UNB Off-site Construction Research Centre | Building Transformations

Université Concordia University

TRANSFORMING CONSTRUCTION 2026-27: AN INTERACTIVE WEBINAR SERIES

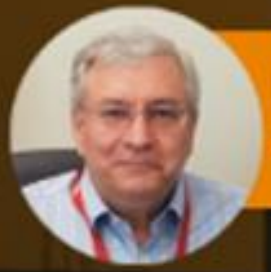
LIVING LAB, AN INITIATIVE SUPPORTED BY THE GNB'S ENVIRONMENTAL TRUST FUND

Webinar 2: Oct. 22

Concordia University presents:

APPLYING BUILDING SCIENCE TO PRE-FABRICATED, OFF-SITE CONSTRUCTION

WEBINAR SPEAKER:



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UNB EST. 1785 UNIVERSITY OF NEW BRUNSWICK | Off-site Construction Research Centre

Transforming Construction 2026-2027: An interactive Webinar Series

Applying Building Science to Pre-fabricated, Off-site Construction

22 October, 2026

Lecturer: Dr. Michael Lacasse, Research Associate

Université Concordia University
Gina Cody School of Engineering and Computer Science

Overview

- **Part 1 - Overview Building Science principles with focus on the needs of Off-site construction technology**
- Part 2 - Overview of the intersection of building science, performance, and prefabrication / modular construction
- Part 3 - Review of sustainability criteria and industry standards

Overview

Background information

- From a building science perspective, the fundamental difference in off-site construction design lies in engineering the structure to withstand transportation stresses and leveraging the controlled factory environment for enhanced quality control over traditional site-built methods
- While both must meet the same building codes for final performance, the design approach to achieve this differs

Overview

The key differences with respect to Building Science Design relate to the following seven (7) elements:

- Structural Engineering for Transport
- Inter-module Connections
- Moisture Control and Air Sealing
- Thermal Bridging
- Precision and Tolerances
- MEP Systems Integration
- Fire Safety

Key differences — Building Science Design

Key differences in respect to Building Science Design relate to the following seven (7) elements:

- Structural Engineering for Transport
- **Inter-module Connections**
- **Moisture Control and Air Sealing**
- **Thermal Bridging**
- Precision and Tolerances
- MEP Systems Integration
- Fire Safety

Effects on these elements, following transport to site

Key differences — Building Science Design

Structural Engineering for Transport

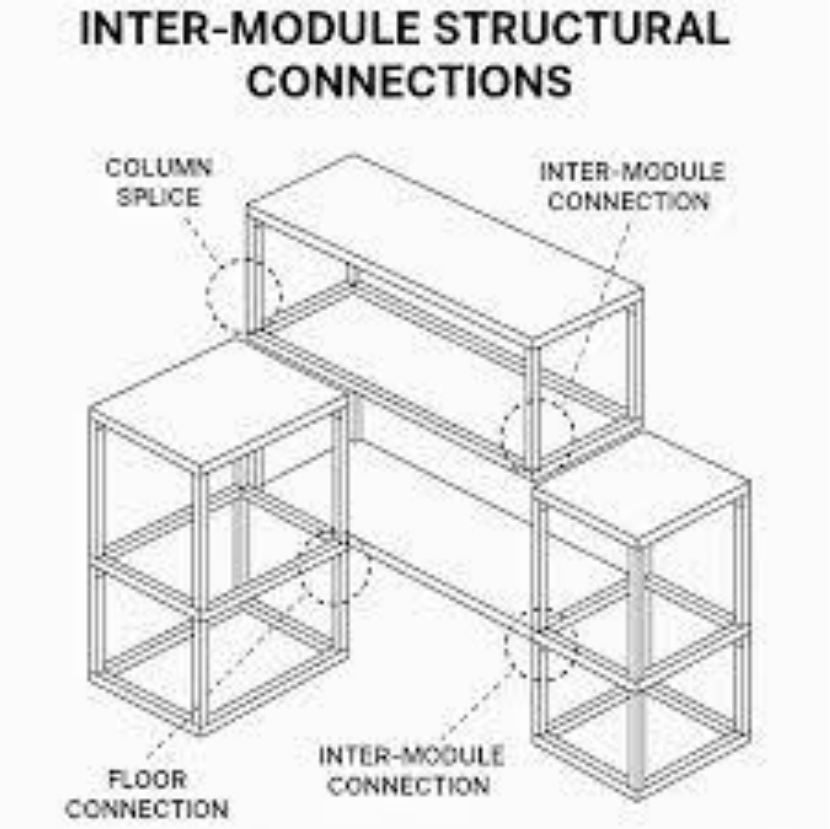
- **Off-site modules must be designed with enhanced structural integrity to endure the unique stresses of lifting, transportation on highways, and craning onto the foundation**
- **Design must account for temporary load conditions that the final, assembled building will not experience; such as**
  - Differential loading and vibrations during transit



Key differences — Building Science Design

Inter-module Connections

- A major design focus in off-site construction is to ensure engineering of robust and **reliable connections between modules**
- Connections must ensure structural continuity, fire safety, and **weatherproofing** once assembled on site
- These connection details need careful planning to facilitate efficient on-site assembly **while maintaining long-term performance**



Key differences — Building Science Design

Moisture Control and Air Sealing

- Factory-controlled environment eliminates weather-related risks during construction phase, preventing materials from being exposed to rain or snow; a common issue on traditional construction sites

- Allows for a more consistent and higher quality installation of insulation, air barriers, and vapor control layers, potentially leading to better energy efficiency and indoor air quality in completed building

Key differences — Building Science Design

Thermal Bridging

- Off-site construction techniques, such as using light steel framing, can present challenges regarding thermal bridging if not addressed during the design phase

- Designers must carefully detail junctions and connections to minimize heat loss through structural elements, which may involve using deeper floor zones or thicker walls

Overview of prefabrication and modular building construction

Design considerations for off-site, modular construction

Precision and Tolerances

- Design in off-site construction demands a much higher degree of precision and coordination using tools such as Building Information Modeling (BIM)
- Because components are manufactured to exact specifications in a factory, there is less flexibility for on-site adjustments, requiring meticulous upfront planning to ensure all modules fit together perfectly during assembly

Overview of prefabrication and modular building construction

Design considerations for off-site, modular construction

MEP Systems Integration

- Mechanical, electrical, and plumbing (MEP) systems are often integrated within the modules during factory production, which
  - Requires detailed pre-planning and design to ensure seamless connection points once the modules are placed on site

Overview of prefabrication and modular building construction

Design considerations for off-site, modular construction

Fire Safety

- Fire safety performance is a key consideration, particularly in panelized and multi-story modular construction.
- Design strategies must ensure that the assembly of modules meets or exceeds fire resistance requirements, with specific attention to the integrity of inter-modular joints

Overview of prefabrication and modular building construction

Design considerations for off-site, modular construction

- Structural Engineering for Transport
- Inter-module Connections
- Moisture Control and Air Sealing
- Thermal Bridging
- Precision and Tolerances
- Mechanical, electrical, and plumbing (MEP) systems Integration
- Fire Safety

Part 2 — Overview of building science, performance, and prefabrication / modular construction

Prefabrication and modular building construction

Design considerations for off-site, modular construction

- Structural Engineering for Transport
- Inter-module Connections
- Precision and Tolerances
- Mechanical, electrical, and plumbing (MEP) systems Integration
- Fire Safety

Prefabrication and modular building construction

Design considerations for off-site, modular construction

Structural Engineering for Transport

- Off-site modules must be designed with enhanced structural integrity to endure the unique stresses of lifting, transportation on highways, and being placed by crane onto the foundation.
- Design must account for temporary load conditions that the final, assembled building will not experience, such as differential loading and vibrations during transit.

Prefabrication and modular building construction

Design considerations for off-site, modular construction

Inter-module Connections

- A major design focus in off-site construction is the engineering of robust and reliable connections between modules
  - Connections must ensure structural continuity, fire safety, and weatherproofing once assembled on site
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Prefabrication and modular building construction

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Prefabrication and modular building construction

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Prefabrication and modular building construction

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Part 3 — Expected performance for off-site, modular construction

Expected performance for off-site, modular construction

Expected performance for building science related issues

- Building science issues: Movement of heat, air and moisture
- **Key Differences in Building Science Design for off-site, modular construction**
- **Thermal Performance: Principles & Analysis**
- **Emerging Tools for Thermal Performance**
- **Air Leakage: Theory and Measurement**
- **Indoor Environmental Quality**

Expected performance for off-site, modular construction

Expected performance for building science related issues

- Building science issues: **Movement of heat, air & moisture (HAM)** across building envelope

- **Differences in Building Science Design for off-site, modular construction**
  - Moisture Control and Air Sealing
  - Thermal Bridging

Expected HAM performance for off-site, modular construction

Key Differences in Building Science Design for off-site, modular construction

- **Moisture Control and Air Sealing**
  - Factory-controlled environment for fabrication eliminates weather-related risks during the construction phase, preventing materials from being exposed to rain or snow — a common issue on traditional sites
  - Allows for a more consistent and higher-quality installation of insulation, air barriers, and vapour control layers, potentially leading to better energy efficiency and indoor air quality in the final building

Expected HAM performance for off-site, modular construction

Key Differences in Building Science Design for off-site, modular construction

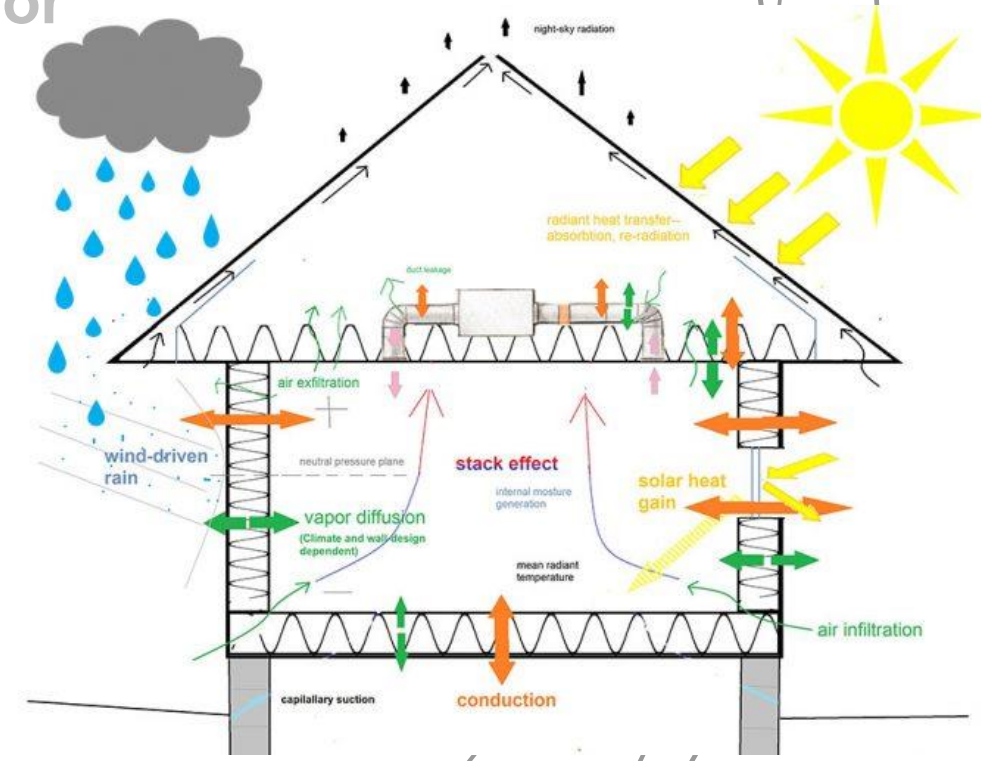
- **Thermal Bridging**
  - Off-site construction techniques, such as using light steel framing, can present challenges regarding thermal bridging if not addressed during the design phase
  - Designers must carefully detail junctions and connections to minimize heat loss through structural elements, which may involve using deeper floor zones or thicker walls

Expected HAM performance for off-site, modular construction

Expected performance for building science related issues

- Building science related issues: Movement of heat, air and moisture

- Key Differences in Building Science Design for off-site, modular construction
- **Thermal Performance: Principles & Analysis**
- **Emerging Tools for Thermal Performance**
- **Air Leakage: Theory and Measurement**
- **Indoor Environmental Quality**



Expected HAM performance for off-site, modular construction

Expected performance for building science related issues

- Building science related issues: **Movement of heat**

- **Thermal Performance: Principles & Analysis | What are the Mechanisms of Heat Transfer?**
  - Conduction
  - Convection
  - Radiation



Expected HAM performance for off-site, modular construction

Expected performance for building science related issues

- Building science related issues: **Movement of heat**

- **Thermal Performance: Principles & Analysis | What are the Mechanisms of Heat Transfer?**
  - Conduction
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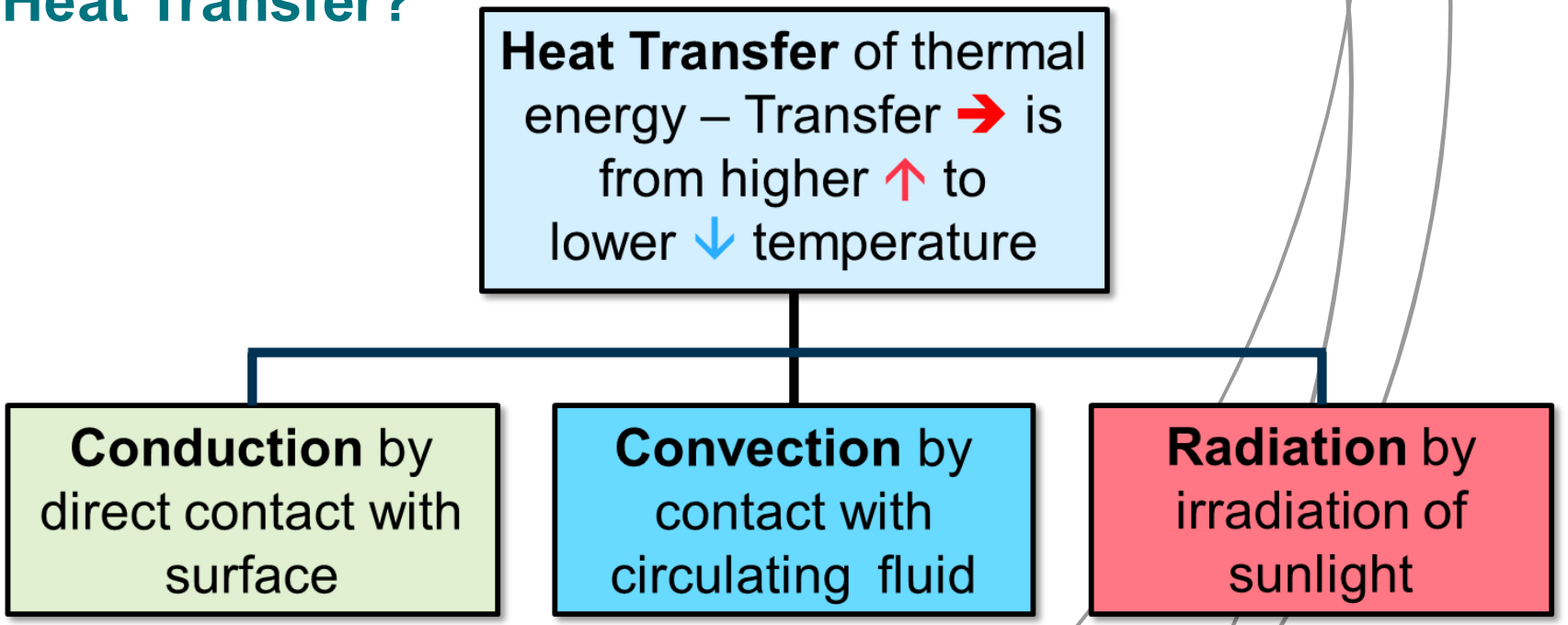
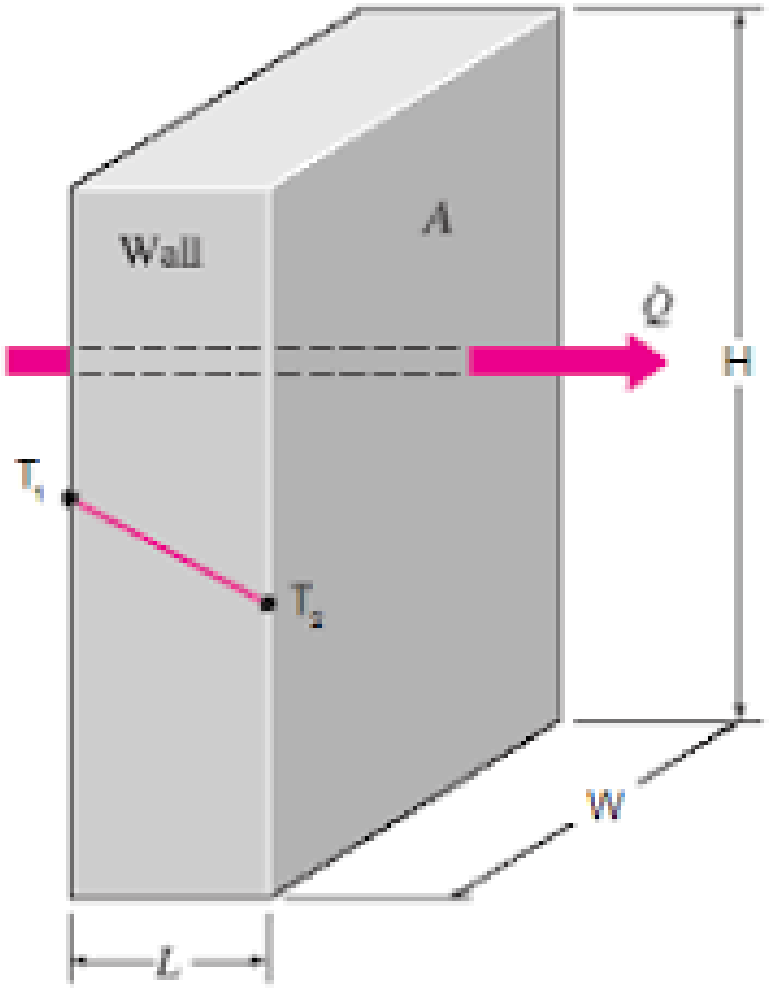


Expected performance for off-site, modular construction

Expected performance for building science related issues

- Building science related issues: **Movement of heat**

- **Thermal Performance: Principles & Analysis**
  What are the Mechanisms of Heat Transfer?
  - **Conduction**
  - Movement of heat energy across ➡ Wall, section A (H x W), in the direction of the higher ↑ temperature (T_1) to the lower ↓ temperature (T_2)



Expected performance for off-site, modular construction

Expected performance for building science related issues

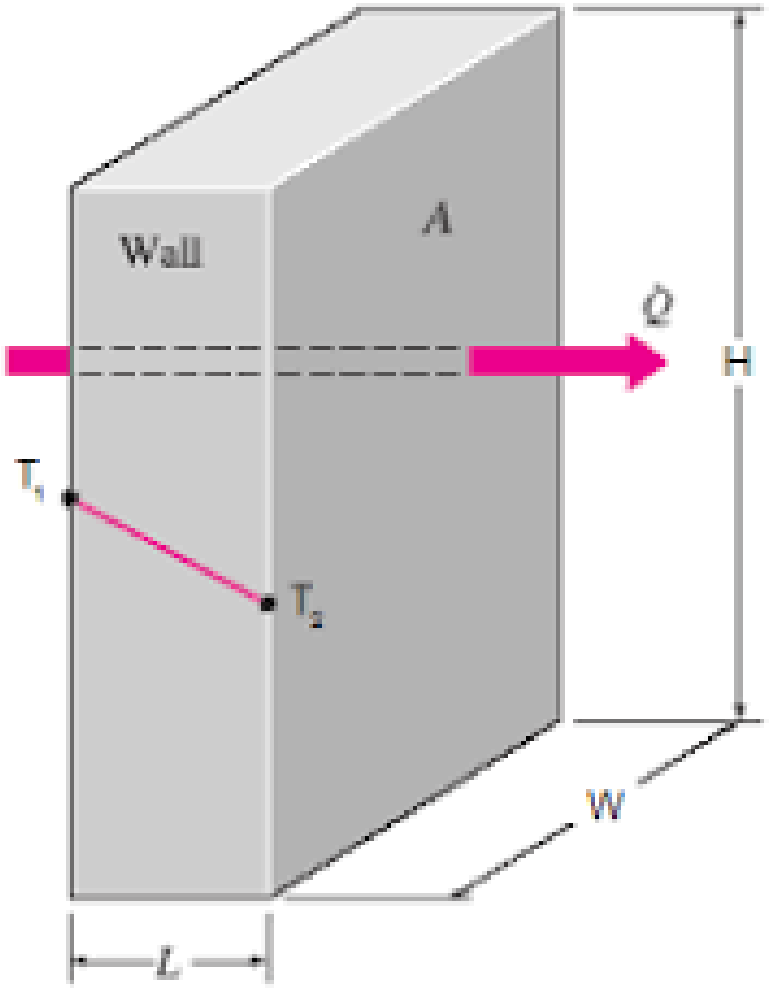
- Building science related issues: **Movement of heat**

- **Thermal Performance: Principles & Analysis**
  What are the Mechanisms of Heat Transfer?

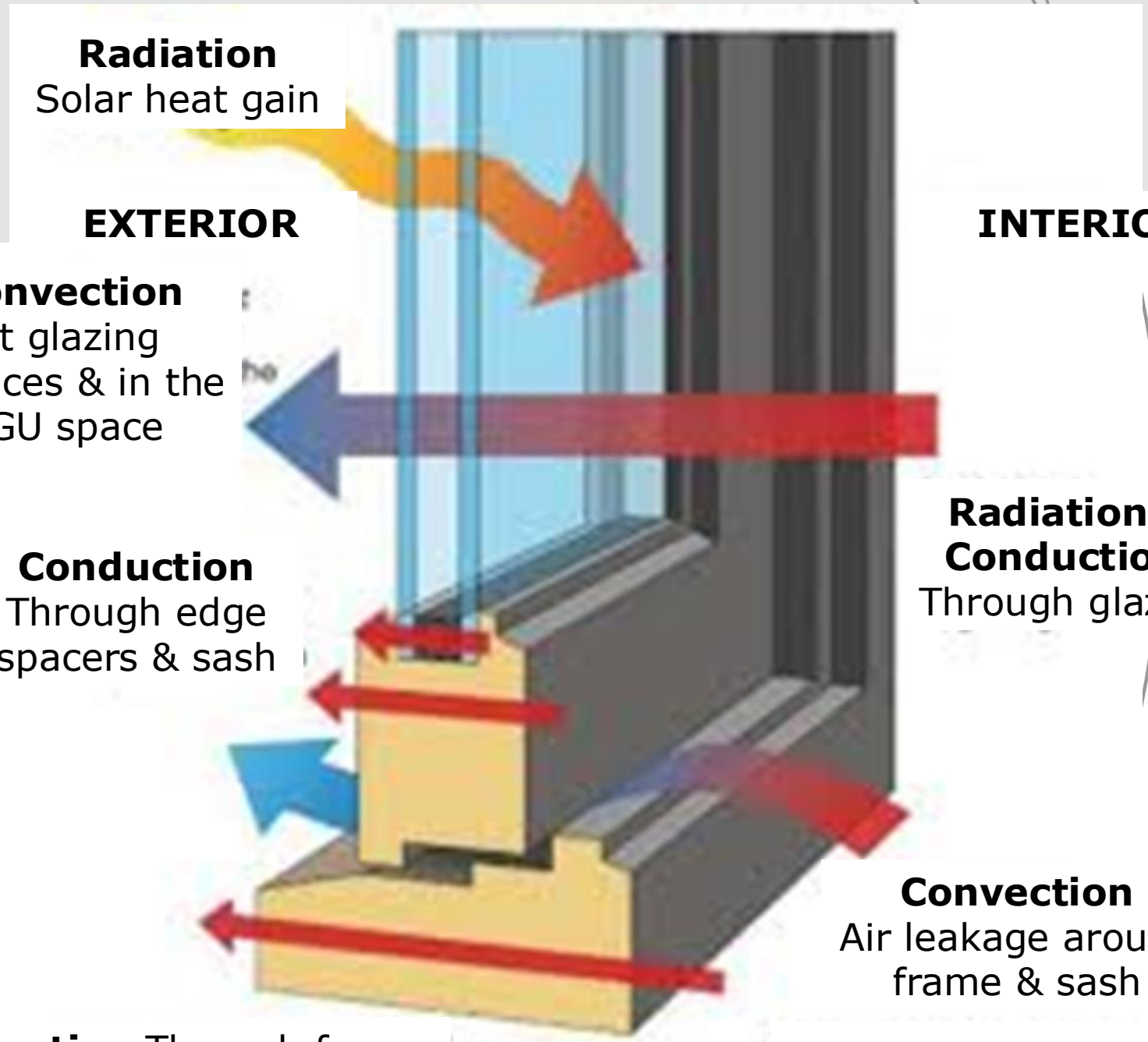
  - **Conduction**
  - The formula for calculating the rate of heat transfer by conduction (Fourier's Law) is

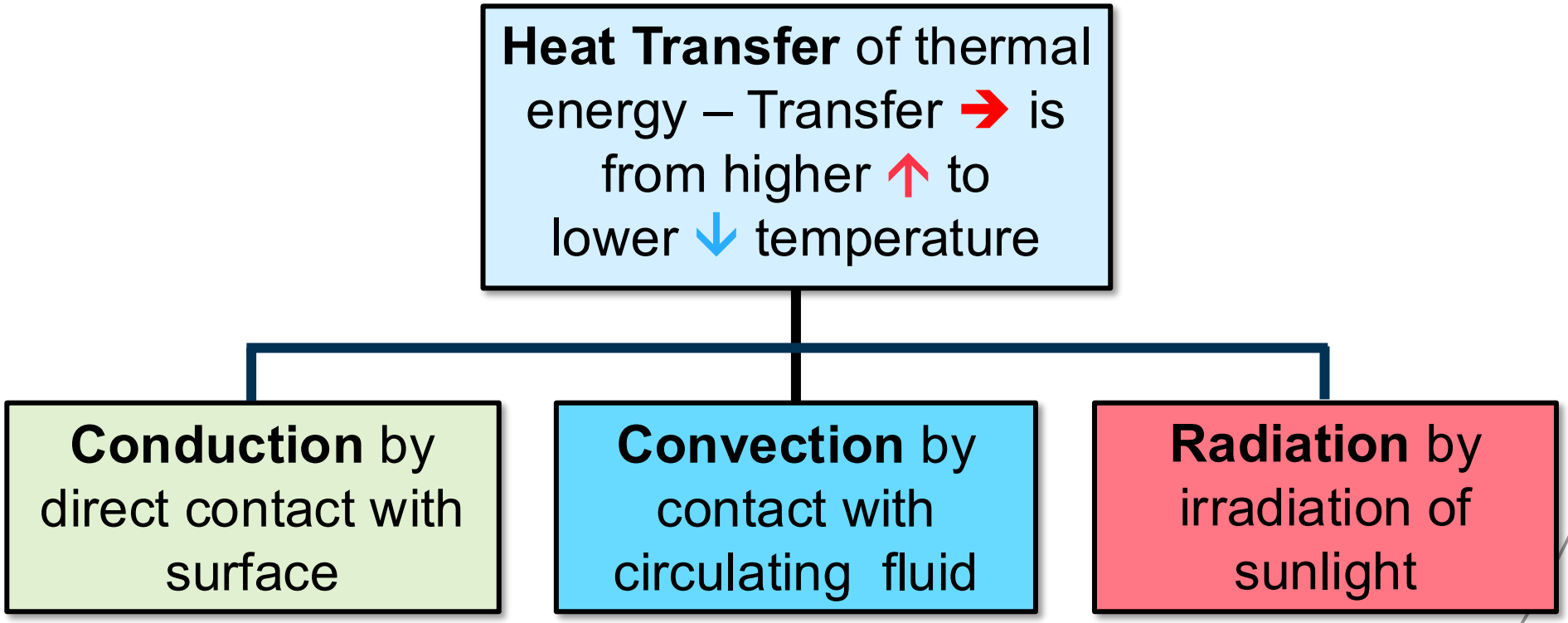
$$Q/t = kA \bullet \Delta T/d$$

Where: (Q / t) is the rate of heat transfer (Watts or J/s)
(k) is the thermal conductivity of the material
(A) is the cross-sectional area
(ΔT) = (T_{hot} - T_{cold}), the temperature difference, and
(d) is the thickness of the material



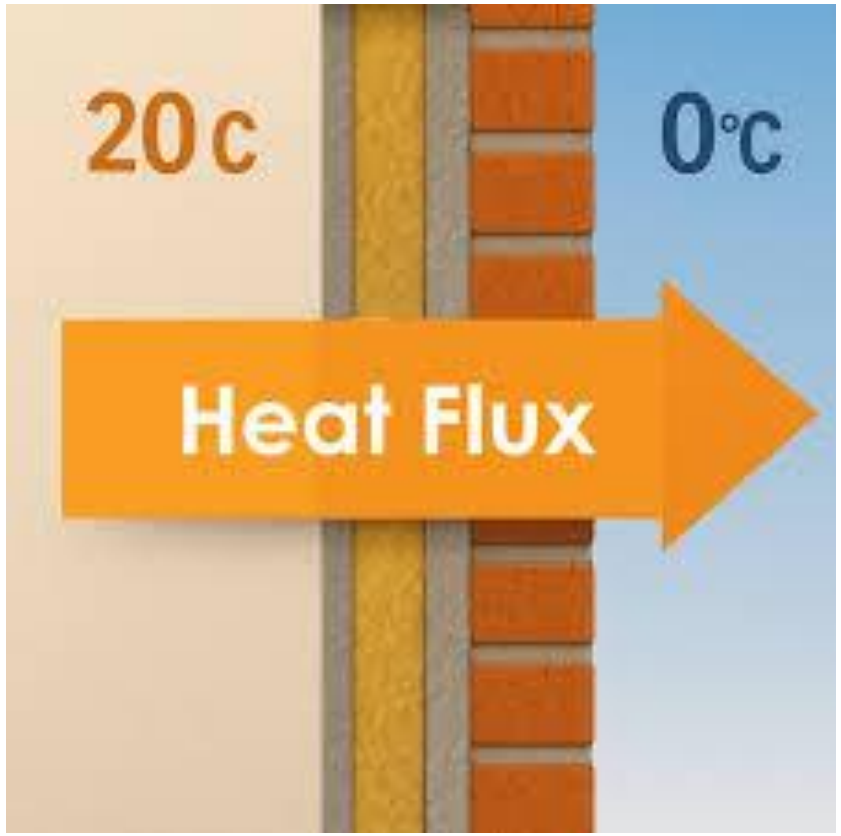
Thermal transfer Fenestration

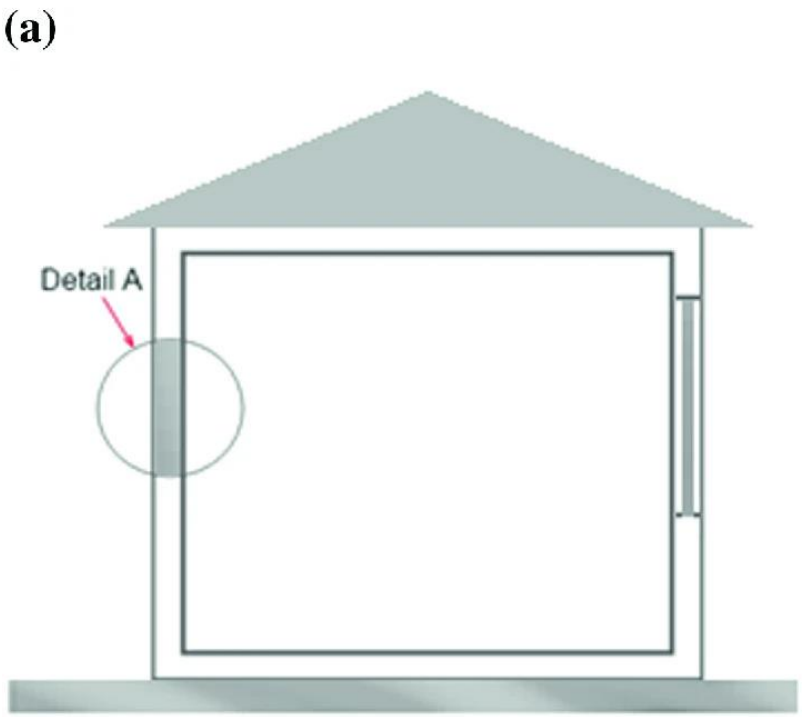


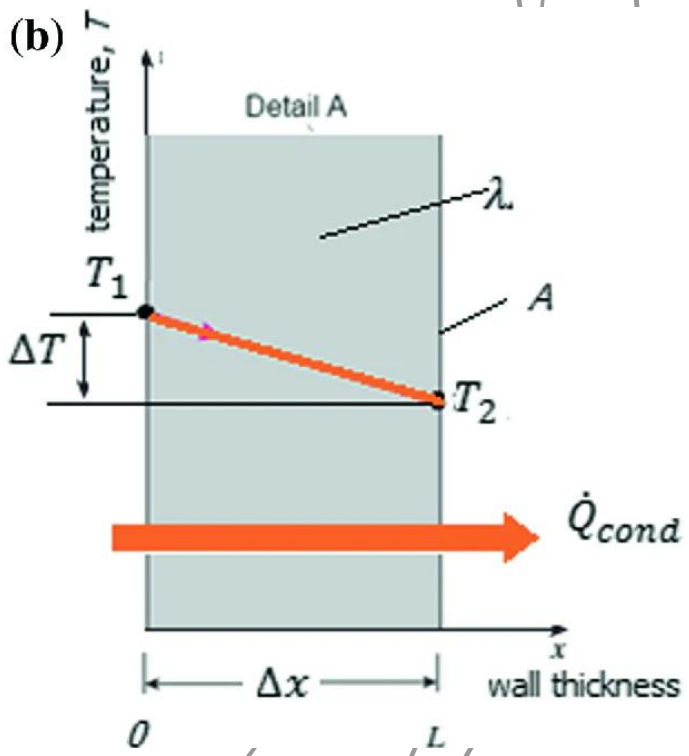

Heat Transfer of thermal energy – Transfer ➔ is from higher ↑ to lower ↓ temperature
Conduction by direct contact with surface
Convection by contact with circulating fluid
Radiation by irradiation of sunlight

Expected performance for off-site, modular construction

- Mechanisms of Heat Transfer?
  - **Conduction**







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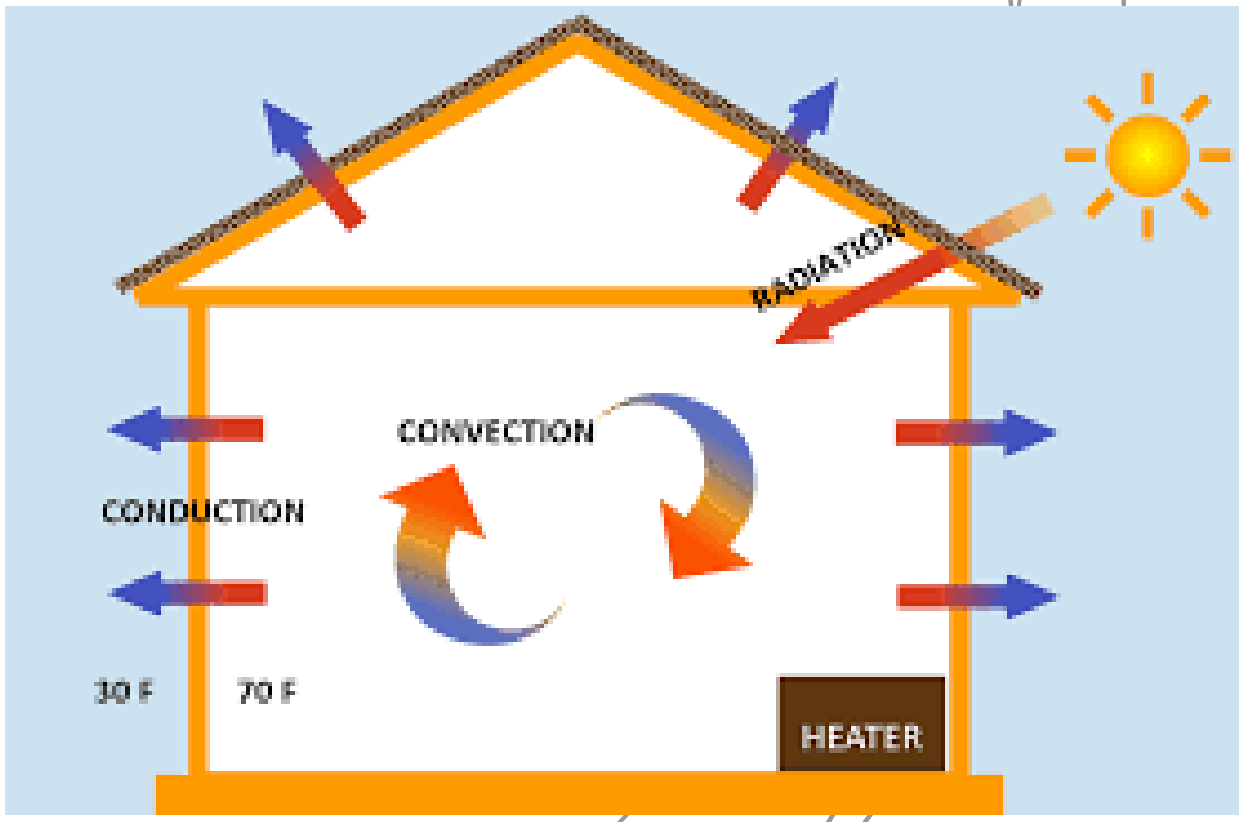

Expected performance for off-site, modular construction

- Mechanisms of Heat Transfer
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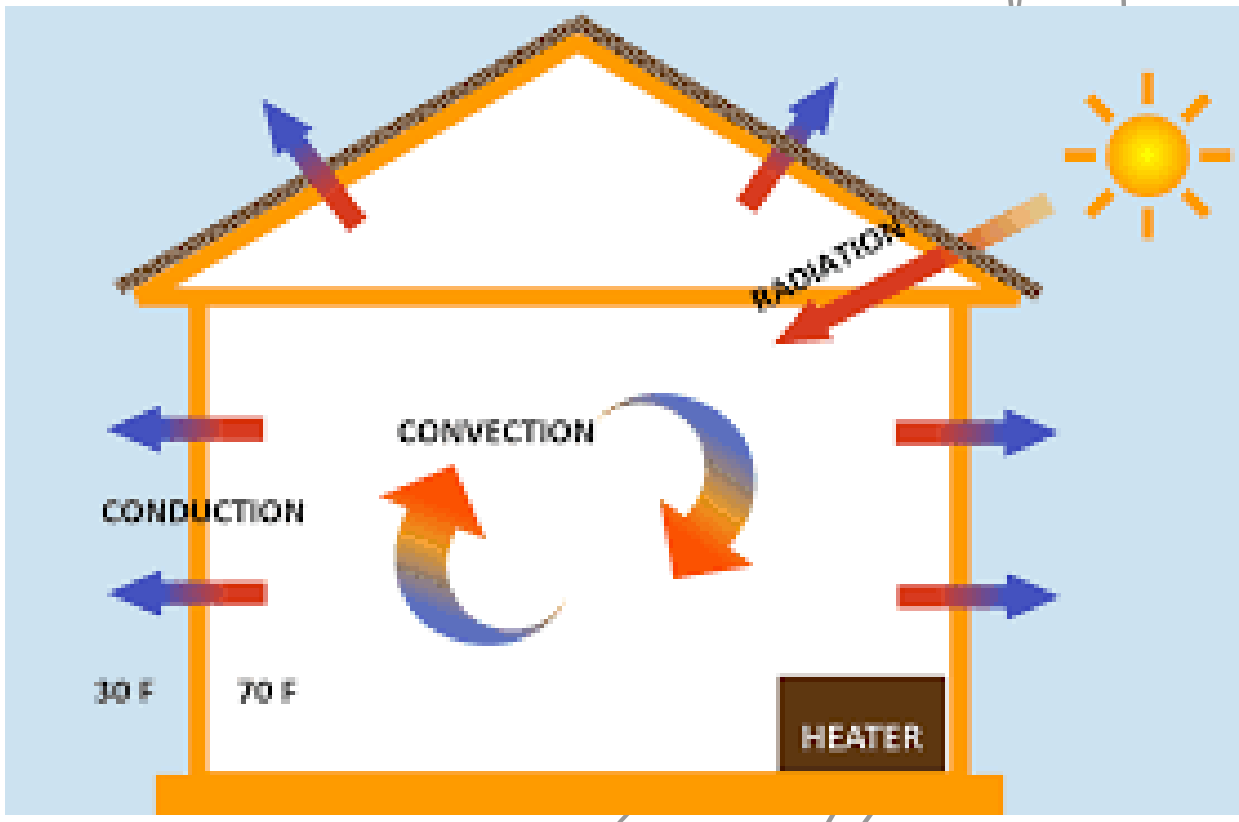

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Expected performance for off-site, modular construction

Expected performance regarding building science issues

- Building science issues: **Movement of heat**

- **Thermal Performance: Principles & Analysis | What are the Mechanisms of Heat Transfer?**
  - How is the degree of Heat Transfer across a wall determined?
  - Calculating R-values and U-factors for off-site assemblies

Expected performance for off-site, modular construction

Expected performance regarding building science issues

- Building science issues: **Movement of heat, air & moisture (HAM)** across the building envelope

- **Emerging Tools for Thermal Performance**
  - Advanced insulation materials
  - Phase change materials, &
  - Thermal bridging mitigation techniques unique to modular connections

Expected performance for off-site, modular construction

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- **Air Leakage: Theory and Measurement**
  - Air barriers & vapour control layers in factory-built structures
  - Quantitative assessment methods
    - e.g., blower door testing and thermography

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- **Indoor Environmental Quality**
  - Humidity, moisture transport, and condensation risks in high-performance off-site buildings
  - Preventing mould and degradation

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Part 4 — Review of sustainability criteria and industry standards

Review of sustainability criteria and industry standards

- Sustainability criteria
- Industry standards and building code

Review of sustainability criteria and industry standards

- **Sustainability criteria —** align with the "triple bottom line" of sustainability
  - **Environmental, economic, and social factors**
  - Offer faster, more efficient, and durable building solutions
- **Relevant sustainability criteria for modular construction:**
  - Significant Waste Reduction
  - Lower Carbon Footprint/Embodied Carbon
  - Energy Efficiency and Envelope Tightness
  - Sustainable Materials and Durability
  - Site Disturbance and Transportation Mitigation
  - Lifecycle Flexibility (Reuse/Repurpose)

Review of sustainability criteria and industry standards

Relevant sustainability criteria for modular construction:

- **Significant Waste Reduction**:
  - Factory-controlled environments enable precise material usage, cutting waste by up to 90% compared to traditional construction.
- **Lower Carbon Footprint / Embodied Carbon**:
  - Off-site methods often reduce greenhouse gas (GHG) emissions by over 40%, with 20-25% lower total CO2 emissions compared to traditional, on-site building
- **Energy Efficiency and Envelope Tightness**:
  - Factory construction allows for higher precision, resulting in tighter building envelopes and better energy performance, often achieving net-zero standards

Review of sustainability criteria and industry standards

Relevant sustainability criteria for modular construction

- **Sustainable Materials and Durability**: Use of sustainable, locally sourced materials, alongside the higher durability of modular units, contributes to long-term sustainability
- **Site Disturbance and Transportation Mitigation**: Reduced on-site construction time decreases site disruption, while optimized logistics cut emissions related to worker and material transport

Review of sustainability criteria and industry standards

Relevant sustainability criteria for modular construction

- **Lifecycle Flexibility (Reuse/Repurpose):** Modular units are designed to be, in some cases, disassembled, relocated, or repurposed, extending their lifecycle
- **Improved Quality and Safety**: Controlled factory environments increase worker safety and material quality, ensuring higher compliance with environmental standards

Review of sustainability criteria and industry standards

Industry standards and building code

- Understanding & interpreting relevant building codes for advanced & sustainable off-site construction projects
- Passive House, Net-Zero Energy, & other high-performance standards as they apply to industrialized construction.
- Life cycle assessment (LCA) in off-site projects
    - Material selection & embodied carbon

Review of sustainability criteria and industry standards

Industry standards and building code

- Understanding & interpreting relevant building codes for advanced & sustainable off-site construction projects

Review of sustainability criteria and industry standards

Industry standards and building code

- Passive House
- Net-Zero Energy
- High-performance standards as relevant to industrialized construction

Review of sustainability criteria and industry standards

Industry standards and building code

- Life cycle assessment (LCA) in off-site projects
  - National guidelines for whole-building life cycle assessment, 2022
  - National Whole-Building Life Cycle Assessment Practitioner's Guide — Guidance for Compliance Reporting of Embodied Carbon in Canadian Building Construction
  - Material selection & embodied carbon

Useful publications

- Roadmap developed for overcoming key barriers to adopting industrialized construction in Canada
- Identify challenges & barriers from industry, & develop a framework to provide practical industry-driven solutions to be supported by NRC Canada

Approach to roadmap development:

1. Literature Review
2. Regional Workshops
3. Virtual Interviews
4. Public Survey



Useful publications

Offsite Wood Construction Handbook,
FPInnovations: Provides technical requirements for professionals focusing on wood-based offsite construction

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2. Design Logistics
3. Manufacturing Logistics
4. Lumber Portfolio

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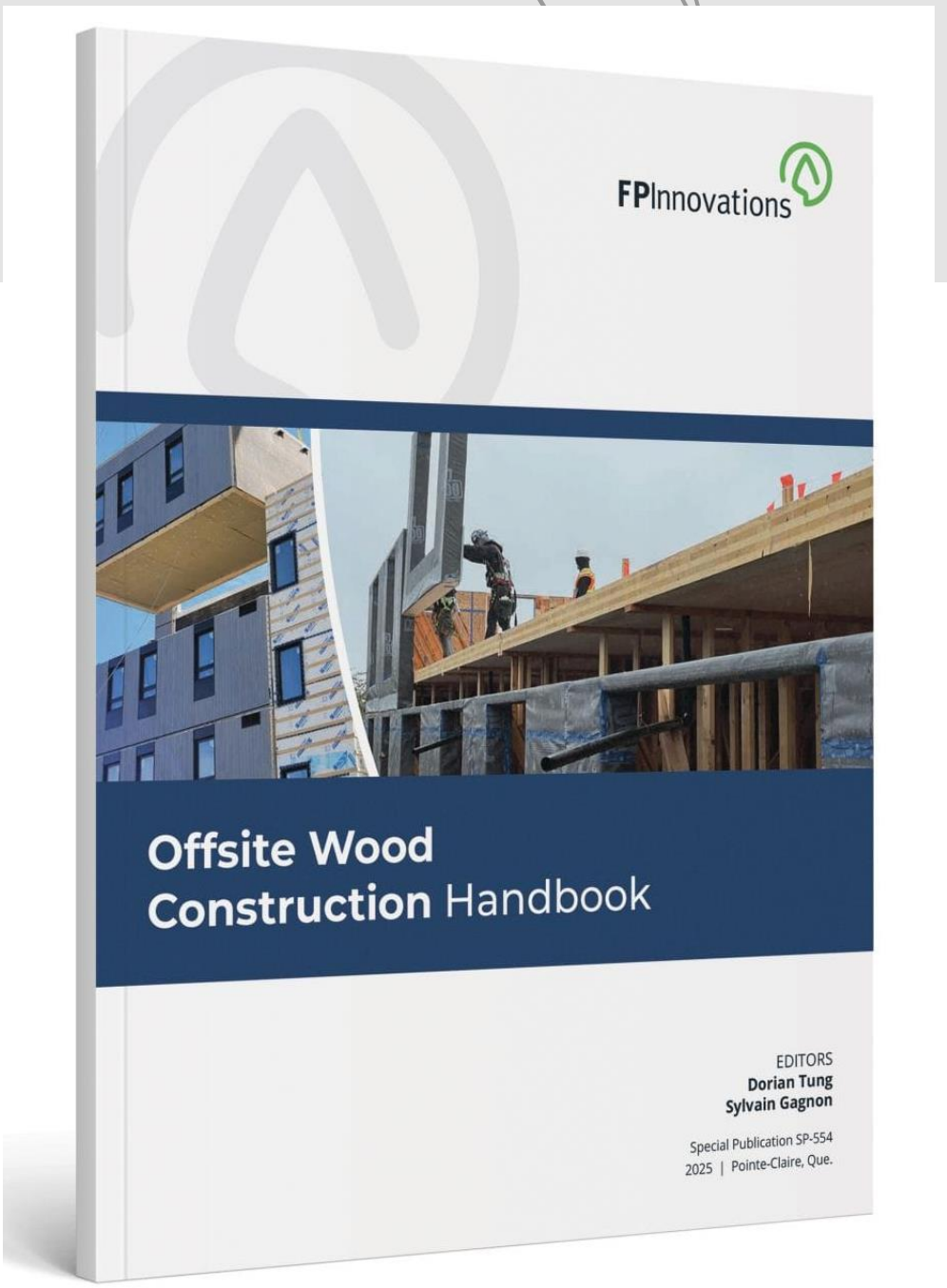
5.2 Energy considerations
5.3 Acoustical considerations
5.4 Structural considerations

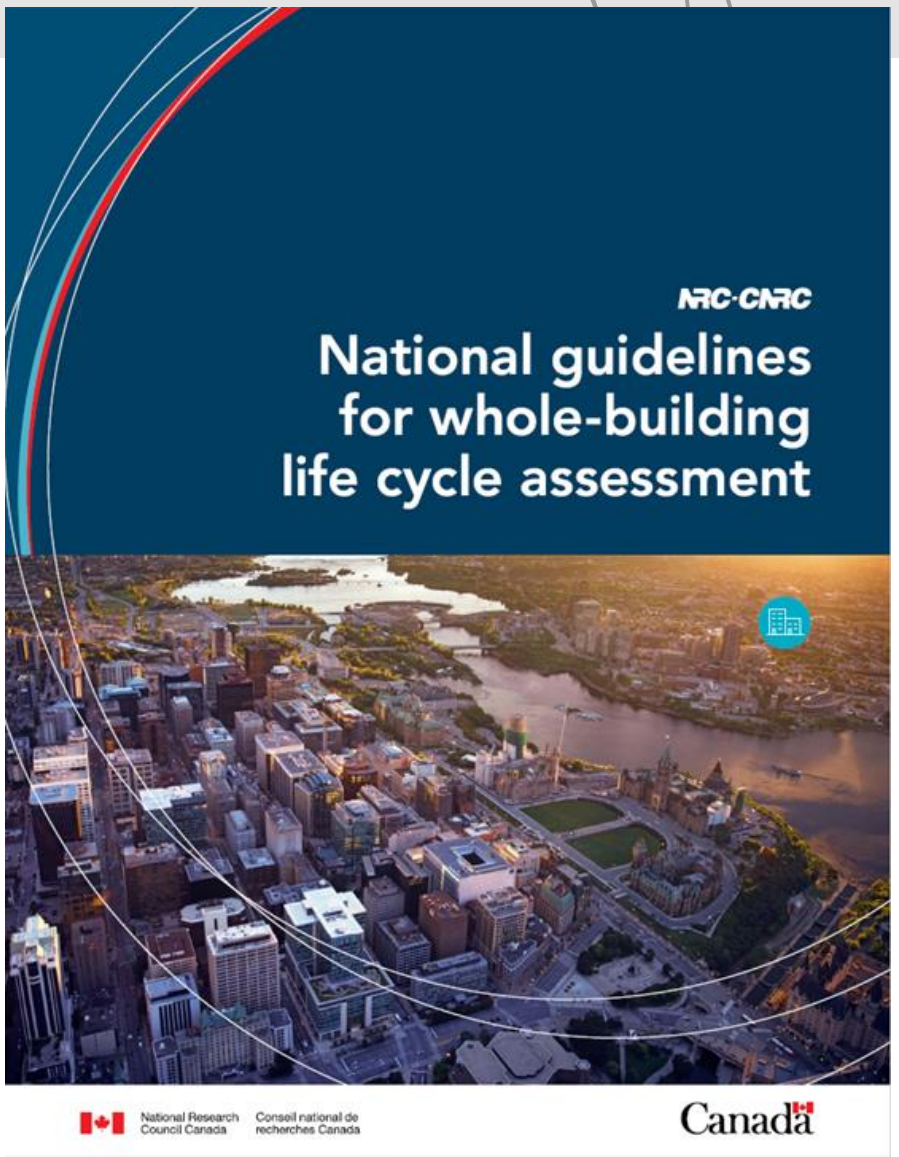
6. Assembly logistics
7. Sustainability



Review of sustainability criteria and industry standards

Industry standards and building code

- Life cycle assessment | off-site projects
  - **National guidelines for whole-building life cycle assessment, 2022**



Review of sustainability criteria and industry standards

National guidelines for whole-building life cycle assessment, 2022

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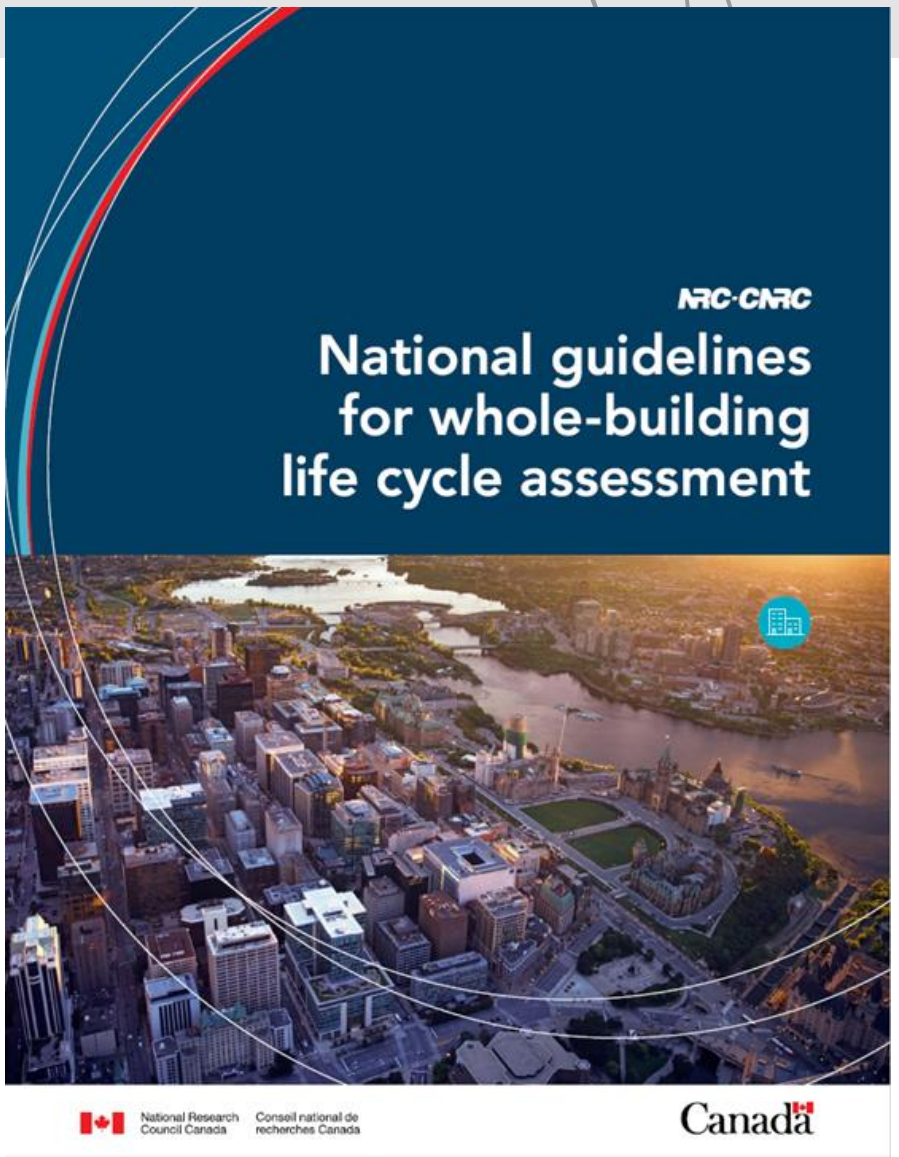
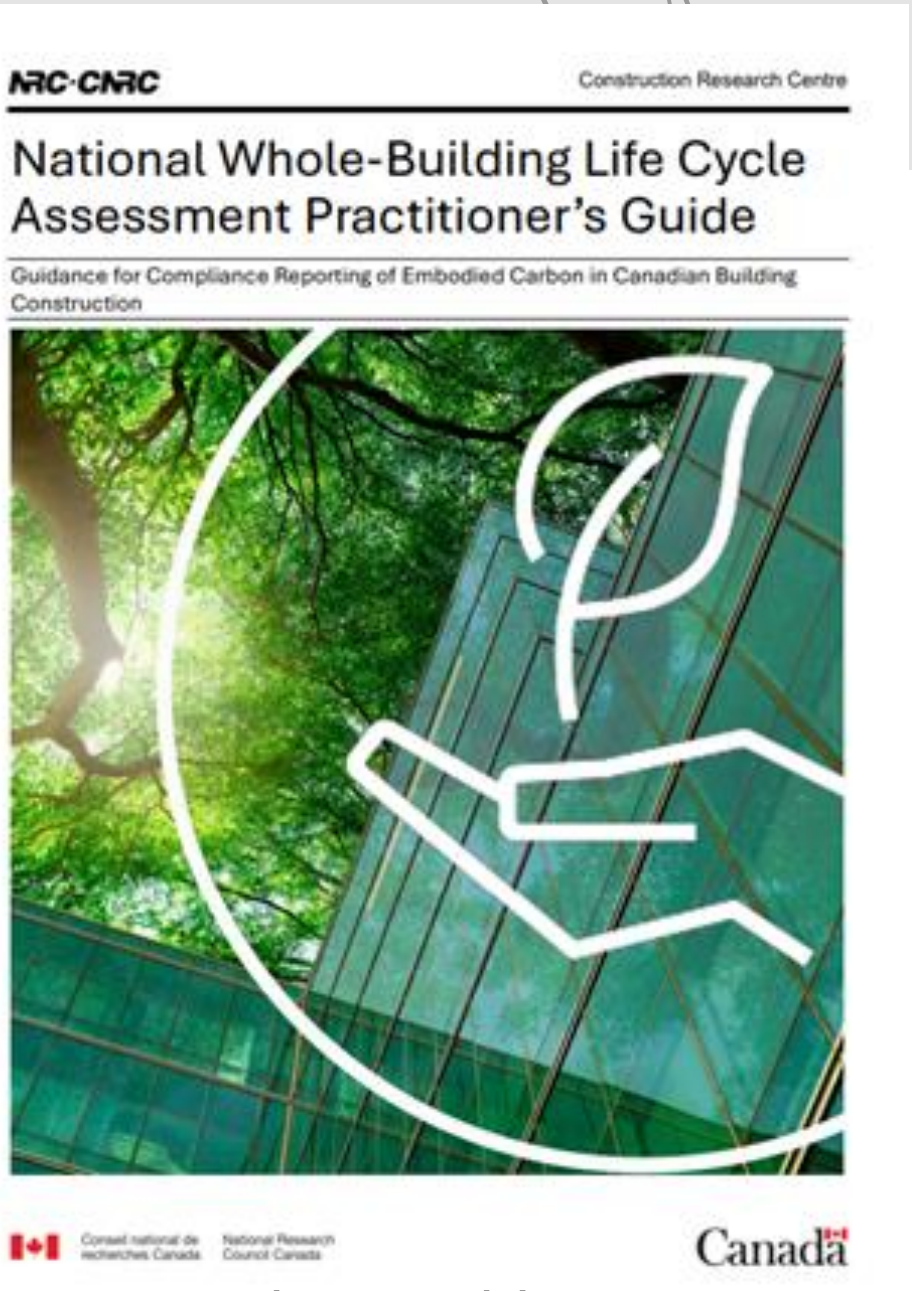
1. Purpose of the assessment
2. Specification of the object of assessment
3. Scenarios for defining the building life cycle
4. Quantification of the building and its life cycle
5. Selection of environmental data
6. Calculation of the environmental indicators
7. Reporting and communication
8. Verification
9. Benchmarking



Review of sustainability criteria and industry standards

Industry standards & building code

- Life cycle assessment | off-site projects
  - National Whole-Building Life Cycle Assessment Practitioner's Guide — Guidance for Compliance Reporting of Embodied Carbon in Canadian Building Construction



Review of sustainability criteria and industry standards

National Whole-Building Life Cycle Assessment Practitioner's Guide — Guidance for Compliance Reporting of Embodied Carbon in Canadian Building Construction

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2 Compliance
3 Specification of Object of Assessment & Life Cycle System Boundary
4 Quantifying Embodied Carbon
5 Determining the Baseline
6 Documentation
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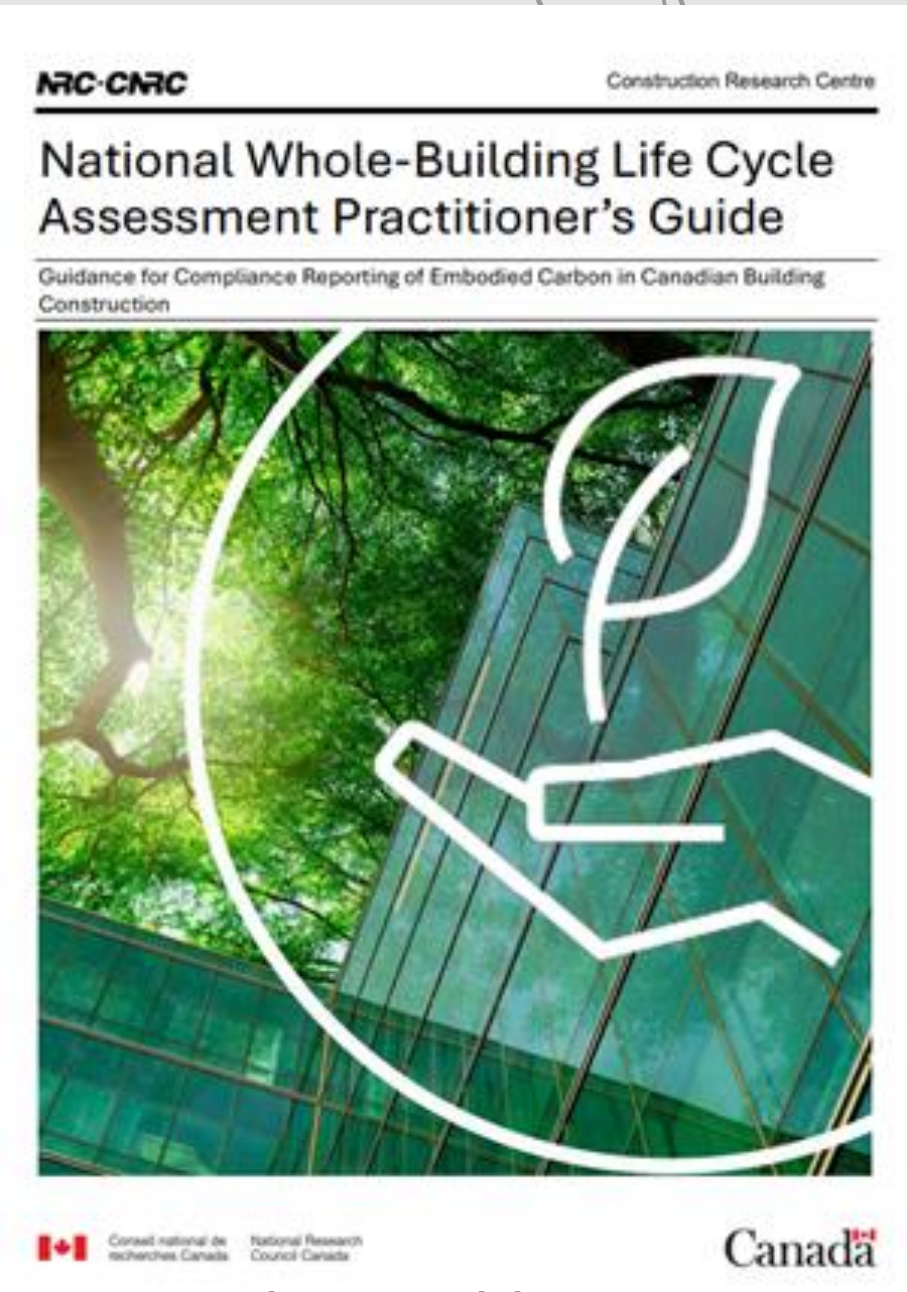
Appendix B: Additional Information | Specification of Object of Assessmen
Appendix C: Additional Information on Quantifying Embodied Carbon



Thank You, Questions?