

In-Person Workshop

Building envelope fundamentals

 Canmore, Alberta

 November 18 | 1:30 – 4:30 PM



BIOSPHERE
INSTITUTE OF THE BOW VALLEY

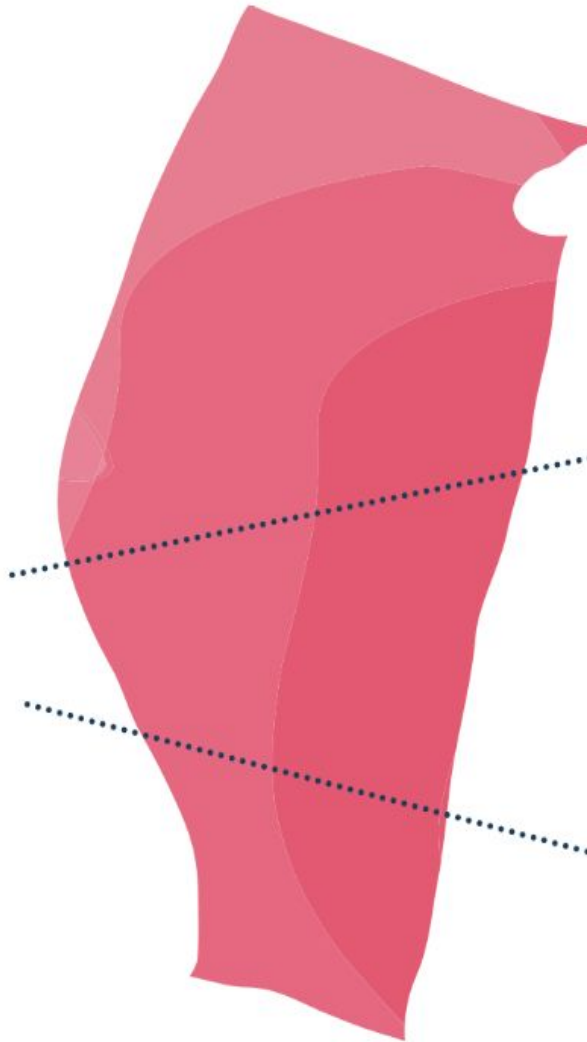


TREATY 8

Signed in 1899

TREATY 7

Signed in 1877



TREATY 6

Signed in 1876

Special thanks to the many organizations that have contributed to this presentation:



Natural Resources
Canada

Ressources naturelles
Canada



BIOSPHERE
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enbix



**BUILDING
KNOWLEDGE**
CANADA INC.



Alberta Ecotrust Foundation

Vision and Mission

→ *Our Vision*

An Alberta where people and nature thrive.

→ *Our Mission*

We realize our vision by recognizing gaps, mobilizing resources, investing in our communities, creating partnerships, and building capacity across sectors.

What we offer

*Programs
& Initiatives*



Grants



*Impact
Investing*



*Strategic
Engagement*



Alberta Ecotrust's Buildings Initiatives

A dark blue line diagram that starts with a vertical line from the bottom of the Ecotrust logo, extends horizontally to the left and right, and then turns vertically down at each end to connect to the Enbix and Retrofit logos respectively.

enbix

Retrofit
accelerator



enbix   ALBERTA ecotrust

Shaping the Exchange

Establishing a platform for the exchange of knowledge around emissions neutral buildings in Edmonton, Calgary and Alberta

Developed by Alberta Ecotrust Foundation in partnership with:
The Calgary Construction Association, the City of Calgary, the City of Edmonton and their Emission Neutral Buildings Industry Advisory Group, and the Smart Sustainable Resilient Infrastructure Association.

November 2023

Our Funders



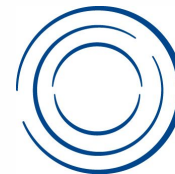
Natural Resources
Canada

Ressources naturelles
Canada



FEDERATION
OF CANADIAN
MUNICIPALITIES

FÉDÉRATION
CANADIENNE DES
MUNICIPALITÉS



Peter Gilgan
Foundation



RBC Foundation

Today's Speaker



Joseph (Joe) Henke, P. Eng, CEM, REA

Program Specialist – ENBIX, Alberta Ecotrust Foundation,

Joe is Certified Energy Manager, Energy Advisor, and holds a diploma in Sustainable Energy Technology.

Prior to joining Alberta Ecotrust Foundation, he worked as a Residential Energy Advisor, and in the manufacturing industry.

Building Envelope Fundamentals

AGENDA

- Attendees Poll (Slido)
- Building Envelope basics
- Air Barriers
- Blower Door Testing
- Thermal Bridging
- Insulation Systems and Options
- Below Grade Insulation
- Questions and exploring the wall library

Presentation ~ 2hrs

Questions ~ 45 minutes

Housekeeping

- Emergency - exits
- Washrooms
- Breaks - there is no break scheduled but please feel free to come and go as you need
- Questions - you can use the Slido Q&A feature, or feel free to ask during the session.
 - I may answer some questions at the end of the session
- Phones/laptops - kindly silence any ringers. If you need to take a call please step out of the room

Building Envelope Fundamentals



ARTICLES, CASE STUDIES, EVENT TAKEAWAYS, REPORTS & WHITE PAPERS

Solar-Ready Design – Training Page

Author/Contributor: ENBIX, Solar Alberta, Local Energy Efficiency Partnerships (LEEP)

Alberta Context: This page is intended to accompany the “Solar-Ready Design” training offered by ENBIX | Alberta Ecotrust Foundation. This training offers an introduction to the principles that can take an Alberta building with solar PV from good to better to best. It features information on Alberta climate, regulations, and building practices.

Summary:

The Solar-Ready Design training session is presented by ENBIX | Alberta Ecotrust Foundation with content provided by both Solar Alberta and Natural Resources Canada (NRCAN) through the Local Energy Efficiency Partnership (LEEP) program.

It covers the following:

- Solar context in Alberta – climate + regulations prepared by Solar Alberta
- Introduction to the LEEP “Planning & Decision Guide For Solar PV System” prepared by LEEP
- Solar Building Best Practices – practical examples of good design prepared by Solar Alberta
- Case Studies – provided by LEEP and Tom Jackman from Simple Solar



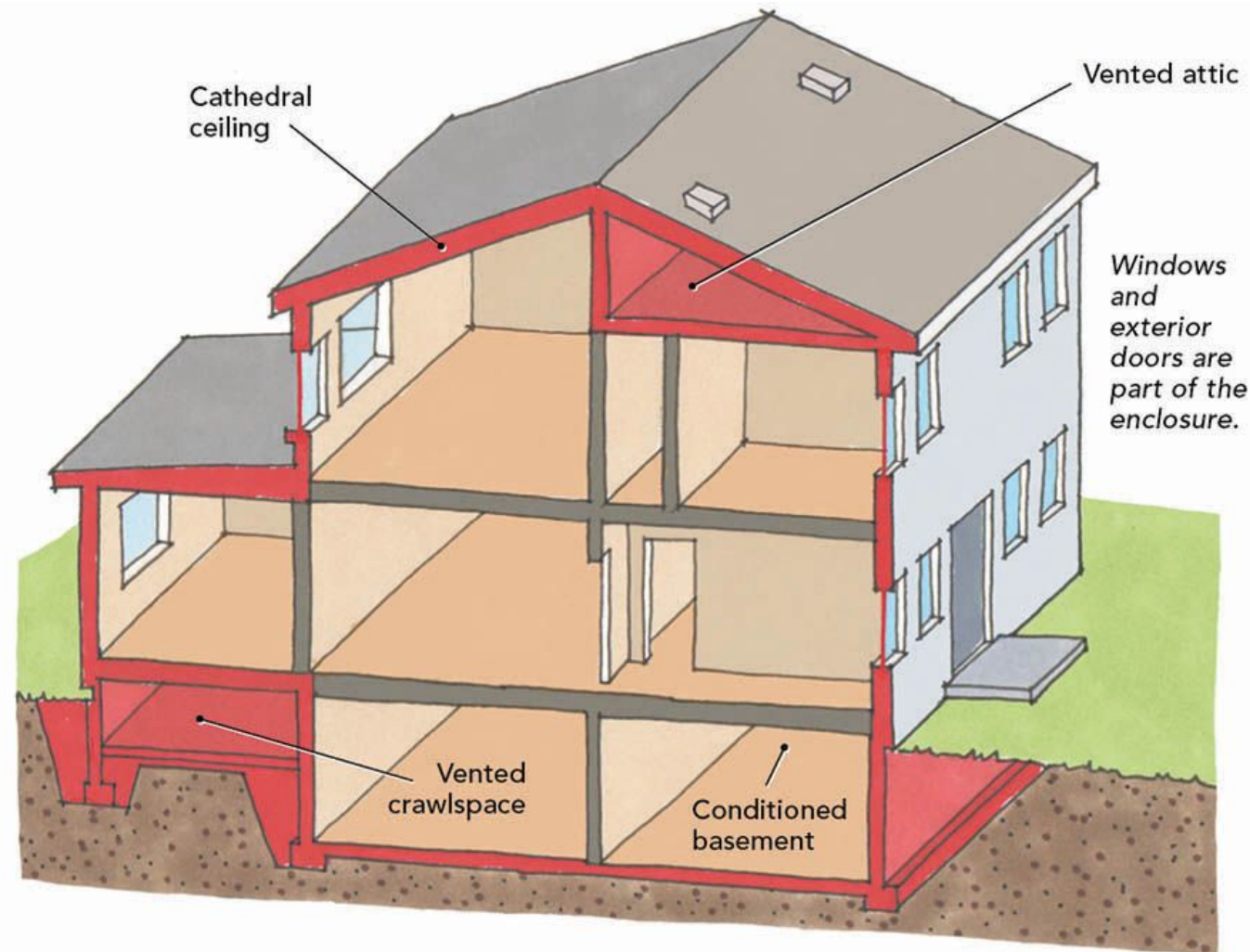
Coming soon

Components of envelope

Building components that separate the indoors from the outdoors

Includes:

- Roof
- Above grade walls
- Windows
- Below grade walls
- Slab



Objective statements from NECB

Section 2.2. Objectives

2.2.1. Objectives

2.2.1.1. Objectives

1) The objectives of this Code are as follows (see Note A-2.2.1.1.(1)):

OE Environment

An objective of this Code is to limit the probability that, as a result of the design or construction of the *building*, the environment will be affected in an unacceptable manner.

OE1 Resources

An objective of this Code is to limit the probability that, as a result of the design or construction of the *building*, resources will be used in a manner that will have an unacceptable effect on the environment. The risks of unacceptable effect on the environment due to use of resources addressed in this Code are those caused by—



OE1.1 – excessive use of energy

Functional Statements

Section 3.2. Functional Statements

3.2.1. Functional Statements

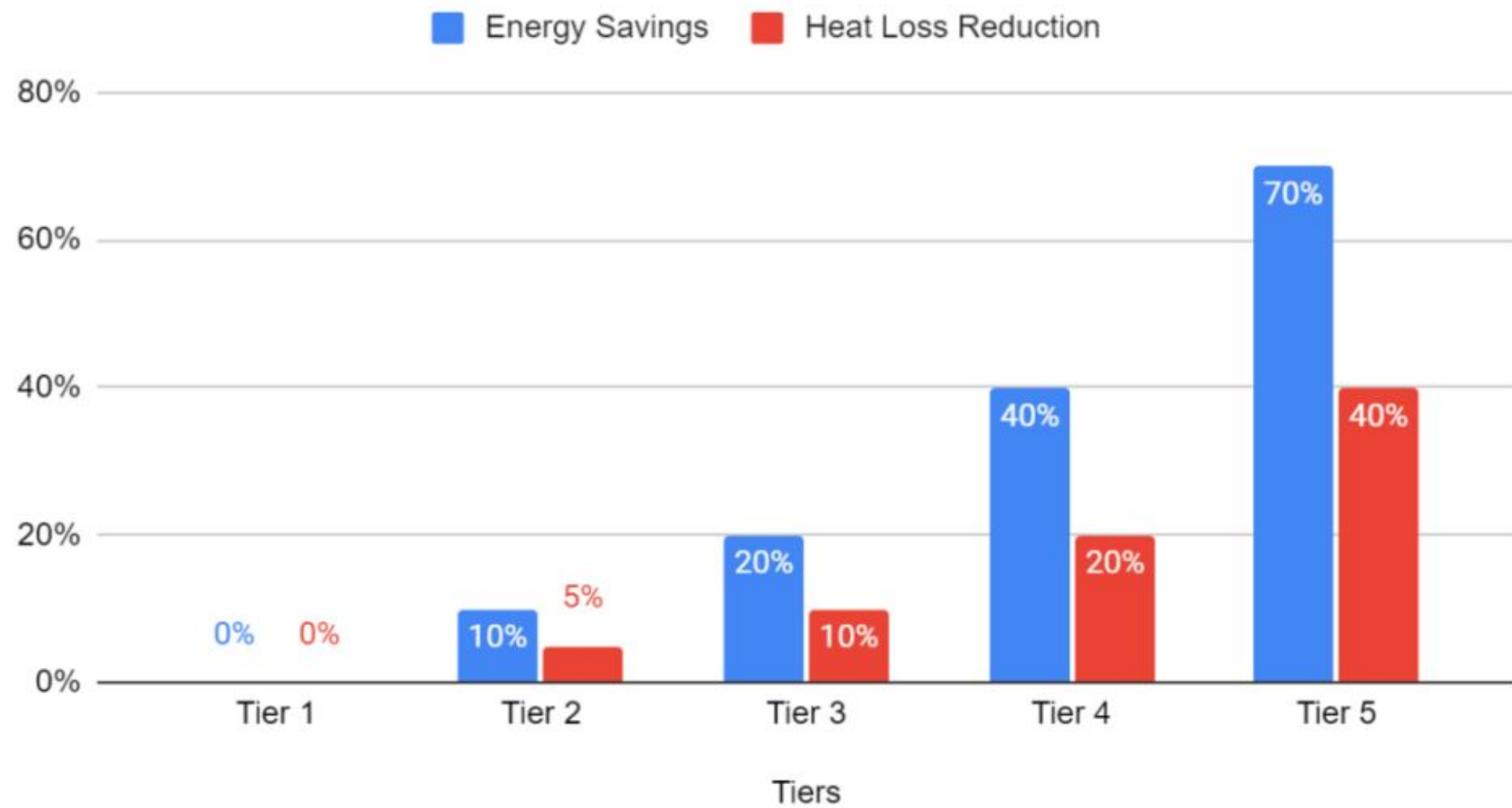
3.2.1.1. Functional Statements

1) The objectives of this Code are achieved by measures, such as those described in the acceptable solutions in Division B, that are intended to allow the *building* or its elements to perform the following functions (see Note A-3.2.1.1.(1)):

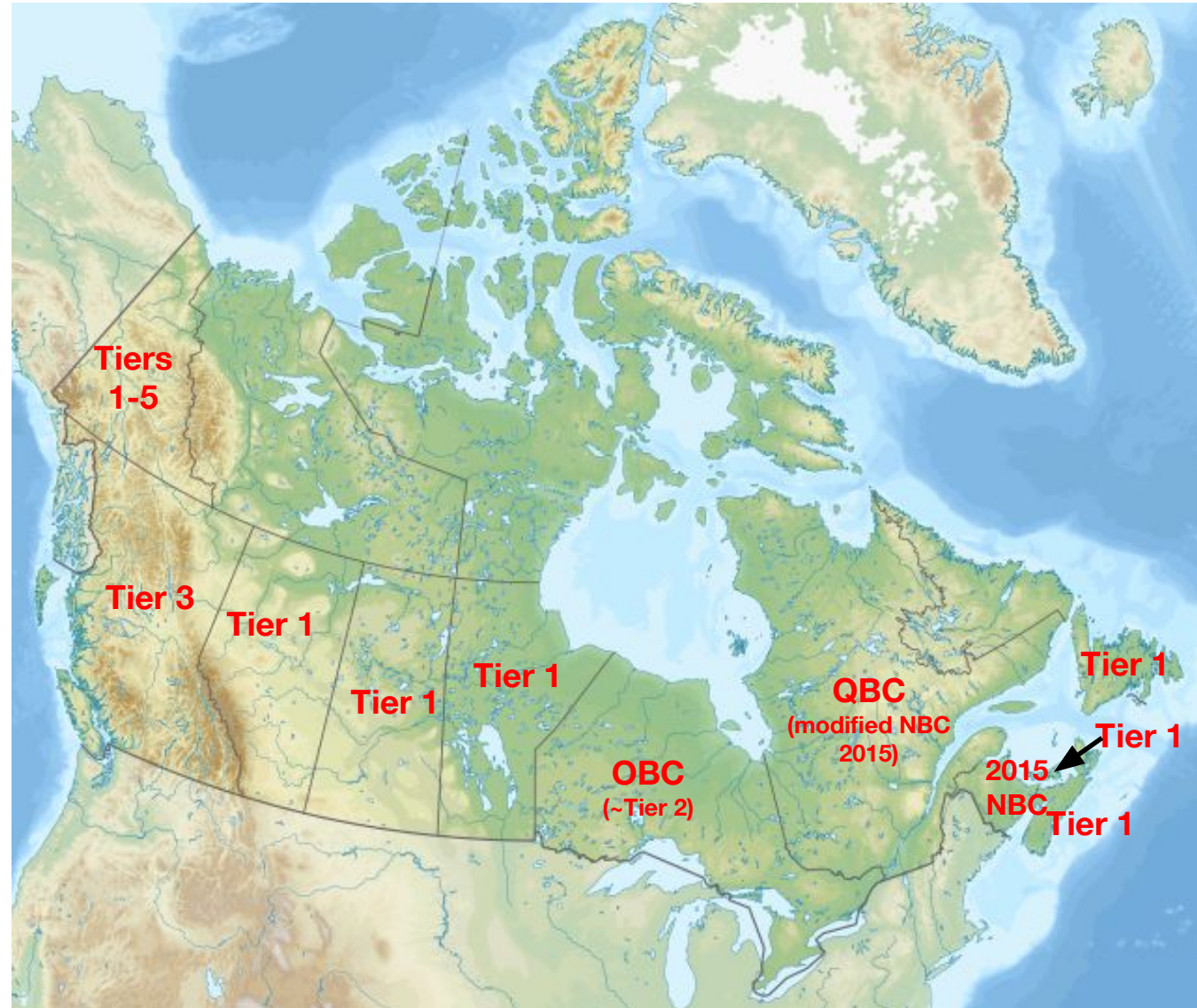
- F90** To limit the amount of uncontrolled **air leakage** through the *building envelope*.
- F91** To limit the amount of uncontrolled **air leakage** through system components.
- F92** To limit the amount of uncontrolled **thermal transfer** through the *building envelope*.
- F93** To limit the amount of uncontrolled **thermal transfer** through system components.
- F94** To limit the unnecessary demand and/or consumption of energy for lighting.
- F95** To limit the unnecessary demand and/or consumption of energy for **heating and cooling**.
- F96** To limit the unnecessary demand and/or consumption of energy for *service water* heating.
- F97** To limit the unnecessary demand and/or consumption of energy for electrical equipment and devices.
- F98** To limit the inefficiency of equipment.
- F99** To limit the inefficiency of systems.
- F100** To limit the unnecessary rejection of reusable waste energy.

What are Tiers

Reference: National Building
Code 2023 Alberta Edition
Table 9.36.7.2

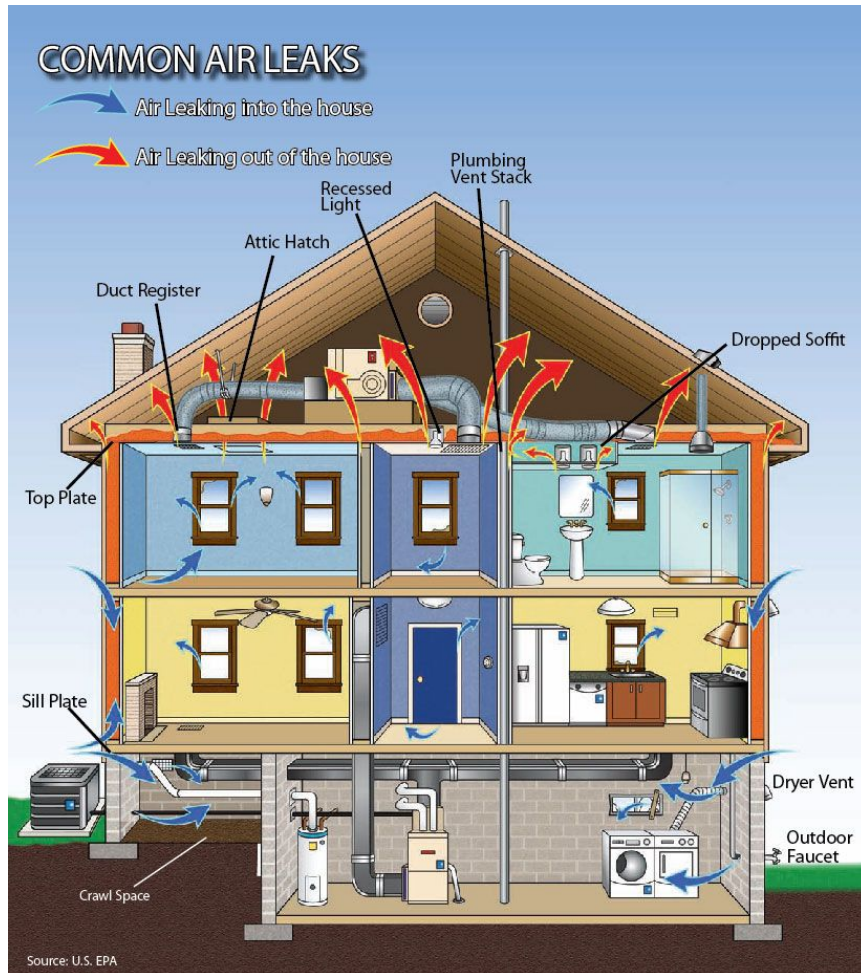


Refresher: NBC 2020 9.36 Tiers Adopted Across Canada



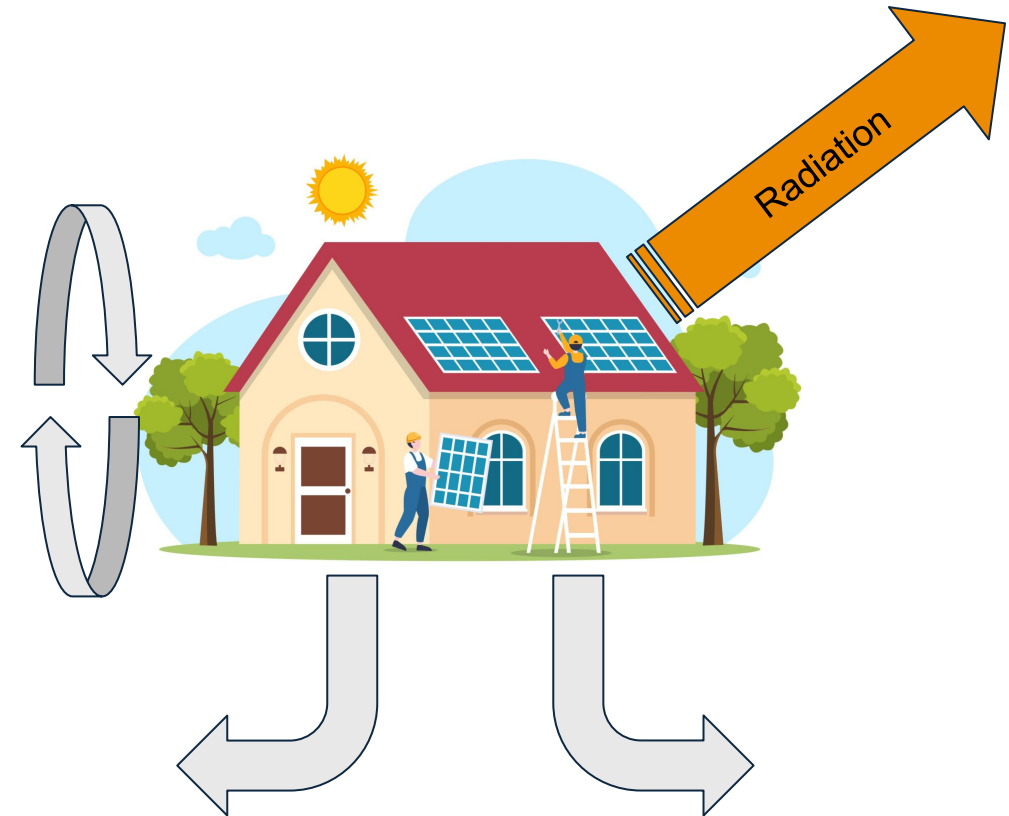
Heat Loss Mechanisms

Advection



Reference: Environmental Protection Agency

Convection

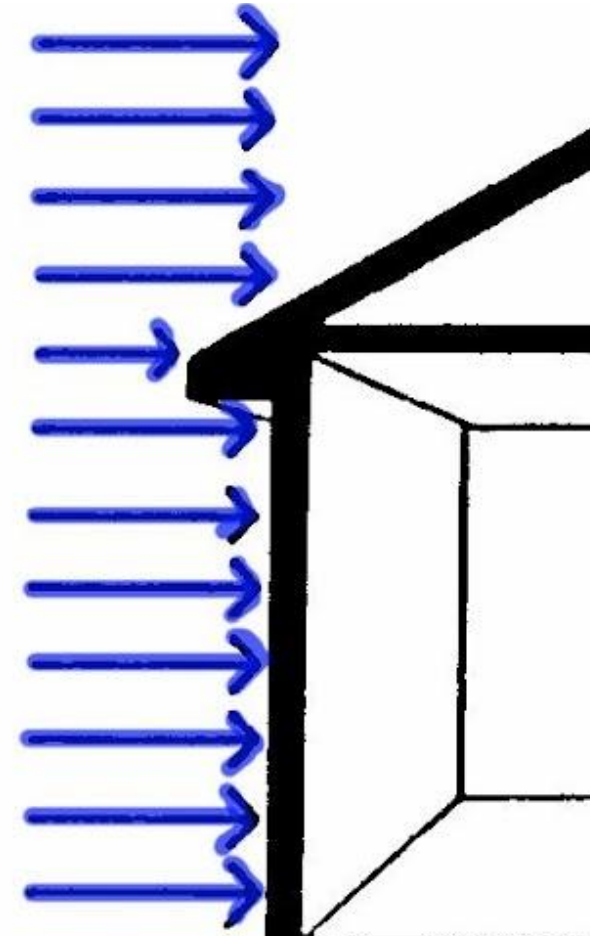


Conduction

Air Leakage and Heat Flow

For air flow to occur, there must be 3 factors in place:

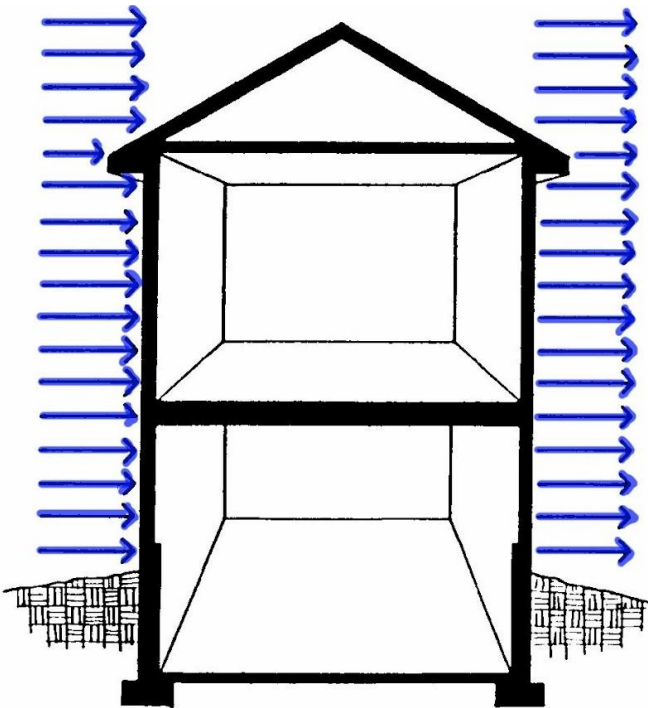
- a **substance** (air)
- a **pressure difference** between two points
- a **continuous flow path** or opening connecting the points



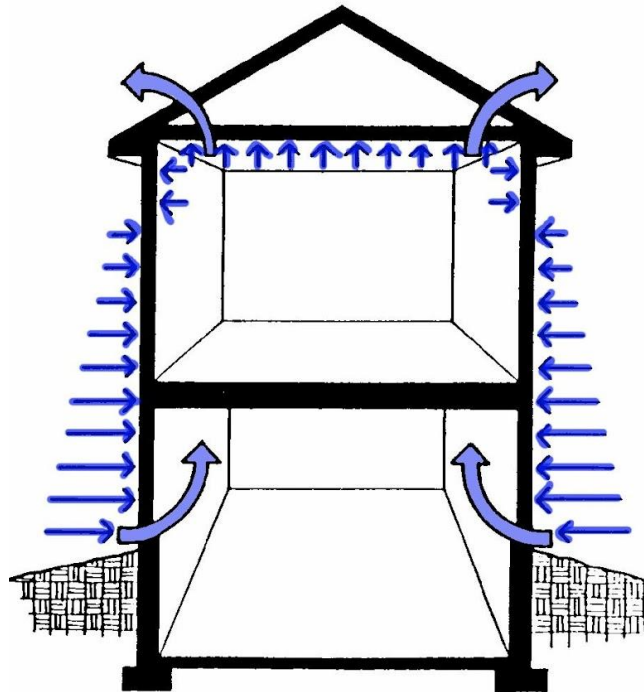
Air Infiltration / Air Leakage

3 drivers of air infiltration:

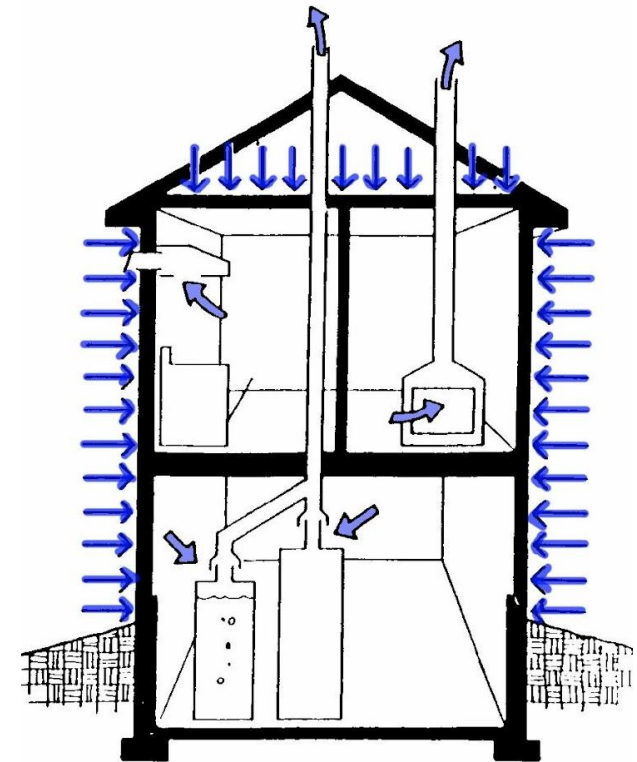
Wind



Stack Effect

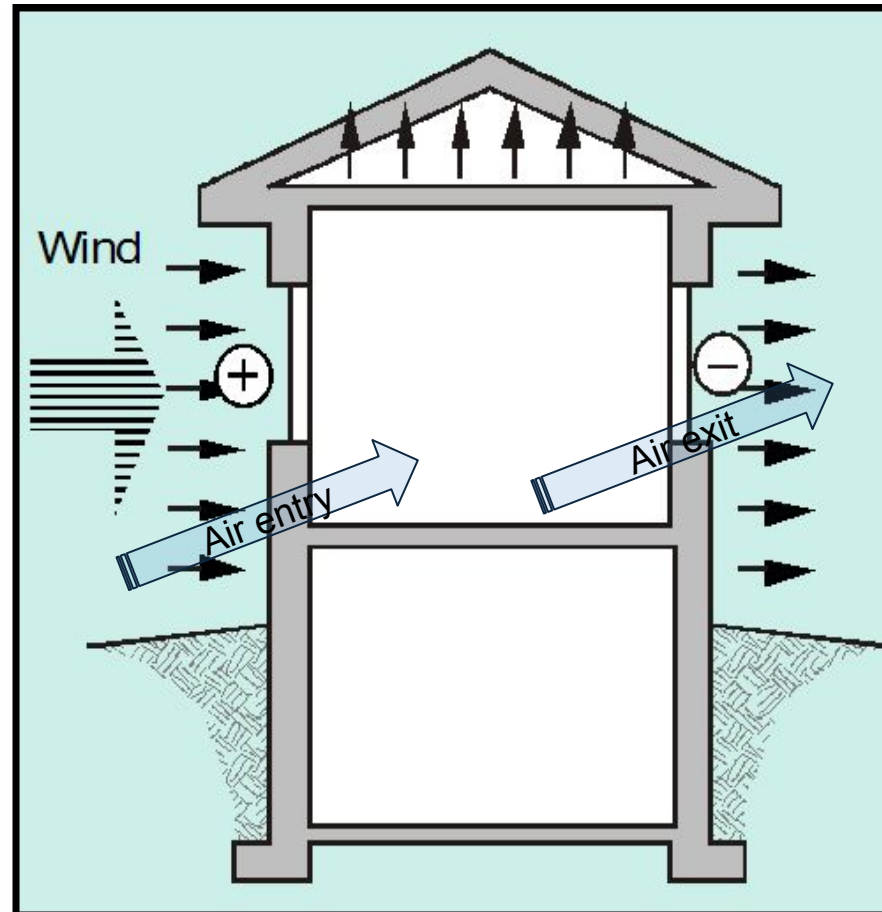


Mechanical



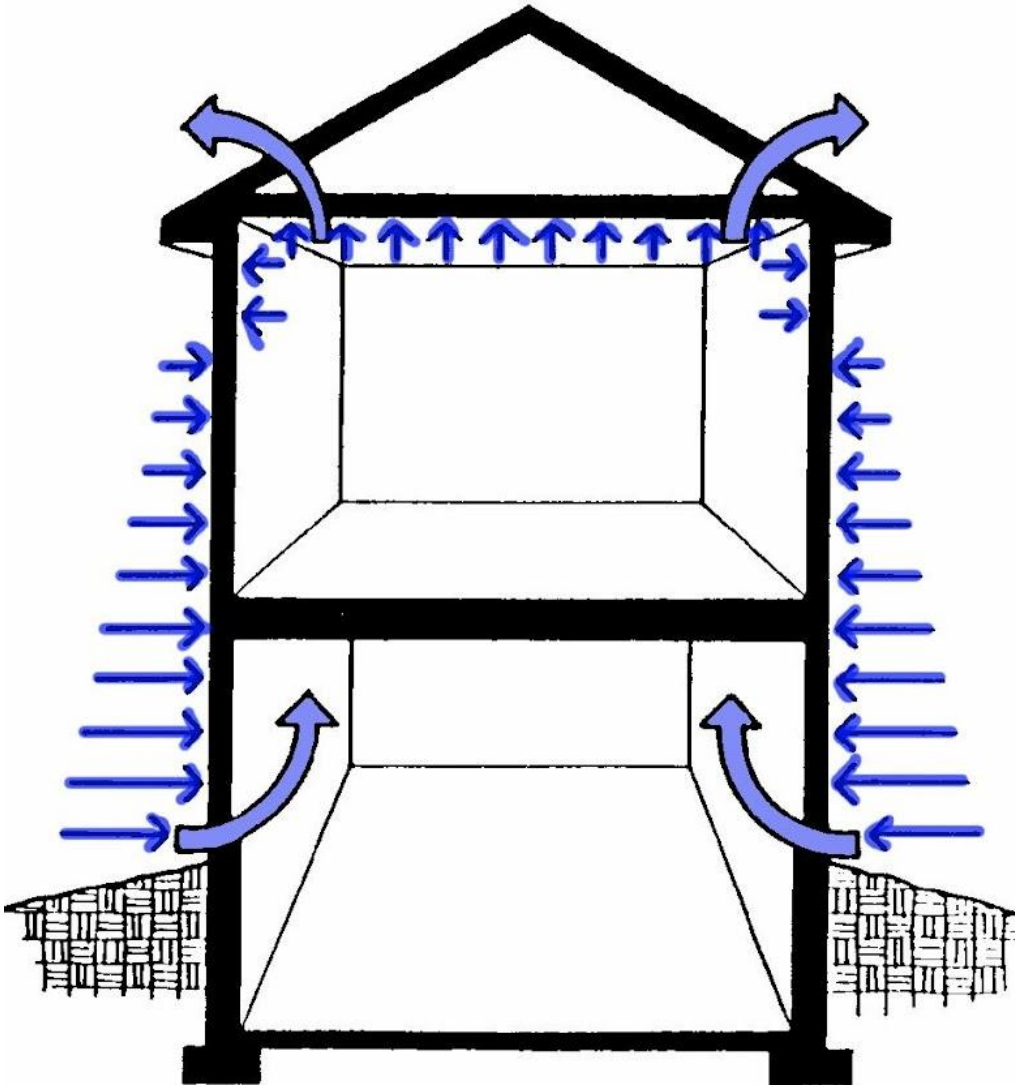
Wind Effect

**Positive outdoor
pressure causes
infiltration**



**Negative outdoor
pressure causes
exfiltration**

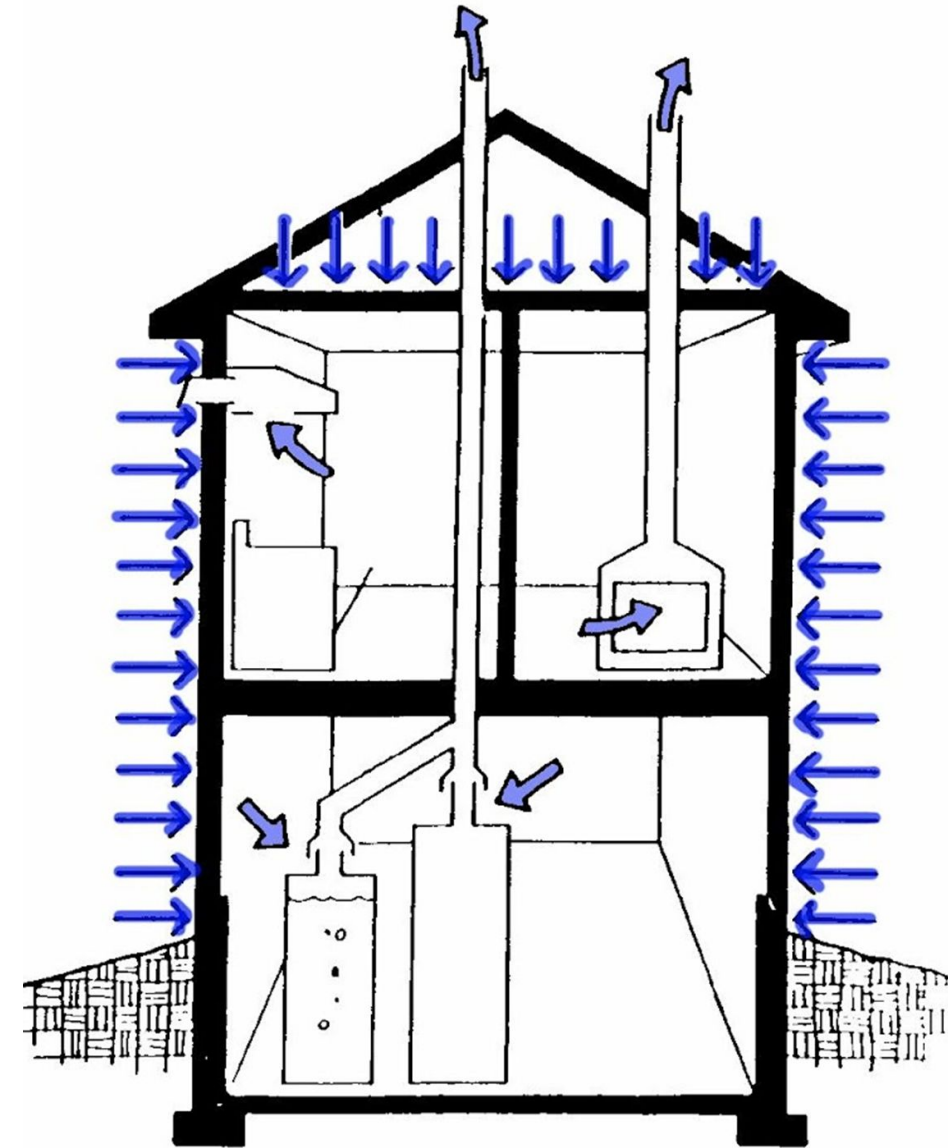
Stack Effect and Pressure Differences



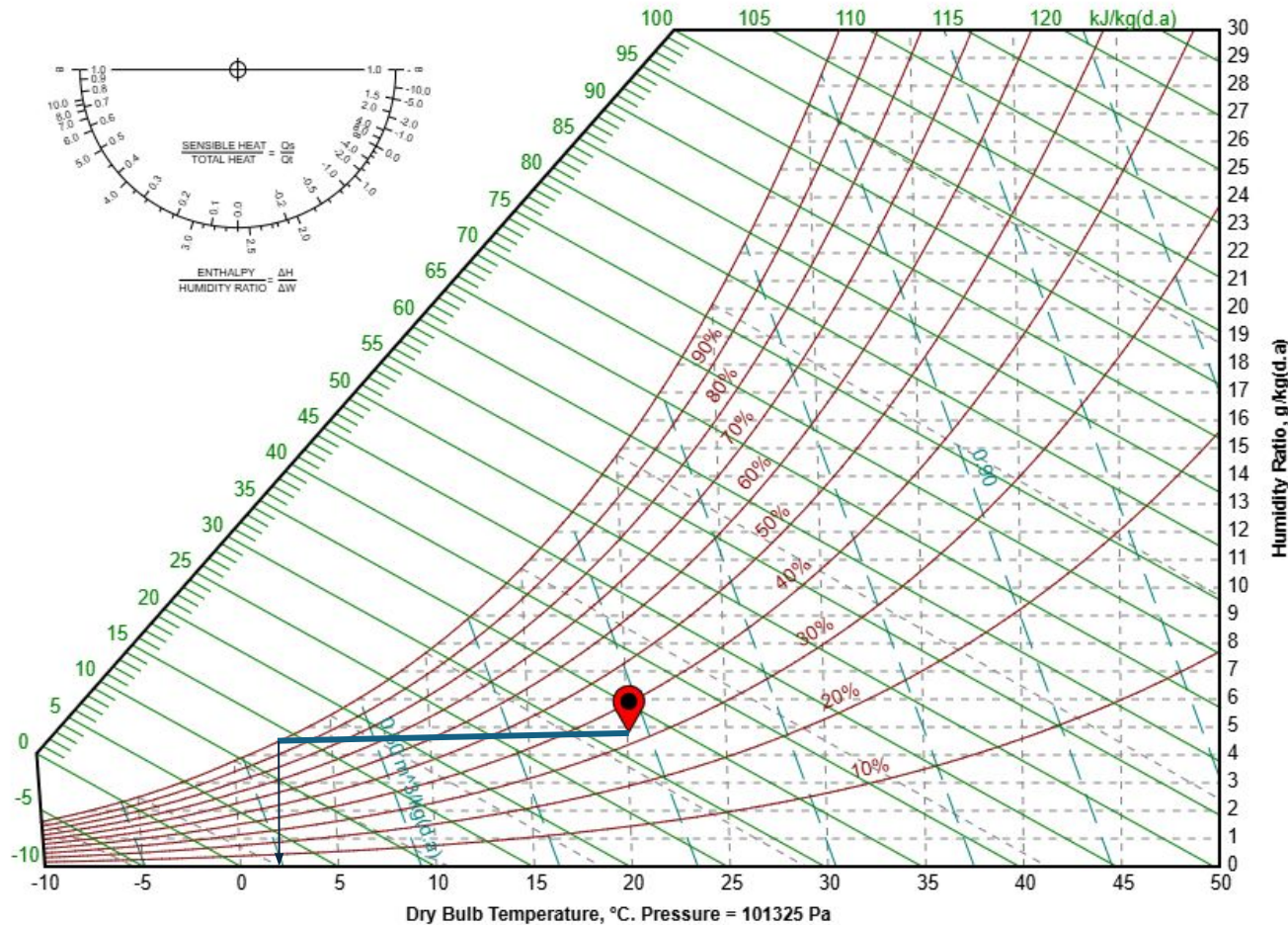
The taller the building,
the colder the day;
the more stack effect

Flue and Mechanical

Combustion safety and ventilation must be carefully considered



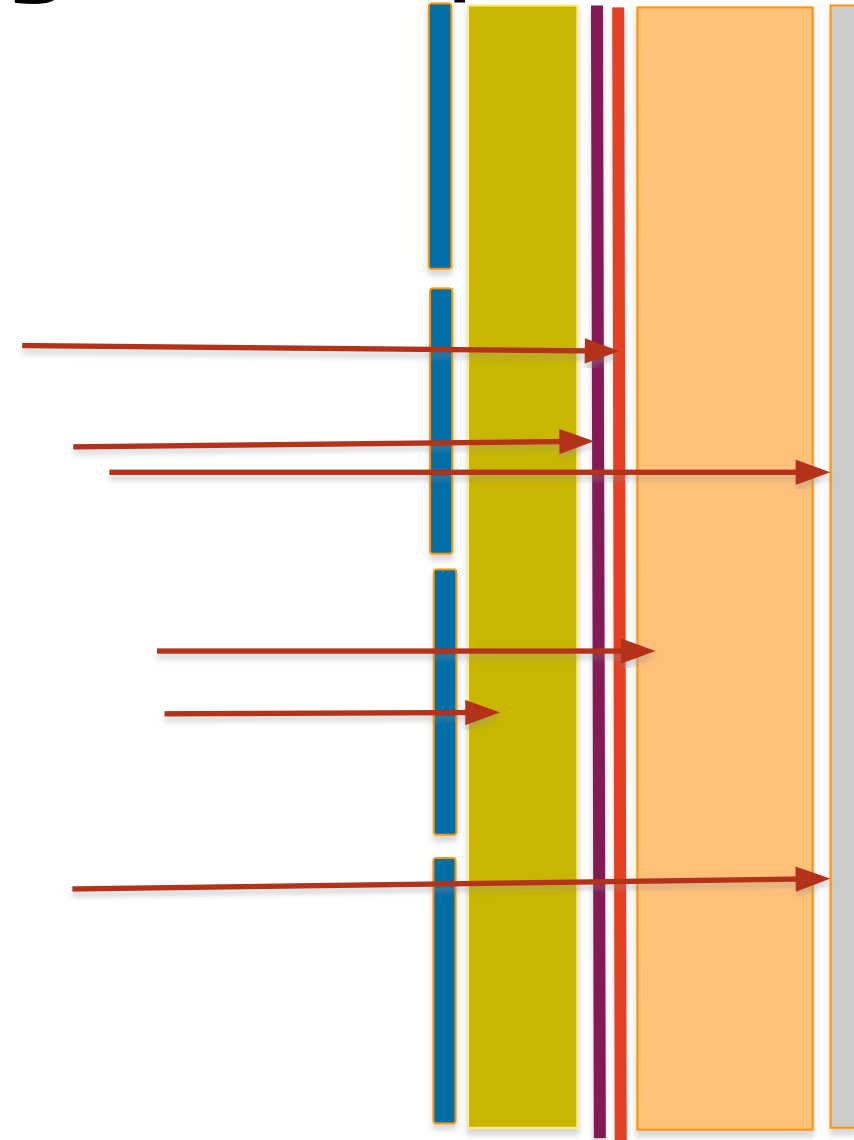
Psychrometric Chart : warm moist air



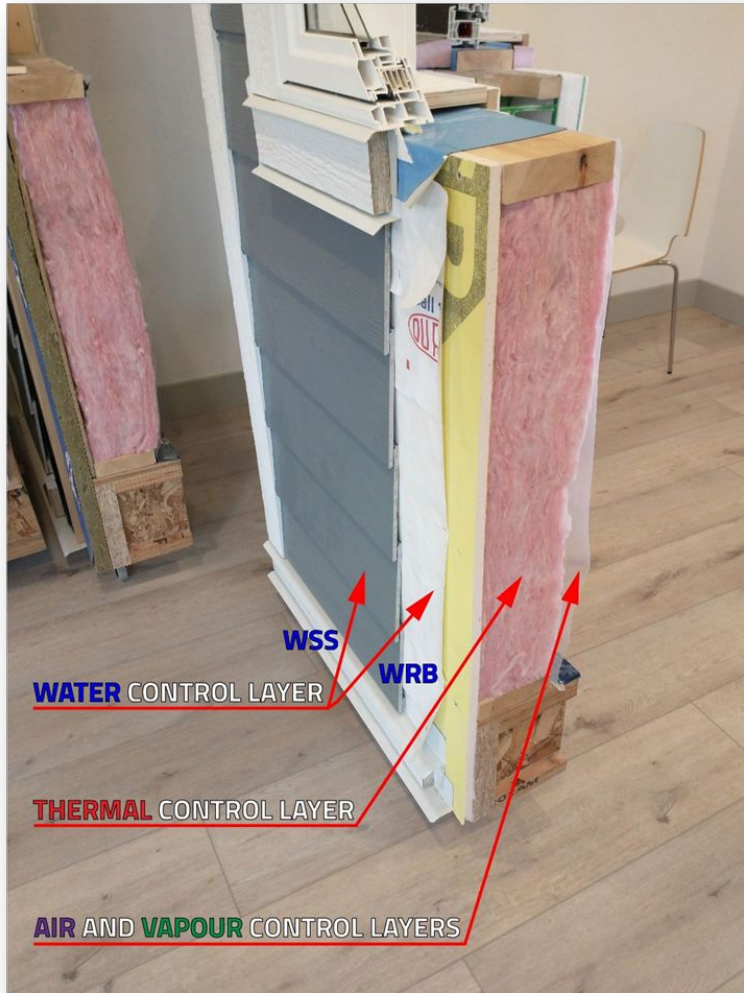
- inside air at 20 C with a relative humidity of 30%.
- As that air is drawn through the building enveloped it cools
- If the air cools to less than 3 C it will approach 100% RH or the dew point
- This is where the risk of condensation occurs - if there is solid surface the moisture laden air will cause condensation.

Control Layers in Building Envelopes

1. Water Control Layer
(WRB / 2nd Plane of Protection)
2. Air Control Layer
3. Thermal Control Layer
4. Vapour Control Layer



Envelope description

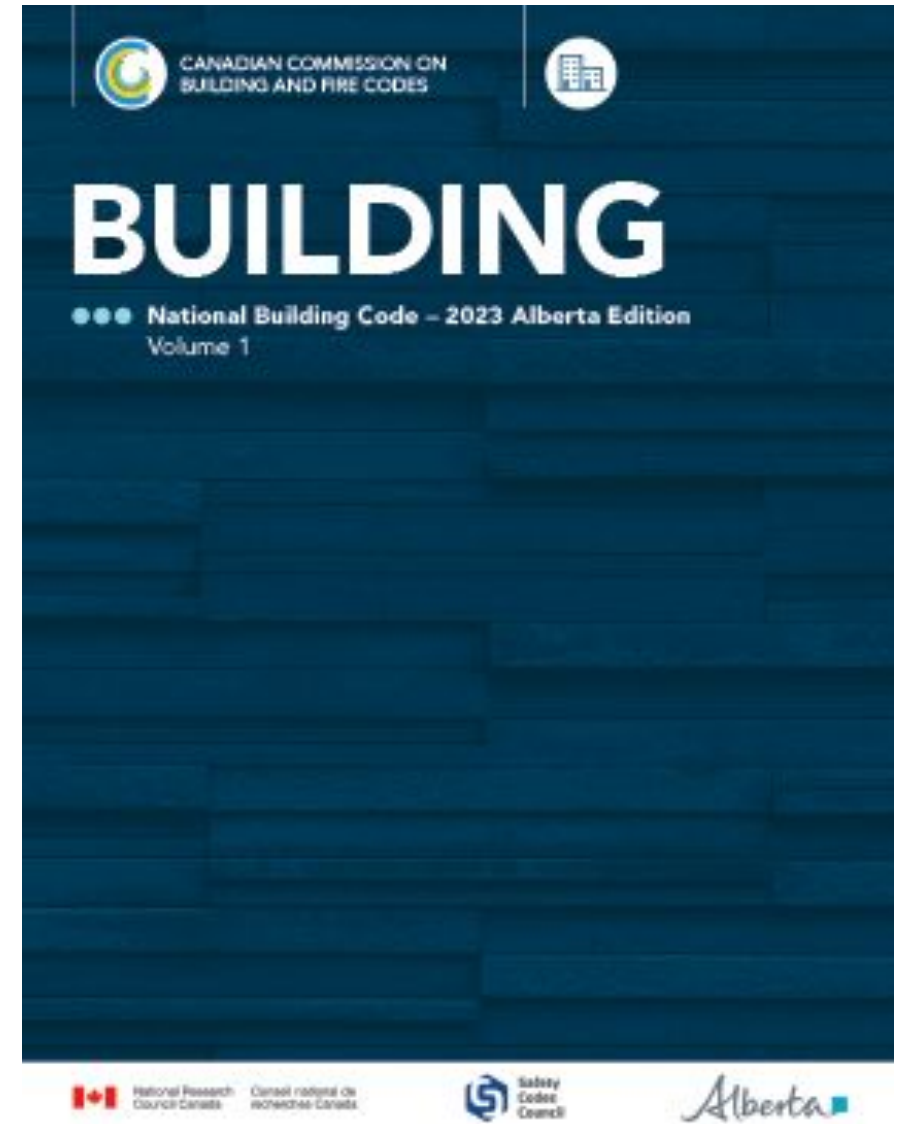


- **The Four Control Layers**
 - 1. Water Control Layer - consists of “Water Shedding Surface” (WSS) and the “Water Resistive Barrier” (WRB).
 - 2. Air Control Layer
 - 3. Vapour Control Layer
 - 4. Thermal Control Layer
 - 5. Wild fire resistant layer (bonus)

Air Barriers

Intent of Code – Air Barriers

NBC 2023 (AE) Functional Statement F55: **To resist the transfer of air through environmental separators**



Air Barrier Requirements

- The objective is to control air movement across the building envelope – which can transport moist air – the main concern is exfiltration of interior air
- The air barrier must “***provide a continuous barrier to air leakage***”.
 - Wall, ceiling and floor assemblies separating conditioned space from unconditioned space must have a continuous air barrier.
 - **Code Section: 9.25.3.1.**

The requirement for air barriers has been in the code since 1990.

What is an Air Barrier?

- Must be impermeable to air flow
- Continuous: all seams, edges, gaps, holes and tears are sealed
- Strong enough to withstand air pressure differences
- Durable during construction and for the expected life of the building

Also:

- Not necessarily impermeable to moisture flow

Air Infiltration is a Big Deal

Airflow plays a critical role in both heat and moisture flows out of a building:

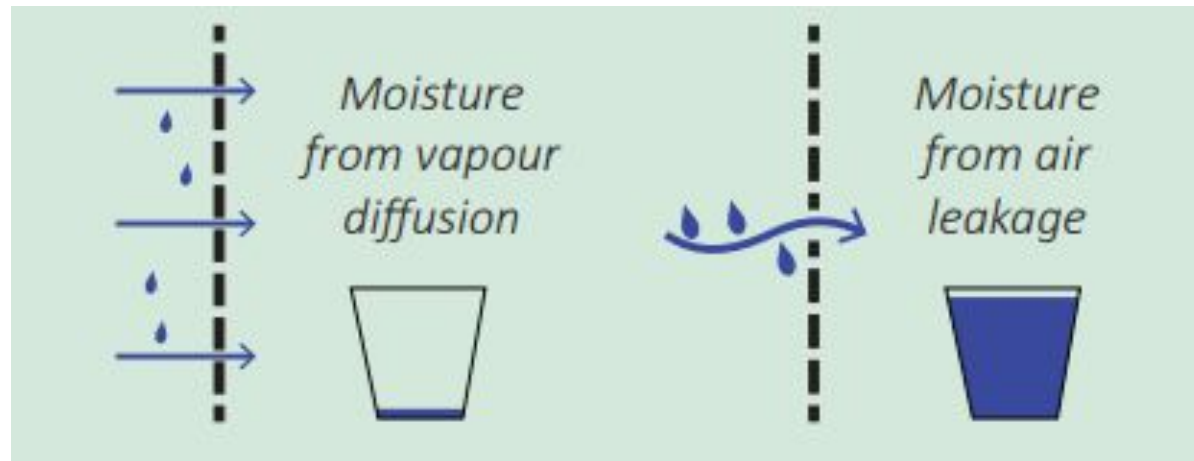
- **Mass airflow carries moisture** into/out of the building enclosure, potentially leading to interstitial condensation
- Air leakage can also account for **25 to 40% of the total heat loss** of a house.

Comparing Air Barriers & Vapour Barriers

Air Barrier Criteria	Vapour Barrier Criteria
• Impermeable to air flow	• Impermeable to moisture flow
• Not necessarily impermeable to moisture flow	• Not necessarily resistant to air flow
• Installed anywhere in building envelope assembly	• Installed to the warm side of the insulation
• Continuous by sealing all seams, edges, gaps, holes, etc.	• Must cover as much space as possible, not necessarily continuous
• Durable during construction and for the expected life of building	• Durable during construction and for the expected life of building
• Rigid and strong enough to withstand air-pressure differences	

Why focus on air v. vapour barrier

The amount of moisture transported due to air movement through an **air leakage path** at normal interior to exterior pressure differences is **many times greater** than the quantity of water vapour moved through the same permeable material due to **vapour diffusion**, depending on climate and interior conditions



Air Infiltration is a Big Deal



This is air leakage



This is air leakage



This is air leakage

Air tightness requirements were put in the building code in the 1990's to avoid interstitial condensation

Moisture Laden Air Flow Can Create Problems



**Greenhouse Gases
Energy Efficiency**



Infrastructure



Durability



**Health
IAQ + Noise**



**Passive Survivability
Climate Resilience**



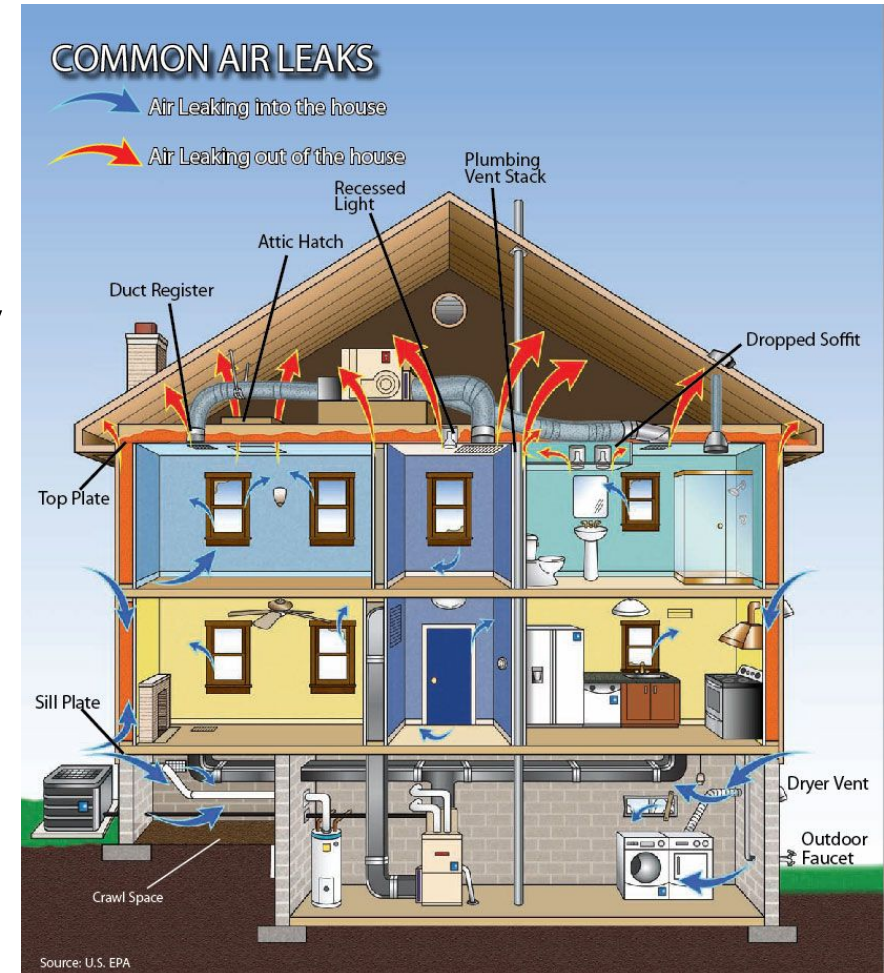
Shelters



Comfort

Can the house be “too tight”

- Indoor air quality
 - Moisture problems
 - Chemical pollutants
- Combustion appliance and venting safety
- “The walls have to breathe”
- Negative air pressure – potential for soil and gas infiltration



Air Leakage Characteristics of Common Building Materials

Materials That Meet Air Barrier Requirements

Material	Air Leakage L/(s.m ²)
6 Mil Polyethylene	negligible
Drywall	0.02
Oriented Strandboard	0.011
Plywood	0.008
1" XPS Foam Insulation	negligible
Spun-bonded Polyolefin	0.02

Materials That Don't Meet Air Barrier Requirements

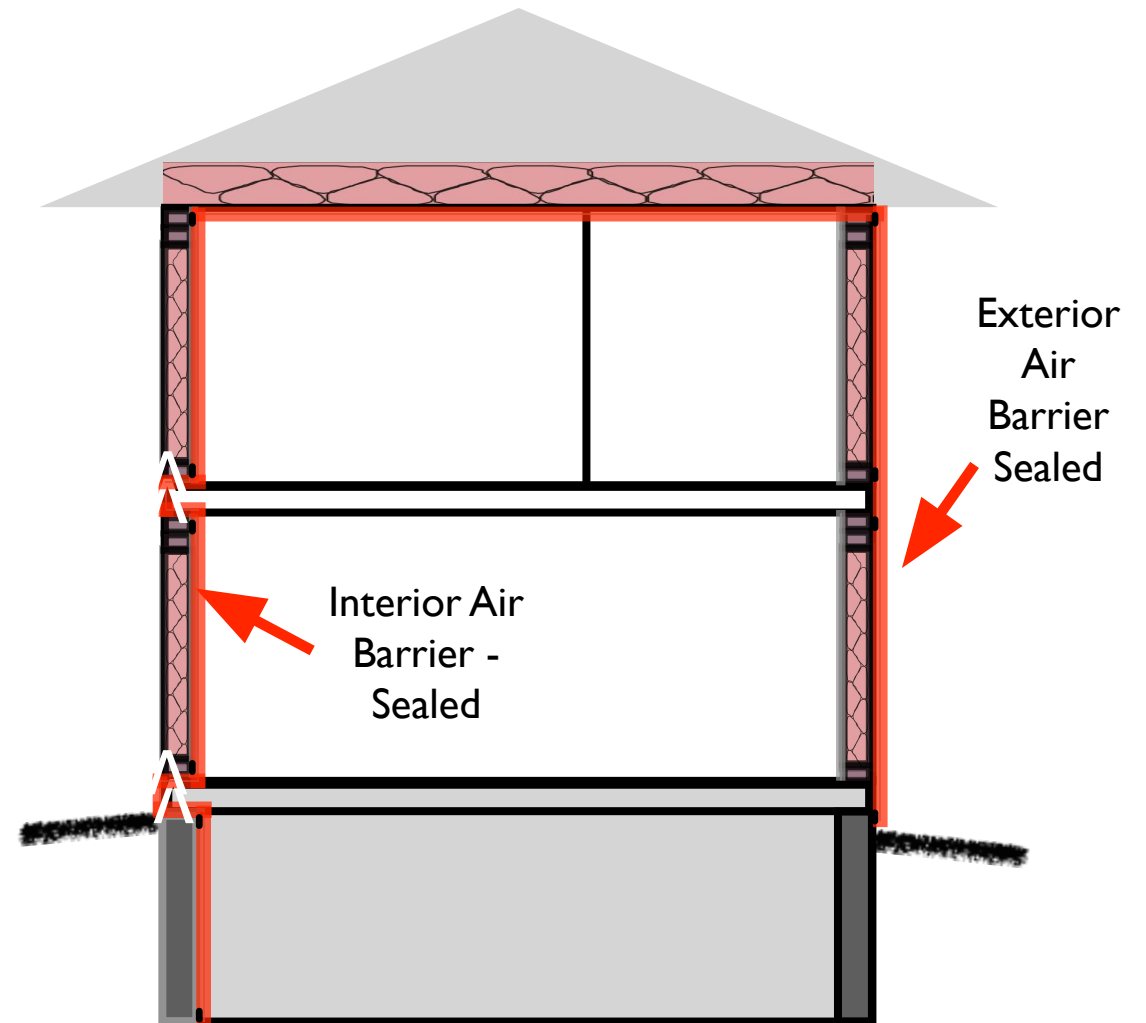
Material	Air Leakage L/(s.m ²)
Fibrous Insulation	Very High
Building Paper	0.27
Asphalt-saturated felt	0.153
Perforated Water Barriers	> 1.0
Fibre board Sheathing	0.012 to 1.9
1" EPS Foam Insulation	0.0214

Air barrier material: Defined as when the material has an air leakage characteristic < 0.1 L/(s x m²) tested at 75 Pa

What Makes Up the Primary Air Barrier?

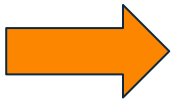
- Drywall
- Poly
- Sheathing
- Foam Sheathing
- Water Resistant Barrier
- Concrete

It is important for building designers to detail the AB correctly



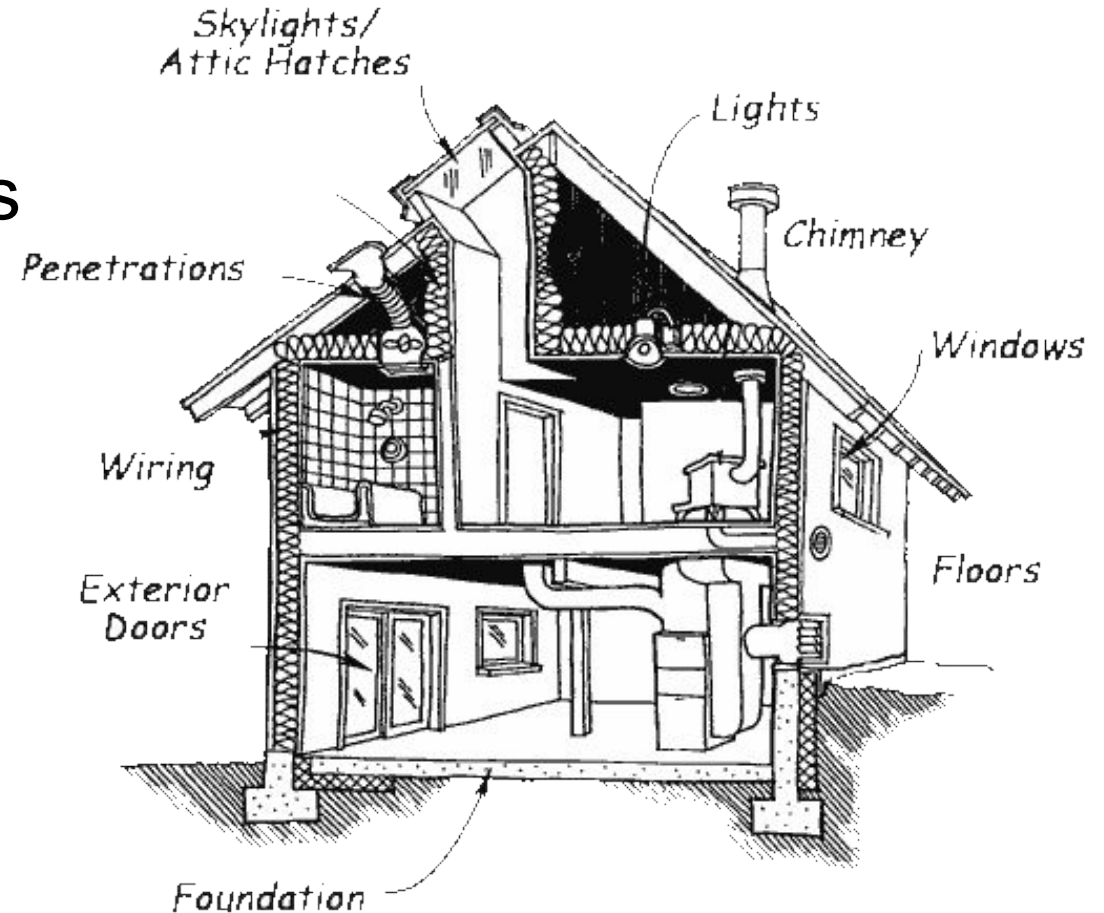
Trades Responsible for a Successful Air Barrier

- Framers
- Insulator
- Drywaller
- Cladding
- HVAC
- Electrician
- Cable
- Plumber
- Site Supervisor



Significant Areas of Air Leakage

- Behind tubs, stairways, bulkheads
- Complex wall to ceiling connections
- Attached garage details
- Electrical penetrations
- HVAC and plumbing penetrations
- Attic hatches
- Rim joists



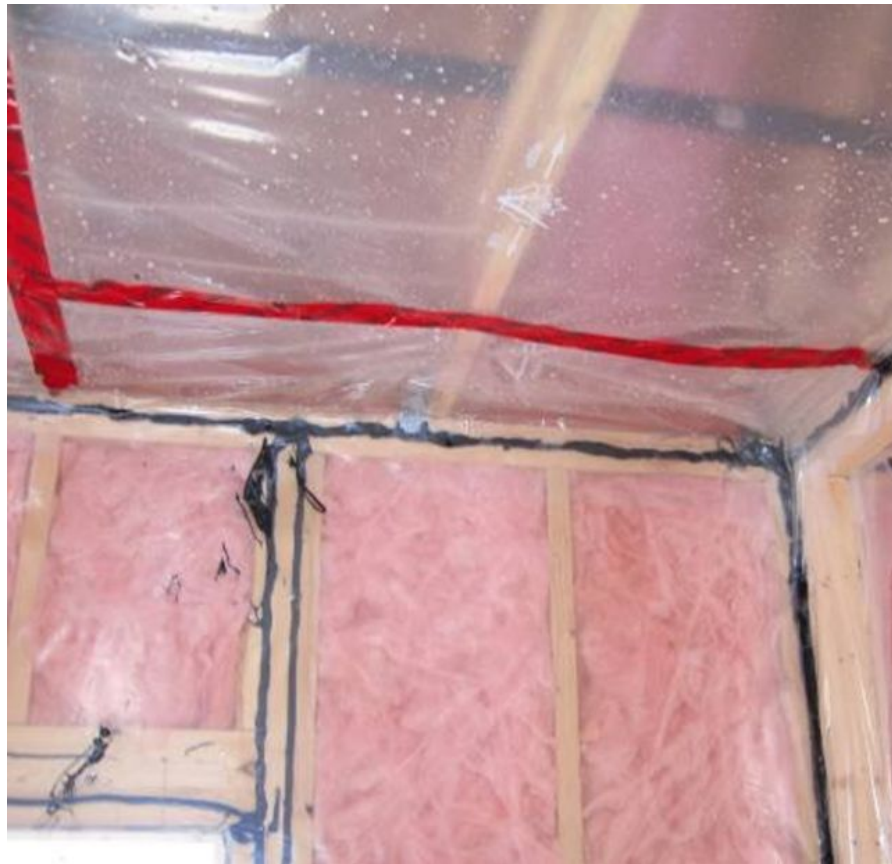
Reference: Keeping the Heat In, Natural Resources Canada

Air Flow Barrier System

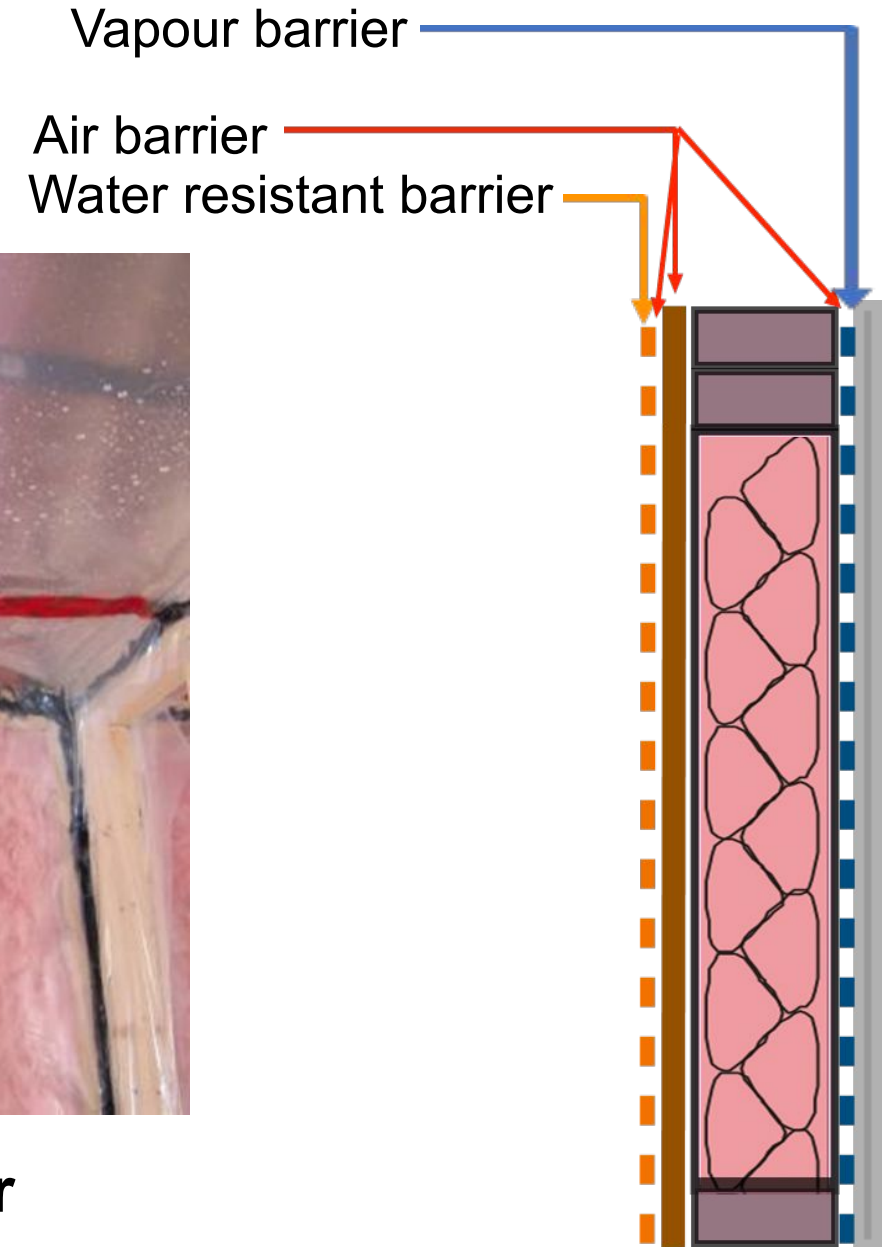
Can be either interior, exterior or a combination of both



Exterior Air Barrier



Interior Air Barrier



Interior Air Barrier Systems



Sealed Polyethylene Approach

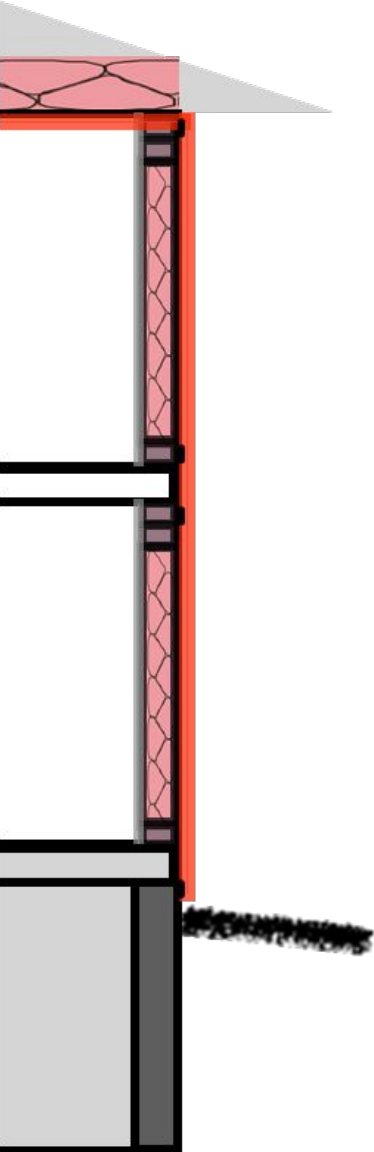


Airtight Drywall Approach

- Must be continuous through all penetrations

Reference: Illustrated Guide Achieving Airtight Buildings

Exterior Air Barrier Systems



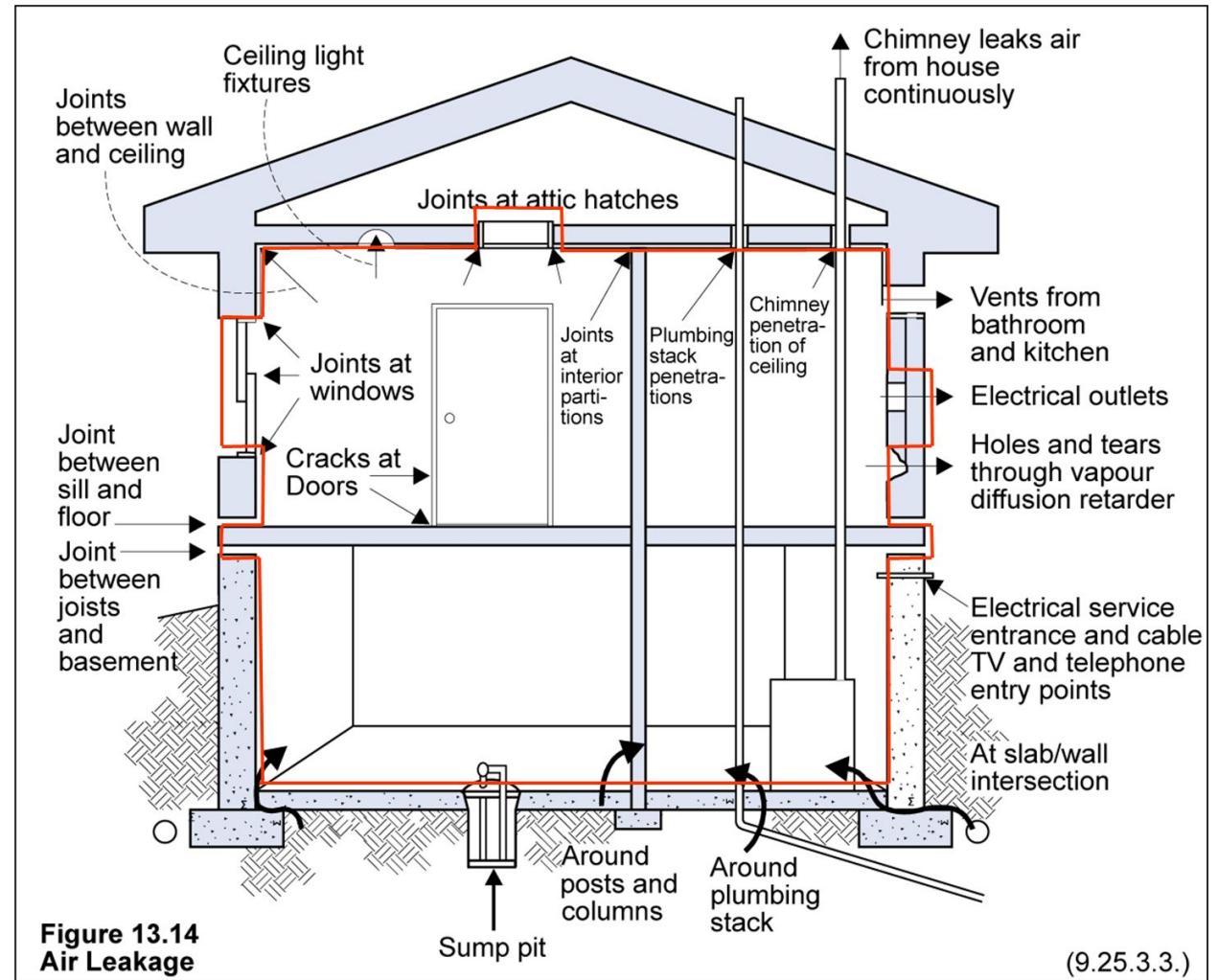
Exterior Insulation Approach



House Wrap Approach

Continuous Air Barrier System

- Continuous air barrier completely around the building
- All penetrations must be sealed
- Must be durable to last the life of the building
- Interior AB = 45+ connections
- Exterior AB = **22+** connections



Reference: CHBA Manual, Fig.2.9, Pg.24

Example of Building Science Synergy

- A well detailed weather barrier or sheathing can also be an effective air barrier
 - It must be continuously connected
 - Simple tapes & caulking applied by one trade
- You get multiple functions from one material & trade



Specific Examples of Envelope Details

Air Sealing

Poor air sealing can lead to moisture in walls



Rubber Gasket Air Sealing Approach



A gasket seals the penetration and allows movement of the pipe

Air Sealing - Poly details



- All beads on solid backing or use tape (tested methods: blue tuck tape, or acoustical sealant clamped)
- Use airtight electrical boxes
- Seal larger penetrations with foam
- Encourage trades to witness an air test

Is this the right location for caulking?

Air Sealing

Caulking



Foam



Tape



Plumbing, Electrical & HVAC Penetrations



Sub must be trained on the importance of air sealing

Air Sealing - use of foam

Foam is ideally suited for areas such as:

- Rooms over garages
- Behind tubs & bump outs
- Around windows and beams



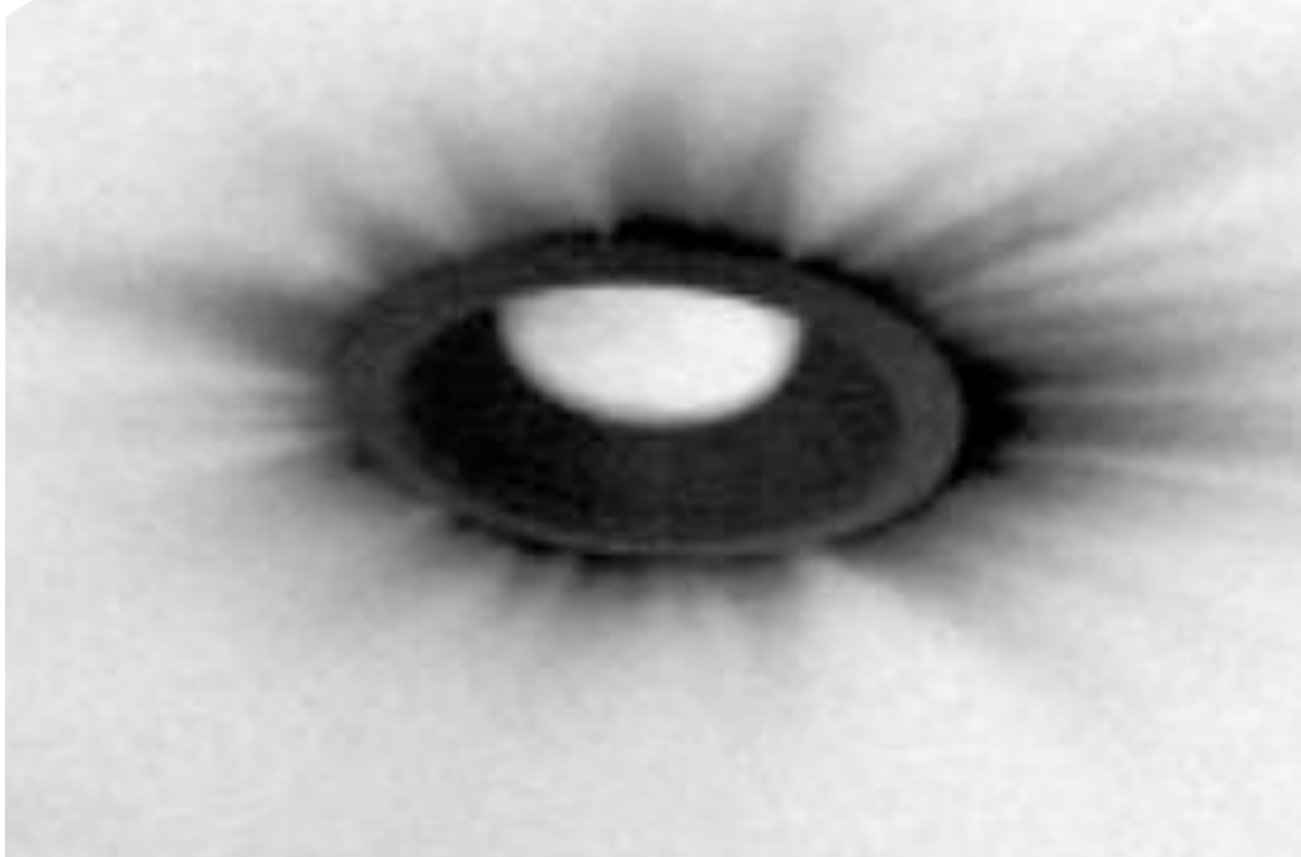
Air Barrier Prior to Tub Installation



Air Barrier Prior to Bulkheads



Air Leakage at Recessed Pot Light



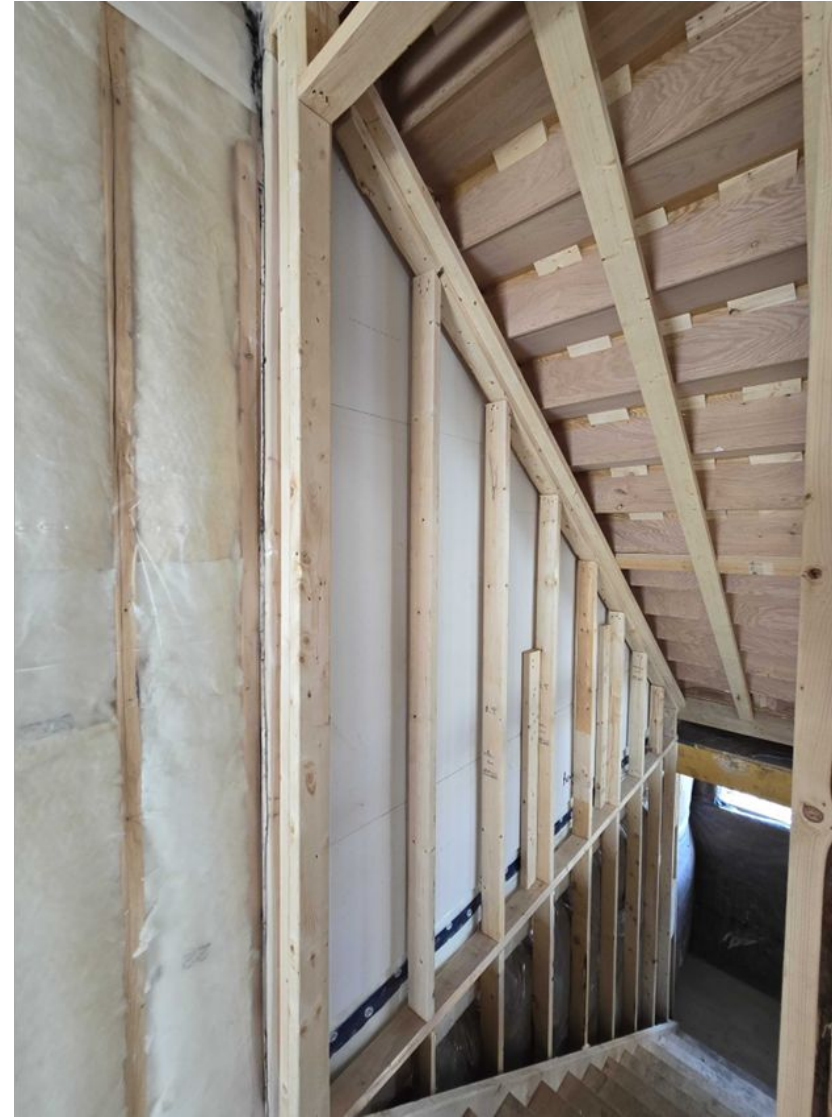
Air Sealing at Recessed Light



Knee Walls: Is There a Better Way?



Where Stairwells Meet Exterior Walls



Floors Over Unconditioned Space



Window and door resources



CSA A440.4:19 (R2024), Window, door, and skylight installation (9)
These tools are based on CSA A440.4:19 (R2024)

View Standard: [CSA A440.4:19 \(R2024\), Window, door and skylight installation](#)



Components of a Flanged Window

Use this tool to identify the components of the head, jamb, and sill of a flanged window

[Learn More](#) 



The Importance of Proper Window Installation

Watch this video to learn why proper window installation is important

[Learn More](#) 



Additional resources on window and door in the envelope

Targets for voluntary programs

ENERGY STAR for New Homes v17.1 revision 2:

Table 1 - Airtightness Targets
Forming part of **section 4.2.1**

Building Type	ACH at 50 Pa	NLA at 10 Pa		NLR at 50 Pa	
		cm ² /m ²	in ² /100 ft ²	L/s/m ²	cfm50/ft ²
Attached	3.0	2.12	3.06	1.32	0.26
Detached	2.5	1.26	1.81	0.93	0.18

- Can receive additional BOP points for higher airtightness levels (2-4)

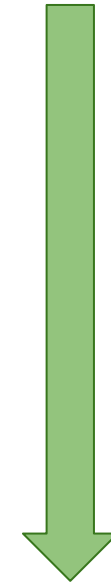
CHBA Net Zero Ready / Net Zero: 1.5 ACH @ 50 Pa (Detached)
2.0 ACH @ 50 Pa (Attached)

Energy & Air Tightness

For a code minimum single detached home in Edmonton

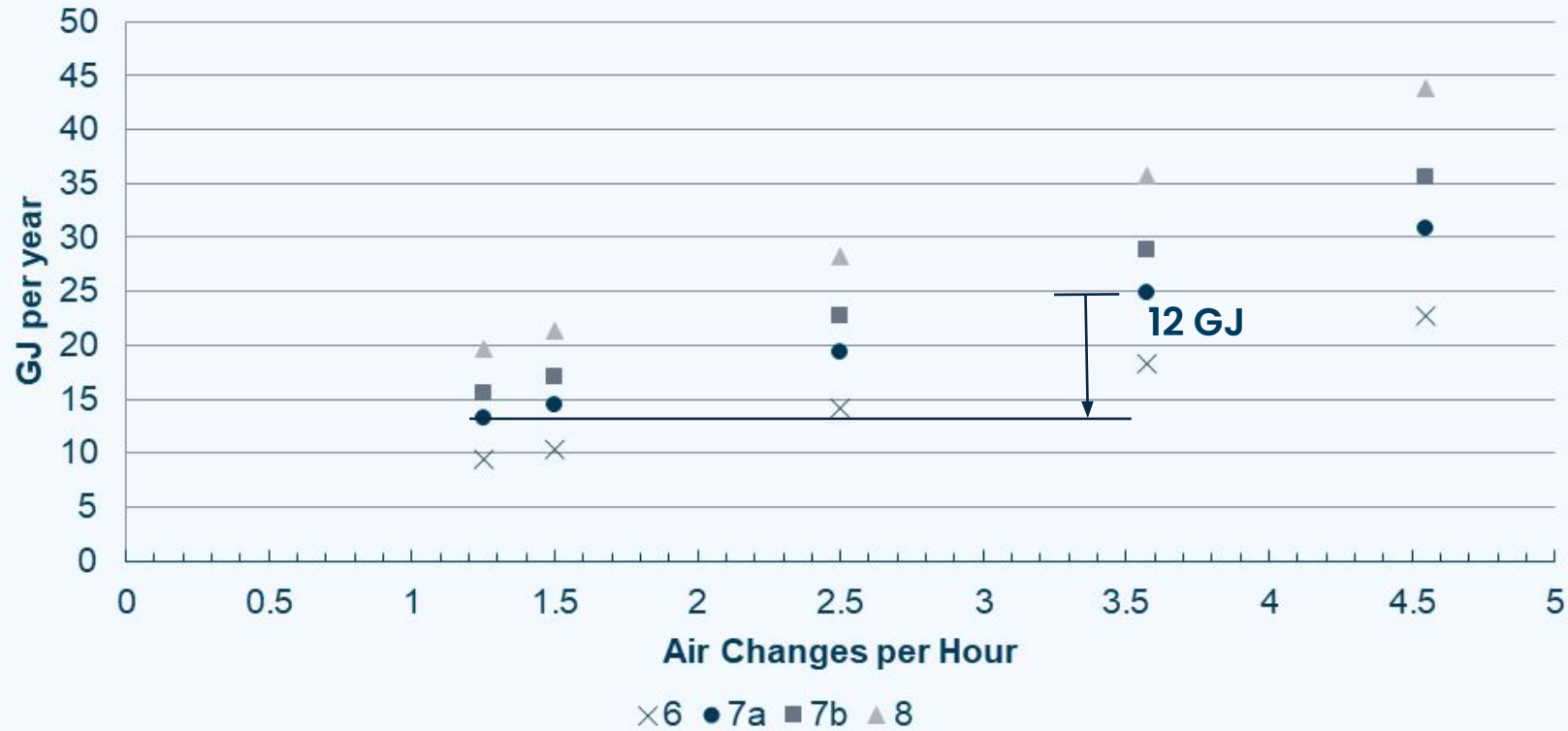
If we only modify air tightness:

ACH @ 50 Pa	GJ/yr
2.5	114.43
2.0	111.46
1.5	108.46
1.0	105.40
0.6	102.87



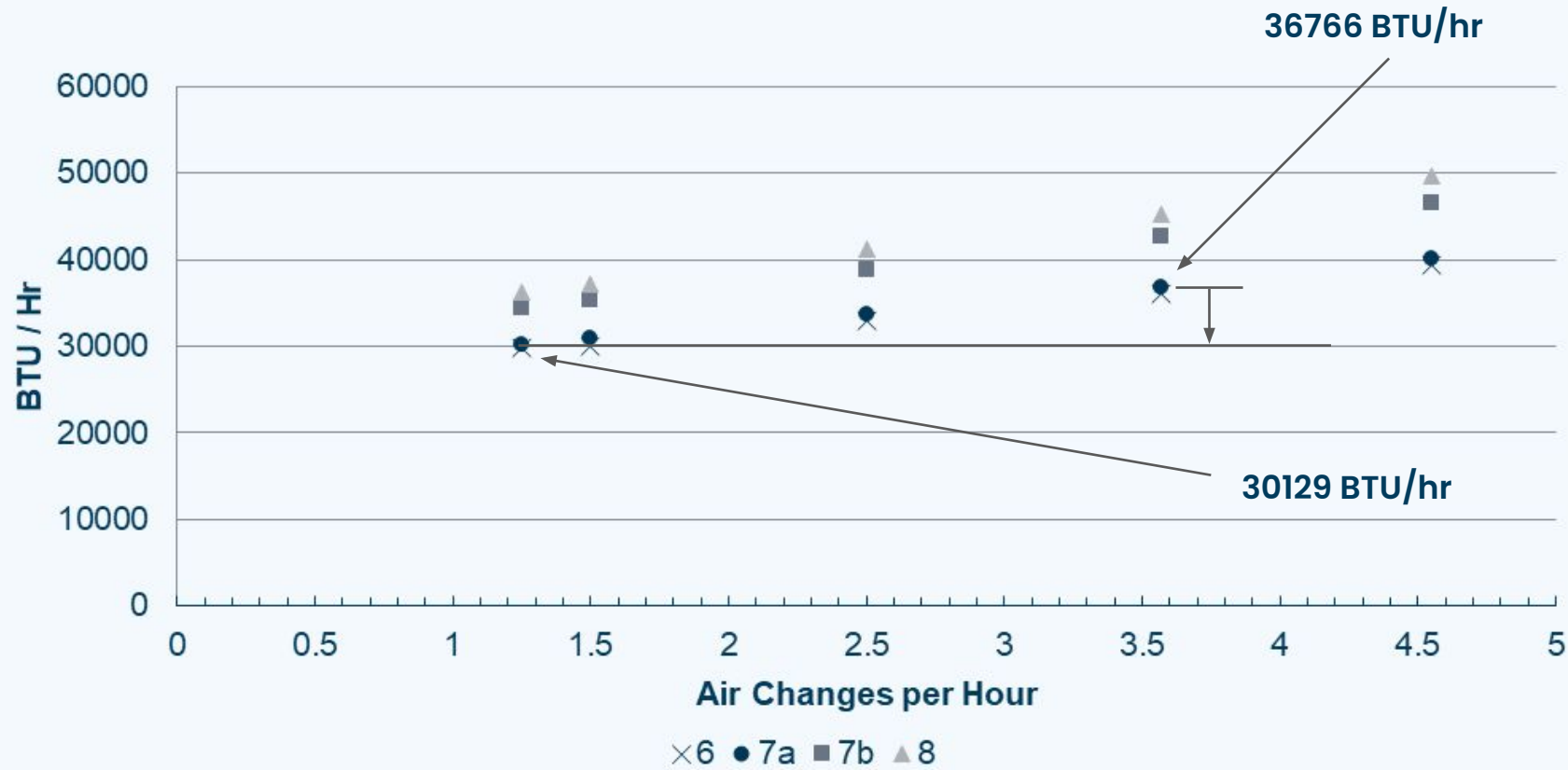
10%

Heat Loss from Ventilation and Air Infiltration (GJ/y)



The warmer climate zones see the greatest percentage improvement (59% in CZ6 versus 55% in CZ 8), but the absolute improvement in GJ/Y is better in colder climate zones (24 GJ/y in CZ 8 v 13 GJ/Y in CZ 6)

Design Heat Loss (BTU/hr)



6644 BTU/hr or 18% reduction

Improving ACH reduced design heat loss (i.e., heating sizing) 24% to 27%

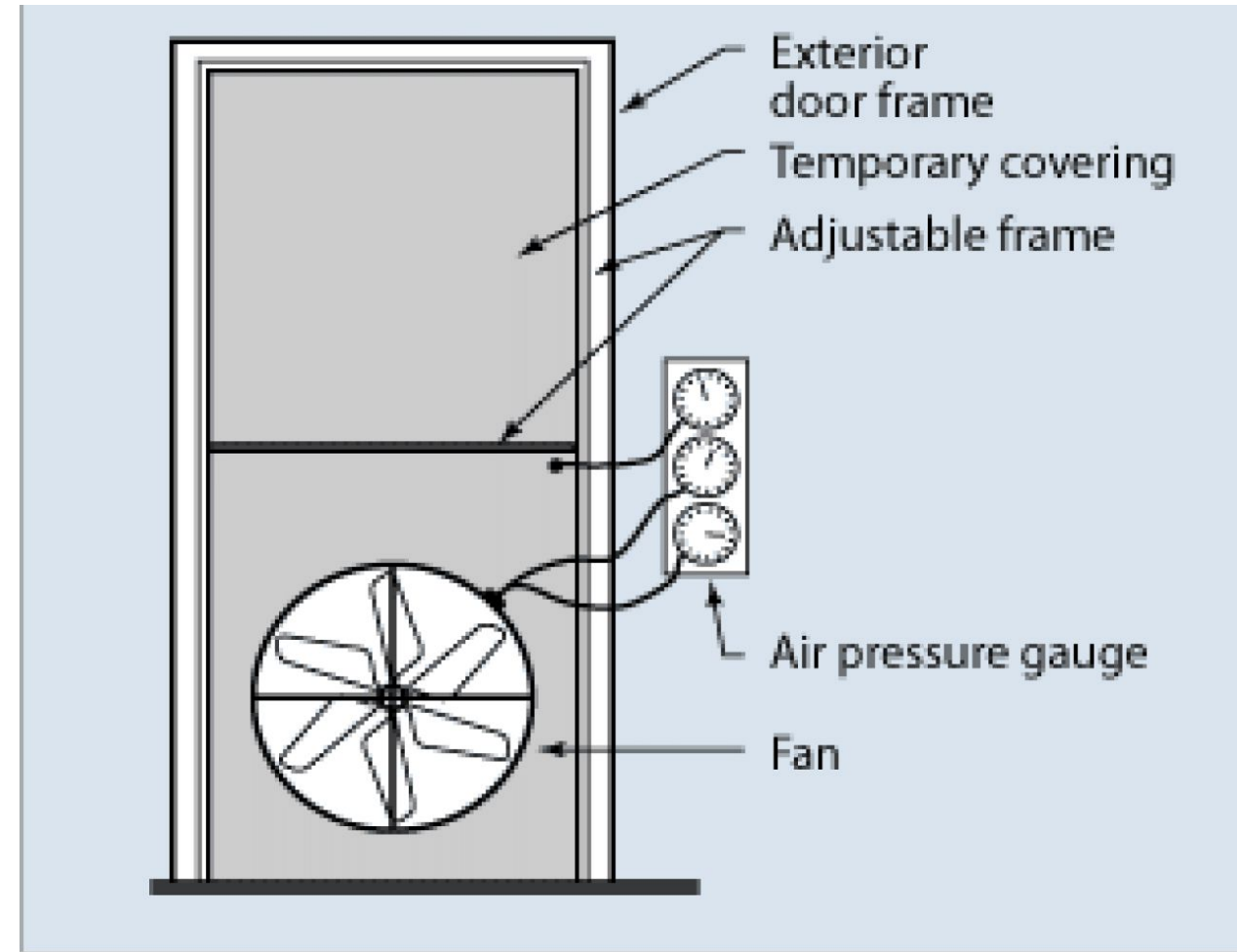
Blower Door Testing

What is a blower door test?

A diagnostic depressurization test used by energy advisors to measure the airtightness of a building and identify air leakage locations in the building envelope

Follows standard:
CAN/CGSB-149.10-2019

EnerGuide Technical Procedures is a modified version of the CGSB standard



Reference:

<https://www.energy.gov/energysaver/blower-door-tests#:~:text=Home%20energy%20professionals%20use%20a,and%20make%20energy%2Dsaving%20improvements.>

Blower door results

Equivalent Leakage Area (ELA)

- An estimate of the total area of all the air leakage holes in the building

Normalized Leakage Area (NLA)

- ELA divided by the total surface area of the building envelope - above and below grade included (in^2/ft^2)
- enables comparison of air tightness of houses of different sizes

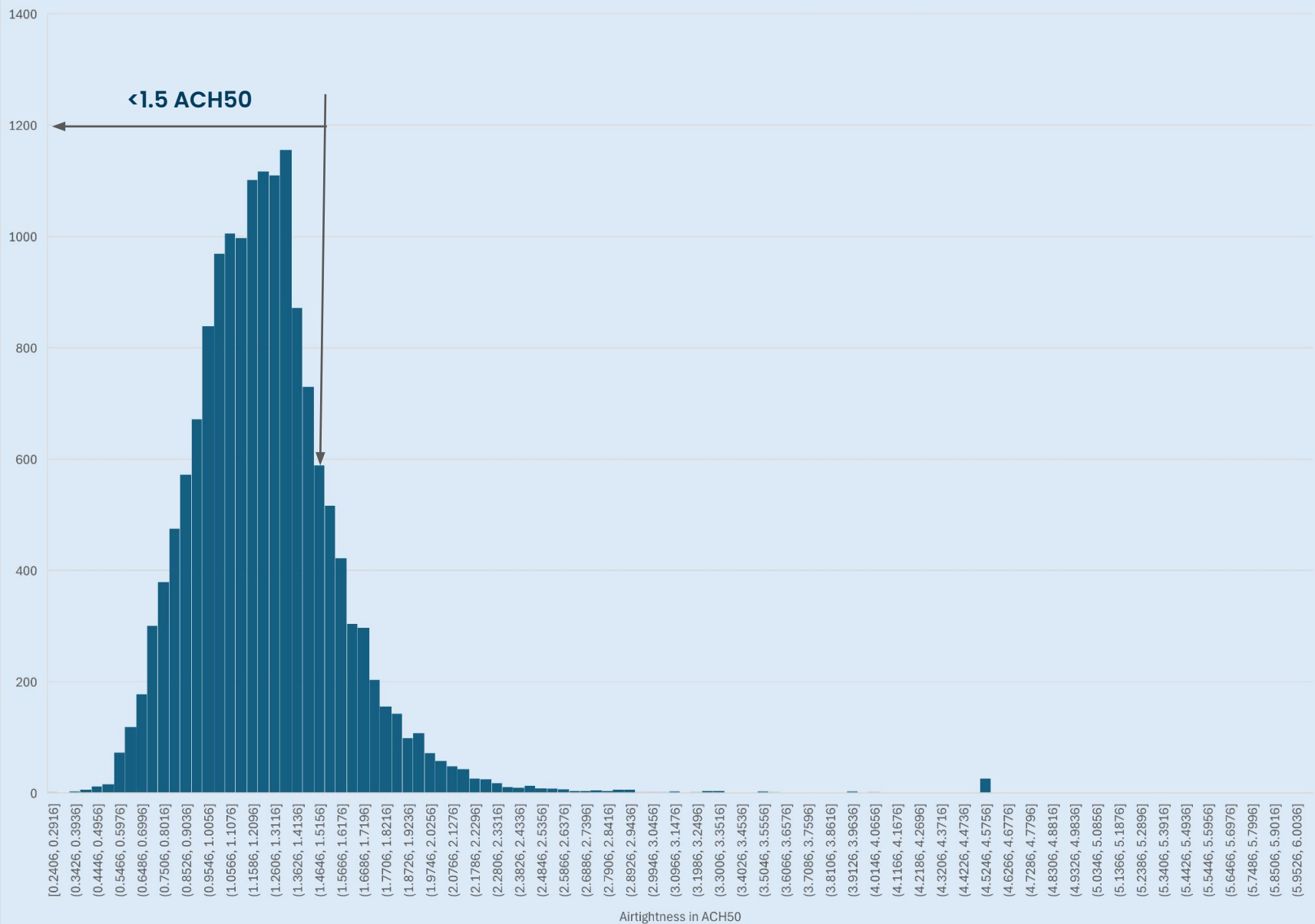
Air Changes per Hour (ACH)

- number of times that a home's total volume of air is exchanged with outside air in an hour at a given air pressure
- ACH permits comparison of air tightness rates between structures of differing volumes

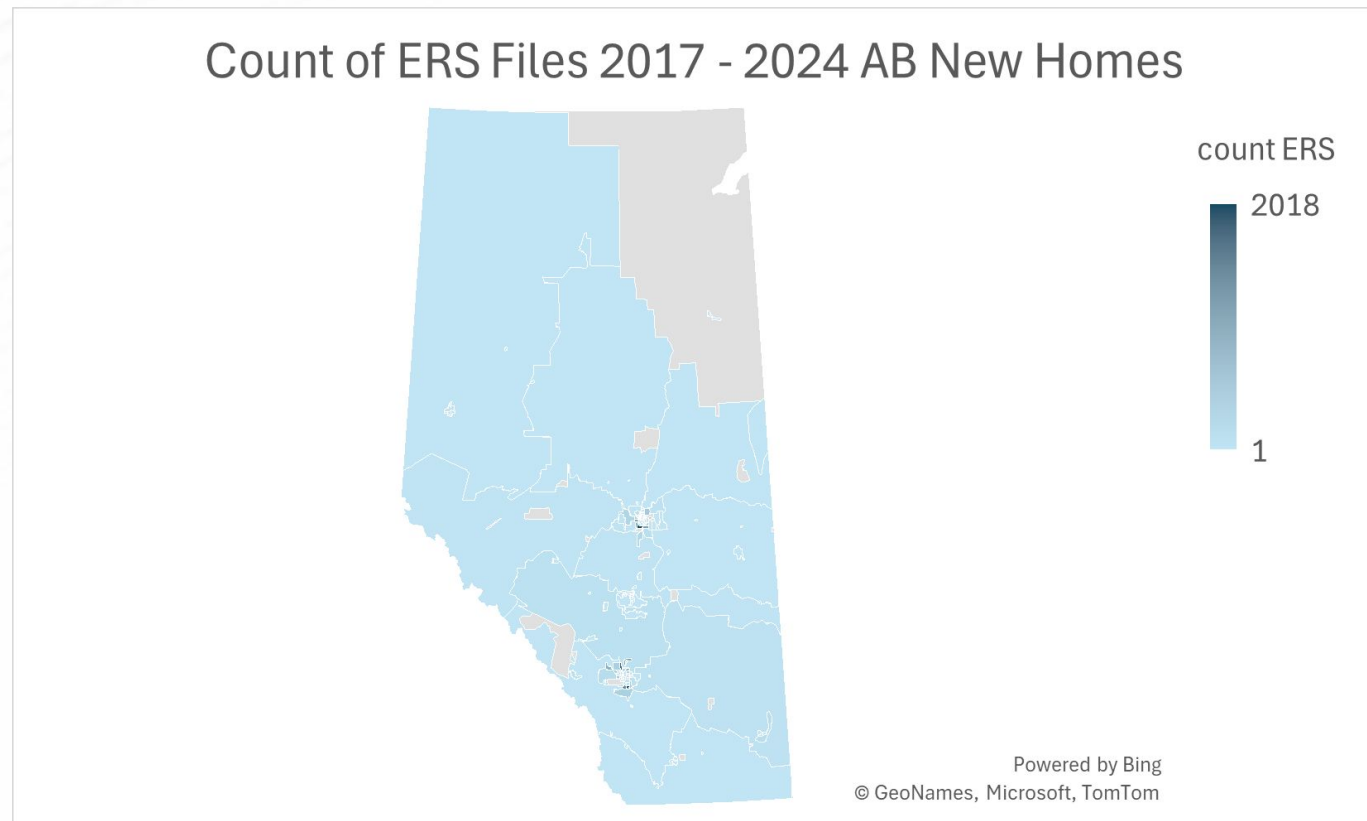
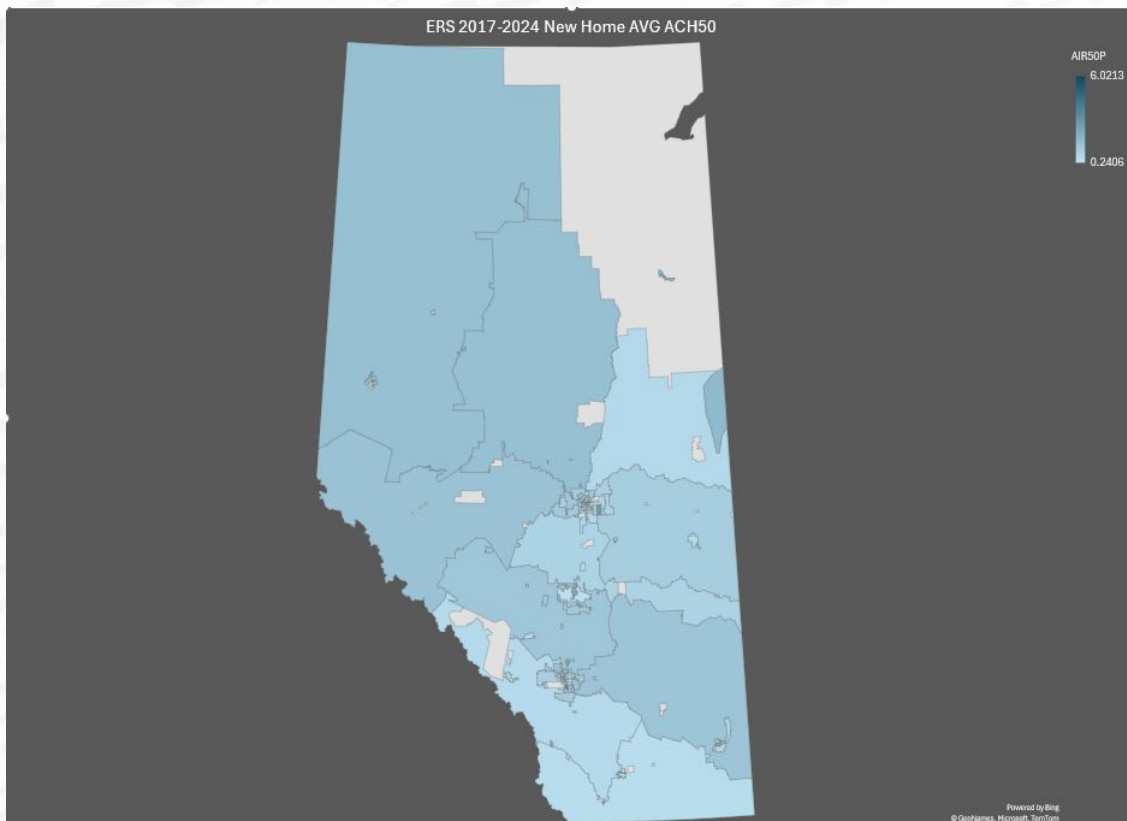
Normalized Leakage Rate (NLR)

- The flow in CFM at 50 Pa pressure divided by the interior surface area of the house

Distribution of Airtightness Testing in ACH50 from Energuide Rating Testing for New Single Family Homes 2017 - 2024



13144 homes with less than or equal to 1.5 ACH

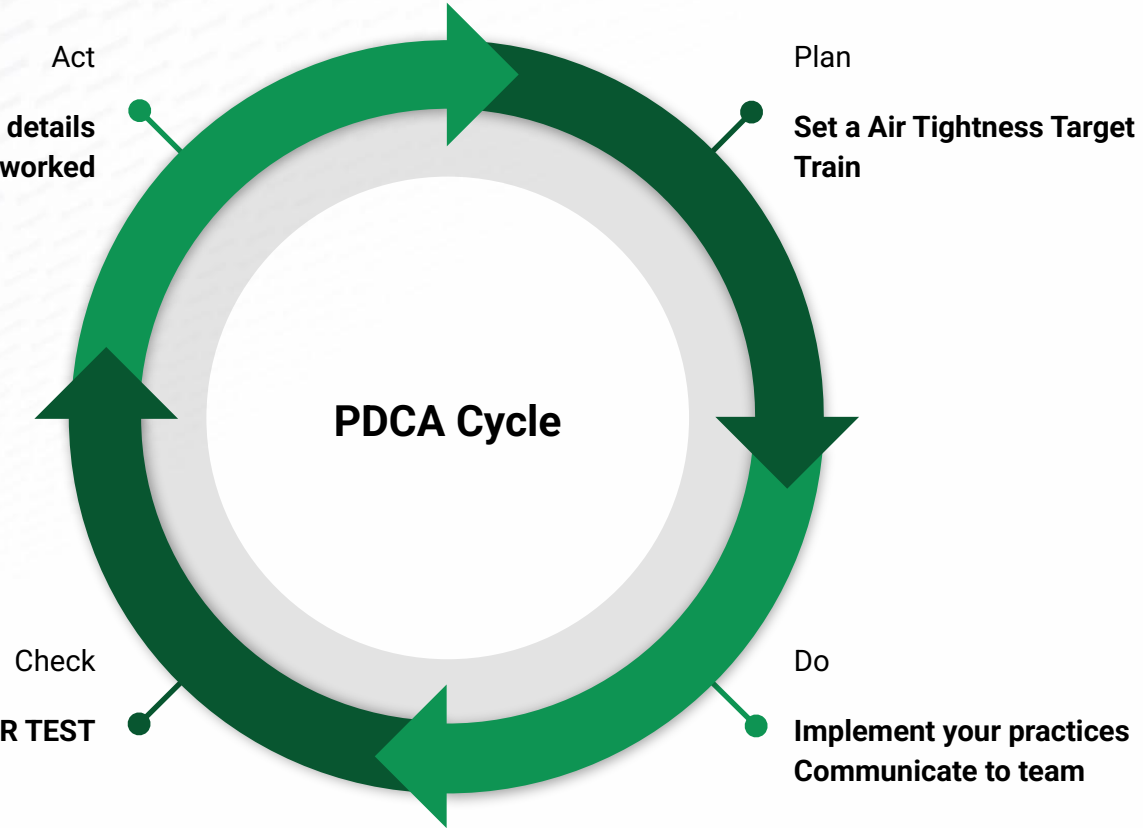


The Continuous Improvement Cycle



Fix issues, change details
ask what worked

DO A BLOWER DOOR TEST





Pre Drywall

Test your air barrier before it is hard to see & Fuxe



Mid-point

Test it again to see if it was damaged



Final

Test it still another time

Testing at different stages

Pre-drywall Inspection: To identify possible problem areas with discontinuous air barrier details. Addressing these issues will save money in the long run

Mid Construction: After drywall is installed to make sure you're on target

Final: To determine the final air tightness value of the home and confirm you're meeting your target

Testing is underrated

- Energy
- Quality
- Durability
- Resilience



Airtightness Testing Results Can be Helpful

Zonal or Series Pressure measurements can help locate areas of significant leaks

With the house at -50 Pa



A pressure tap into the attic indicates significant area of leakage when the pressure is closer to -50 Pa



Use the same technique between the house and garage or to the crawlspace

Building Code Airtightness Levels

For new construction (NBC 2020):

- 2.5 ACH for single detached home
- 3.0 ACH for attached home



EnerGuide Rating

The EnerGuide rating demonstrates the energy performance of your home. It is an estimate of the net amount of energy your house consumes in a year

The EnerGuide Rating System underpins the delivery of NRCan's initiatives:

- ENERGY STAR® for New Homes
- R-2000
- Many other programs delivered by partners across the country

Blower door testing is required for the Basic Service, Renovation Upgrade Service and the Construction Blower Door Service

LEARN ABOUT YOUR HOME'S ENERGY rating

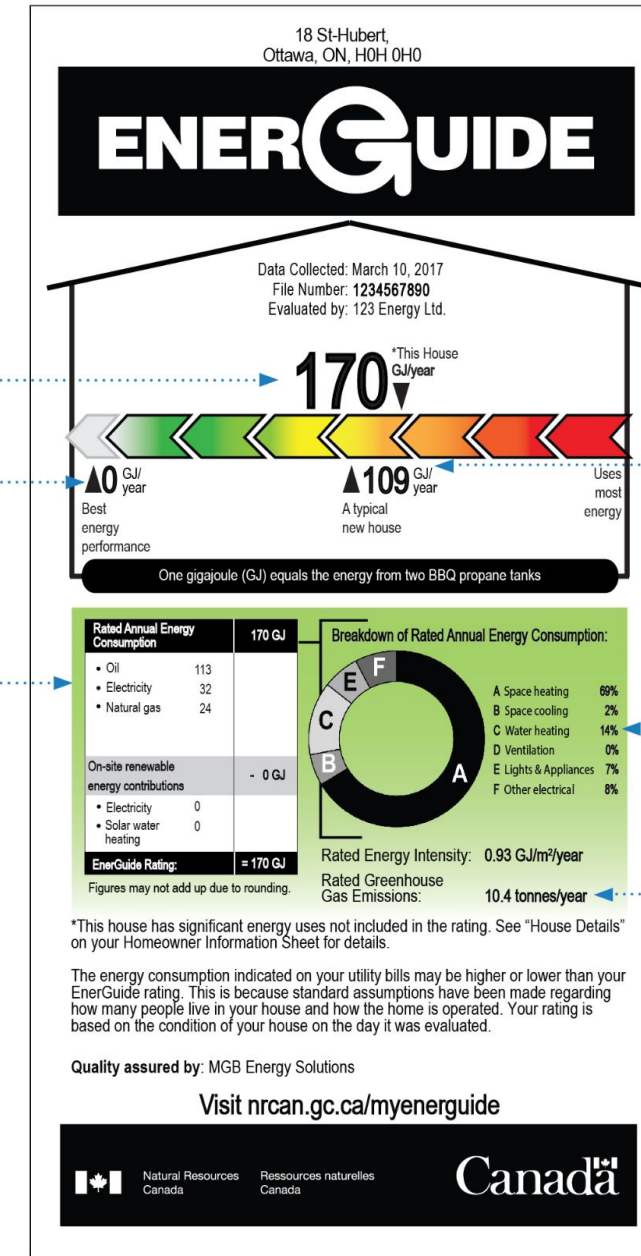
You will receive a rating of the home's energy consumption in gigajoules

AIM TOWARDS zero

The lower the number on the new **EnerGuide** scale, the better the energy performance of your home

UNDERSTAND HOW YOU USE energy

The label breaks down energy consumed by source



COMPARE YOUR HOME'S performance

The label shows how your home's performance compares to a benchmark home

FIND OUT WHERE MOST ENERGY IS consumed

The label shows proportion of energy consumed by heating, cooling, ventilation, etc.

SEE YOUR IMPACT ON THE environment

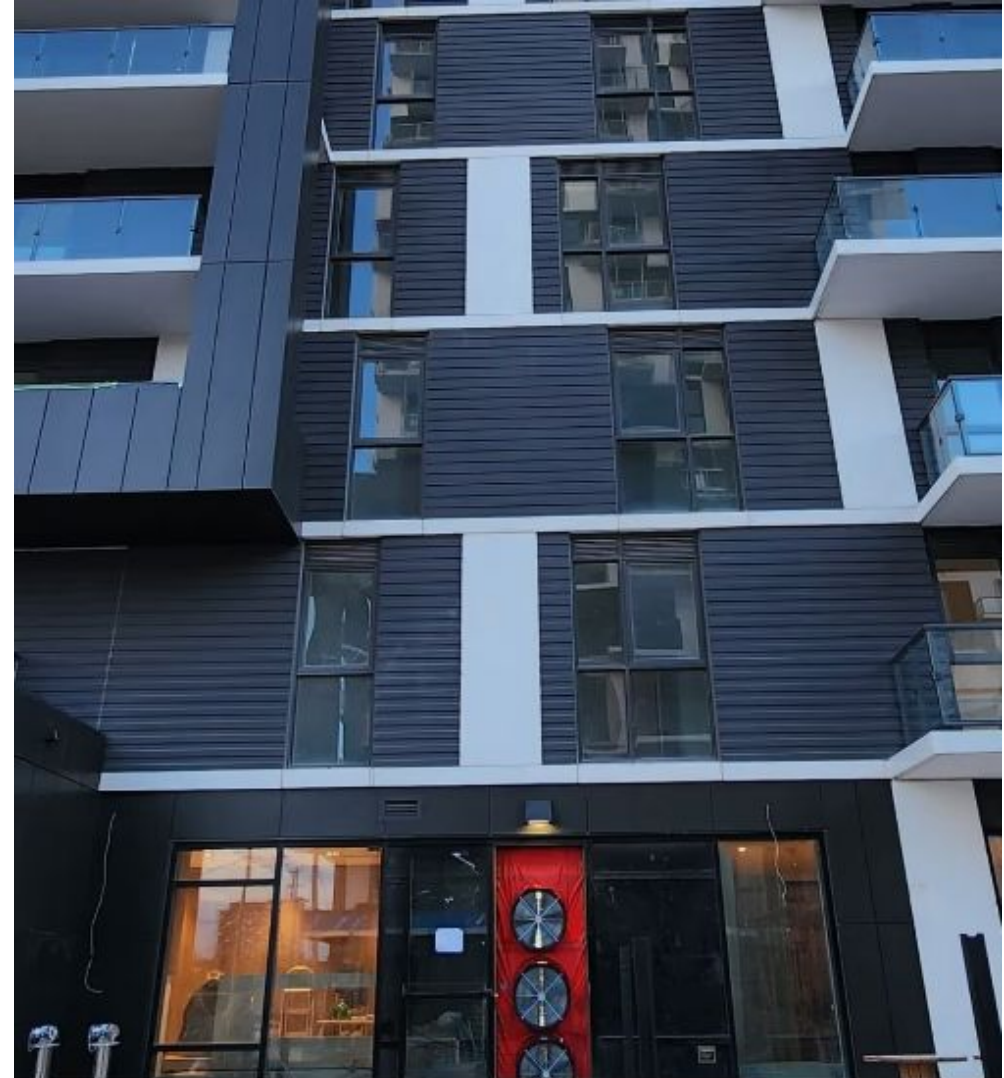
The label shows your home's Greenhouse Gas Emissions

Large building Air Tightness Testing

Reduces the need for costly adjustments during building construction

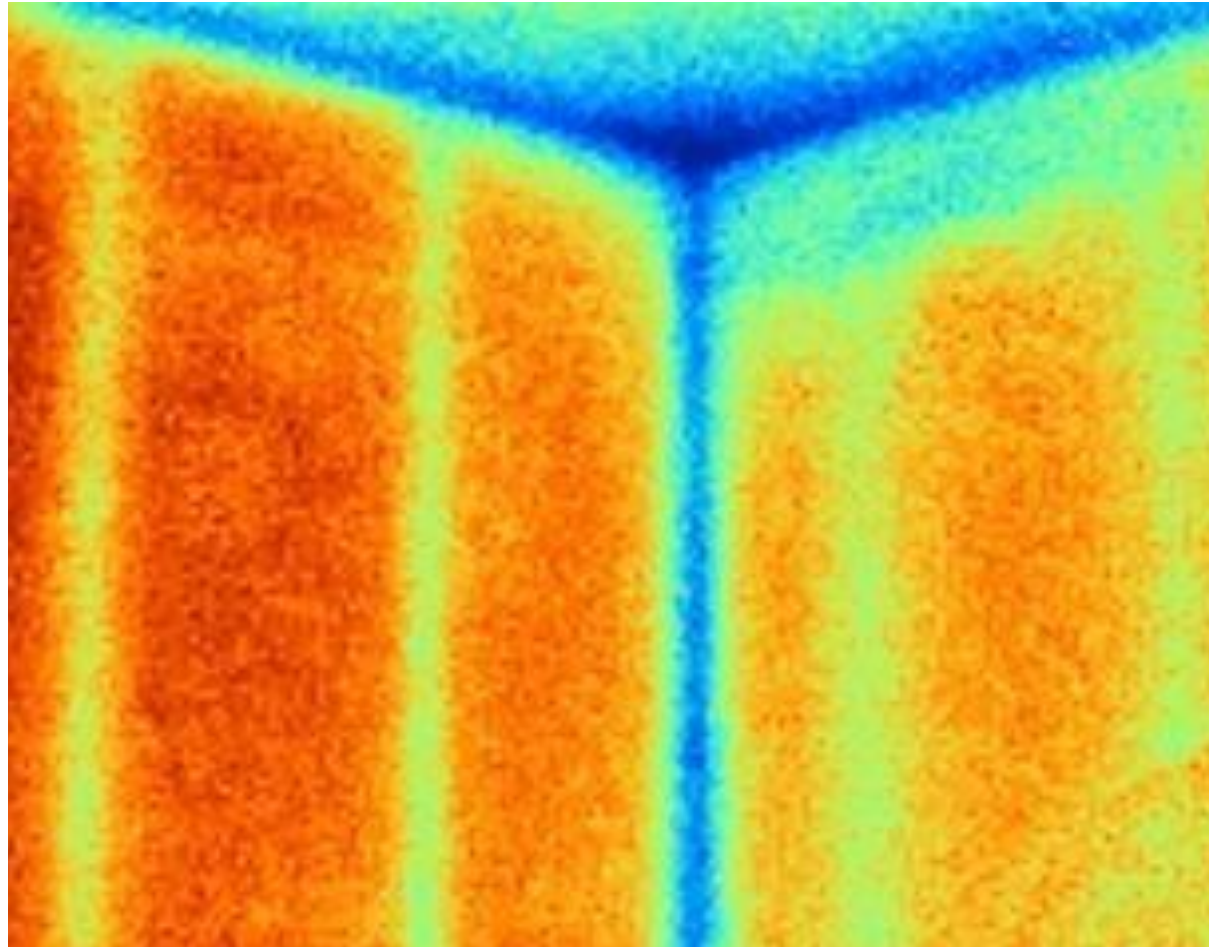
Commonly required for low carbon, near-zero, compliance with building energy codes such as the 2020 NECB or Municipal Green Development Standards

Across Canada, many provincial building codes will soon require air tightness testing of large buildings before occupancy



Thermal Bridging

Thermal Bridges

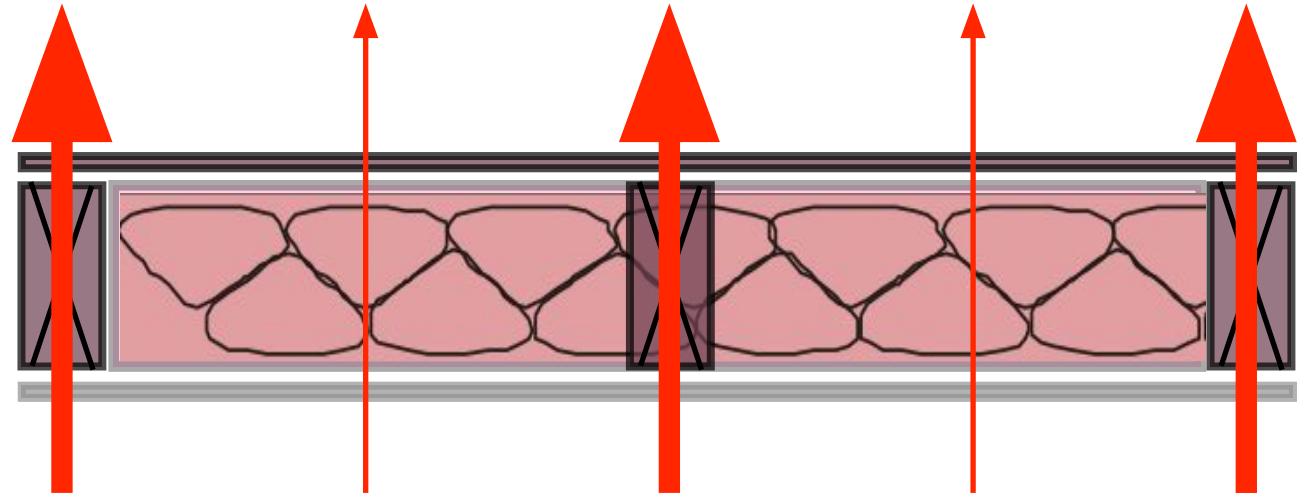


Thermal Bridging – Problem

Heat flows via conduction more easily through wood studs

2" x 6" stud = R-5.5

Insulated cavity = R-20

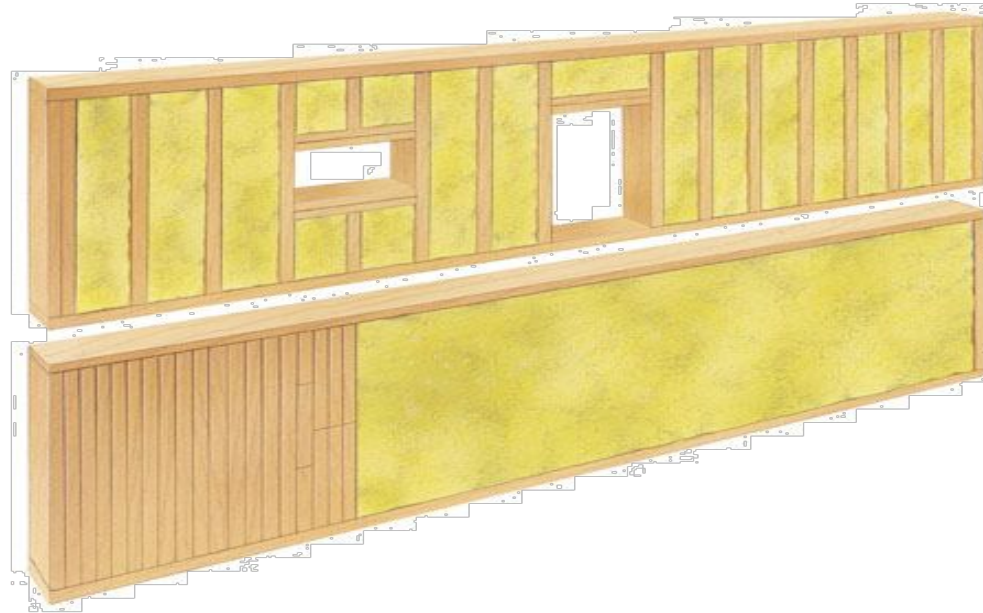


What about... double, triple studs, rim joists, headers and partition wall intersections?

Thermal Bridging – Stud Loss

- Without insulated sheathing, a quarter of your walls are not insulated!
- On a square house, it's equivalent to one whole wall!

**25% of the
surface area
is wood!**



**An emphasis on Total Effective
R-Value**

Effective R-Value of 2x6 Wall – No Windows or Doors

23% framing-no windows	R-Value	
	Cavity	Studs
Outside air film	0.17	0.17
½” OSB	0.62	0.62
2 x 6 stud-wood	n/a	5.5
cavity insulation*	20	n/a
½” gypsum	0.45	0.45
Interior air film	0.68	0.68
Totals	21.92	7.42
Total Effective R-Value	15.26	

Reference: ENERGY STAR Tables for Calculating Effective Thermal Resistance of Opaque Assemblies

*Denotes “perfect” insulation installation

Remember this number

There are 3 Ways to Reduce Conduction Heat Flow



Increase cavity insulation



Reduce thermal bridges
- Reduce framing



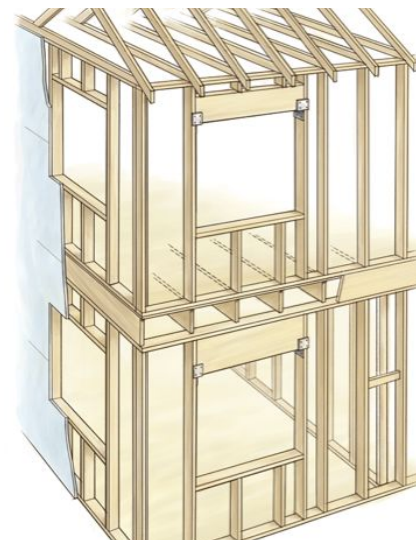
Add continuous insulation

2x6 Wall with High Density Foam Cavity Insulation

23% framing	R-Value	
	Cavity	Studs
Outside air film	0.17	0.17
Cladding/Siding	0.62	0.62
Exterior insulation	0	0
1/2" OSB	0.62	0.62
2 x 6 stud-wood	n/a	5.83
cavity insulation*	35	n/a
1/2" gypsum	0.45	0.45
Interior air film	0.68	0.68
Totals	37.54	8.37
Total Effective R-Value	18.81	

3 Ways to Improve Effective R-Values

- More cavity insulation
- **Advanced / Optimized framing**
- Continuous insulation



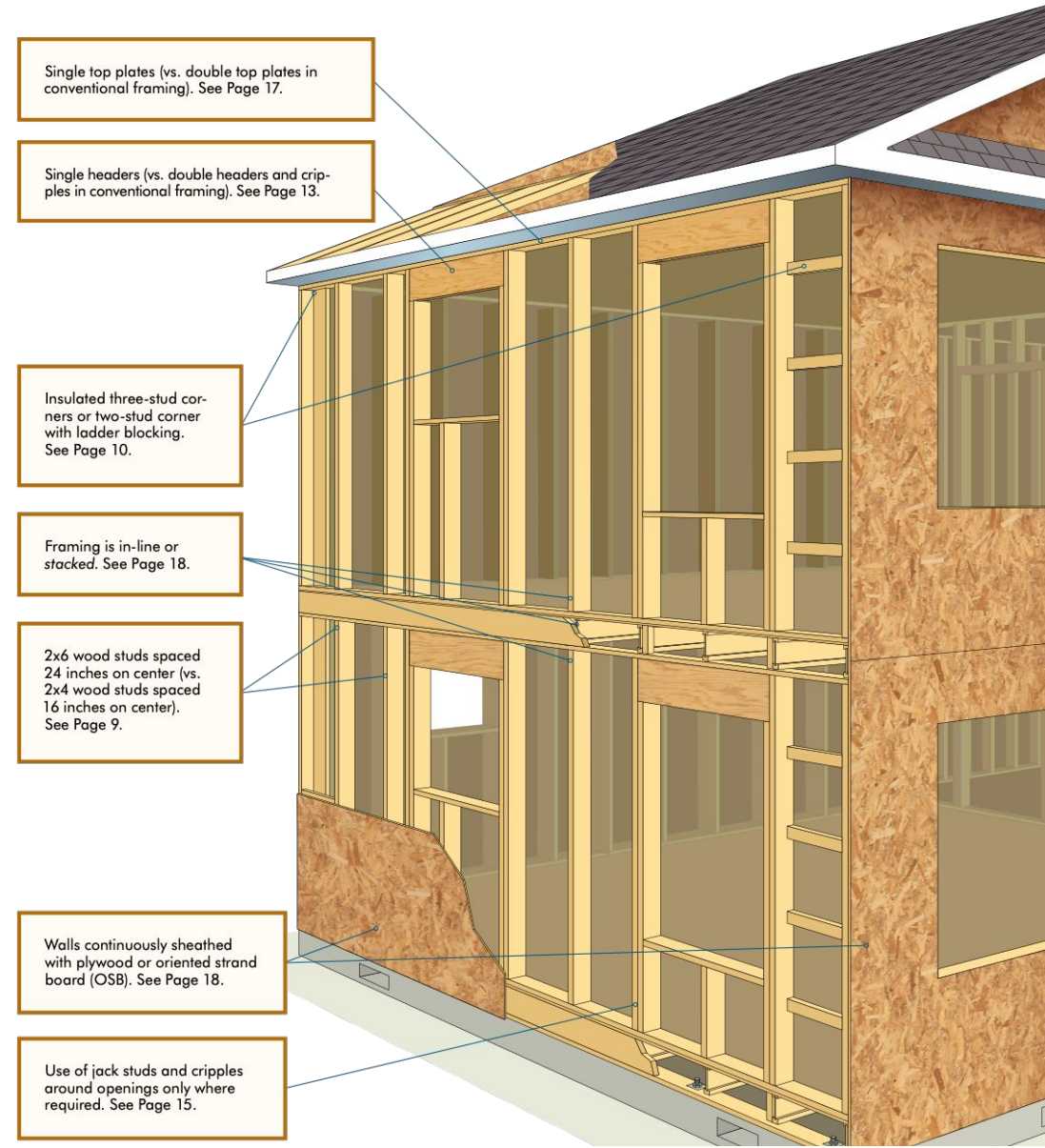
Advanced Framing

Elements:

- Two stud corners
- Ladder framing
- Wider stud spacings
- Properly sized headers
- Single top plates

COMPONENTS OF ADVANCED FRAMING

Houses constructed with advanced framing techniques may include some or all of the following details:

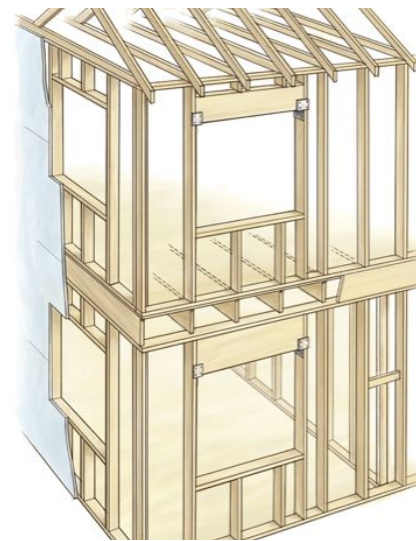


2x6 Wall with “Advanced” Framing

19% framing	R-Value	
Outside air film	0.17	0.17
	0.62	0.62
Exterior insulation	0	0
	0.62	0.62
2 x 6 stud-wood	n/a	5.83
	20	n/a
½” gypsum	0.45	0.45
	0.68	0.68
Totals	22.54	8.37
	16.22	

3 Ways to Improve Effective R-Values

- More cavity insulation
- Advanced / Optimized framing
- **Continuous insulation**



2x4 R13 Wall + R5 Continuous Exterior Insulation

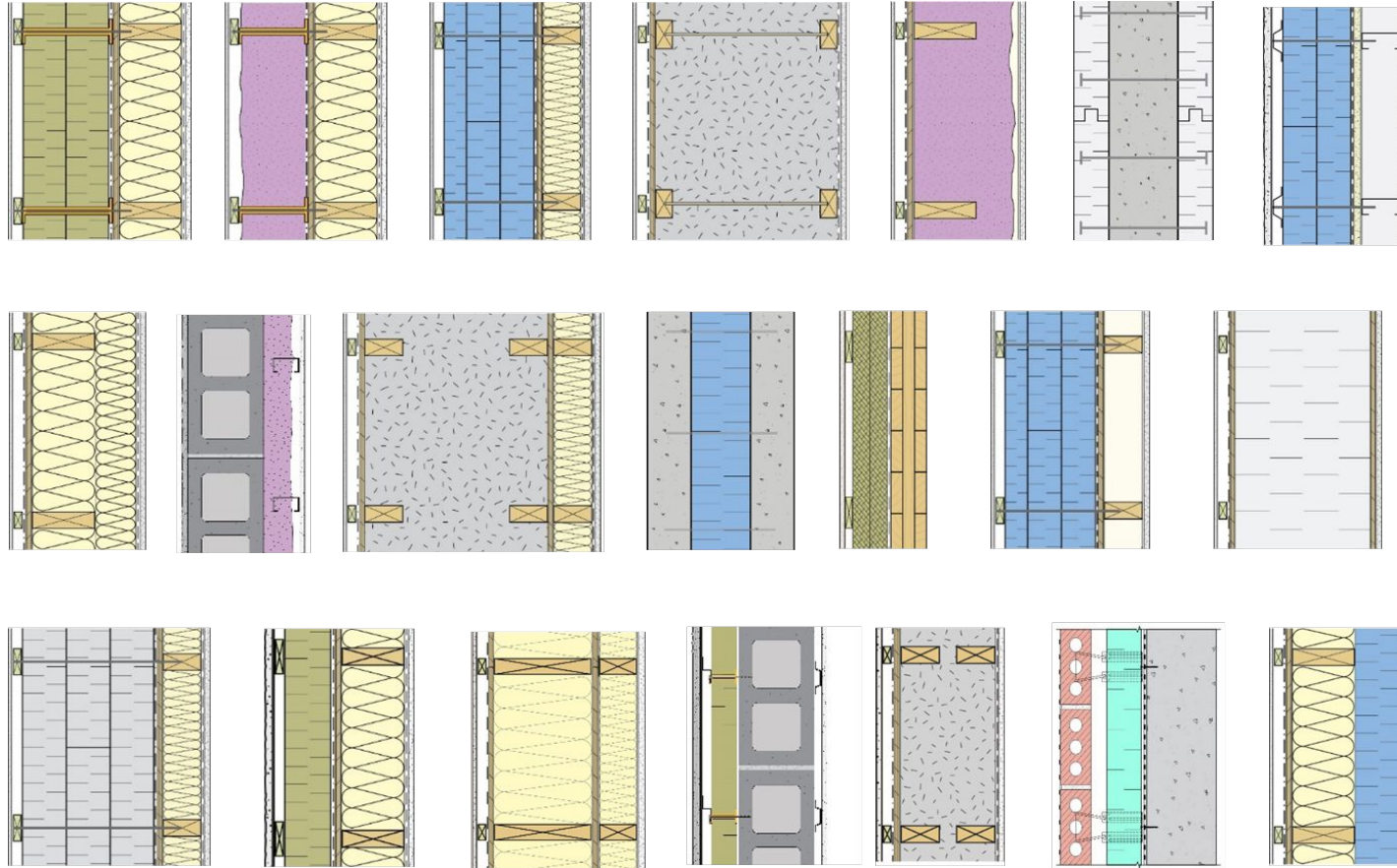
23% framing	R-Value	
Outside air film	0.17	0.17
	0.62	0.62
Exterior insulation	5	5
	0.62	0.62
2 x 4 stud-wood	n/a	3.71
	13	n/a
½" gypsum	0.45	0.45
	0.68	0.68
Totals	20.54	11.25
	15.79	

2x6 Wall + R5 Continuous Exterior Insulation

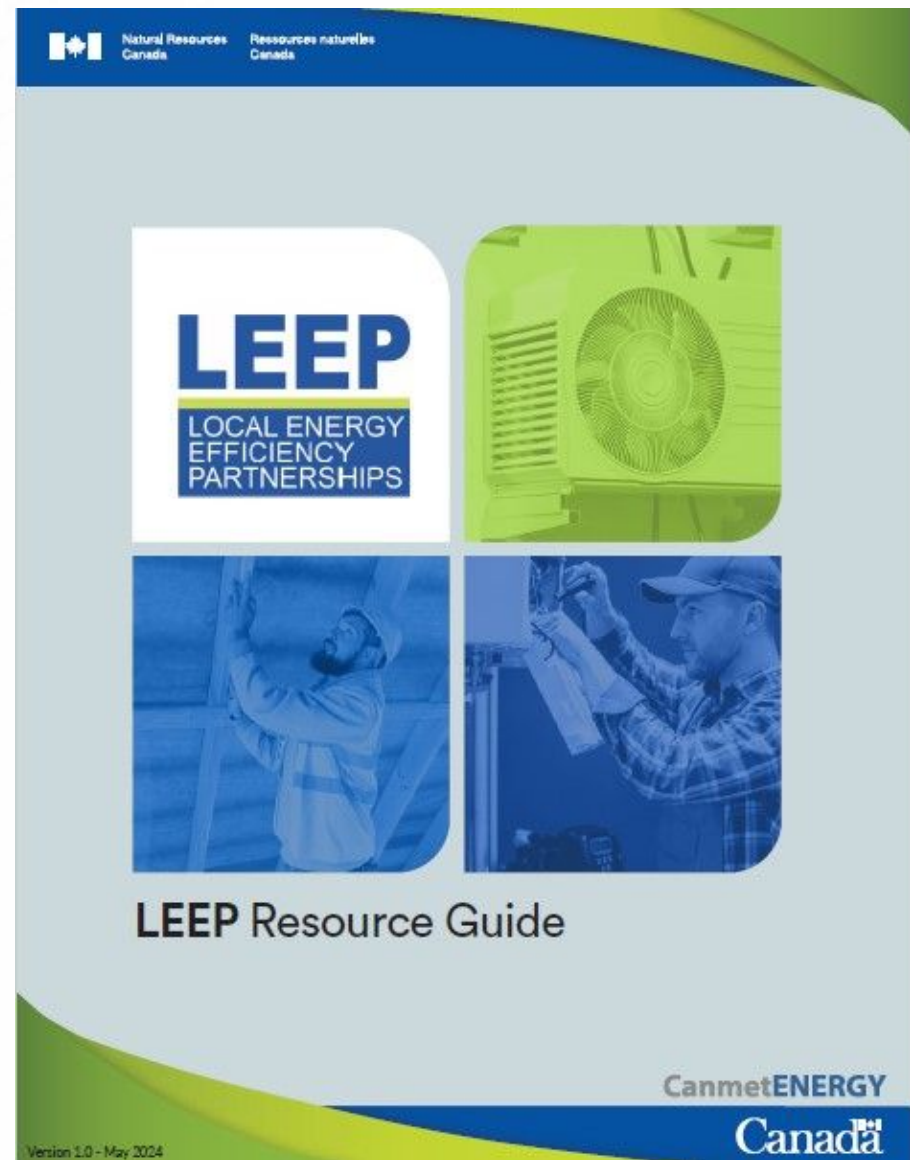
23% framing	R-Value	
Outside air film	0.17	0.17
	0.62	0.62
Exterior insulation	5	5
	0.62	0.62
2 x 6 stud-wood	n/a	5.83
	20	n/a
1/2" gypsum	0.45	0.45
	0.68	0.68
Totals	27.54	13.37
	20.37	

Insulation Systems and Options

There are many ways to do it!



Ref: LEEP
Technical Training:
Net Zero energy
Wall Assemblies



LEEP NZE Wall Guides (7 Documents)

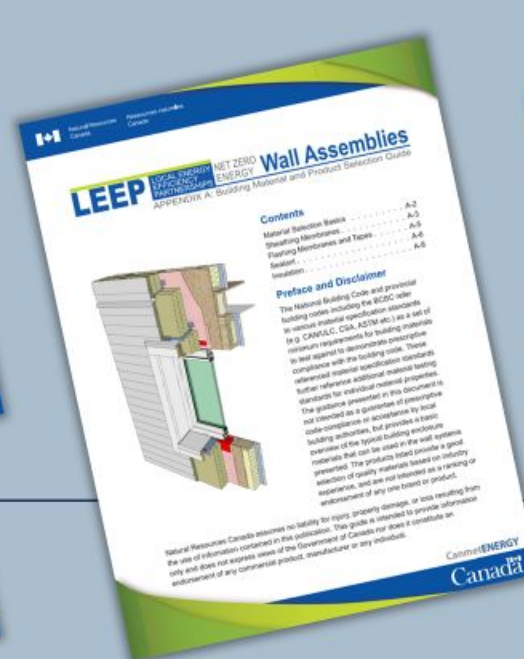
Free Download. Search: "LEEP Technology Guides and Tools"



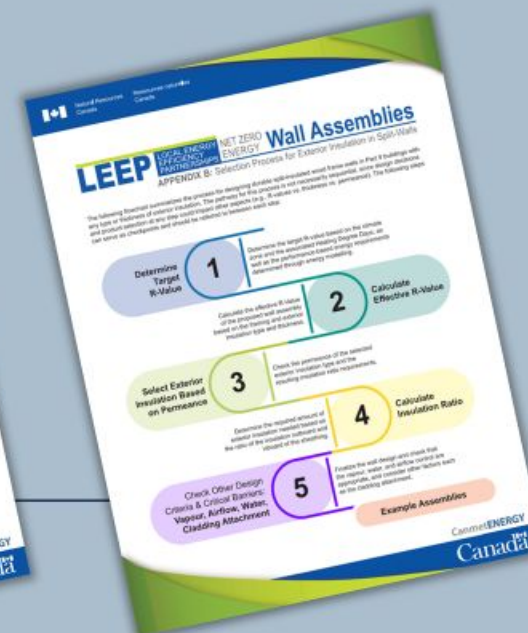
Intro and Wall
Selection Guide



4 NZE Wall
Assembly Guides



Appendix A
Material Selection



Appendix B
Exterior Insulation
Selection



Business as
Usual
R17 effective



Exterior Mineral
Wool
R26 effective



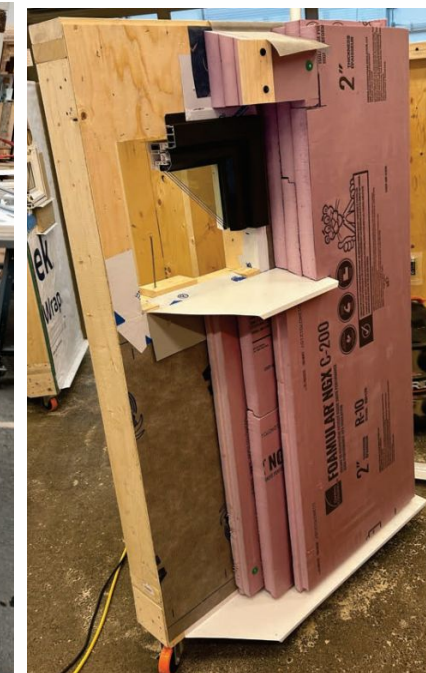
Fire Resistant
R27 effective



Double Sud
R32 effective



Laresen Truss
R37 effective



Exterior foam
R46 effective

Demonstration Walls

- Business As Usual
- Double Stud
- Exterior Mineral Wool
- Larsen Truss – retrofit
- Wild Fire Resistant
- Exterior XPS

Bonus wall
BTTR board (not part of SAIT S

ENBIX Wall Library – Larsen Truss Retrofit

Summary

The "Larsen Truss Retrofit" assembly provides a net-zero solution for retrofits. This assembly was approached as if there was only an exterior retrofit being performed on an existing home renovation from the mid-twentieth century, and can be closely compared to constructing the "Fire Resistant Retrofit" assembly, except with an 8" dense pack cellulose cavity insulation instead of exterior insulation strapped.

This [video](#) highlights the key features of the assembly.

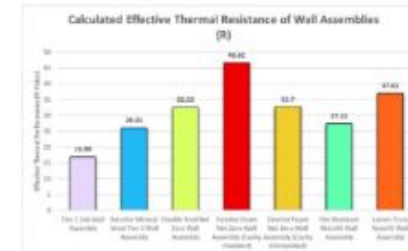
Advantages:

- Using a more affordable WRB/Air control membrane resulted in cost savings.
- Most materials were able to be found at a common hardware or building supply store.
- The Larsen Truss can be as thin or thick as needed, allowing for more, or less insulation.
- Retrofitting an existing home saves waste and new construction costs.

Disadvantages:

- Dense pack cellulose requires installation by a certified installer.
- Installing the flangeless window was more difficult for this mockup than the flanged windows for the other assemblies.
- Utilizing a liquid applied membrane required a drying time before the next steps could be completed.
- It may be difficult to find tradespeople who can or are willing to install this type of assembly in a residential setting.

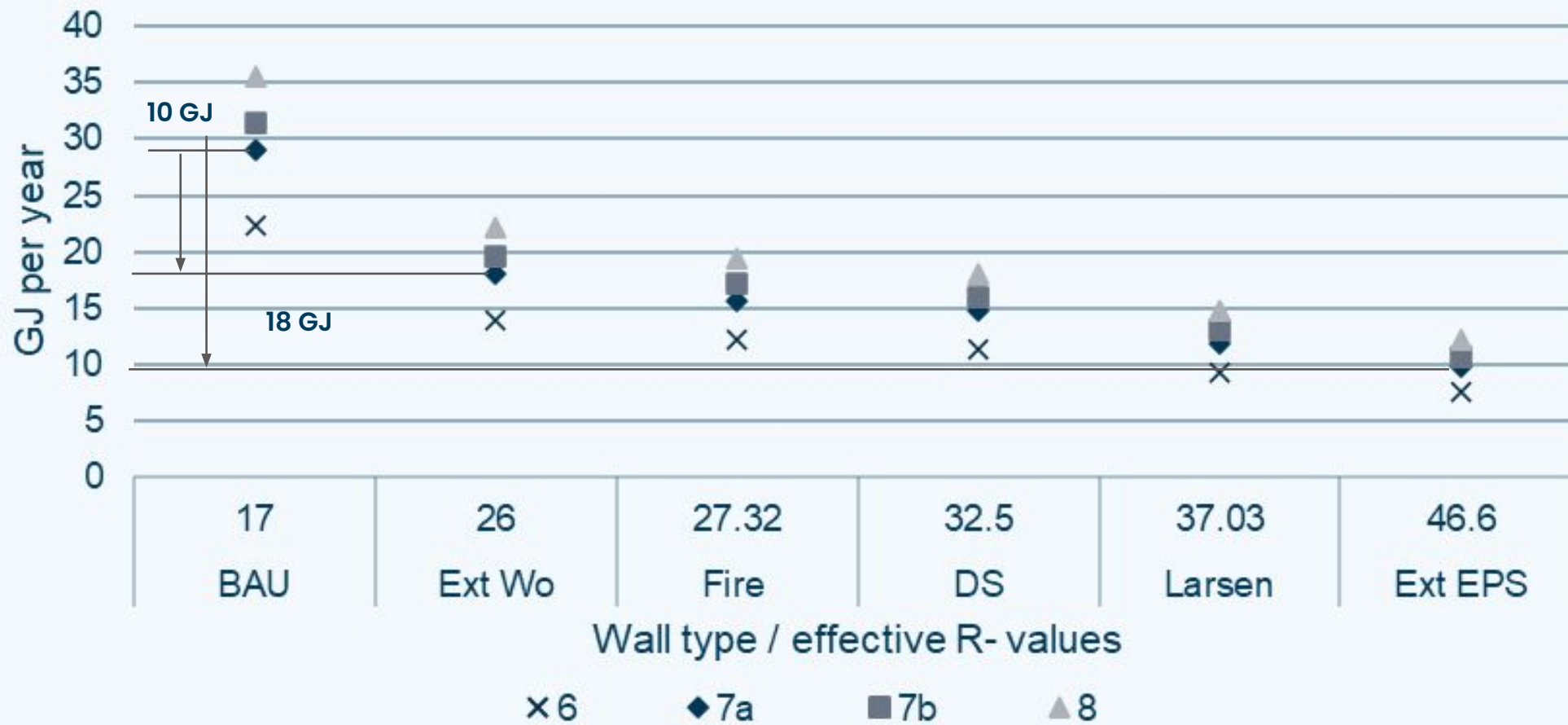
Figure 1: Calculated Effective Thermal Resistance of Wall Assemblies (R)



[Direct Link](#)

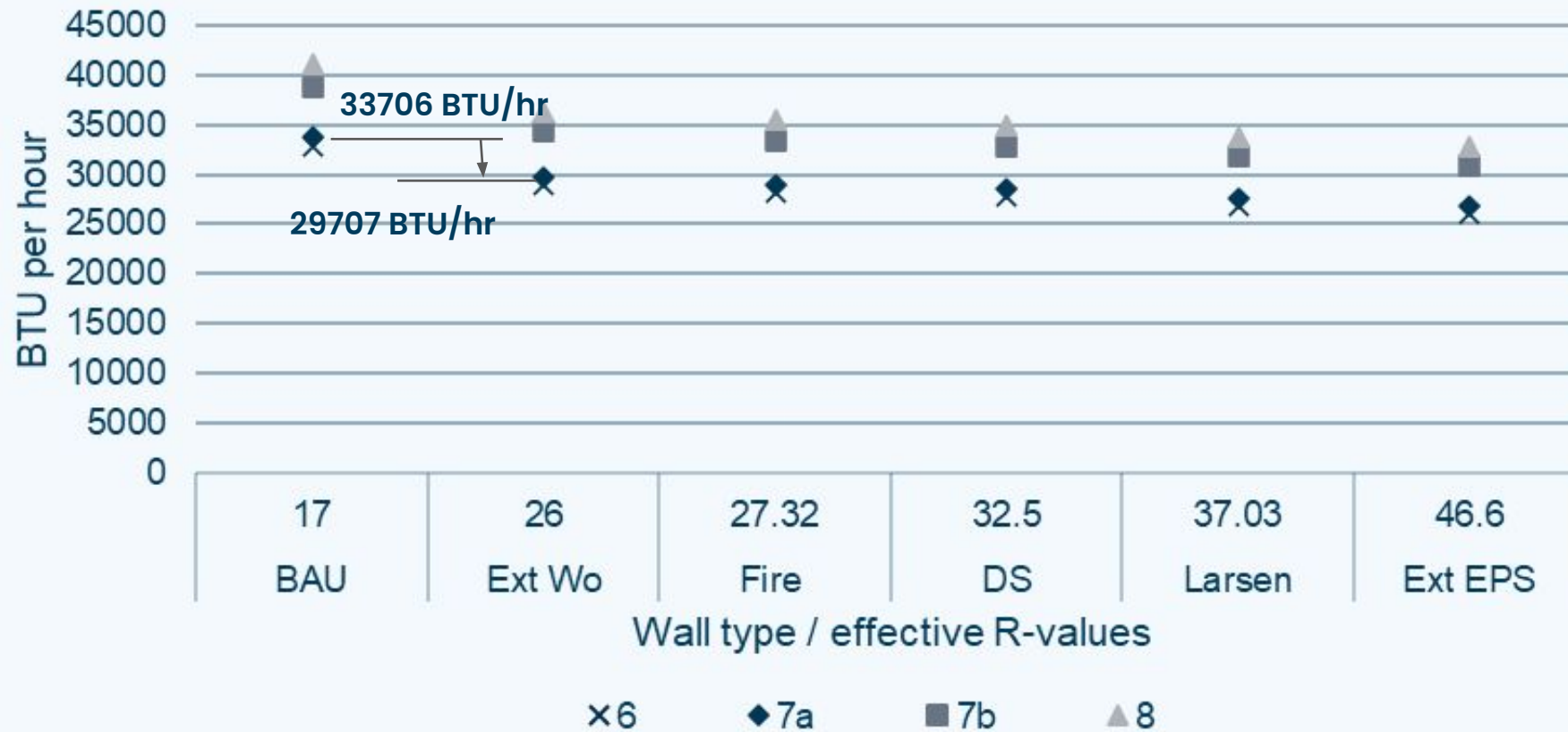


Main Wall Heat Loss (GJ/y)



Main wall heat loss shows the impact of improving the insulation alone.

Design Heat Loss (BTU/hr)



Increasing the wall insulation results in a reduction of design heat loss , i.e., smaller HVAC systems. These walls were all modelled at 2.5 ACH50

Proper Insulation Selection Ensures:

- R-value (effective) is assured
- Reduced thermal bridging AND control of cold-spots / dew point
- Real R-values for HVAC calculations and load and equipment match
- Thermal comfort
- Sound reduction
- Energy savings



Decision Criteria for Exterior Insulation

- Type of insulation to be used
- Which trade will apply it
- Appropriate fasteners
- Impact on structural design
- How to integrate windows
- Impact on cladding attachment
- Impact on water management
- Impact on the drying potential of the assembly
- Fire resistance



Insulated Sheathing will Become Normal

Options:

- Expanded polystyrene foams
- Extruded polystyrene foams
- Polyisocyanurate foams
- Mineral wood semi-rigid panels
- Spray in place foam
- Composite materials
- Wood and straw fiber boards



Other Options for High Performance Walls

Structural Insulated Panels



Insulated Concrete Forms



Composite Panels

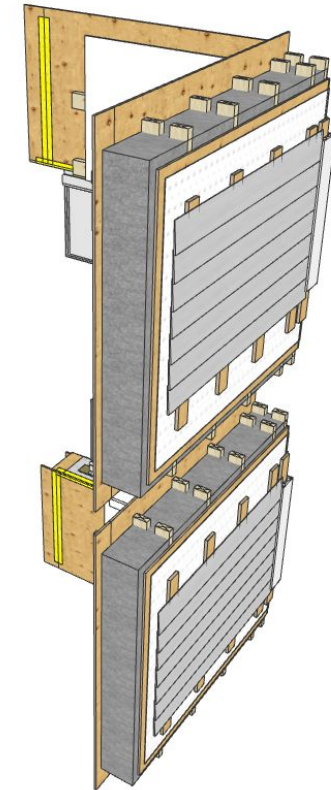
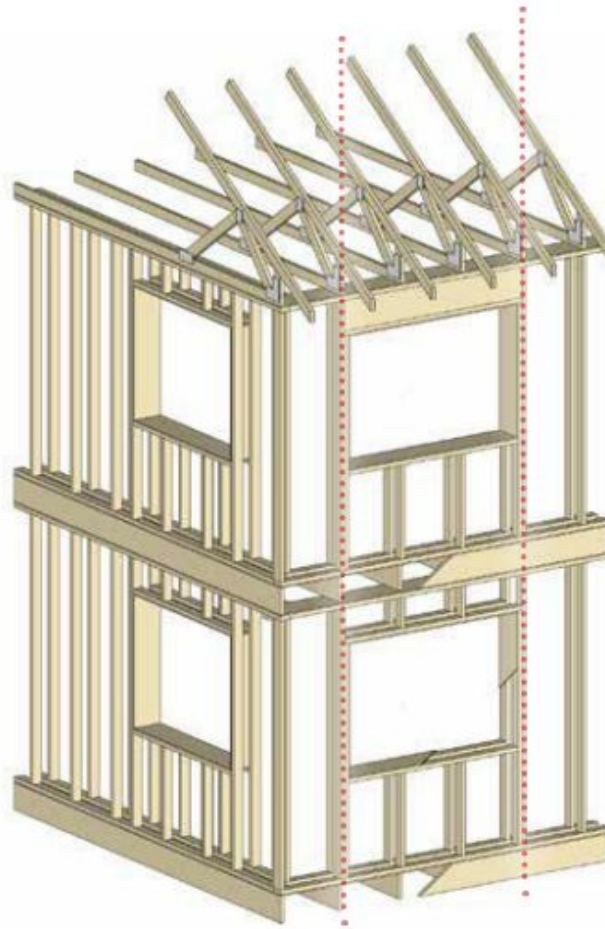


Advanced Wall Systems Improve Effective R-Values

Double Stud Walls

Double stud walls reduce the amount of thermal bridging and optimizes the use of insulation by creating a deeper wall cavity with more room for insulation

Enables you to locate air barrier outboard of your plumbing and electrical penetrations (ie. using a service cavity)



Reference: LEEP LOCAL ENERGY EFFICIENCY PARTNERSHIPS
NET ZERO ENERGY Wall Assembly #4

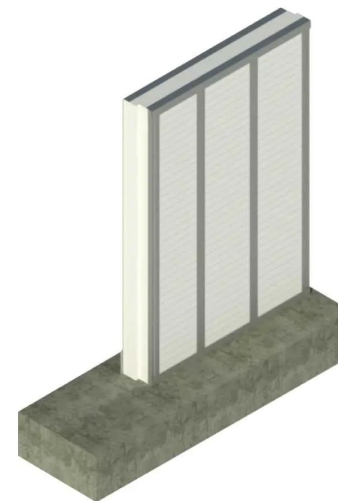
ICE Panels



Figure 3 - ICE panels during erection

Insulated Composite Envelope (ICE Panel) is an engineered combination of EPS and galvanized steel

This panel was designed to eliminate thermal bridging



Reference:
<https://gsbp.ca/what-are-ice-panels/>

Larsen Trusses



Larsen trusses are non-structural trusses attached to walls after a house is framed and sheathed

This creates a thick wall that can fit above average amounts of insulation

Insulation Concerns

Insulation

Careful installation of all insulating systems are essential for good performance



Walls

Poor installation affects comfort, performance and durability
Can reduce **effective R-value** of the entire wall by 15-30%



Walls

Compressions and voids reduce performance



SPF – Spray Polyurethane Foam

High Density (R6.0/inch)

Closed cell

AB and VB (see manufacturer info)

Low Density (R4.1/inch)

Open cell

AB (see manufacturer info)

Installation is critical:

Temp and RH

Surface dryness

“Lift” timing and cure rate



SPF – Spray Polyurethane Foam

Poor spray foam installation

Requires careful control of temperatures, humidity and chemical mix



Keeping Water Out of Wall Assemblies

#1 Goal: Keep water out of wall assembly

- Good eavestroughing and draining
- Cladding to keep bulk water off the wall (first line of defense)
- weather resistant barrier which allows water to drain away from the wall (second line of defense)
- Need proper flashing and detailing around penetrations (e.g. windows)
- Prevent capillary action (rain screen)

Drying Potential of Insulation

- Increasing levels of insulation reduces the available energy to dry enclosures (walls, roof, floors)
- We're most concerned about how well a wall can dry
- Low permeability exterior insulation can be used if the inboard/outboard insulation levels are appropriate
- Limiting air infiltration – making walls “tighter”; reduces potential moisture damage inside walls
- The predominant source of moisture in enclosures come from air leakage, not vapour diffusion

Inboard / Outboard Ratios

NBC 9.25.5.2

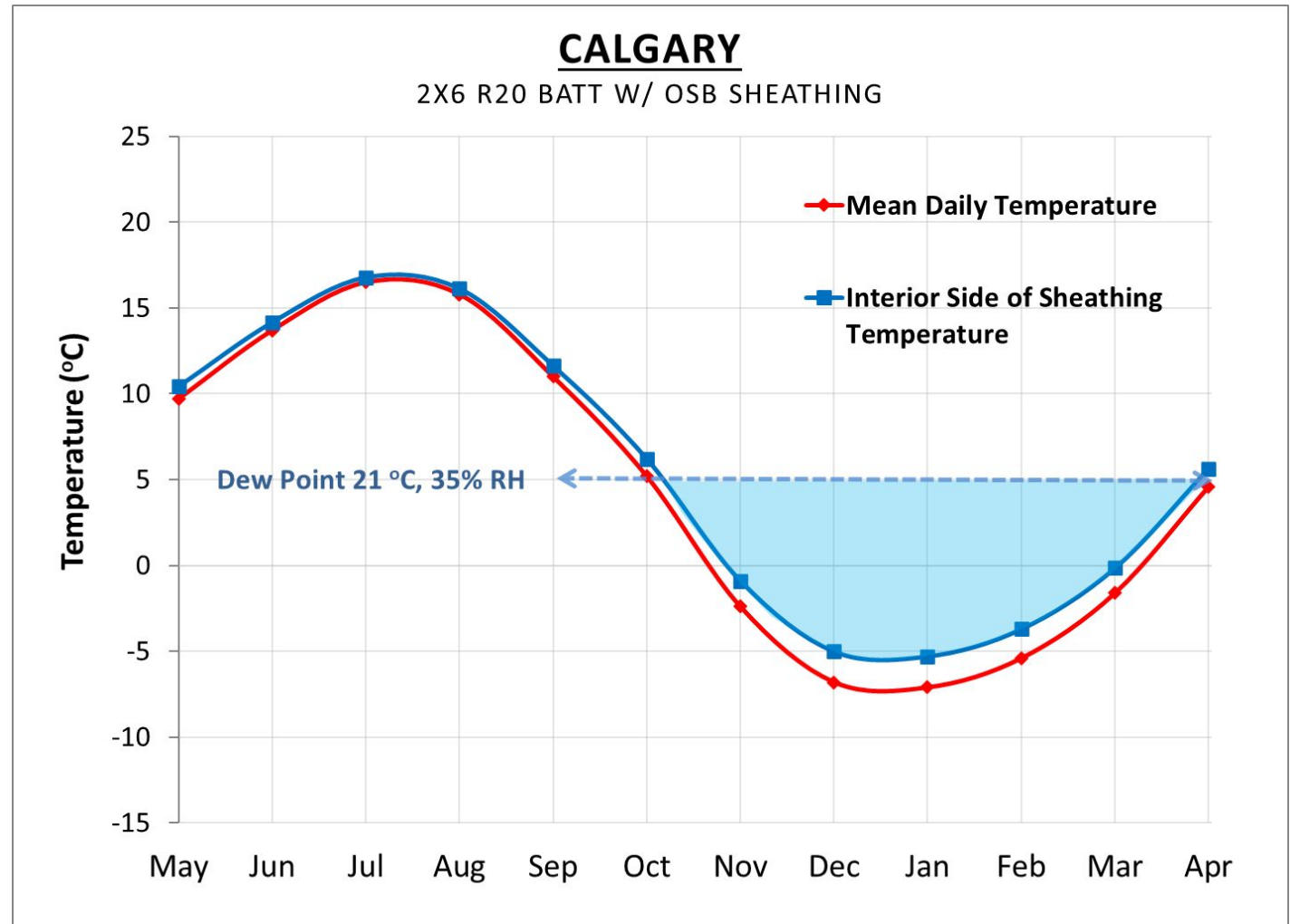
If exterior insulation products are classified as vapour barriers, then follow the appropriate regional IB/OB ratios as per the code

Heating Degree Days of <i>Building Location</i> ⁽¹⁾ , Celsius Degree-days	Minimum Ratio, Total Thermal Resistance Outboard of Material's Inner Surface to Total Thermal Resistance Inboard of Material's Inner Surface
up to 4 999	0.20
5 000 to 5 999	0.30
6 000 to 6 999	0.35
7 000 to 7 999	0.40
8 000 to 8 999	0.50
9 000 to 9 999	0.55
10 000 to 10 999	0.60
11 000 to 11 999	0.65
12 000 to 12 999	0.75

Dew Point

Condensation potential in walls

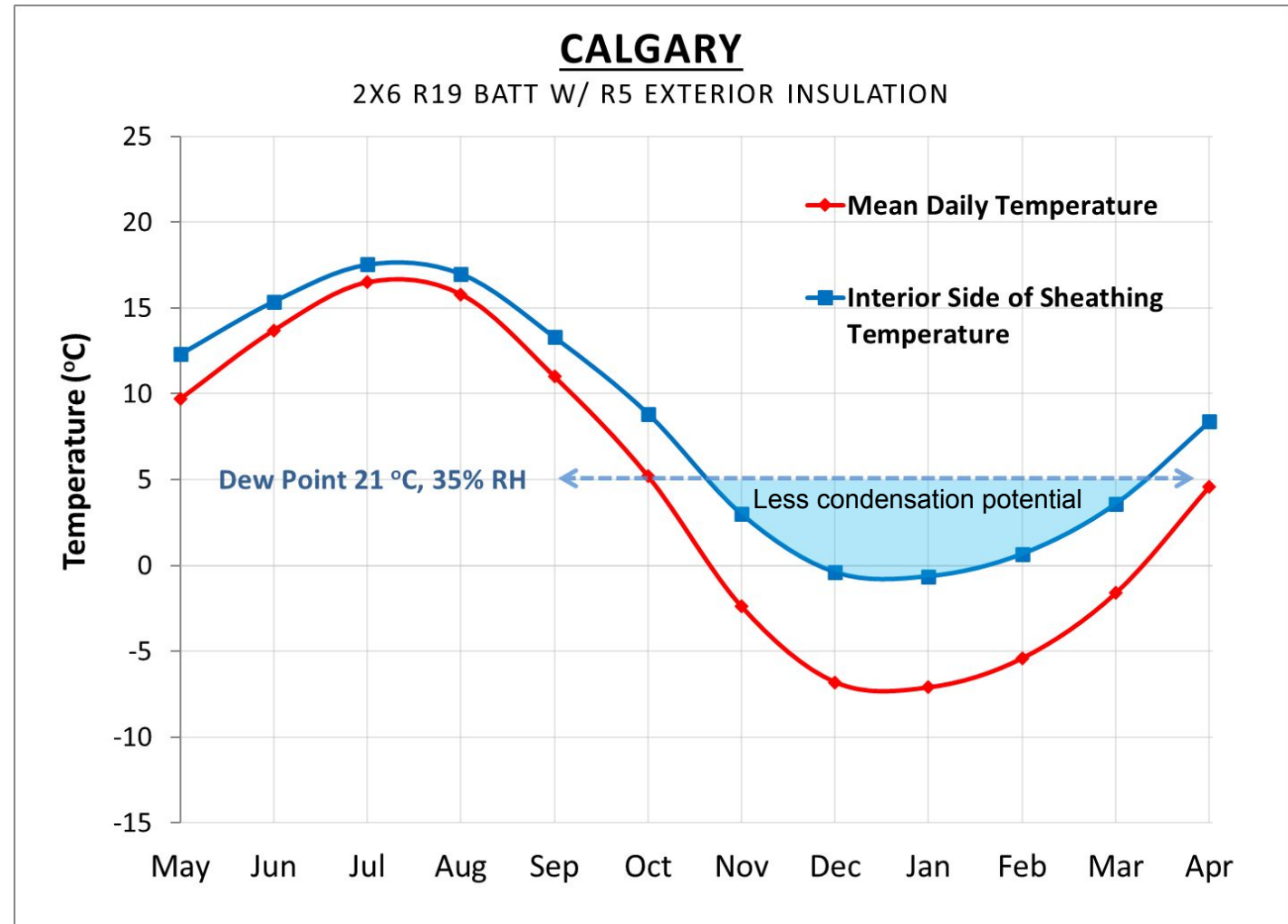
Example: 2x6 R20 wall, OSB sheathing



Dew Point

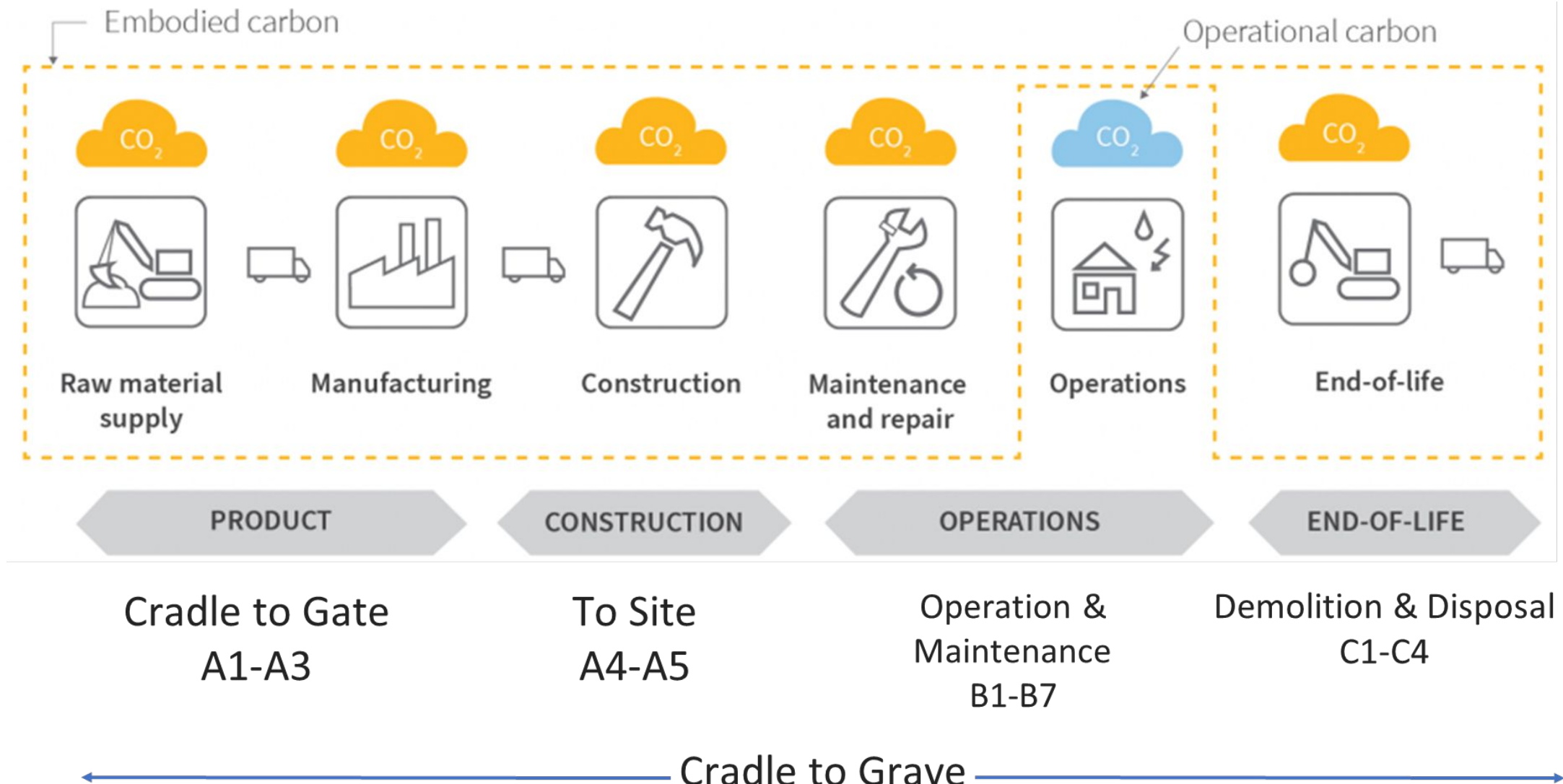
**Reduced
Condensation
potential in wall**

**Example: 2x6 R19 +
R5 continuous
insulation**



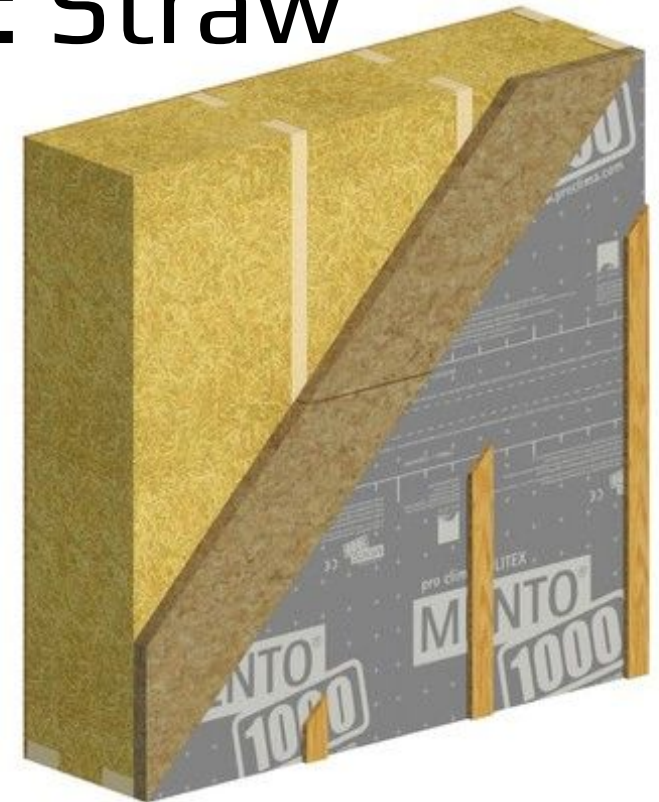
Embodied Carbon

Embodied Carbon



Sustainable Insulation Products: Straw

- Straw is a carbon storing material
- Products such as panelized straw walls and blown chopped straw walls have lower embodied carbon emissions



Example from BEAM Embodied Carbon calculator:

Reference: <https://www.savick.ca/panels>

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS kg CO ₂ e
COMPOSITE SIP PANELS						
	Straw Insulated Panels with wood framing (SIP) / EcoCocon / Prefabricated panel, 40 cm / R35 [EU]	100.0	m ²	100%	☐	-7,068

Sustainable Insulation Products: Wood Fibre Board

- Wood fiber board insulation is a carbon storing material



Reference: <https://wood100.ca/wood-fibre-insulation/>

Sustainable Insulation Products: Wood Fibre Board

Example from BEAM Embodied Carbon calculator:

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS kg CO ₂ e	GROSS EMISSIONS kg CO ₂ e	STORAGE Short Cycle kg CO ₂ 🖐️
WOOD FIBER BOARD								
	Wood fiber board / R 2.7-inch / NAFA [Industry Avg US & CA]	100.0	m ²	100%	☐	-1,817	1,873	3,690
	Wood fiber board / Pavatex / Pavatherm / R 3.3-inch / 110 kg/m3 [EU]	100.0	m ²	100%	☐	-269	1,104	1,373
	Wood fiber board / Steico / STEICOprotect S dry, STEICOsafe 40, STEICOuniversal dry / R 3.6-inch, 210 kg/m3 [EU]	100.0	m ²	100%	☐	-317	2,007	2,325
	Wood fiber board / Steico / STEICOprotect M dry, STEICOroof dry, STEICOspecial dry, STEICOtop / R 3.6-inch, 140 kg/m3 [EU]	100.0	m ²	100%	☐	-403	1,146	1,550
	Wood fiber board / Steico / STEICOtherm dry, STEICOprotect L dry, STEICOsafe / R 3.6-inch, 110 kg/m3 [EU]	100.0	m ²	100%	☐	-440	777	1,218
	Wood fiber board / Pavatex / Pavawall Smart, Pavawall Light, Pavawall FW / R 3.3-inch / 115 kg/m3 [EU]	100.0	m ²	100%	☐	-963	426	1,388
	Wood fiber board / GUTEX / Multi-Therm / R 3.6-inch, 40-200 mm [EU]	100.0	m ²	100%	☐	-1,000	546	1,546

Wood Fibre Board vs. Other Continuous Insulation Products

Example from BEAM Embodied Carbon calculator:

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS kg CO ₂ e	GROSS EMISSIONS kg CO ₂ e	STORAGE Short Cycle kg CO ₂ 🖐️
WOOD FIBER BOARD								
	Wood fiber board / R 2.7-inch / NAFA [Industry Avg US & CA]	100.0	m ²	100%	☐	-1,817	1,873	3,690
XPS FOAM BOARD								
	XPS foam board / R 5.0/inch [BEAM Avg US & CA]	100.0	m ²	100%	☐	962	962	0
	XPS foam board / Owens Corning / Foamular NGX CodeBord/C200 / R 5/inch, 20 psi	100.0	m ²	100%	☐	1,499	1,499	0
EPS FOAM BOARD								
	EPS foam board / Type II / R 4.0-inch, 15 psi / EPS Industry Alliance [Industry Avg US & CA]	100.0	m ²	100%	☐	604	604	0
MINERAL WOOL BOARD								
	Mineral wool board - heavy density / NAIMA / R 4.4-inch [Industry Avg N.America]	100.0	m ²	100%	☐	1,201	1,201	0

Considerations for Insulation Selection

- R-Value
- Cost
- Product Availability
- Moisture Management
- Embodied Carbon
- Constructability
- Trades' Knowledge
- Other Design Factors

Cost and MCE Comparison of Wall Cavity Insulation Options				
Wall Cavity Insulation	Type	R/inch	kgCO ₂ e for 10 m ² @ R10	Cost for 10 m ² @ R10
	Straw bale	3.3	-128	\$49.11
	Hempcrete	2.1	-76	\$213.15
	Hemp fiber batt	3.7	-31	\$96.33
	Wood fiber batt	3.8	-19	\$210.33
	Cellulose batt	3.6	-14	\$70.79
	Cellulose dense packed	3.7	-13	\$40.83
	Fiberglass batt	3.6	12	\$55.47
	Mineral wool batt	3.8	23	\$75.84
	Wool batt	3.6	23	\$133.93
	ccSPF with HFO blowing agent	6.6	73	\$11.73
	ccSPF with HFC blowing agent	6.6	232	\$10.66

Reference: Achieving Real Net-Zero Emission Homes Report, 2021 Natural Resources Canada & Builders for Climate Action

Below Grade Insulation

Foundation Types



Basement



Crawl Space



Slab-on-Grade

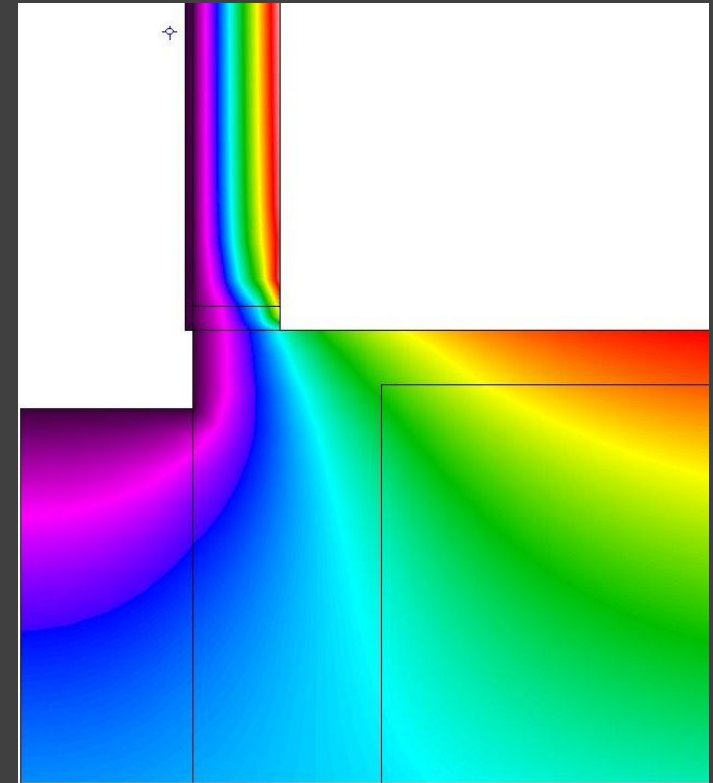
Below Grade Heat Flow is Complex

Below grade: Heat loss...Its weird down there.

- The ground is a **heat sink**
- Predominant **heat loss is at edge of slab OR at slab /foundation/footing interface**
- Ground temperatures (3'+) are ~ 4-5 months behind above grade temperature conditions e.g. May/June –foundation walls the coldest.

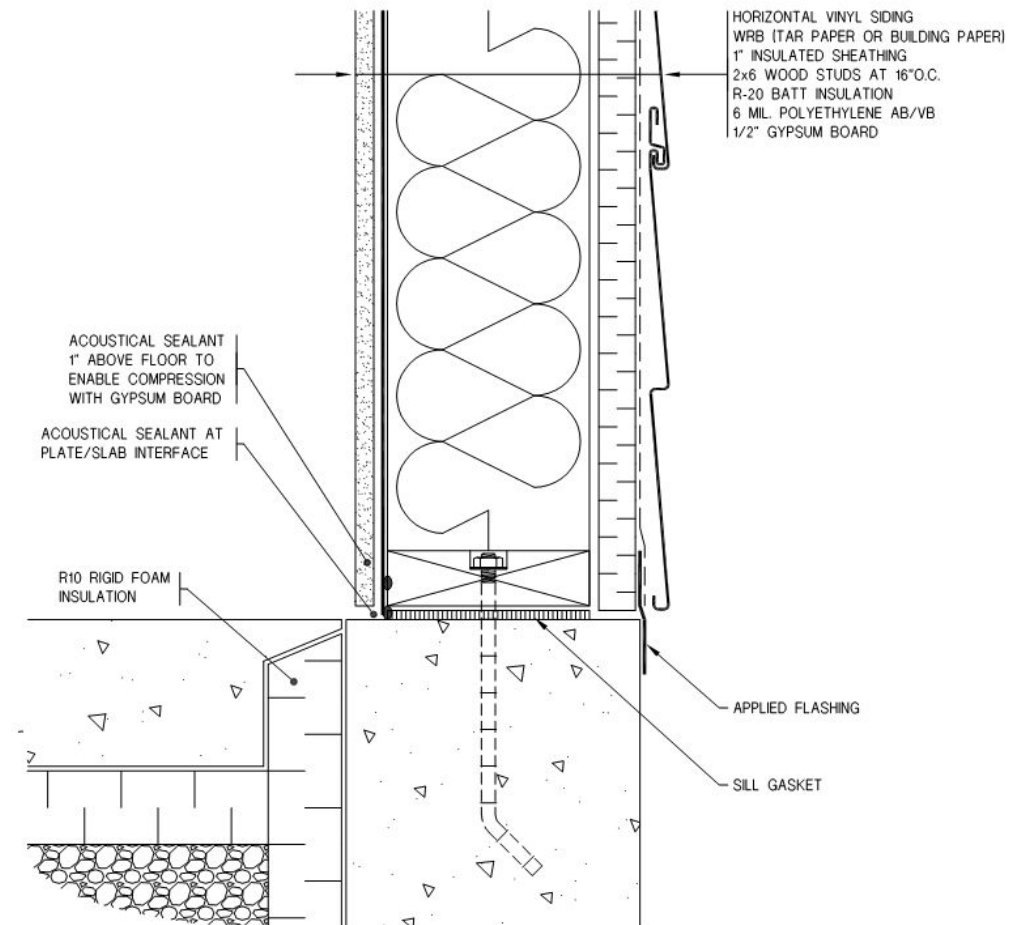
Heat loss below grade is a function of:

Depth of the foundation and the presence of water



Insulation Options for Slab-on-Grade

- Isolate the slab from soil and outdoor air temperatures with insulation
- Edge of slab should be insulated to levels equal to the exterior walls (or as high as possible)
- Foundation walls that support a slab or above-grade walls should be insulated from the exterior
- Place slab on 125 mm (5") bed of compacted gravel
- A poly moisture barrier must be installed beneath the slab



Below Grade Insulation Placement

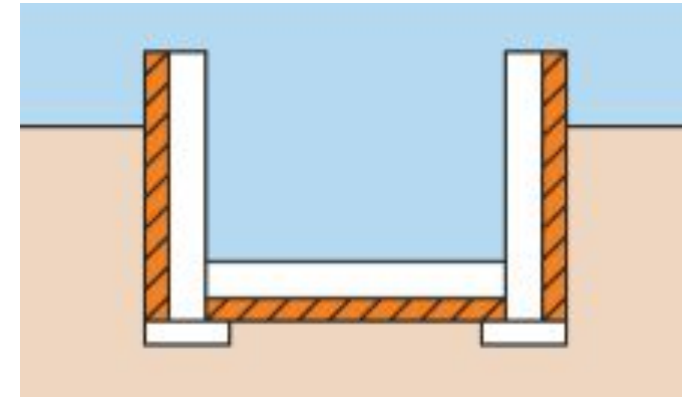
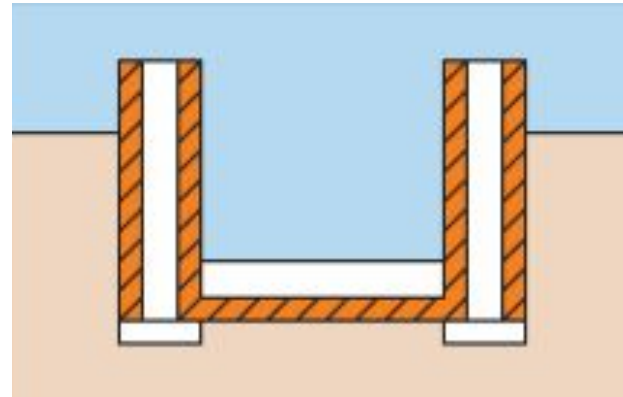
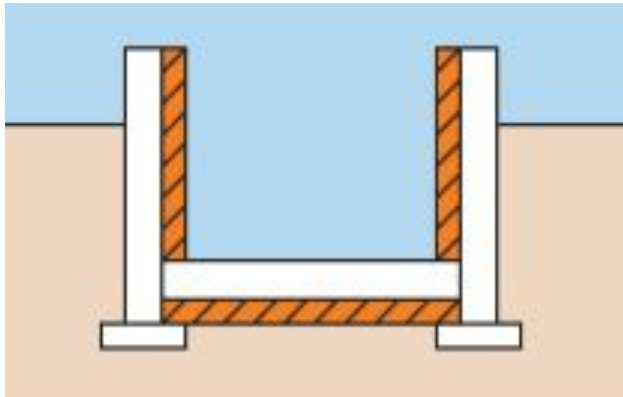
Examples:

Interior

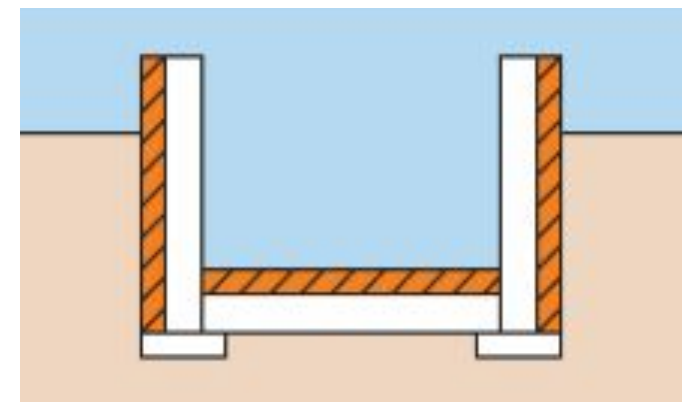
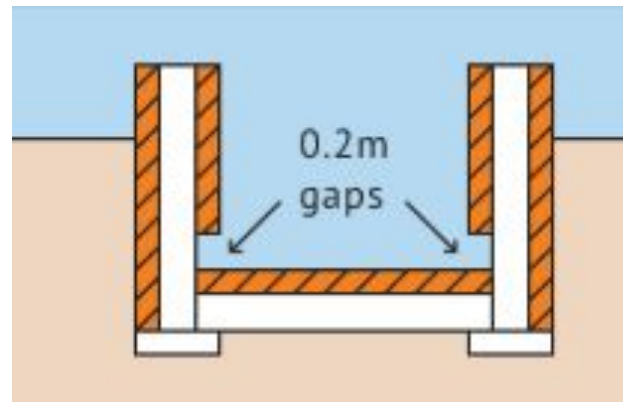
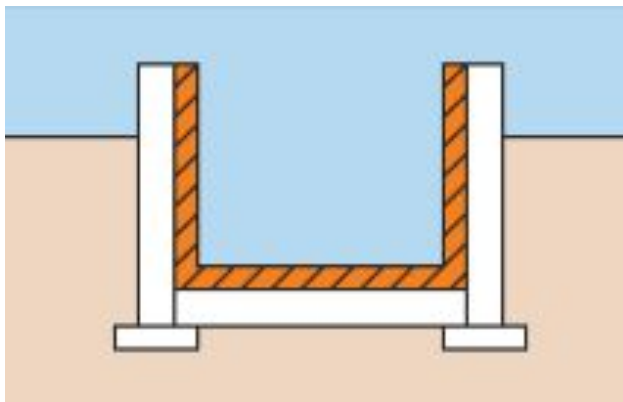
Combination

Exterior

Below
Slab



Above
Slab



Exterior Insulation is the “Ideal” Solution

- Thermal control / limit thermal bridging
- Acts as drainage and hydrostatic control (see manufacturer specifications)
- Can act as an air barrier
- Can act as a vapour control/throttle, mitigating rate of inward vapour drive
- Limits freeze-thaw cycle damage to concrete pore structure and durability
- Warms first condensing surface – condensation control
- Can act as part of radon barrier when continuous with under slab
- **Remember:** edge of slab thermal break



Exterior Insulation Below Grade

3 types of insulation are used on the exterior of basement walls:

- rigid mineral wool boards,
- high-density polystyrene (Type IV) *most common
- polyurethane/polyisocyanurate boards

Insulation with drainage capability, such as mineral wool board, must be used only if:

- It is applied to the full depth of the foundation wall.
- There is a drainage system.
- The insulation has no horizontal seams that break the drainage path.

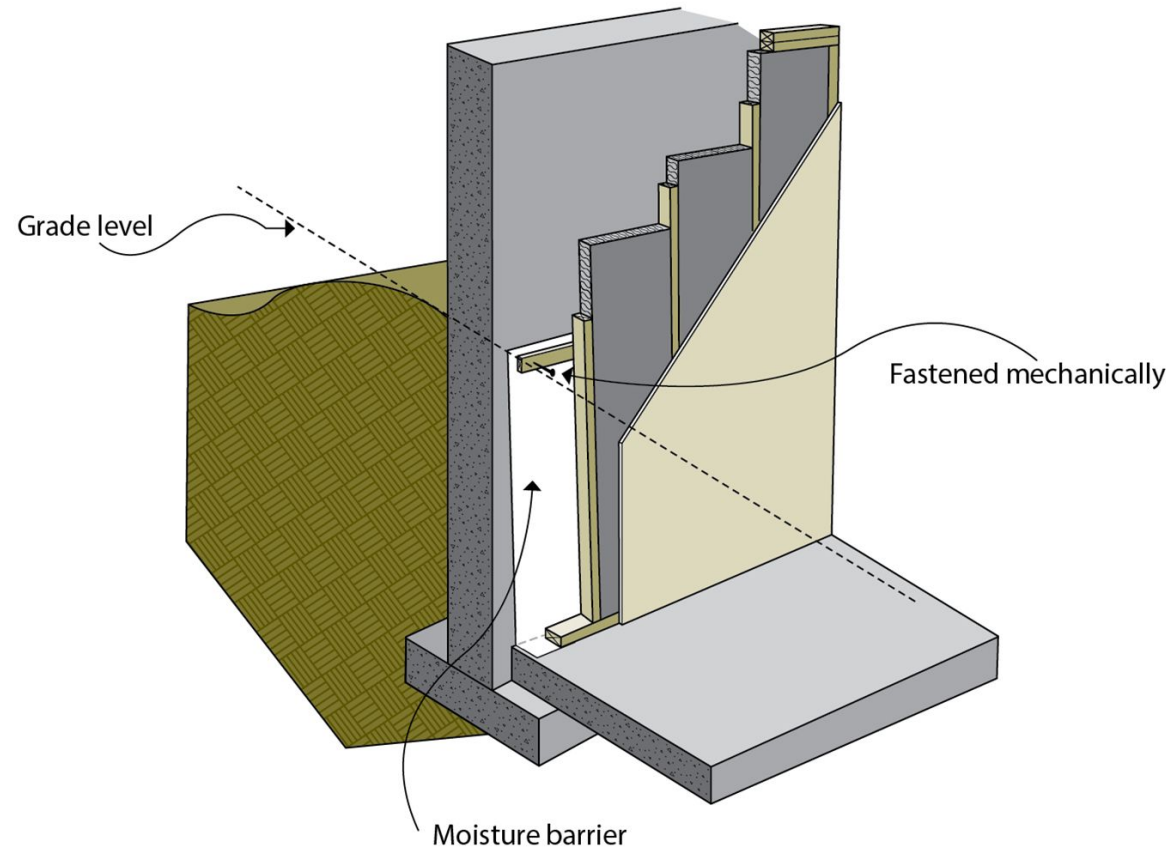
Impact on construction schedule:

- Outside wall tends to be more continuous and easier to insulate
- Need to dig a trench around the house. Excavation cannot be done in winter and can be a problem in the spring or throughout the year if the property has a high water table

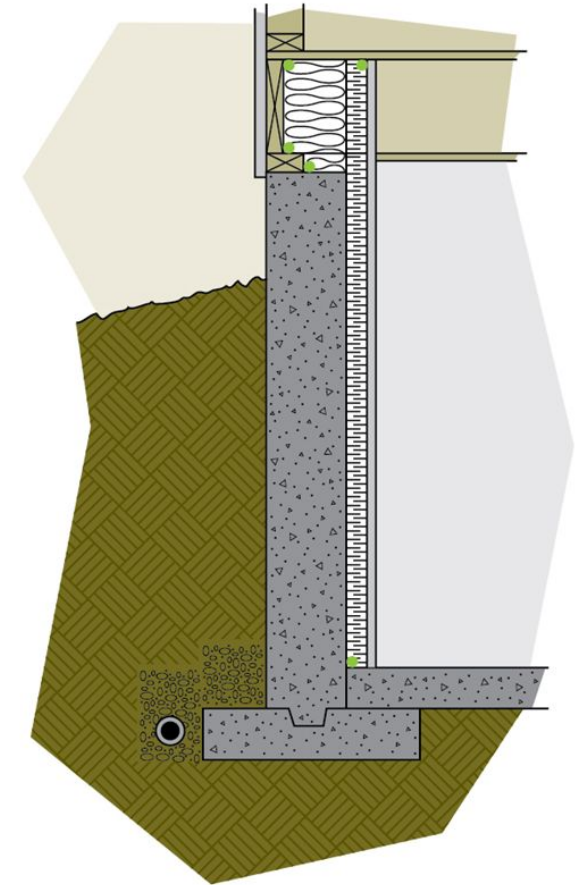


Interior insulation options below grade

Interior insulation is the most economical, but moisture management can be a challenge



Framed wall with cavity insulation



Rigid insulation

Other basements



Insulated Concrete Forms

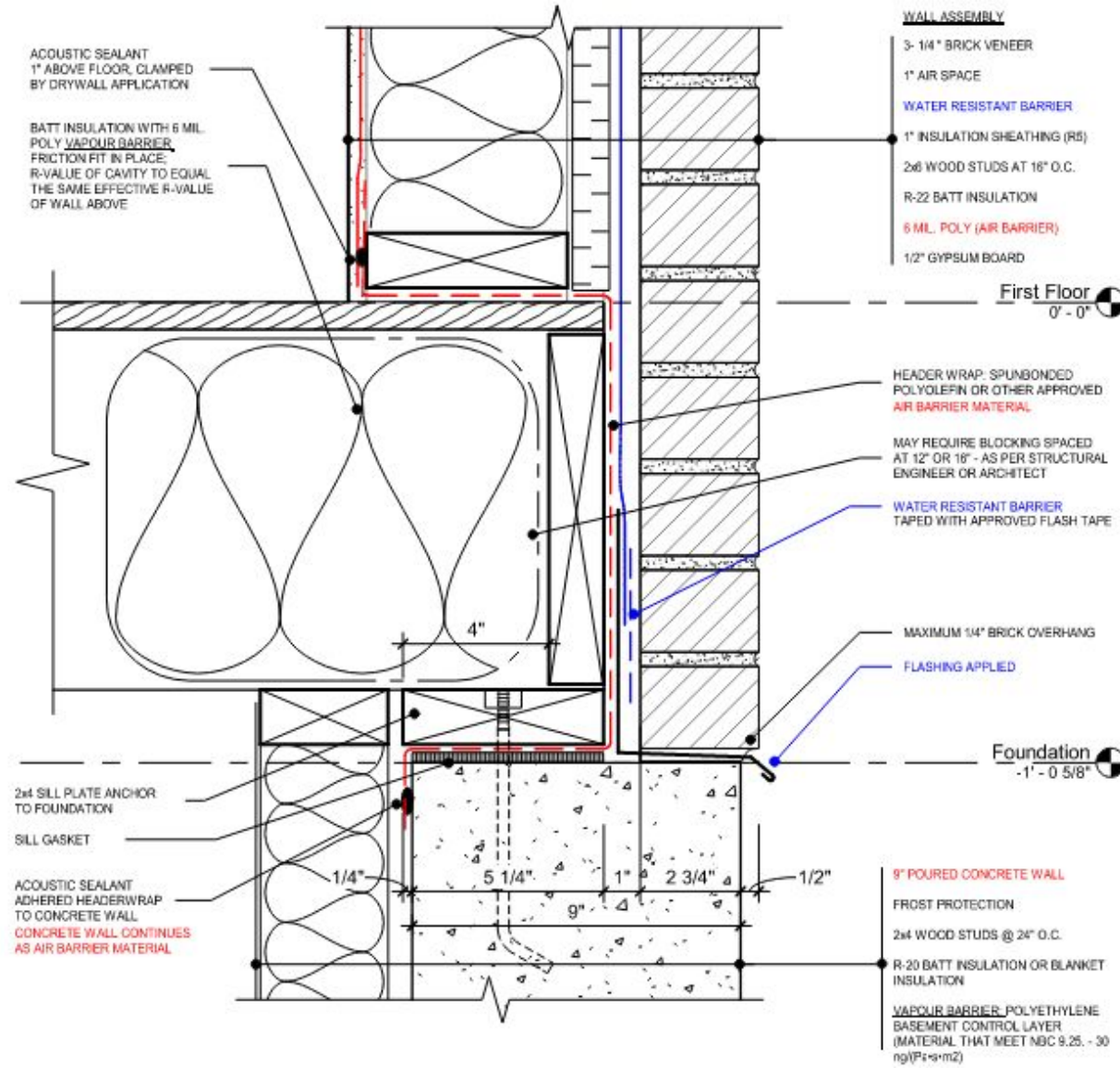


Preserved Wood

Reference: <https://drydirect.co.uk/how-to-waterproof-icf-walls-insulated-concrete-formwork/>

Reference: <https://cwc.ca/wp-content/uploads/2023/03/Permanent-Wood-Foundations-2023.pdf>

Header & Foundation Connection



Ensure the air barrier is **continuous** through the transition

Common details that are used:

- gaskets between concrete and frame,
- wrapping poly or building wrap,
- spray foam in cavity,
- etc.

Can we Make Basements Comfortable Living Spaces?

In cold climates:

- Below grade walls primarily **dry to the inside**
- Above grade walls primarily **dry to the outside**

Design Elements for Livable Basements

Basement design priorities in new homes:

1. Liquid water – rain or ground water
2. Soil dampness – wet and humid (water vapour diffusion)
3. Construction moisture
4. Air leakage (and soil gas)
5. Cool surfaces (and surface condensation control)
6. Space conditioning – humidity (and temperature) control

Managing Liquid Water Rain or Ground Water

- Drain the rain
- Drain the ground water
- Drain **everything**
- 5% slope away

During construction:

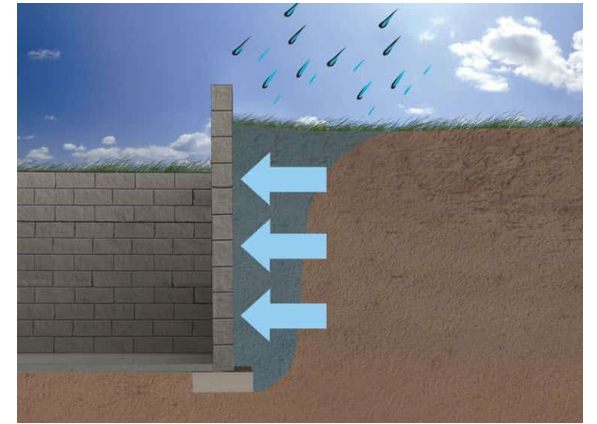
Keep water away from foundations



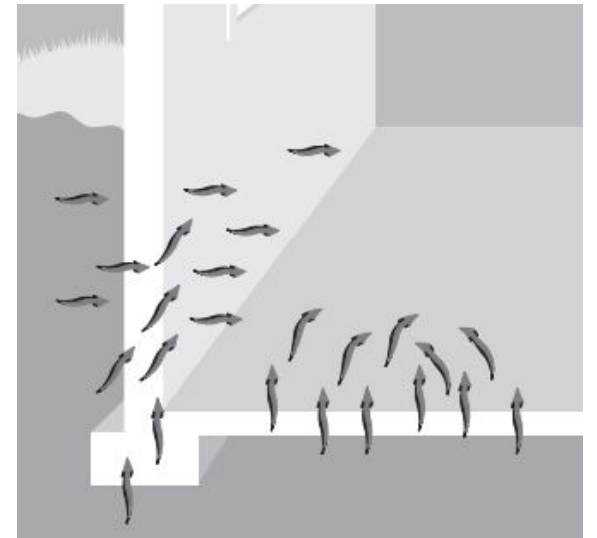
Reference: Massachusetts Home Inspections
<https://homeinspectionmassachusetts.com/know-your-home/wet-basements/>

How does liquid water enter?

- Hydrostatic pressure – liquid leaks through **holes**
- Capillarity – “sponge” action; concrete sucking up water through surface tension
- The leak equation:



Reference: <https://amshieldcorp.com/understanding-the-impact-of-hydrostatic-pressure-on-basements-and-foundations/>

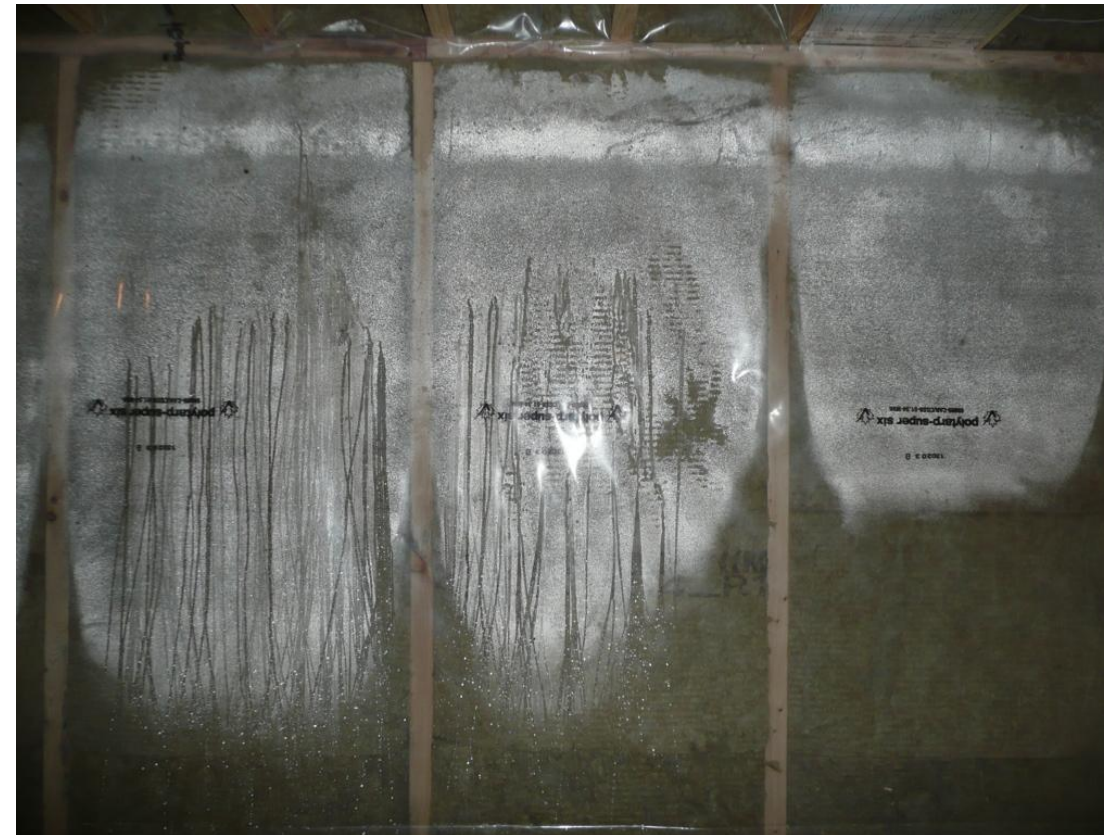


Reference: A GUIDE TO FIXING YOUR DAMP BASEMENT. CMHC

Wet and Humid: Water Vapour Diffusion to the Inside of the Basement

New concrete walls and slabs can hold 1000+ gallons of un-bound construction water.

This water will continue to dry as the structure cures and ages. Much of this drying is done through **inward vapour diffusion**



Wet and Humid: Water Vapour Diffusion to the Inside of the Basement

Inward vapour drive – inward drying

Only 2 options for controlling:

- 1) **Stop the vapour drive or throttle it back** (slow it down)
- 2) **Let it through** (allow water vapour to move freely into the basement)



Option 1: Throttle it Back with Low Perm Continuous Insulation

Use XPS (1" or more) as a vapour control / insulation layer against the concrete, with framing in front and no poly or membrane



Reference: <https://atimprovements.com/how-to-install-rigid-foam-insulation/>

Option 2: Let it Through

This can be done using a smart vapour retarder

Smart vapor retarders dynamically adjust their permeability to moisture

- act as a barrier in low-humidity winter conditions
- open up to allow drying in high-humidity summer conditions



There is an argument to be made that using nothing is better than using poly!

Air Leakage and Soil Gas Control

Protection against soil gas (eg. radon) is achieved by providing a **continuous air / soil gas barrier** (typically poly)

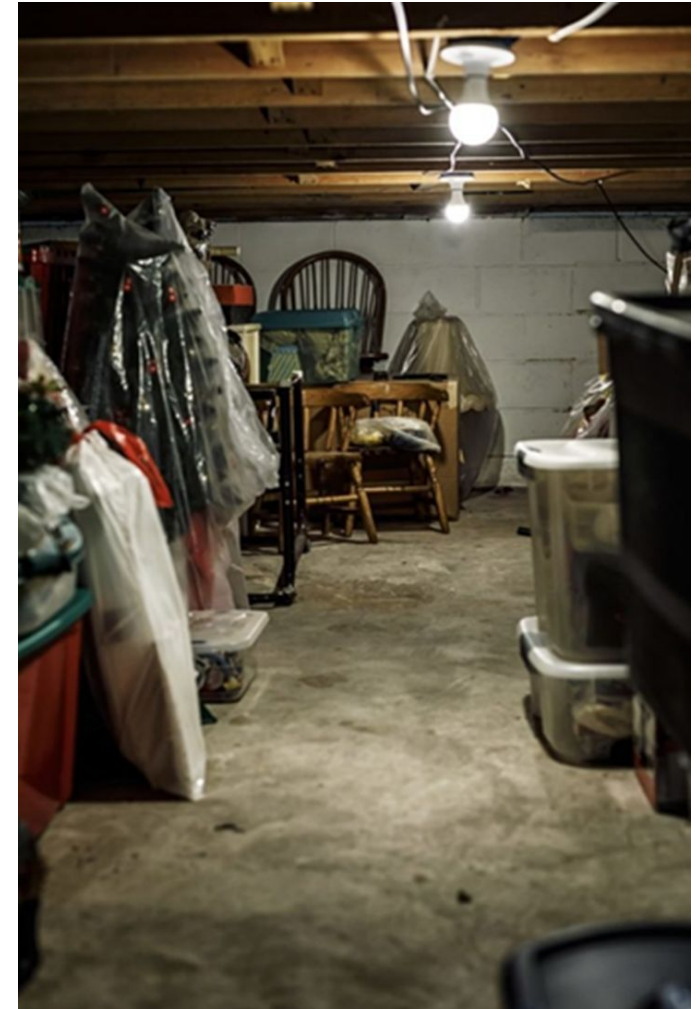
Building Science Rule: Air OUT = Air IN

- Leaky house = cold, drafty basement
- Leaky House = humid basement
- (humid soil and water vapour)
- Leaky house = soil gas concerns.

Why Basement Materials & Furnishings get “Damp” and Smell

Cool surfaces (and surface condensation control)

- Year-round COLDER surfaces
- Minimum humidity control = high relative humidity
- Below grade areas need to be treated like separate living spaces



Space Conditioning: Humidity and Temperature Control in Basements

- Always recommend a dehumidifier
- Perform proper load calculations (CSA F280)
- Right Size Equipment selection - Air conditioning NOT too big - just right to enable **dehumidification**
- Consider 2 stage OR Modulating AC to enable optimal humidity control (latent load)
- Sealing of supply side duct work AND RETURN DUCTS in basement, Leaky ductwork can turn the basements into a “meat locker” in the spring/summer.
- Consider ERV in lieu of HRV for better removal of humidity in during AC , spring and summer use.

Summary

Summary – Air Barriers and Blower Door Testing

- Air leaks need pressure difference and a hole
- Pressure differences are caused by wind, stack effect, and mechanicals
- Air barriers and air tightness protect from moisture damage and uncomfortable spaces
- Air barriers can be made up of different materials, they must be continuous
- Build it tight and ventilate right!
- Air tightness is the most cost-effective way to achieve comfort, healthy indoor air quality, and reduce moisture issues
- If you don't test it, you don't know!

Summary - Thermal Bridging and Insulation Systems

- Continuous insulation and advanced/optimized framing can reduce heat loss through thermal bridging
- There are many benefits to adding more insulation
- Consider the design effects of different amounts/types
- Lots of options but proper installation is key
- Can affect the drying potential of the wall
 - Inboard/outboard ratio
 - Dew point

Summary – Below Grade Insulation

- Keep the water out!
- Exterior insulation is the 'best' solution
- Don't forget the slab edge!

Questions?

What Can you do next?

- Access the LEEP Guide
- Watch a video
- Talk to your teams about air sealing
- Talk to your customers
- Do a blower door test on your next project - what can you learn?
- Talk to your marketing team - can you sell comfort, durability, and safety? All at no long term cost



Thank you

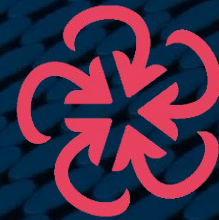
j.henke@albertaecotrust.com

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