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Building Envelope Consultants

Continuous Insulation – Overall Effective R-Value of Exterior Walls

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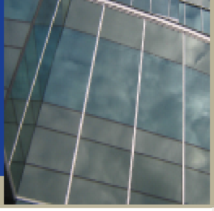
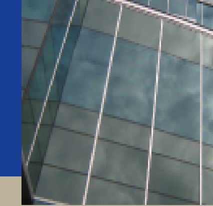
Topics



- ✓ Overview of energy use and direction of Energy Codes
- ✓ 2030 Challenge
- ✓ Modes of heat transfer
- ✓ Assembly R-value vs. Insulation R-value
- ✓ Innovative wall systems and Projects

Energy Use & Greenhouse Gas Emissions



Buildings…

- ✓ #1 contributor to greenhouse gas emissions causing global warming
- ✓ Amount to over 40% of US greenhouse gas emissions
- ✓ Up to 50% of energy used in US buildings is for heating & cooling
- ✓ 40% of energy used for heating & cooling US buildings results from air leakage losses *- US DOE*

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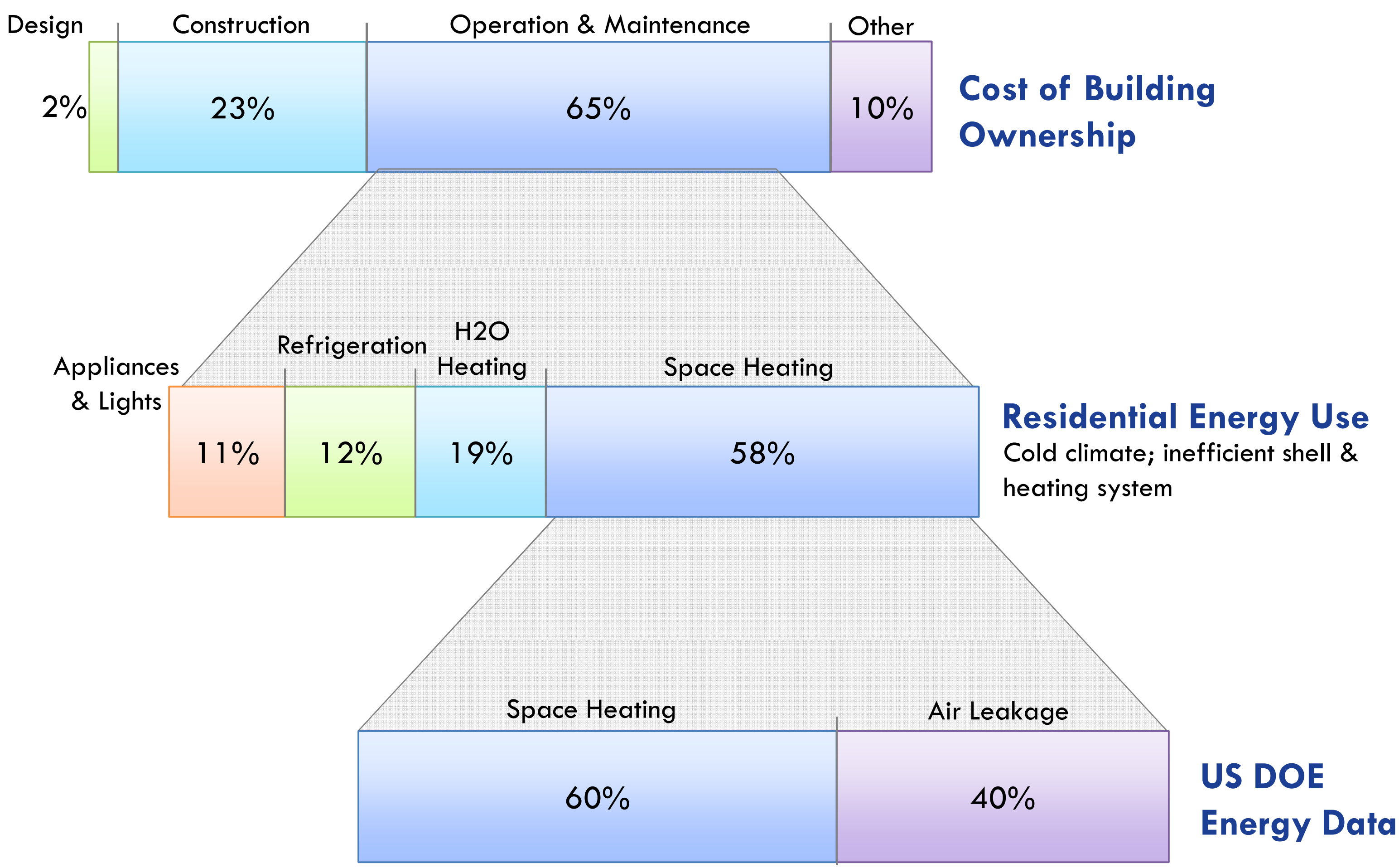
Energy Use in Perspective



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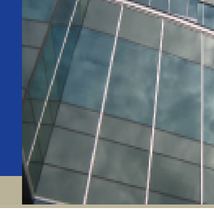
Codes & Standards

- **Energy Policy Act of 1992**
  - States' codes must be at least as stringent as ASHRAE 90.1-89, and DOE can require States to update their energy codes as 90.1 is updated.
- **ASHRAE 90.1**
  - 2010 Version goal is 30% energy savings over 2004 version
  - 2010 Version has been adopted by British Columbia Building Code in December 2014.

Codes & Standards

- ✓ **2011 National Energy Code of Canada**
  - 25% more efficient than MNECB 1997
- ✓ **Awareness and enforcement increasing.**

Codes & Standards



✓ **Alberta's codes are changing.**

NOTICE

New Alberta Building, Fire and Energy Codes

The 2014 editions of the Alberta Building Code and the Alberta Fire Code based on the 2010 National Building and Fire Codes were adopted at the end of February 2015 by provincial regulation. Also adopted by regulation is the National Energy Code for Buildings (NECB) 2011 edition. Key changes in the codes include:

- A new building class known as "B3" to address the demand for a more flexible range of care accommodation for an aging population. The B3 provides safe and affordable housing options for seniors and persons with disabilities.
- New provisions to allow for the construction and fire protection during construction of six-storey wood buildings entirely based on the national code requirements for the upcoming 2015 national building and fire code editions.
- New building protection against radon gas.
- Energy efficiency requirements for housing and small buildings under section 9.36 of the Alberta Building Code.

Each code has a coming into force date and a transition period. **The coming into force date is the date on which the codes apply or may be used in Alberta.** The transition period is to allow construction under the previous 2006 Alberta Building Code or under the new codes. All coming into force dates have a standard 6 month transition period to construct in the previous code provided a permit has been issued prior to the end of the transition period; or the safety codes officer is satisfied that the preparation of the plans and specifications for the project commenced prior to the coming into force date. The objective of this section is to prevent unnecessary and costly changes to construction already underway or plans that have been substantially developed for construction. In addition, the transition period will allow for the 2006 Code application during any delay in the distribution of the 2014 Code editions.

The timelines for the Alberta codes are:

Codes	Coming into force or Implementation Date	Transition Period End Date
Alberta Building Code 2014	May 1, 2015	November 1, 2015
Alberta Fire Code 2014	May 1, 2015	No transition required
National Energy Code of Canada for Buildings 2011	November 1, 2015	May 1, 2016
Section 9.36 Energy Efficiency, Alberta Building Code 2014	May 1, 2016	November 1, 2016

The Alberta Building and Fire Codes 2014 and the National Energy Code for Buildings 2011 are available from the National Research Council, both online and in hard copy. Follow this link to the National Research Council for purchase information.

May 1, 2015

For further information contact Municipal Affairs, Safety Services Branch toll-free at 1-866-421-6929.

Alberta Government

ISBN 978-1-4601-2201-3

Prescriptive Energy Code Requirements For Above Ground Opaque Building Assemblies, For Calgary (zone 7A)

	U Value (W/m2K)	R.S.I.	R
Walls	0.21	4.8	27
Roofs	0.162	6.2	35
Floors	0.162	6.2	35

2030 Challenge

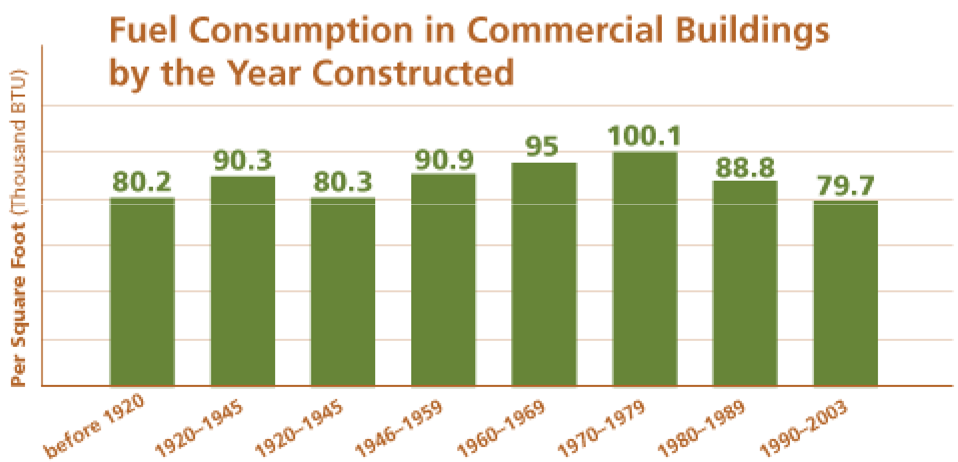
✓ **2030 Challenge**

- New buildings to reduce fossil fuel use by:
  - 70% in 2015
  - 80% in 2020
  - 90% in 2025
  - Carbon Neutral in 2030
- Adopted by US Conference of Mayors, AIA, USGBC, ASHRAE…

2030 Challenge

✓ **2030 Challenge**

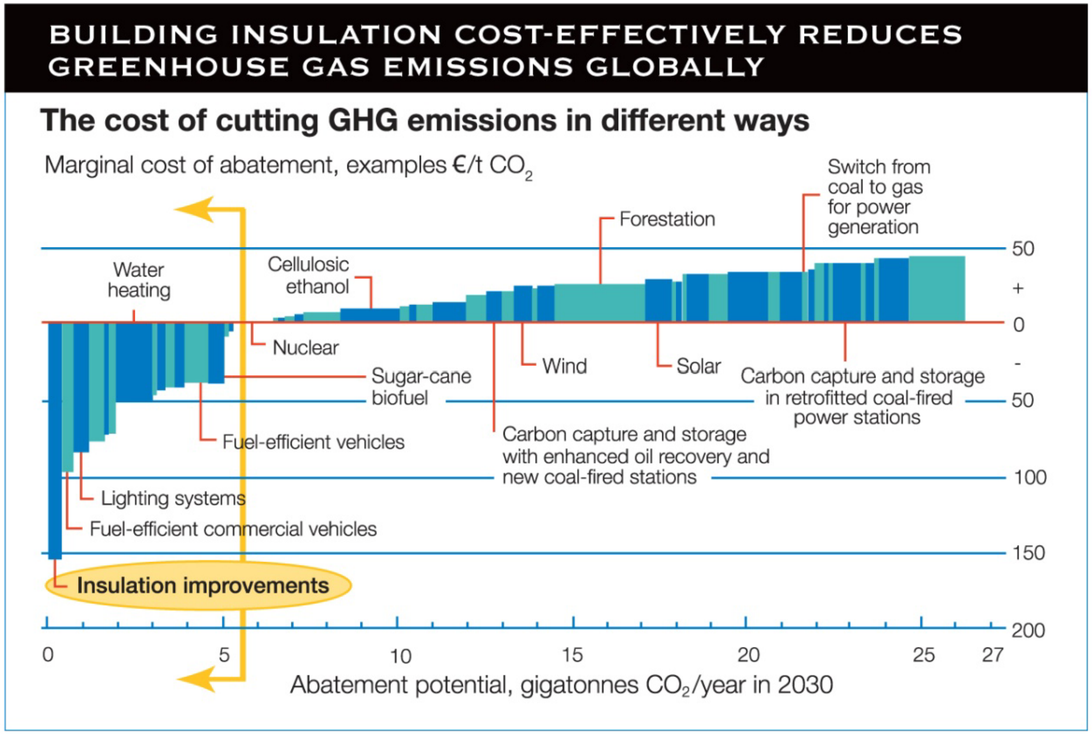
In case we think this is difficult, lets look at historic energy usage:



Source: Energy Information Administration, 2003 Commercial Buildings Energy Consumption Survey,

http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=consumption#c1a

- Applying greater amounts of insulation during initial construction is the least capital intensive GHG abatement measure.



Source: Study conducted by McKinsey & Company, and Vattenfall

McKinsey & Company studied the costs of implementing various GHG abatement options. "Insulation improvements" is among the more economical measures at the left of the arrows that provide the fastest payback and should be implemented before doing any of the other measures. And as the graph shows, "insulation improvements" is by far the best measure in terms of a negative marginal cost. This graph represents only a few of the abatement options researched. For the graph in its entirety, visit www.mckinseyquarterly.com/A_cost_curve_for_greenhouse_gas_reduction_1911.

Building Envelope

- ✓ A well-designed envelope:
  - improves durability
  - reduces heating & cooling requirements
  - enables use of smaller heating & cooling systems
- ✓ Primary goal to reduce heat transfer through increased levels of insulation and air-tightness

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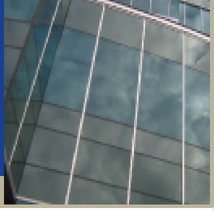
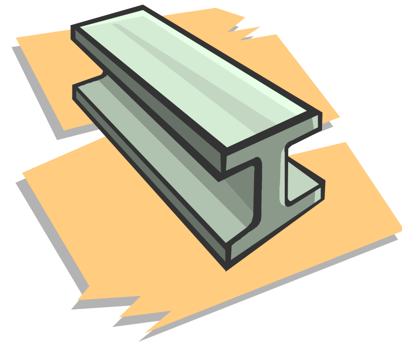
Heat Flow



- ✓ Heat flows from regions of higher temperatures to regions of lower temperatures.
- ✓ Modes of heat flow:
  - ***Conduction*** – Transfer of heat through direct contact
  - ***Convection*** – Transfer of heat due to the movement of gas or liquid over a surface (air movement)
  - ***Radiation*** – Transfer of heat from one object to another due to electromagnetic waves

Conduction

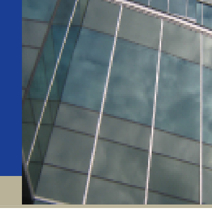
- ✓ Materials that conduct heat well are called *conductors*
  - Metal is a good conductor
  - High U-values / low R-values



- ✓ Materials that do not conduct heat well are called *insulators*

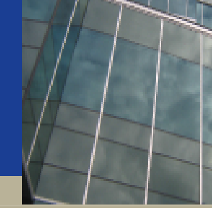
  - Foamed plastic, batt insulation are good insulators
  - Low U-values / high R-values

Thermal Resistance



- ***Thermal resistance*** is a measure of heat flow. Under uniform conditions, it is the ratio of the temperature difference across an insulator and the heat flux (heat flow per unit area)
- In construction, thermal resistance is typically expressed as R-value ($ft^2 \bullet °F \bullet h/Btu$)
- U-value ($Btu/ft^2 \bullet °F \bullet h$) is the reciprocal of R-value
- The conversion between SI and US units of R-value is $1\ h \cdot ft^2 \cdot °F/Btu = 0.176 K \cdot m^2/W$, or $1\ K \cdot m^2/W = 5.68\ h \cdot ft^2 \cdot °F/Btu$.

Assembly R-values



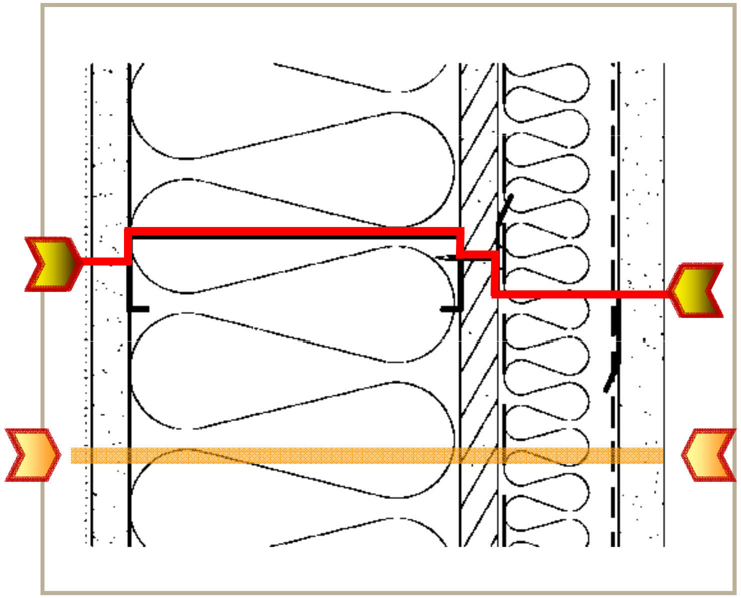
- ✓ R-value: heat transfer rating of the insulation
- ✓ Total assembly R-values typically less than insulation R-values, due to parallel heat flows through more conductive materials (wood/metal studs, window/door frames, floor structures)
- ✓ In light-gauge steel-framed assemblies, parallel heat flows through steel studs can reduce R-value by more than half!

Example: Steel Framed Wall Assemblies

Steel framing 16" on centre + 3.5" R-15 cavity insulation	Steel framing 24" on centre + 6.0" R-19 cavity insulation
Effective Insulation R-value = **6.0**	Effective Insulation R-value = **8.6**

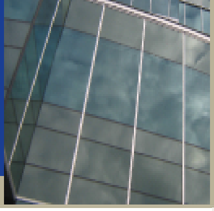
Parallel Heat Flow Through Metal Framing

- ✓ Occurs through thermally-conductive parts of assembly
  - Studs, tracks
  - Floor, slab & roof connections
  - Structural members
  - Cladding support
- ✓ Effects
  - Reduces effective R-value; more insulation needed to achieve required R-value
  - Cold or warm spots that can cause stud shadowing and lead to condensation



Continuously Insulated Assemblies

Calculating Effective R values (U)

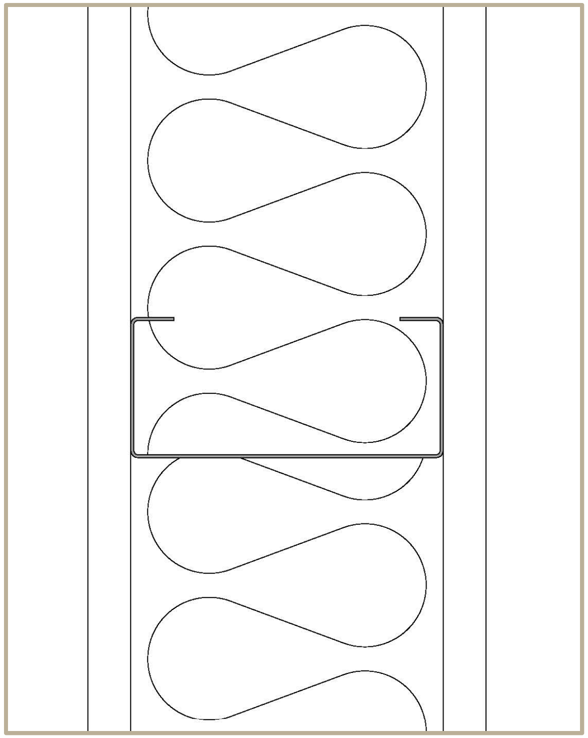


- ✓ Effective R-value (R_{eff})of an assembly is calculated by area, averaging the R-values of the various components that are parallel and adding the R values that are in series
- ✓ Calculating system R-value is same as an electrical circuit (series and parallel relationship)

Series circuit: $R_1+R_2+R_3 = R_{total}$

Parallel circuit: R2 = 1/(Aix1/Ri+Asx1/Rs) , where Ri is insulation, Rs is stud, A represents areas

Example: Standard Steel-Frame Wall



Element	R (Insul)	R (Framing)
1. ½" gypsum	0.45	0.45
2. 3 ½" batt Insulation	13.0	-
3. Steel framing	-	0.68
4. ½" gypsum	0.45	0.45
	R1=13.9	R2=1.58

Uavg = 0.92(1/13.9) + 0.08(1/1.58) = **0.117**

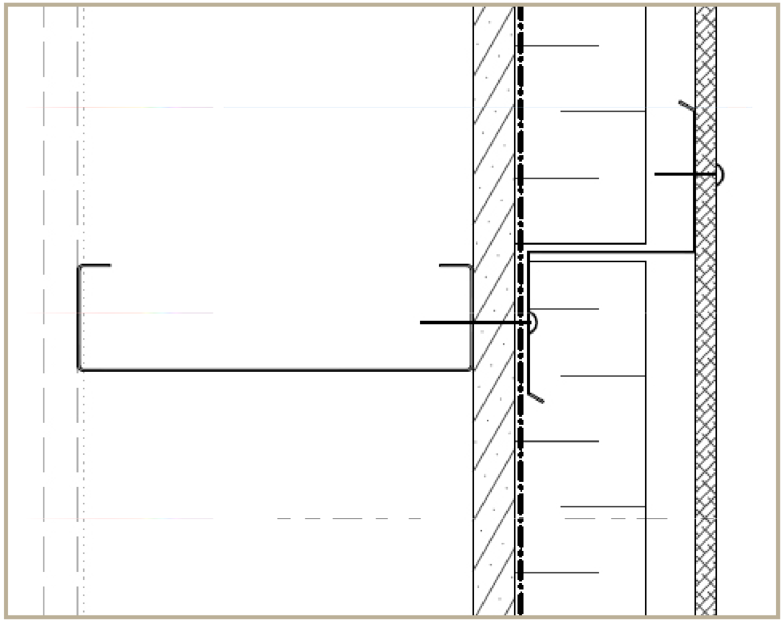
Ravg = 1/Uavg= **8.6** *(ASHRAE Value Ravg = 8.1)*

- Window and door openings, corners, etc. contain more framing and further reduce effective R-value

Exterior-Insulated Steel-Frame Wall

Conventional assembly

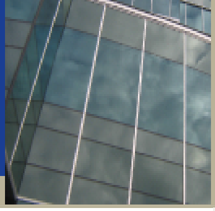
- cladding
- 3” vertical Z-girts
- 2-½” rigid insulation (R-12.5)
- self-adhesive membrane
- exterior gypsum sheathing
- steel framing
- interior gypsum wall board

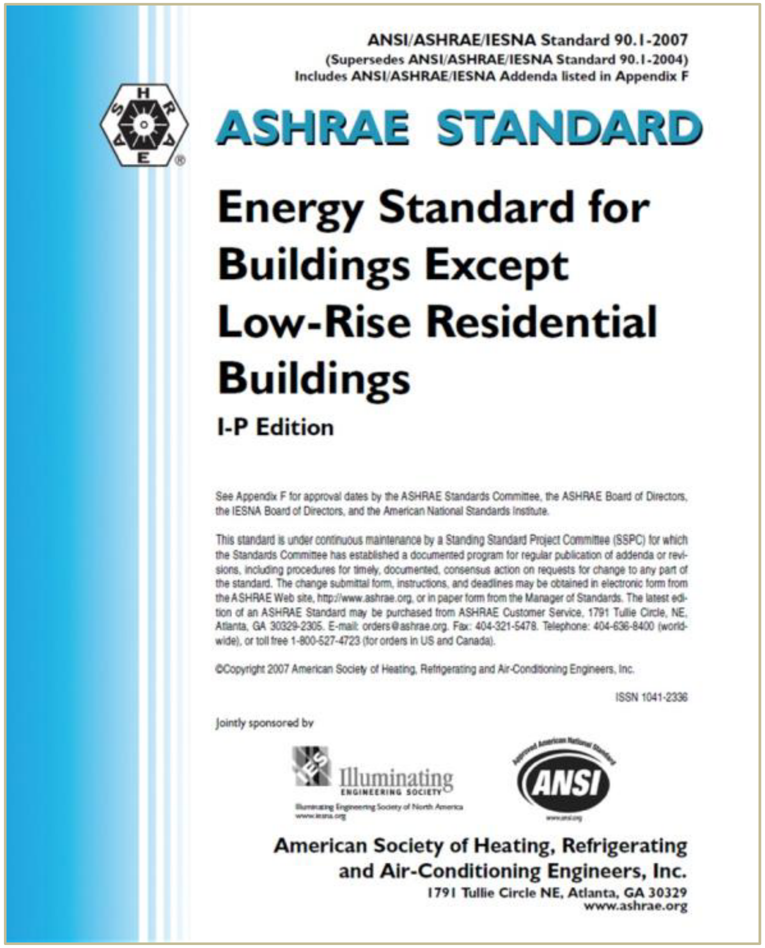


Attachment girts penetrate exterior insulation, causing thermal bridges

Exterior Insulation ≠ Continuous Insulation

What is Continuous Insulation?





ANSI/ASHRAE/IESNA Standard 90.1-2007
(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2004)
Includes ANSI/ASHRAE/IESNA Addenda listed in Appendix F

ASHRAE STANDARD

Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IESNA Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site, http://www.ashrae.org, or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada).

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Continuous insulation is defined by ASHRAE as follows:

> "***continuous insulation*** (c.i.): *insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior, or is integral to any opaque surface of the building envelope.*"

Seattle Definition of CI

- ✓ Seattle revised their energy code in November 2010 and added commentary to the definition of Continuous Insulation as follows:

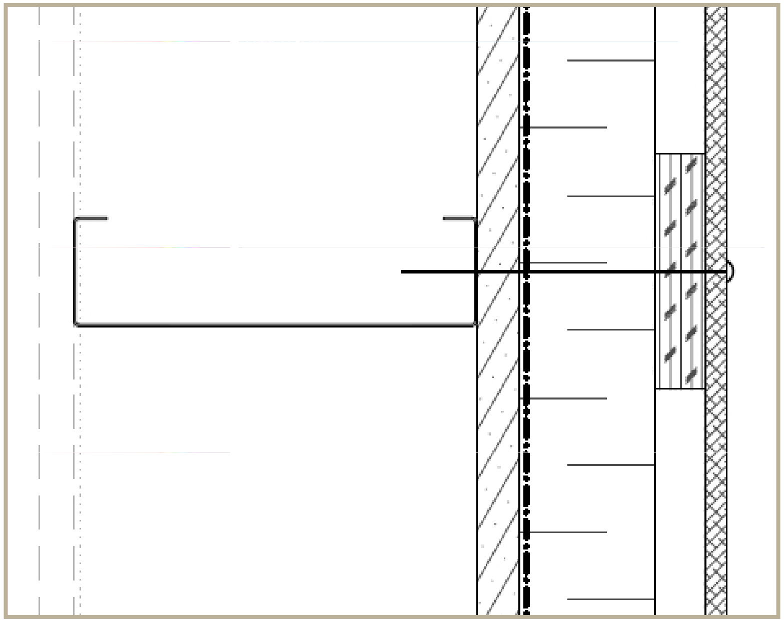
- ✓ *"CONTINUOUS INSULATION (c.i.): Insulation that is continuous across all structural members without thermal bridges other than fasteners (i.e. screws and nails) and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope. For the purposes of this definition of continuous insulation, only screws and nails are considered fasteners. Insulation installed between metal studs, z-girts, z-channels, shelf angles, or insulation with penetrations by brick ties and offset brackets, or any other similar framing is not considered continuous insulation, regardless of whether the metal is continuous or occasionally discontinuous or has thermal break material. (See Section 1332 for determination of U-factors for assemblies that include metal other than screws and nails.)"*

- ✓ *"Even isolated discontinuous metal elements such as brick ties have a thermal impact that is too large to be ignored."*

Continuous Exterior-Insulated Wall

CI-compliant assembly

- cement board / metal / stucco
- 1x4 plywood furring
- 2-½" insulation (R-12.5)
- building wrap
- exterior gypsum sheathing
- 2x6 steel framing
- interior gypsum wall board
- vapor retarder

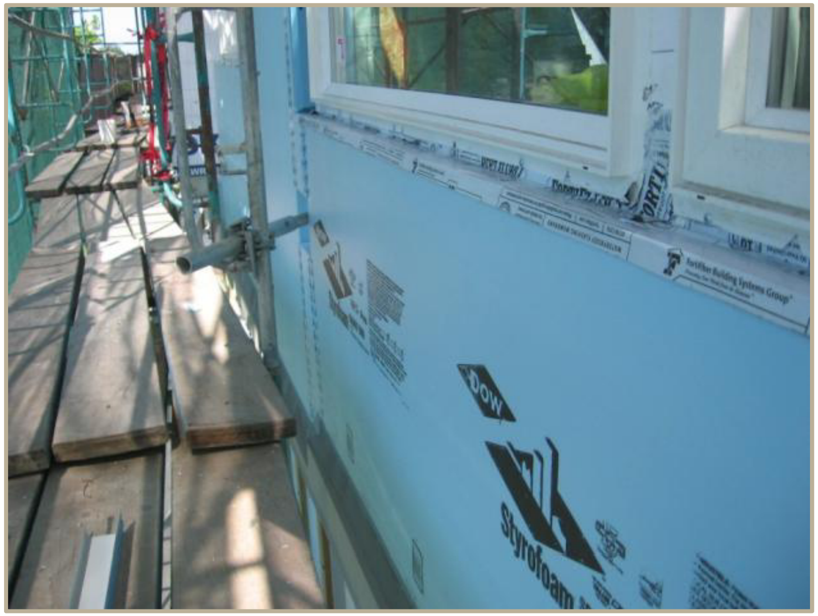


True continuous insulation

Bridging effect of fastener penetrations is considered negligible

Continuous Insulation (CI)

- ✓ No framing or other significant thermal conductors passing through the insulation (fasteners can be ignored)



- ✓ R_{eff} of insulation layer is rated R-value
- ✓ R_{eff} of wall assembly can be very high if combined with insulation in framing cavity (add layers)

Benefits of Continuous Insulation

✓ Advantages of using a CI assembly:

- Maximizes thermal efficiency; R_{eff} = nominal R-value
- Less insulation needed to meet required U-value
- Installed on exterior, keeps wall assembly warmer (in heating climates), reducing risk of condensation
- Eliminates thermal shorts (bridging)
- Improves occupant comfort
- Reduces material costs
- Can reduce labor costs

Continuously Insulated Assemblies

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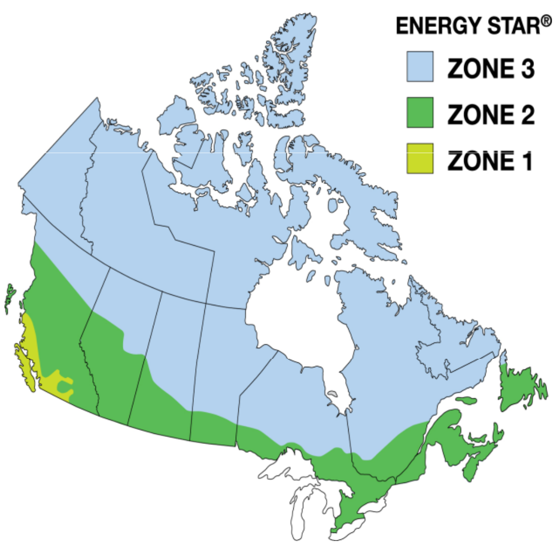
ASHRAE and Energy Codes

- ✓ ASHRAE 90.1 Requires CI in steel-framed walls in almost <u>all</u> climate zones for prescriptive option. Residential occupancy has more stringent CI requirements.



Zone 3: >= 6000 HDDs
Zone 2: >= 3500 to < 6000 HDDs
Zone 1: < 3500 HDDs

Picture copied from the NRC website.

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ASHRAE & Energy Codes – Example 1

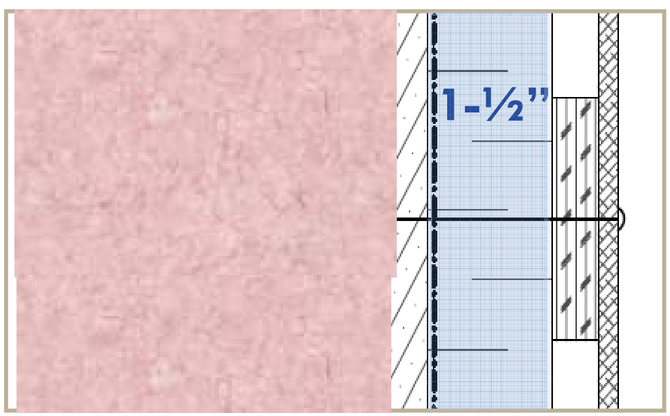
- ✓ Table 5.5-5 (Zone 5) required min. R-value is R-13+R-7.5 c.i. for steel-framed residential & non-residential walls

U=0.064 or

Reff = 15.6

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A, B, C)*

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.119	R-7.6 c.i.
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.090	R-11.4 c.i.	U-0.080	R-13.3 c.i.	U-0.151[a]	R-5.7 c.i.[a]
Metal Building	U-0.113	R-13.0	U-0.057	R-13.0 + R-13.0	U-0.123	R-11.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.064	R-13.0 + R-3.8 c.i.	U-0.051	R-13.0 + R-7.5 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Gr[illegible]	[illegible]0.119	[illegible]	C-0.[illegible]	R-7.5 c.i.	C-1.140	[illegible]



- ✓ R-value of R-13 + R-7.5 c.i. is equivalent to a 2x4 steel stud with R-13 batt insulation & **1-½** inches of Type 4 (XPS) rigid foam insulation

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Continuously Insulated Assemblies

ASHRAE & Energy Codes – Example 2

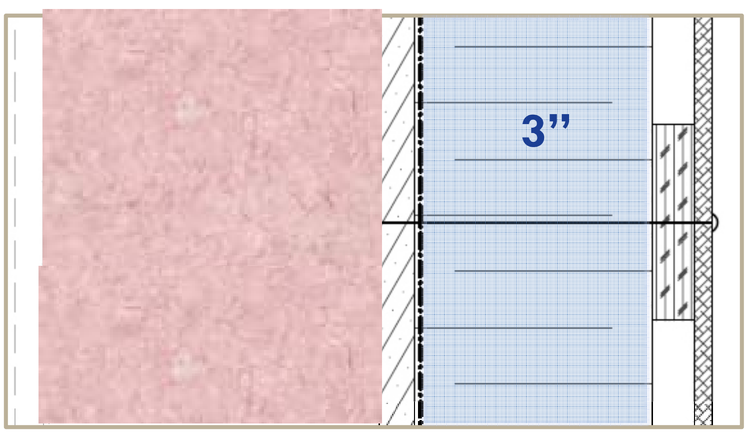
- ✓ Table 5.5-7 states required minimum R-13.0+R-15.6 c.i. for residential (Zone 7)

U=0.042

Reff = 23.8

TABLE 5.5-7 Building Envelope Requirements For Climate Zone 7*

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.093	R-10.0 c.i.
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.034	R-30.0
Walls, Above-Grade						
Mass	U-0.071	R-15.2 c.i.	U-0.071	R-15.2 c.i.	U-0.123	R-7.6 c.i.
Metal Building	U-0.057	R-13.0 + R-13.0	U-0.057	R-13.0 + R-13.0	U-0.113	R-13.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.042	R-13.0 + R-15.6 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.051	R-13.0 + R-7.5 c.i.	U-0.051	R-13.0 + R-7.5 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-... Wall	C-0.119	... c.i.	C...	R-10.0 c...	C-1.140	R...



- ✓ R-13.0 + R-15.6 CI is equivalent to a 2x4 steel stud with R-13 batt insulation & **3** inches Type 4 (XPS) rigid foam insulation

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Continuously Insulated Assemblies

Considerations

- R_{eff} and thermal bridging often misunderstood
- Many steel-framed buildings do not include continuous insulation
- Most exterior-insulated cladding systems are interrupted by framing members
- Some cladding systems (e.g. EIFS) <u>do</u> comply with the c.i. definition
- Fasteners do reduce thermal performance.

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Thermally Bridged Assemblies

- ✓ Typical exterior insulated system
    - Steel framing members penetrate through spray-applied urethane
    - Framing used to attach cladding, significantly reducing R-value

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Continuously Insulated Assemblies

Thermally Bridged Assemblies

- Typical aluminum composite panel exterior installation system. Anchoring of panels with metal framing through mineral wool insulation reduces effective R-value.

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Discussion on efficient non-ci systems

- ✓ U value is rating of the assembly while R value is rating of the insulation.
- ✓ Meeting U value requirements can be done with different assemblies and details and still conform to the prescriptive path.

Engineered Assemblies T-Clip

- Discreet aluminum clip with thermal break holds horizontal light gauge metal z-girts.
- Adjustable in and out.
- Vertical hat tracks installed over to accommodate panel fastening.
- Used with spray foam or mineral wool.
- U = 0.061 (16.4eff) with 4 inches of mineral wool

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KWS MFI System

- ✓ Discreet steel clip with thermal isolators holds metal C-channels off wall.
- ✓ Channels can be installed horizontally or vertically
- ✓ Adjustable in and out.
- ✓ Use with spray foam or mineral wool
- ✓ U= 0.058 (17.2 R_{eff}) with 4 inches of mineral wool

Continuously Insulated Assemblies

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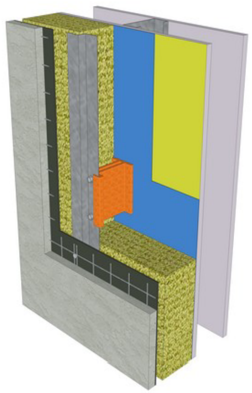
Cascadia Isolator



- ✓ Discreet fibreglass clip holds metal Z bar off wall.
- ✓ Use with spray foam or mineral wool
- ✓ $U = 0.064$ ($15.7R_{eff}$) with 4 inches of mineral wool

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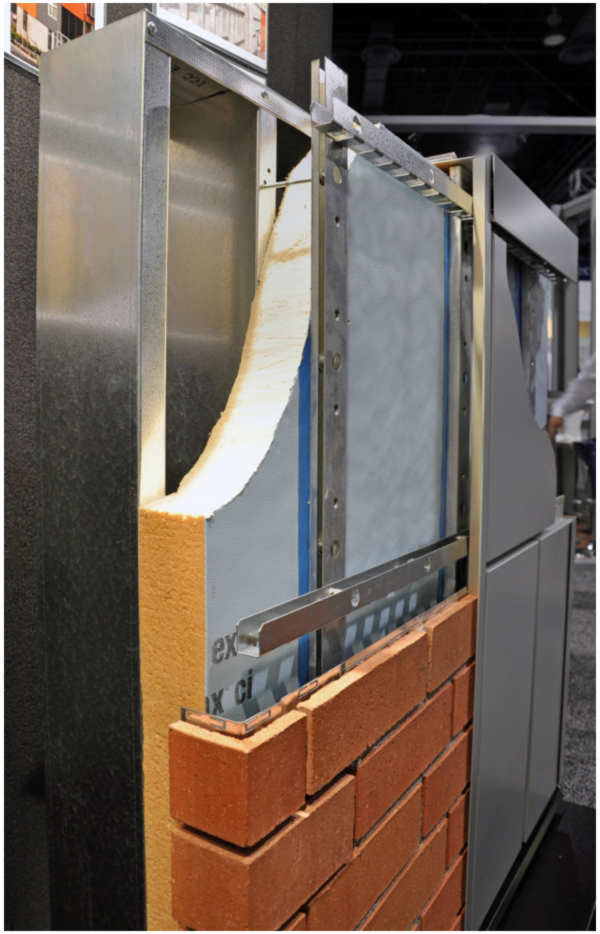
Continuously Insulated Assemblies

Dow/Knight Wall System



- ✓ Includes thermal, air, vapour and moisture barrier as well as cladding mounting system.
- ✓ Complies with definition of Continuous Insulation (CI)
- ✓ Consists of faced polyiso insulation, closed cell polyurethane spray foam and facers. Exterior framing creates the rainscreen and allows for attachment of cladding.

Exterior Mineral Wool CI Insulation

- Conventional insulated 2x6 wall with batt insulation and plywood sheathing.
- Covered with building wrap, 4” of mineral wool and treated furring strips for mounting siding.

Everett Fire Hall, Washington

- Replacement of failed face sealed EIFS cladding system with an exterior insulated rainscreen cement board and metal cladding assembly.

- Conventional insulated 2x6 wall with batt insulation and plywood sheathing.
- Covered with building wrap, 2” of XPS and treated plywood furring strips at 16” oc
- Effective R-28.
- Panels nailed to furring.

Everett Fire Hall, Washington

- Building wrap detailed as primary air barrier but detailed to shed to exterior.

- Face of insulation acts as moisture barrier. Building wraps strips installed in horizontal joints to shed to exterior.
- Furring is thick enough to satisfy manufacturer’s nailing requirements and rigid to transfer dead and wind loads to insulation.

Everett Fire Hall, Washington

- 1x3 borate-treated plywood furring strips.
- 4-½" corrosion-resistant wood screws.
- Siding and trims nailed to furring.

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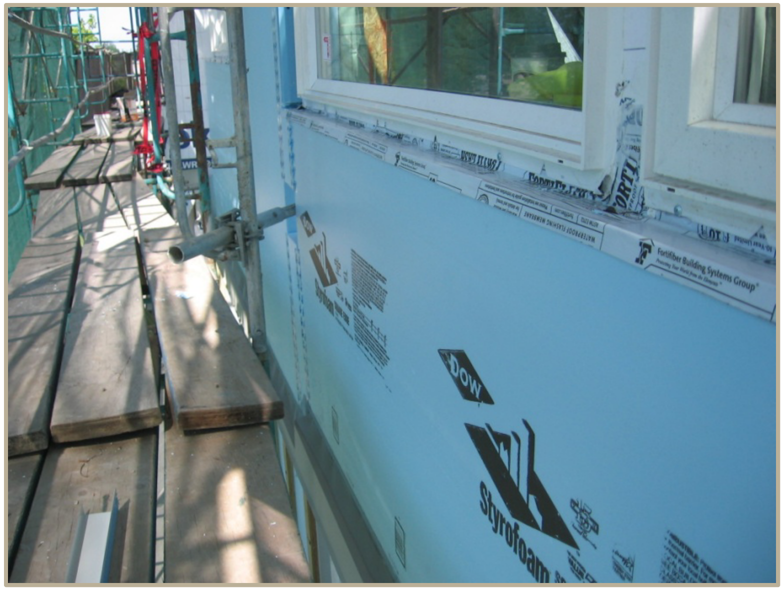
Burien Town Square, Washington

- New 7 storey condominium building.
- Exterior insulated rainscreen cement board, metal, stucco and brick claddings.
- 2x6 steel stud back-up wall covered with fibreglass reinforced gypsum sheathing.
- 2-½" Type 4 (XPS) rigid insulation with no cavity insulation, Reff = 15.5

Burien Town Square, Washington



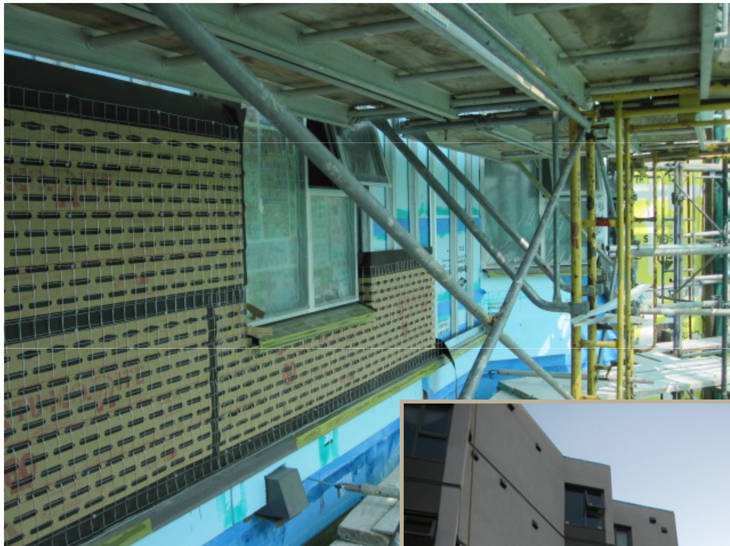
- Face of insulation detailed as the moisture barrier. Joints are taped and details shed over insulation.
- Building wrap detailed as air barrier but detailed to shed moisture to exterior.
- 1x4 borate-treated plywood furring strips screwed to steel stud walls with 5” self-tapping roofing screws.
- Siding systems nailed to plywood furring.

Hugh Bird Residence, Vancouver

- Restoration of failed face-sealed stucco wall assembly with new exterior insulated rainscreen stucco, new windows and roofing.

- Wall assembly includes new drained stucco over vertical metal furring.
- Metal furring installed over 3” XPS insulation.
- 2x4 steel stud infill wall with fibreglass-faced gypsum sheathing.

Hugh Bird Residence, Vancouver



- Self adhered membrane installed over the sheathing acts as the air, vapour and moisture barriers.
- Insulation detailed as moisture shedding surface.
- Galvalume Z-girt furring channels transfer cladding weight and wind loads back through insulation to steel stud wall.

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Hugh Bird Residence, Vancouver

- Building was instrumented in six locations to measure cladding movement, temperature, humidity and heat loss.
- Data collection in initial stages.
- Deflection measured in x, y and z direction to 0.1mm. Data analysis underway.

Applied to Residential Construction

- Applying continuous insulation to the exterior of homes is an easy way to improve thermal performance of walls.
- Plywood furring air nailed through to sheathing. Siding conventionally air nailed to furring strips.

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Applied to Residential Construction

- Insulation can improve air tightness and warm sheathing, reducing condensation potential.

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High School Re-cladding, Prince Rupert

- Original assembly was 2 by 6 steel stud with batt insulation Reff=9.17
- New assembly includes 4 inches of exterior mineral wool insulation with girts mounted on the Cascadia fibreglass clip Reff=15.7
- Installed over a continuous air, vapour and moisture barrier.

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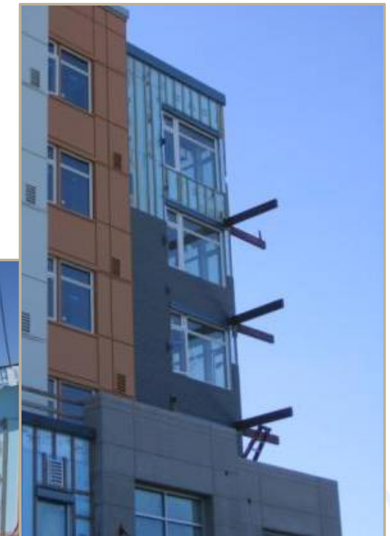
QUESTIONS?



Continuously Insulated Assemblies

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