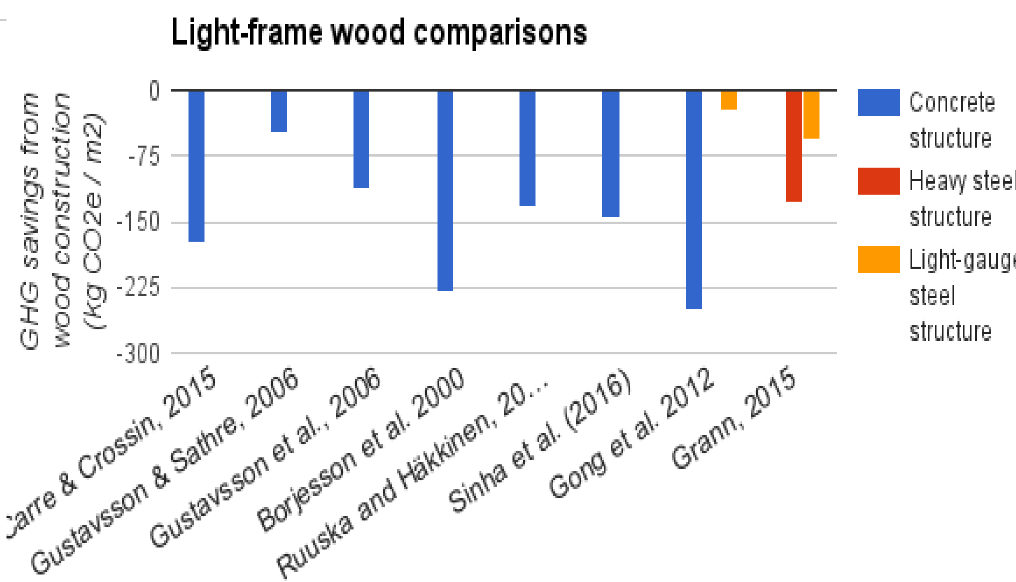
Additional Slides

Avoided GHGs: disaggregated results





Note: comparisons limited to GHGs from material extraction and manufacturing (see Assumptions and Limitations)

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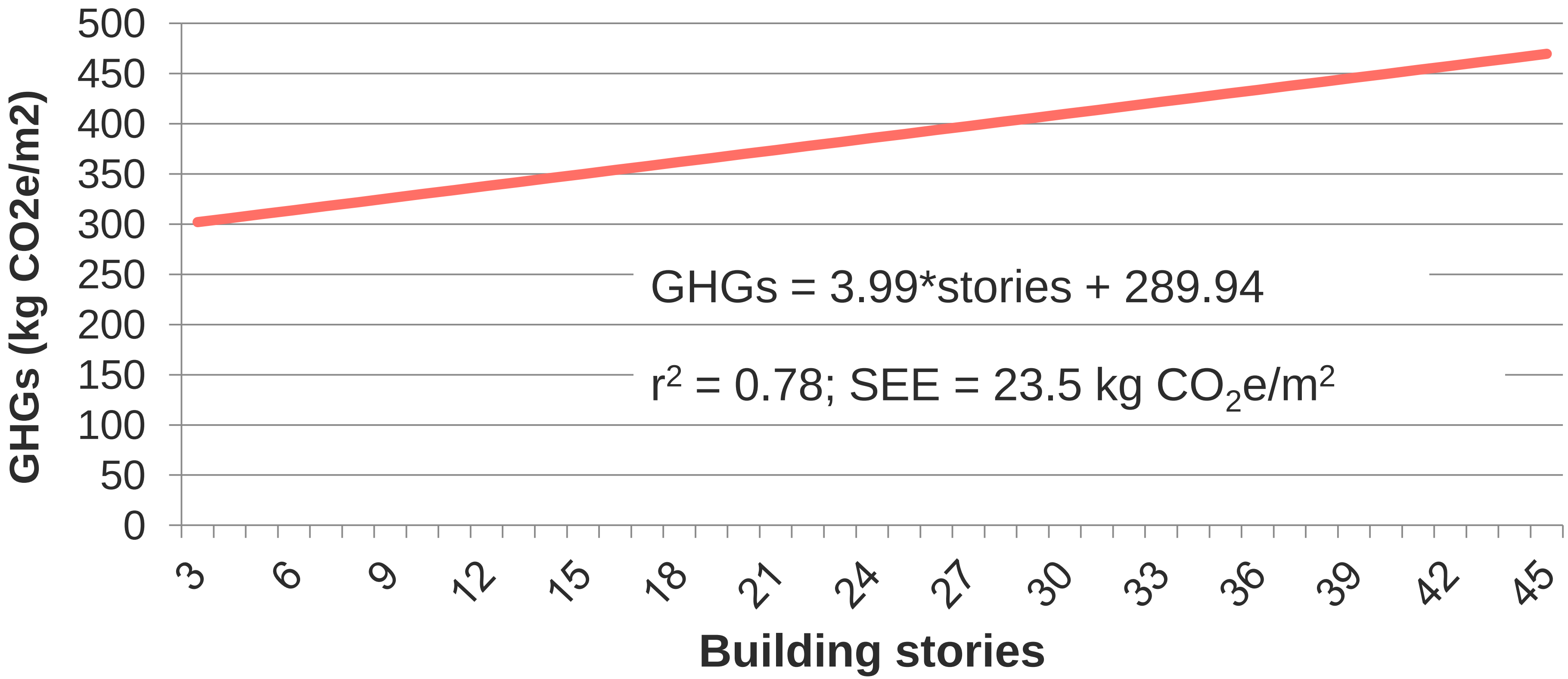
Building height and GHG emissions: concrete buildings in China



Source: Zhixing, Yang and Lu, 2016

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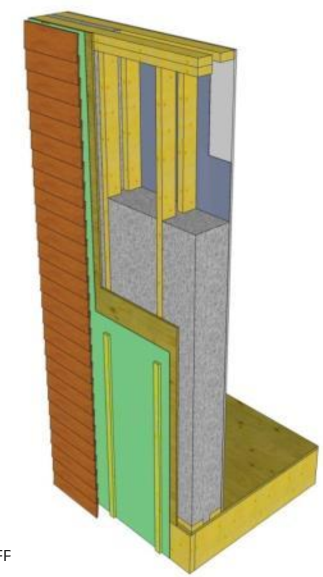
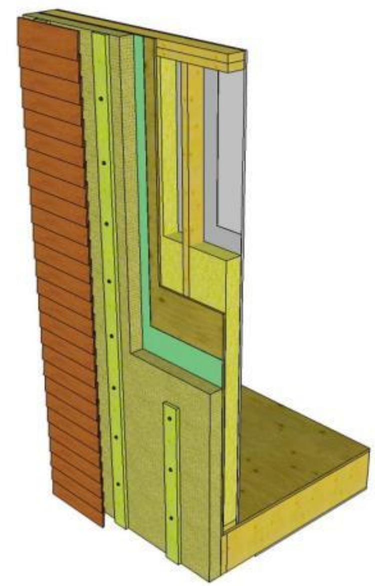
Energy efficiency and moisture management in wood buildings

Building Envelope: Thermal Efficiency

- Measures to improving thermal insulation
  - Deeper wall/roof cavities to install more fibrous insulation
    - Deeper studs
    - Double- or staggered studs
  - Installing semi- or rigid exterior insulation





Building Envelope: Durability

- Moisture management becomes particularly important for highly insulated assemblies
  - Due to reduced heat loss to dry wall or roof; and
  - Increased interstitial condensation potential
- Solutions
  - Measures to preventing rain penetration
  - Being airtight to reduce condensation potential
  - Exterior insulation to keep sheathing warm and dry
  - Design to improve drying capacity
    - e.g., reduce use of low-permeance material (membrane, insulation etc.)

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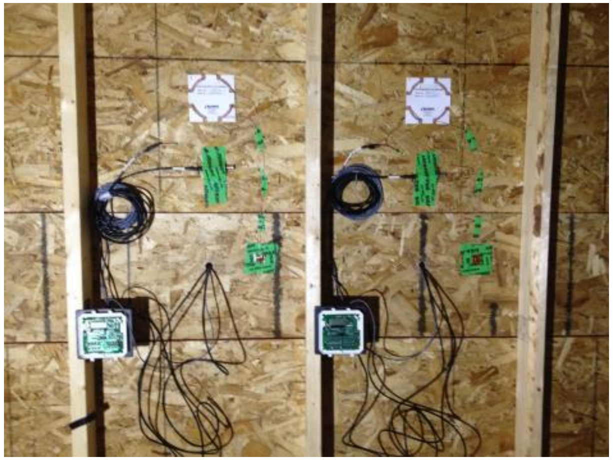
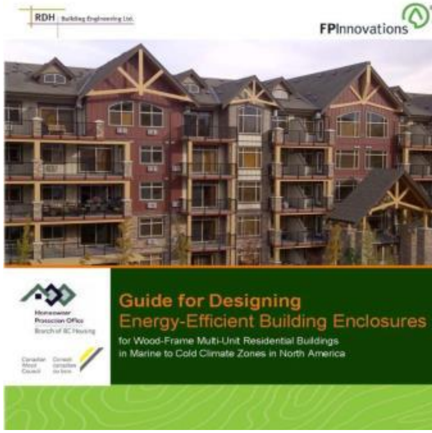
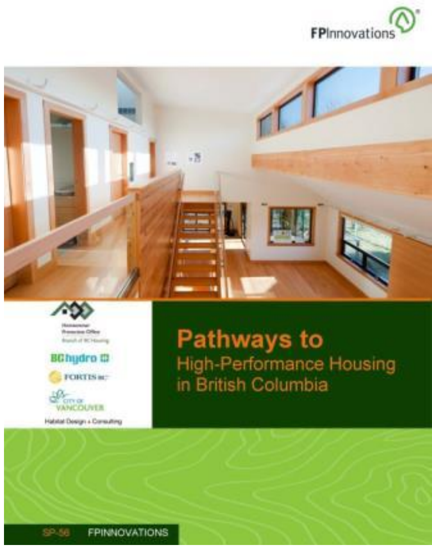
Building Envelope: Resources

- Ongoing research to improve durability
  - Field monitoring of highly insulated assemblies
  - Lab test to assess drying capacity
    - e.g., impact of closed-cell foam, various membranes
- Best practice guides developed
  - In collaboration with partners (HPO, RDH…)
  - Free download from FPInnovations website







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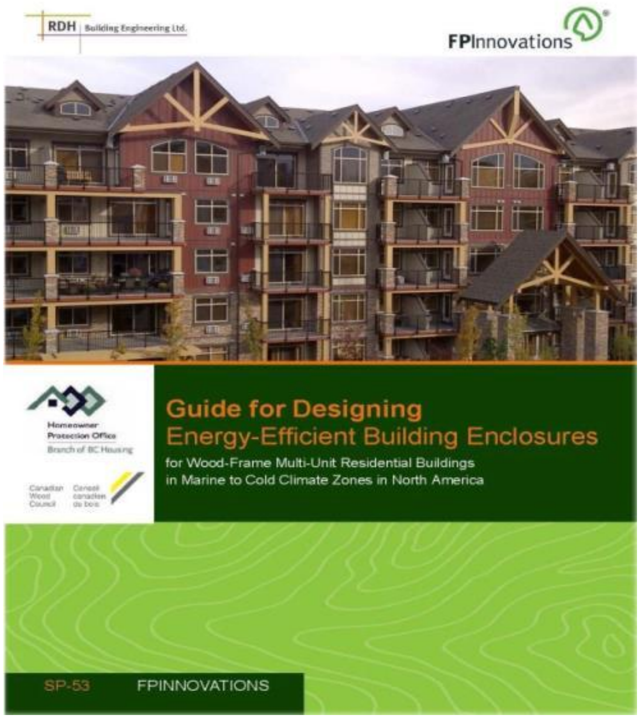
Building Energy Design Guide Published

- FPInnovations published a building energy design guide in March 2013
  - In collaboration with RDH, HPO, and CWC
  - Available on website for free



http://www.fpinnovations.ca/ResearchProgram/AdvancedBuildingSystem/designing-energy-efficient-building-enclosures.pdf