Lecture Series 1/2: **Building Performance:**

Maximizing Energy Savings through an Integrated Design Approach

Jordan Lanoway & Afaf Azzouz

Agenda

1 Introduction

2 Heat Transfer Basics

3 In-Depth Review of Compliance Paths

4 Next Lecture Series

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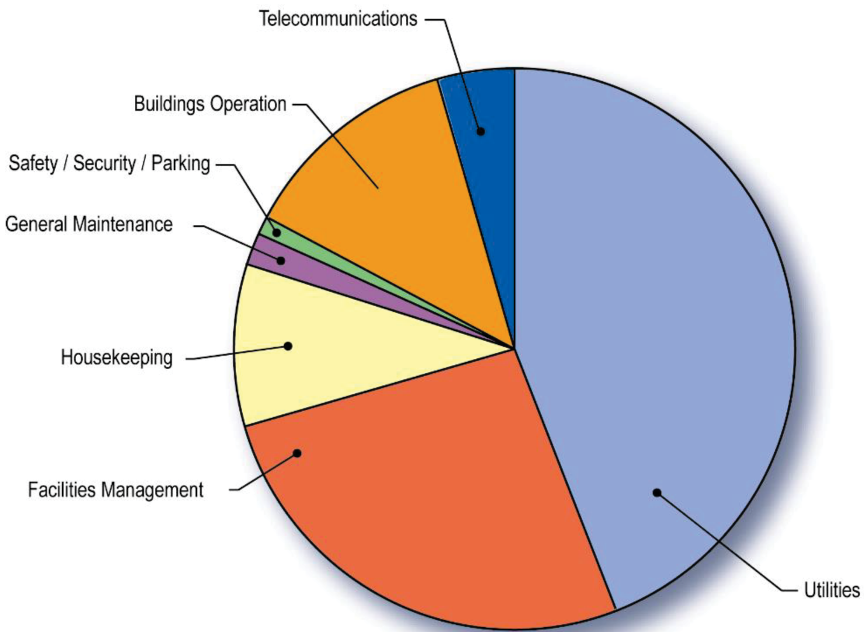
Why have an Energy Code?

Operating Costs excluding Labor & Supplies



Once salaries are removed which are generally market driven, energy becomes a significant portion of the puzzle.

Utilities = 42% of Operating Budget

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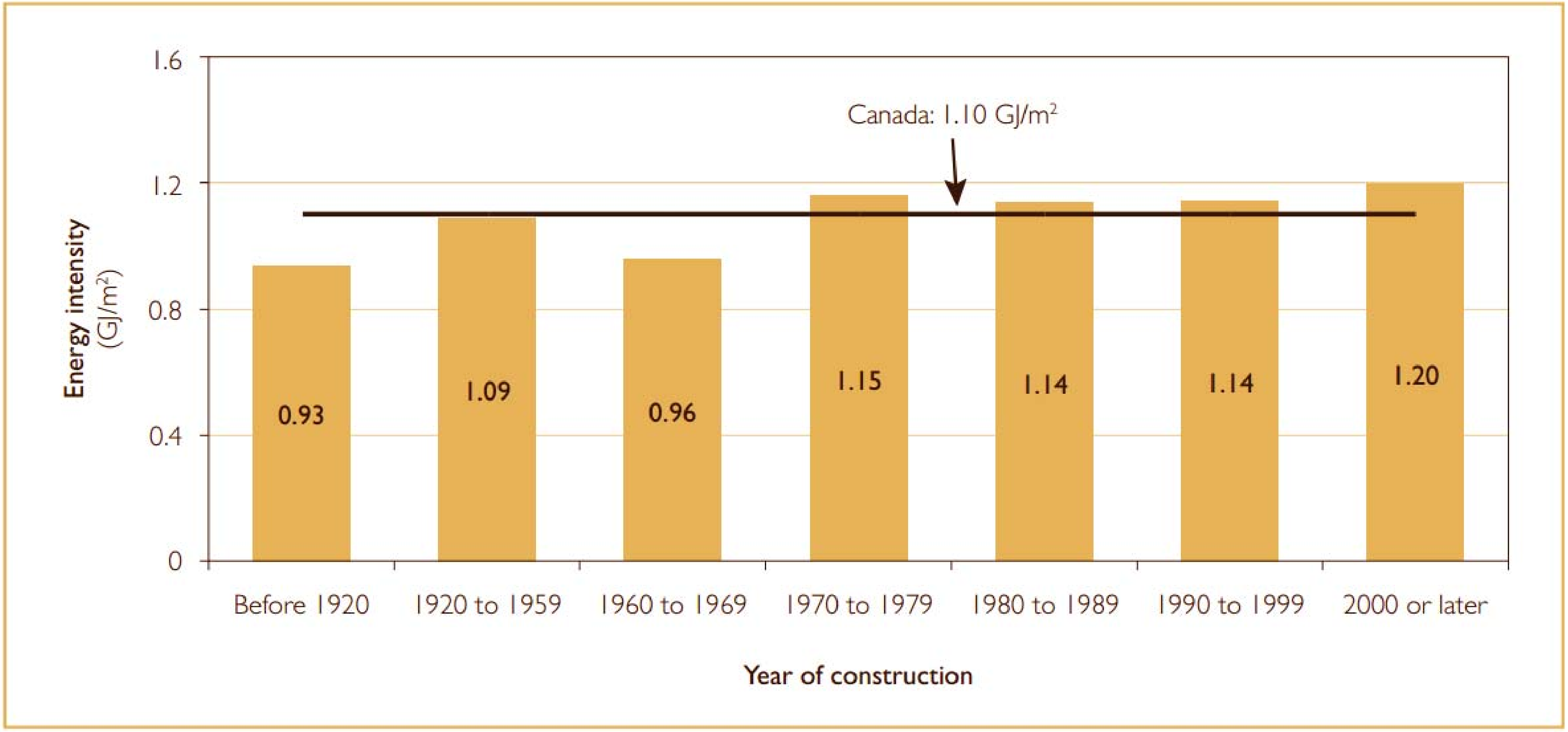
Why have an Energy Code?



Ref: Survey of Commercial and Institutional Energy Use – Buildings 2009, NRCAN

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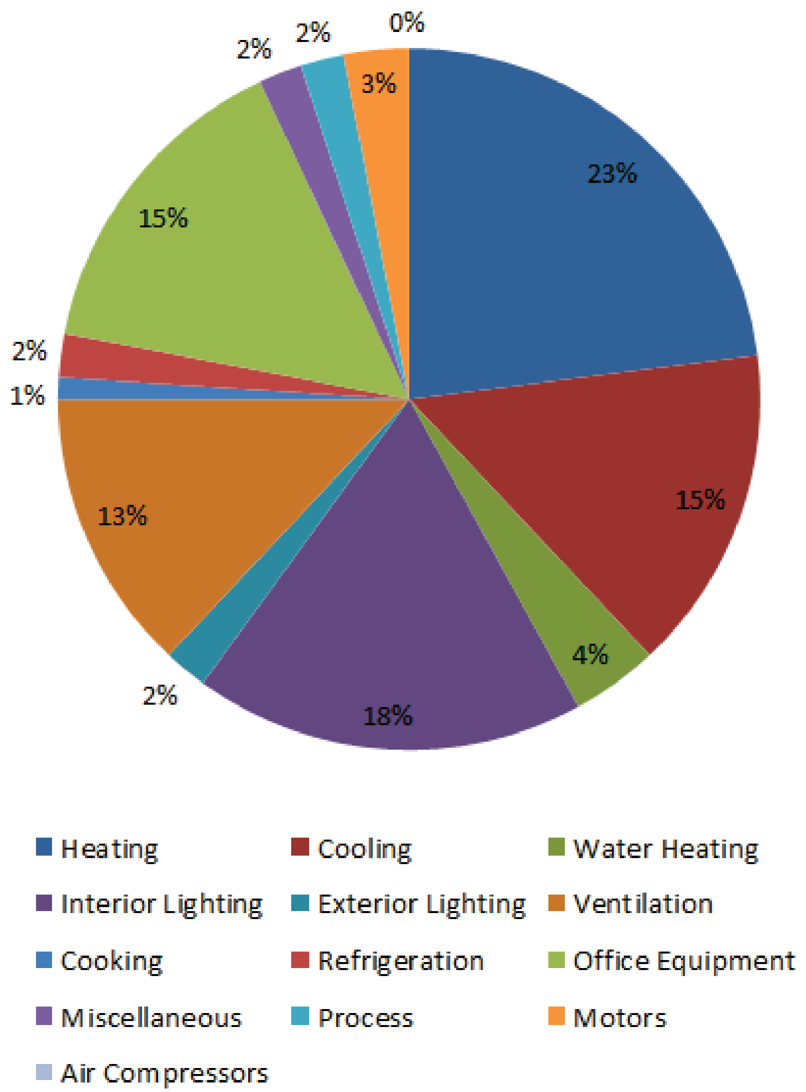
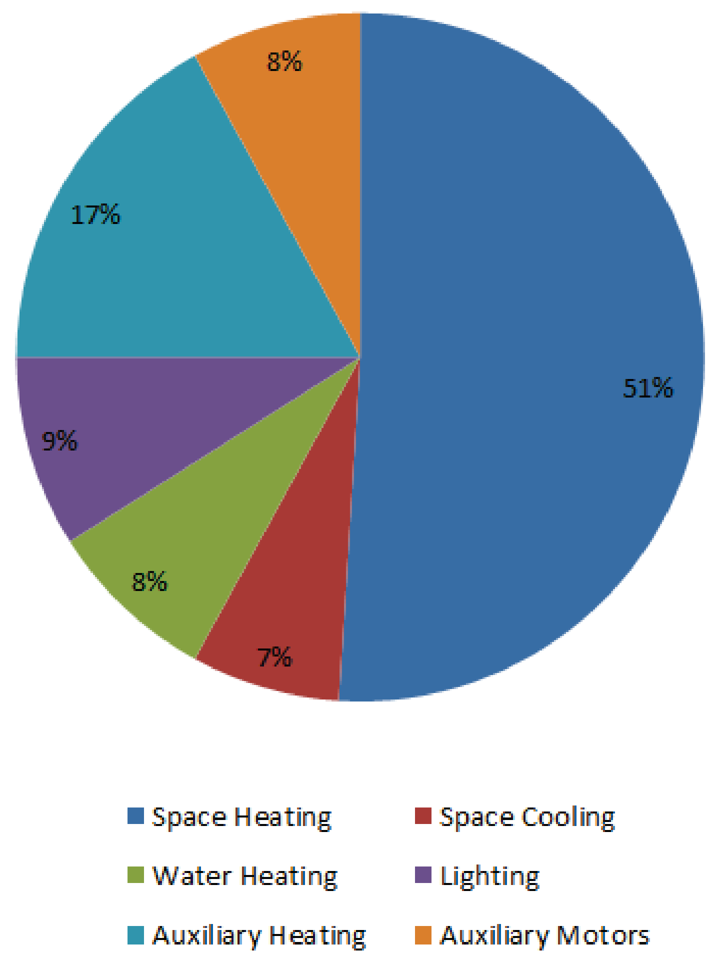
Why have a *Canadian* Energy Code?

Energy consumption of large California office buildings [CEC 2006]



Energy consumption of Canadian office buildings [NRCan 2007]



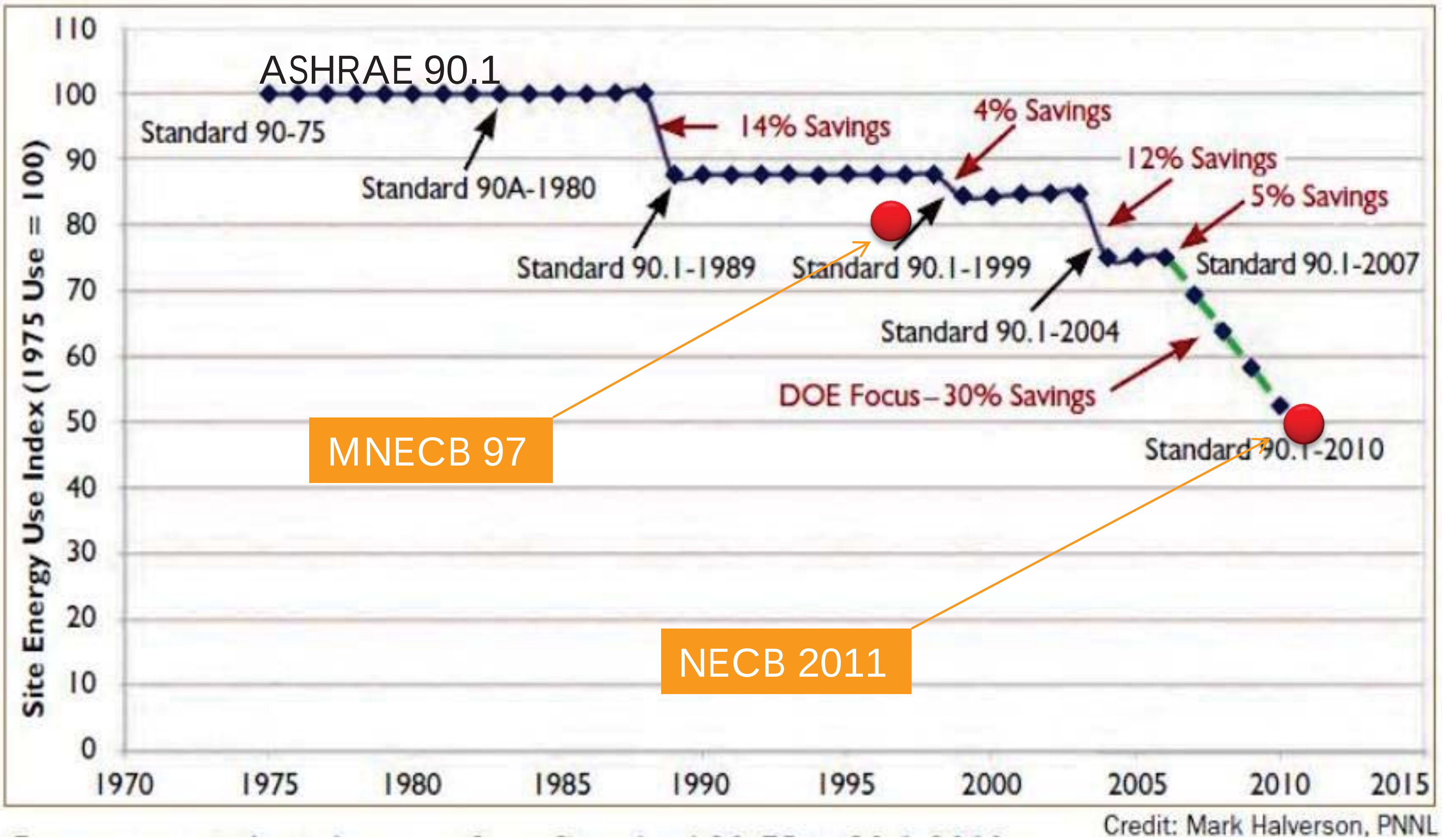
History of Energy Codes in Canada

- **MNECB 1997**
  - Introduced as ‘Canadian’ energy code
  - Not adopted by Provinces (except ON)
  - Used in LEED, Commercial Buildings Incentive Program, Utilities programs (ex MB Hydro)

- **NECB 2011**
  - Supersedes MNECB 1997
  - Goal: 25% better than MNECB 1997
  - Provinces are currently adopting

- **Note:** NECB 2015 already complete, 2020 in the works

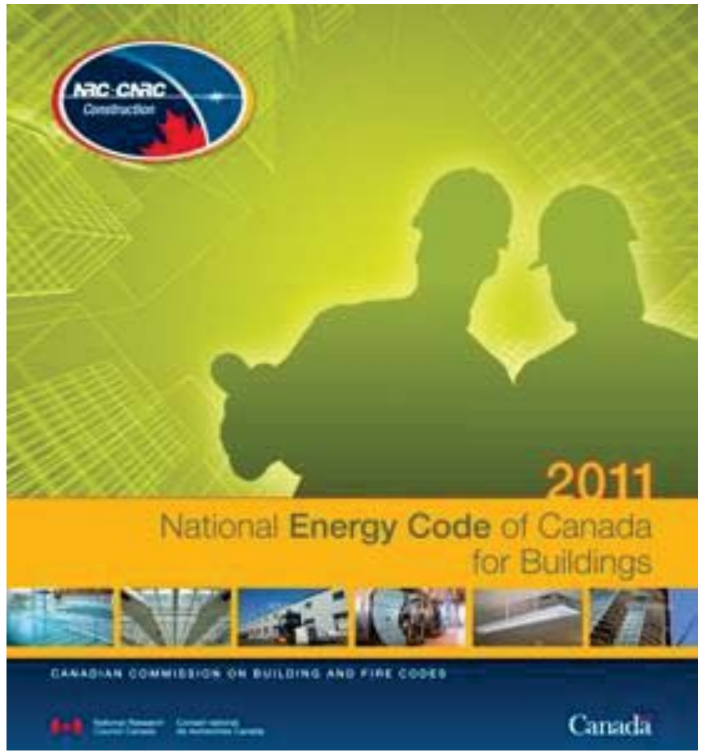
History of Energy Codes in Canada



Relevant Sustainability Codes/ Requirements

- **Manitoba Energy Code for Buildings (MECB)**
- **MB Hydro Power Smart – New Buildings Program**
- **LEED**
- **Green Globes**
- **etc.**

Manitoba Energy Code (MECB)



Key MB Amendments:

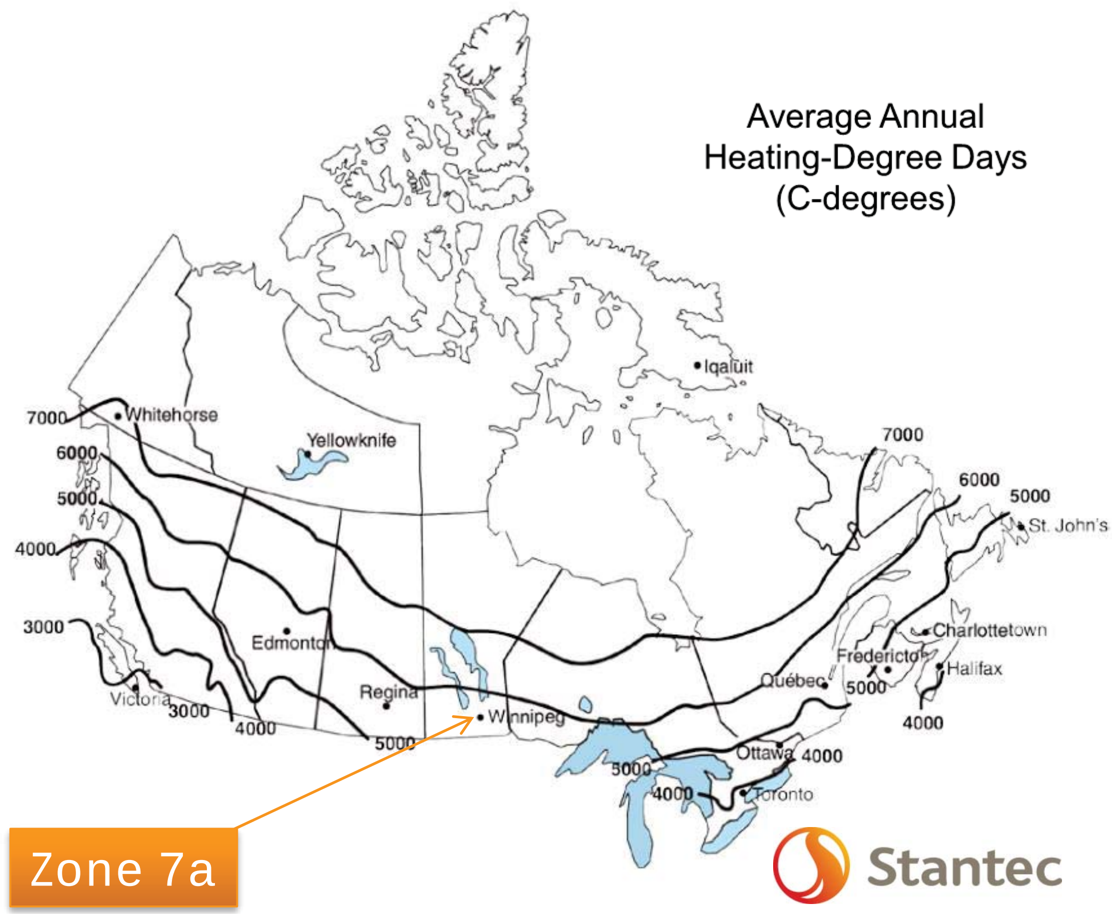
- Increased window performance (U=2.0 W/m2K)

MECB Approach & Application

- Applies to new buildings & additions / not reno’s
- Targets based on climate zone

Six Climate Zones in Canada

4   < 3000 HDD
5   3000 – 39999 HDD
6   4000 – 49999 HDD
7A 5000 – 5999 HDD
7B 6000 – 6999 HDD
8   > 7000 HDD



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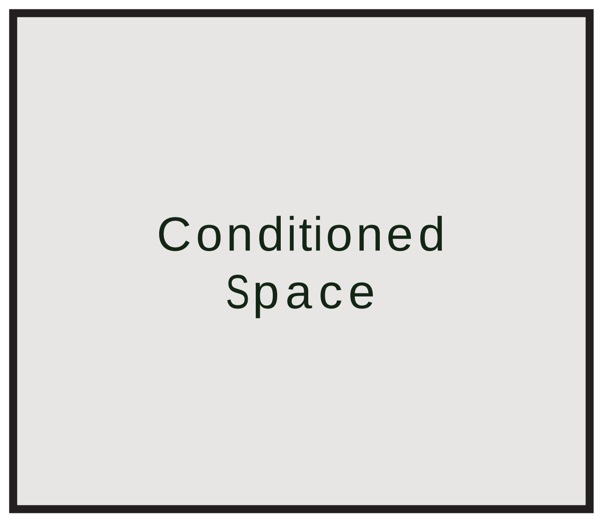
MECB Compliance Paths

- **Prescriptive Path**
- **Trade-Off Path**
  - Envelope: simple or detailed*
  - Lighting / HVAC / Service Water
  - Limited to system level only
- **Performance Path**
  - Unlimited trade-off between all systems

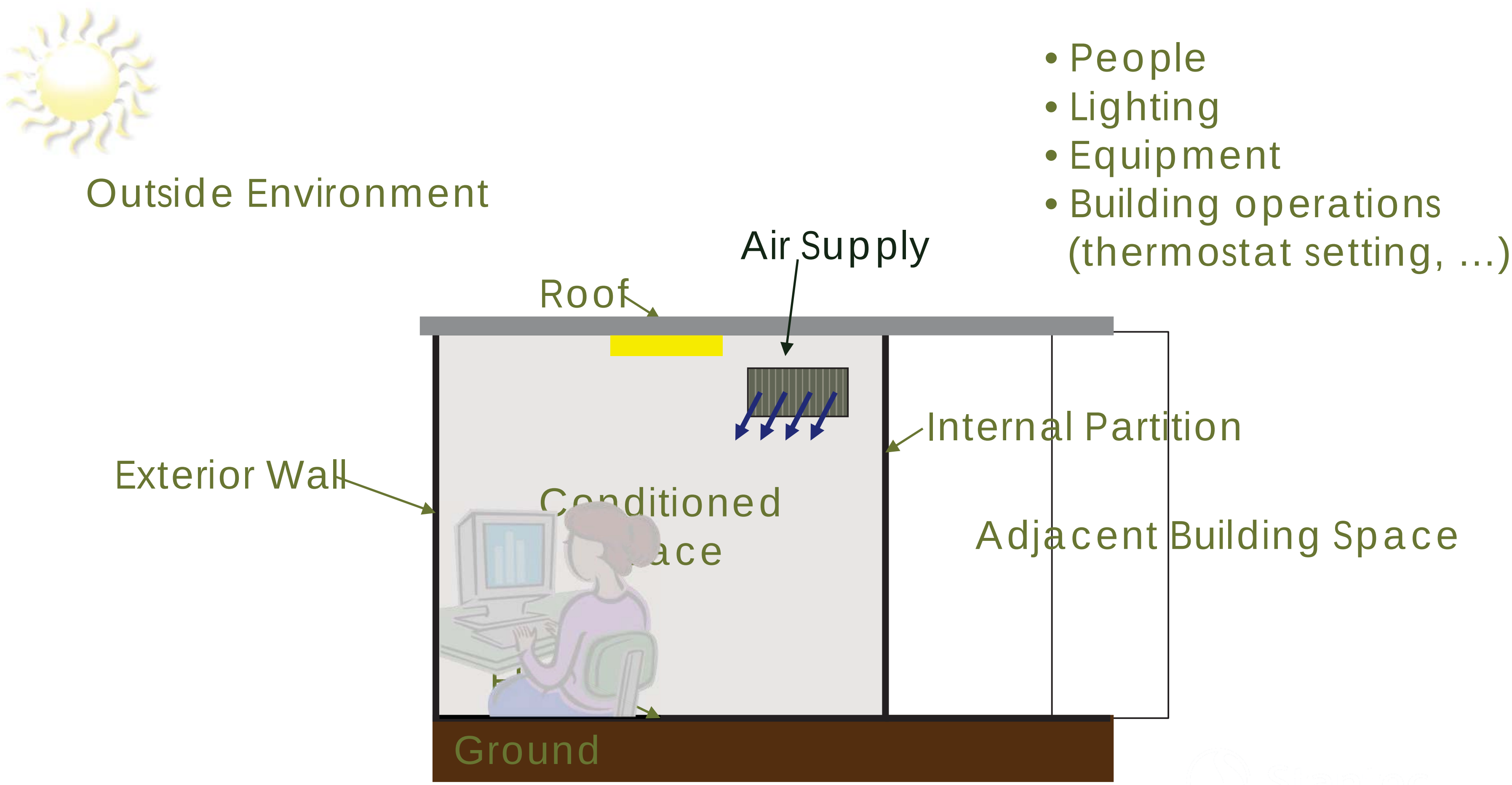
* Detailed envelope trade-off not included in 2015 Code

Heat Transfer Basics

Heat and Mass Transfer in Buildings



Heat and Mass Transfer in Buildings



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Heat Transfer Basics

U-Value vs. R-Value?

Thermal Bridging Thermal Break?

Heat Transfer Calculations

1. Thermal bridging is dictated by the cladding material and the means of tying it to the backup wall

2. Thermal bridging calculations are different for concrete, wood and steel structures

3. Hand calcs are just an estimate

Heat Transfer Calculations

Layer	Thickness (inch)	**Nominal** Resistance ($h.ft^2.^oF/Btu$)
Exterior Air Film	-	**0.17**
6mm Fiber Cement Panel	0.24	**0.12**
13mm OSB Sheathing	0.51	**0.72**
140mm Batt Insulation w/ Wood Studs @ 406mm O.C.	5.51	R-4 per inch = 4* 5.51 = **22.20** (ignores impact of wood stud)
16mm Gypsum Board	0.63	**0.55**
Interior Film	-	**0.68**
Total	**6.89**	**24.44**

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Heat Transfer Calculations

Layer	Thickness (inch)	Nominal Resistance through Insulation ($h.ft^2.^oF/Btu$)	Nominal Resistance through Frame ($h.ft^2.^oF/Btu$)
Exterior Air Film	-	**0.17**	**0.17**
6mm Fiber Cement Panel	0.24	**0.12**	**0.12**
13mm OSB Sheathing	0.51	**0.72**	**0.72**
140mm Batt Insulation w/ Wood Studs @ 406mm O.C.	5.51	R-4 per inch = 4* 5.51 = **22.20** (ignores impact of wood stud)	**6.75** (ignores impact of insulation)
16mm Gypsum Board	0.63	**0.55**	**0.55**
Interior Film	-	**0.68**	**0.68**
Total	**6.89**	**24.44**	**8.99**

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Heat Transfer Calculations

Layer	Thickness (inch)	Nominal Resistance through Insulation (h.ft^2.^{o}F/Btu)	Nominal Resistance through Frame (h.ft^2.^{o}F/Btu)
Framing %		**77%**	**23%**
Total R-Value		**24.44**	**8.99**

Overall effective R-Value of Assembly

$$= 100\% / [(\%Framing_{Insulation}/Total\ R_{Insulation}) + (\%Framing_{Frame} / Total\ R_{Frame})]$$

= 17.5 h.ft^2.^{o}F/BTU

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Heat Transfer Calculations

Overall nominal R-Value of Assembly

= 24.4

Overall effective R-Value of Assembly

= 17.5

%overall assembly degradation:
28%

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Prescriptive Envelope Requirements

Prescriptive Path
Opaque Building Assemblies

Above-ground *Opaque Building Assembly*	Heating Degree-Days of *Building* Location,(1) in Celsius Degree-Days					
	Zone 4:(2) < 3000	Zone 5:(2) 3000 to 3999	Zone 6:(2) 4000 to 4999	Zone 7A:(2) 5000 to 5999	Zone 7B:(2) 6000 to 6999	Zone 8:(2) ≥ 7000
	Maximum *Overall Thermal Transmittance*, in W/(m²·K)					
Walls	0.315	0.278	0.247	0.210	0.210	0.183
Roofs	0.227	0.183	0.183	0.162	0.162	0.142
Floors	0.227	0.183	0.183	0.162	0.162	0.142

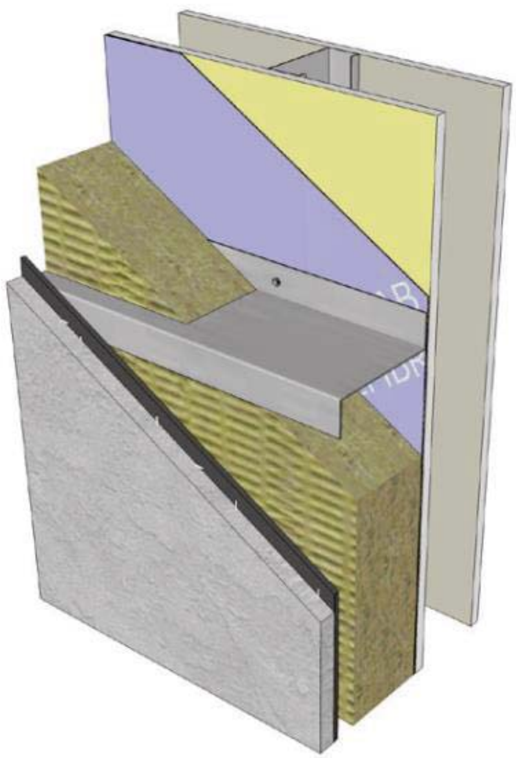
R-27

R-35

Examples Walls

Horizontal Z-Girts

RELATIVE COST	THERMAL EFFICIENCY	CONSTRUCTABILITY
$$$	30-50%	



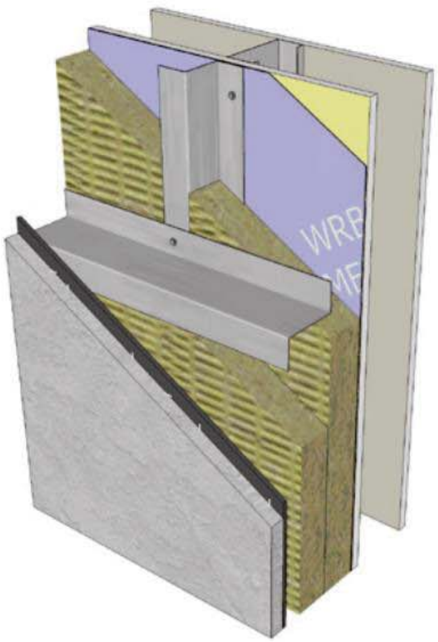
Horizontal Z-girts over a steel stud wall assembly. Girts are fastened every 36" here to reduce the thermal bridging.

Ref: Roxul Cladding Attachment Solutions for Exterior Insulated Commercial Walls – RDH Building Engineering Ltd and RDH Building Sciences Inc.

Examples Walls

Crossing Z-Girts

RELATIVE COST	THERMAL EFFICIENCY	CONSTRUCTABILITY
$$$	40-60%	



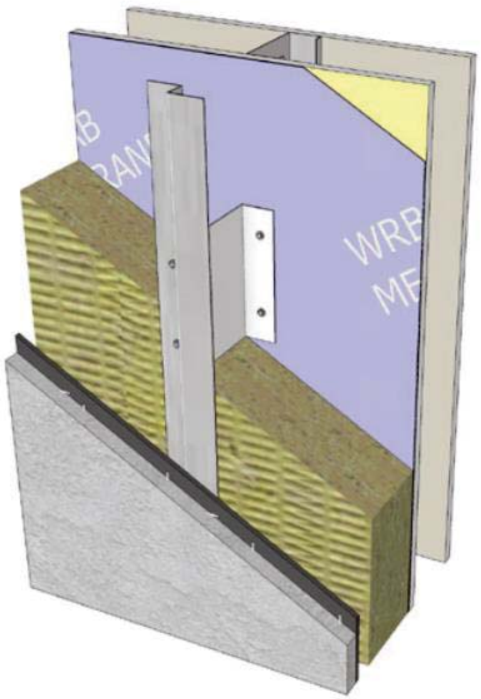
Crossing Z-girt assembly consisting of horizontal and vertical Z-girts attached at crossing points.

Ref: Roxul Cladding Attachment Solutions for Exterior Insulated Commercial Walls – RDH Building Engineering Ltd and RDH Building Sciences Inc.

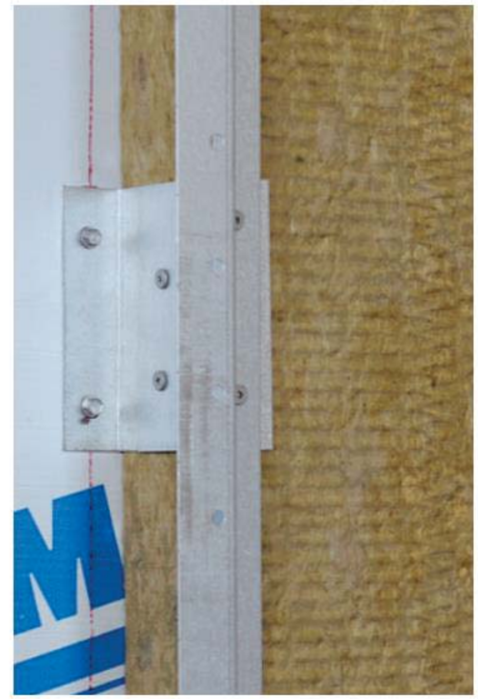
Examples Walls

Galvanized Steel Clips

RELATIVE COST	THERMAL EFFICIENCY	CONSTRUCTABILITY
$$$	50-75%	



Intermittent galvanized steel clips with vertical girts.

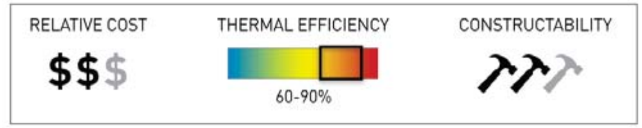


Generic adjustable back to back L-angle clips.

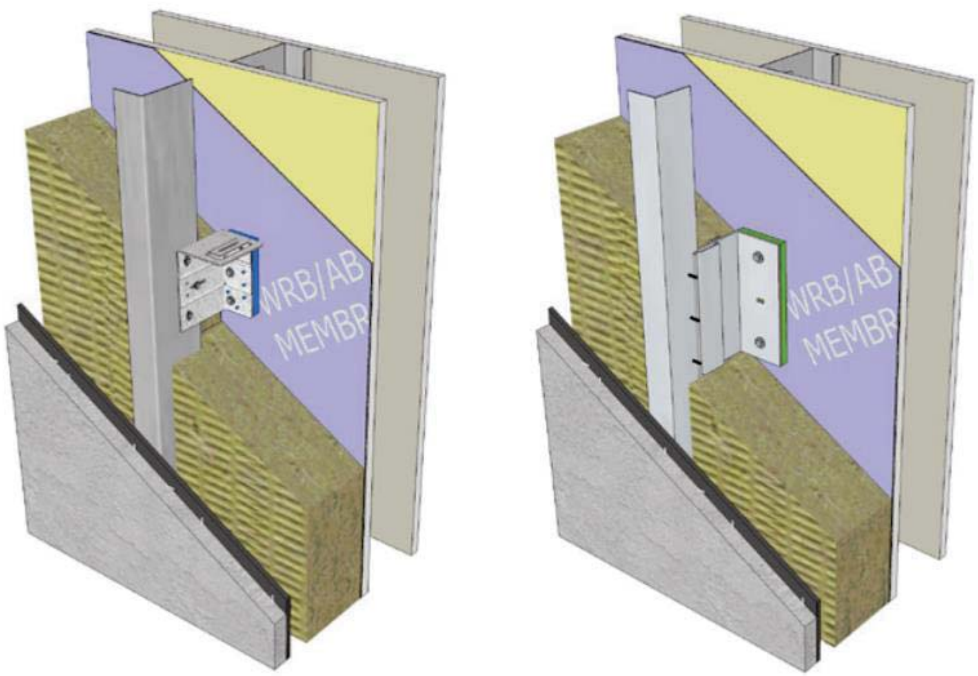
Ref: Roxul Cladding Attachment Solutions for Exterior Insulated Commercial Walls – RDH Building Engineering Ltd and RDH Building Sciences Inc.

Examples Walls

Thermally Isolated Galvanized Clips



Thermally isolated galvanized steel clip attached to wall with screws through plastic isolation pad.



Ref: Roxul Cladding Attachment Solutions for Exterior Insulated Commercial Walls – RDH Building Engineering Ltd and RDH Building Sciences Inc.

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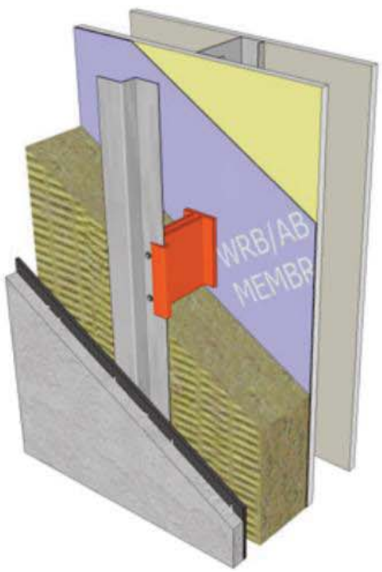
Examples Walls

Fiberglass Clips

RELATIVE COST	THERMAL EFFICIENCY	CONSTRUCTABILITY
$$$	70-95%	



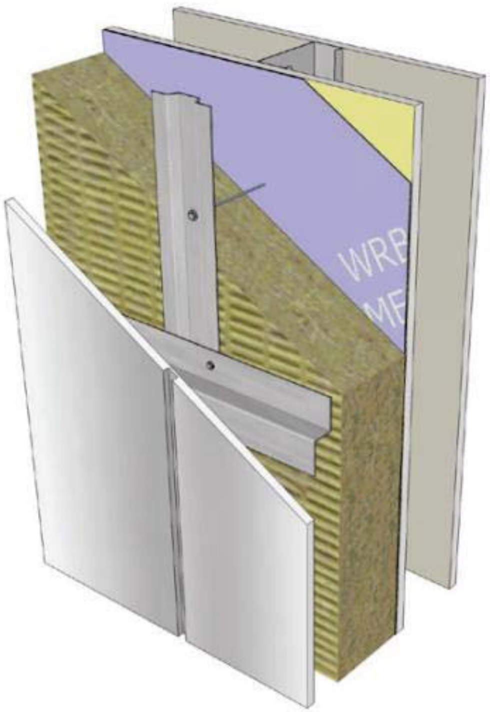
Fiberglass clips with vertical Z-girt attached with screw fasteners through the fiberglass clips into the back-up wall.

Ref: Roxul Cladding Attachment Solutions for Exterior Insulated Commercial Walls – RDH Building Engineering Ltd and RDH Building Sciences Inc.

Examples Walls

Long Screws through Insulation

RELATIVE COST	THERMAL EFFICIENCY	CONSTRUCTABILITY
$$$	75-95%	



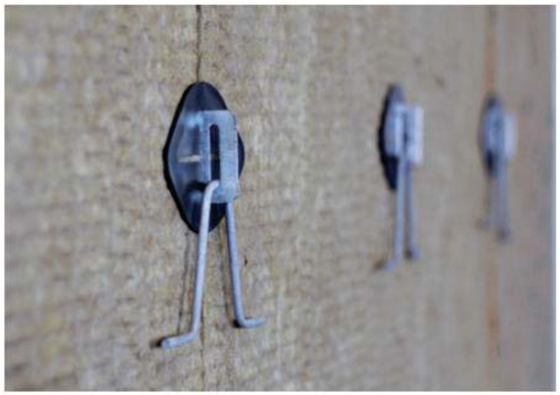
Long screws through horizontal metal hat tracks and rigid insulation on a commercial building project.

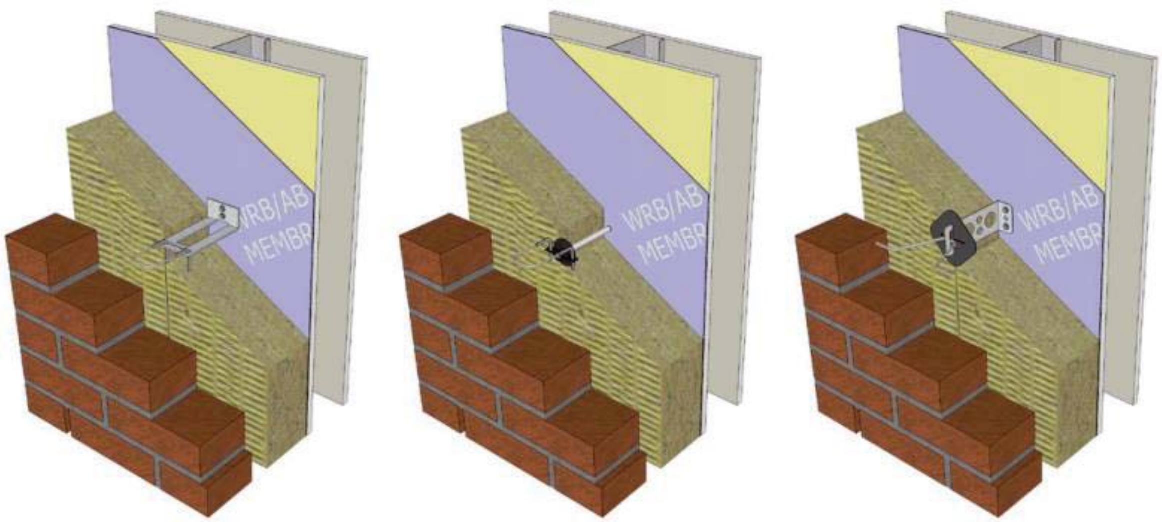
Ref: Roxul Cladding Attachment Solutions for Exterior Insulated Commercial Walls – RDH Building Engineering Ltd and RDH Building Sciences Inc.

Examples Walls

Masonry Ties

RELATIVE COST	THERMAL EFFICIENCY	CONSTRUCTABILITY
$$$	40-90%	





Ref: Roxul Cladding Attachment Solutions for Exterior Insulated Commercial Walls – RDH Building Engineering Ltd and RDH Building Sciences Inc.

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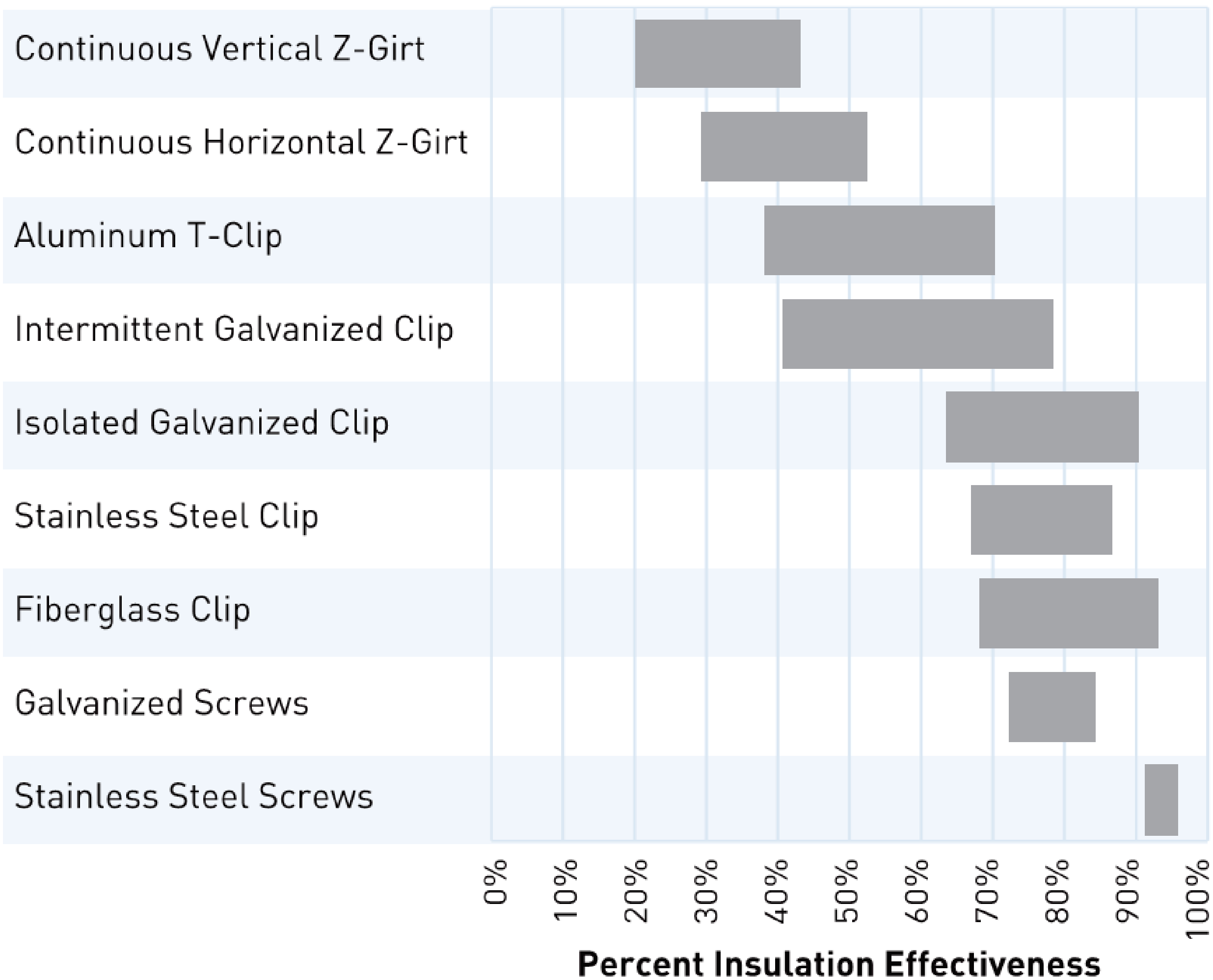
Examples Walls



Ref: Roxul Cladding Attachment Solutions for Exterior Insulated Commercial Walls
– RDH Building Engineering Ltd and RDH Building Sciences Inc.

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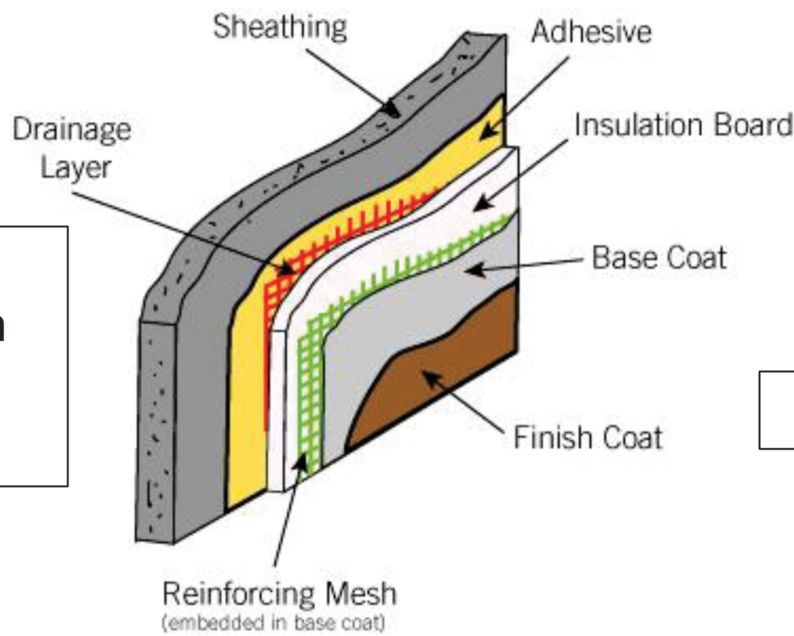
Can you think of assemblies that don't have thermal bridging?

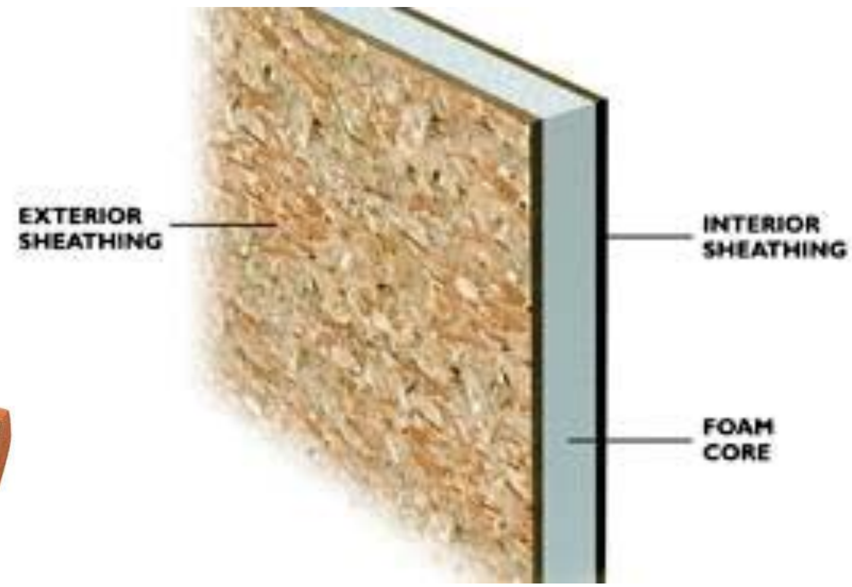
Ref: altushost.com

Exterior Insulation Finish Systems



Ref: livingwithmyhome.com

Structural Insulated Panels



Ref: newevergreen.buildevergreen.com

Double-Stud Walls

Ref: goldeneagleloghomes.com

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Prescriptive Path

Window/Door Requirements:

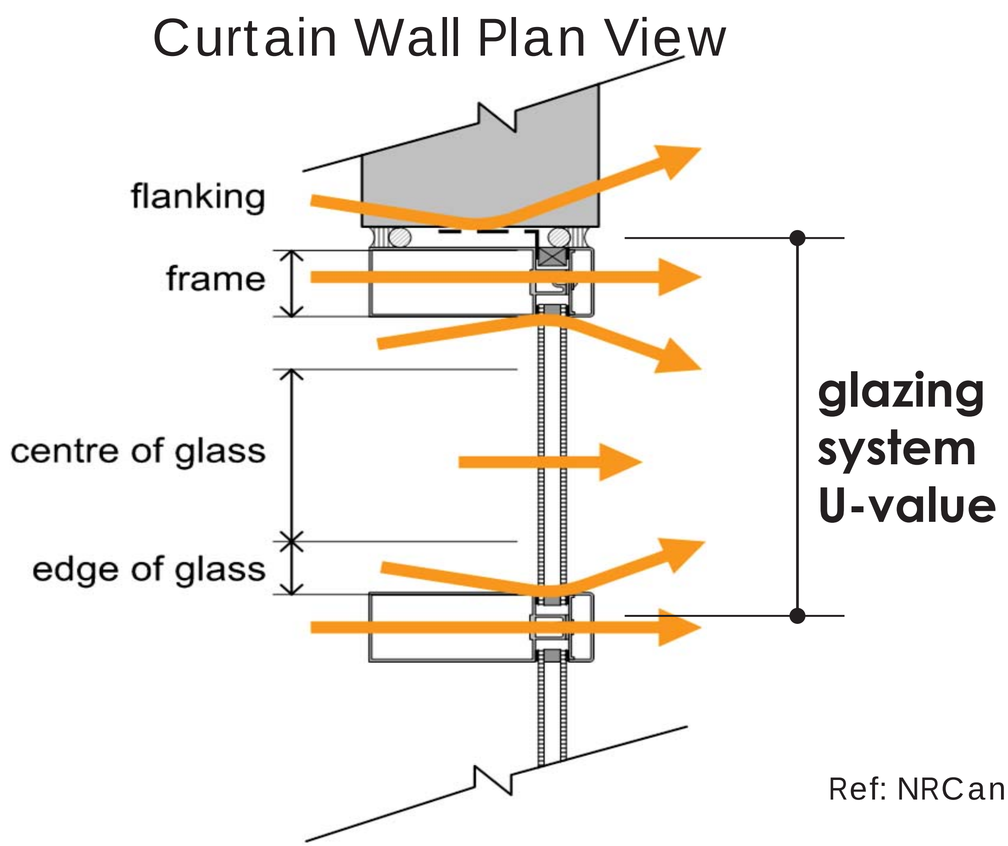
Component	Heating Degree-Days of *Building* Location,(1) in Celsius Degree-Days					
	Zone 4:(2) < 3000	Zone 5:(2) 3000 to 3999	Zone 6:(2) 4000 to 4999	Zone 7A:(2) 5000 to 5999	Zone 7B:(2) 6000 to 6999	Zone 8:(2) ≥ 7000
	Maximum *Overall Thermal Transmittance*, in W/(m²·K)					
All *fenestration*	2.4	2.2	2.2	~~2.2~~ → 2.0	~~2.2~~ → 2.0	1.6

Whole Frame Performance

Component	Heating Degree-Days of *Building* Location,(1) in Celsius Degree-Days					
	Zone 4:(2) < 3000	Zone 5:(2) 3000 to 3999	Zone 6:(2) 4000 to 4999	Zone 7A:(2) 5000 to 5999	Zone 7B:(2) 6000 to 6999	Zone 8:(2) ≥ 7000
	Maximum *Overall Thermal Transmittance*, in W/(m²·K)					
All doors	2.4	2.2	2.2	2.2	2.2	1.6

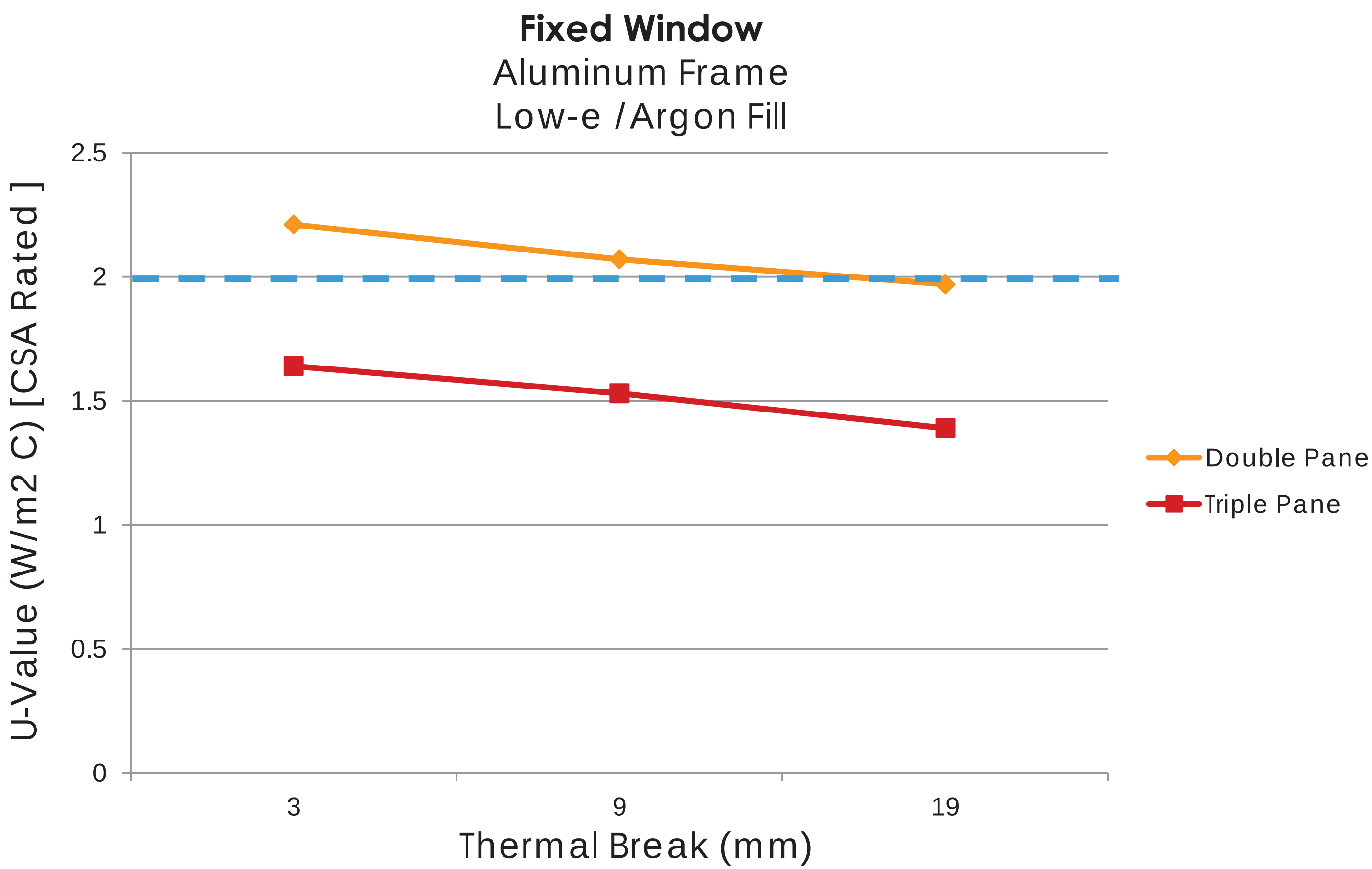
Prescriptive Path

Window/Door Requirements:



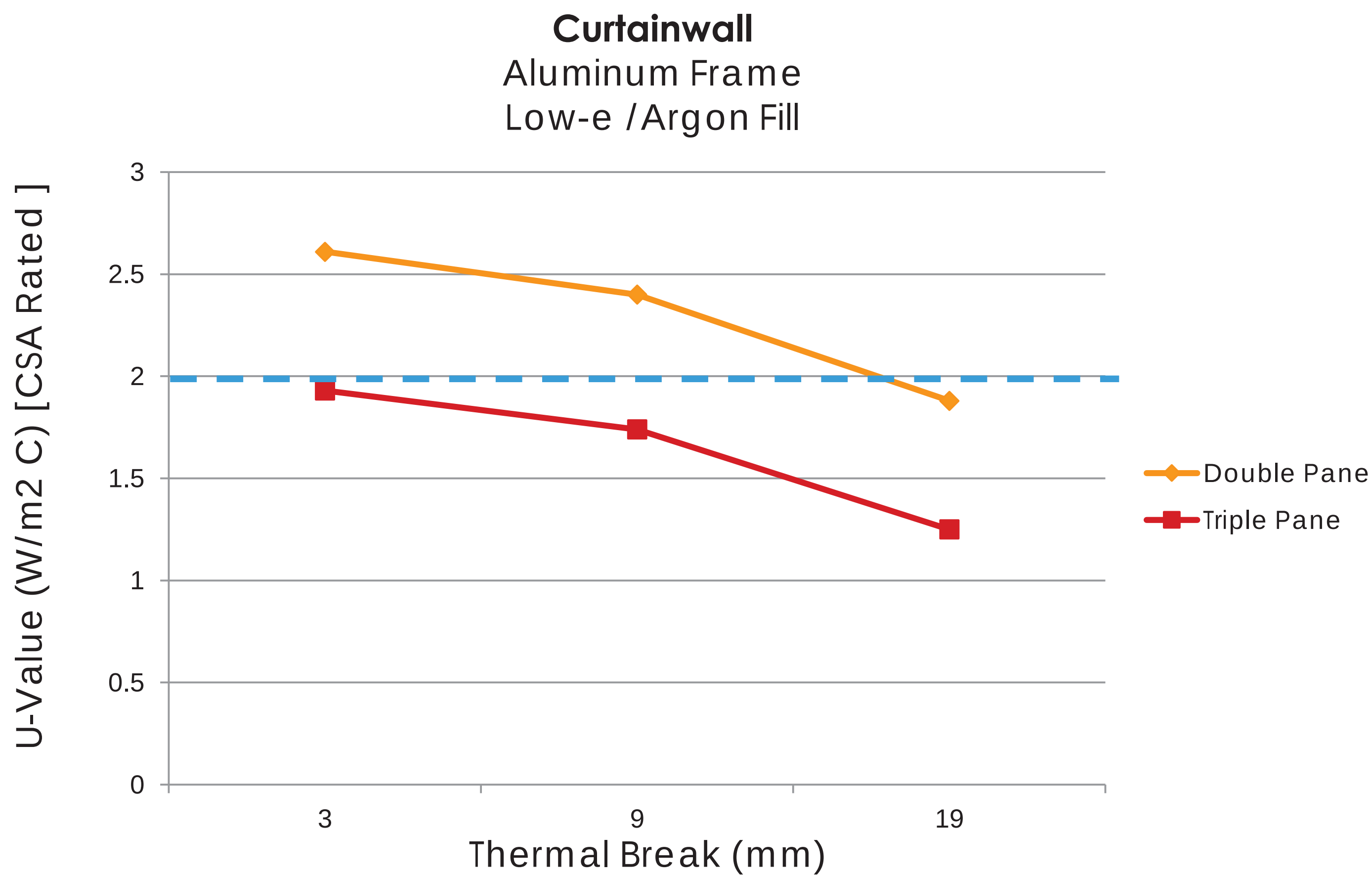
Ref: NRCan

Example Windows



Ref: Frameplus Online

Example Windows



Ref: Frameplus Online

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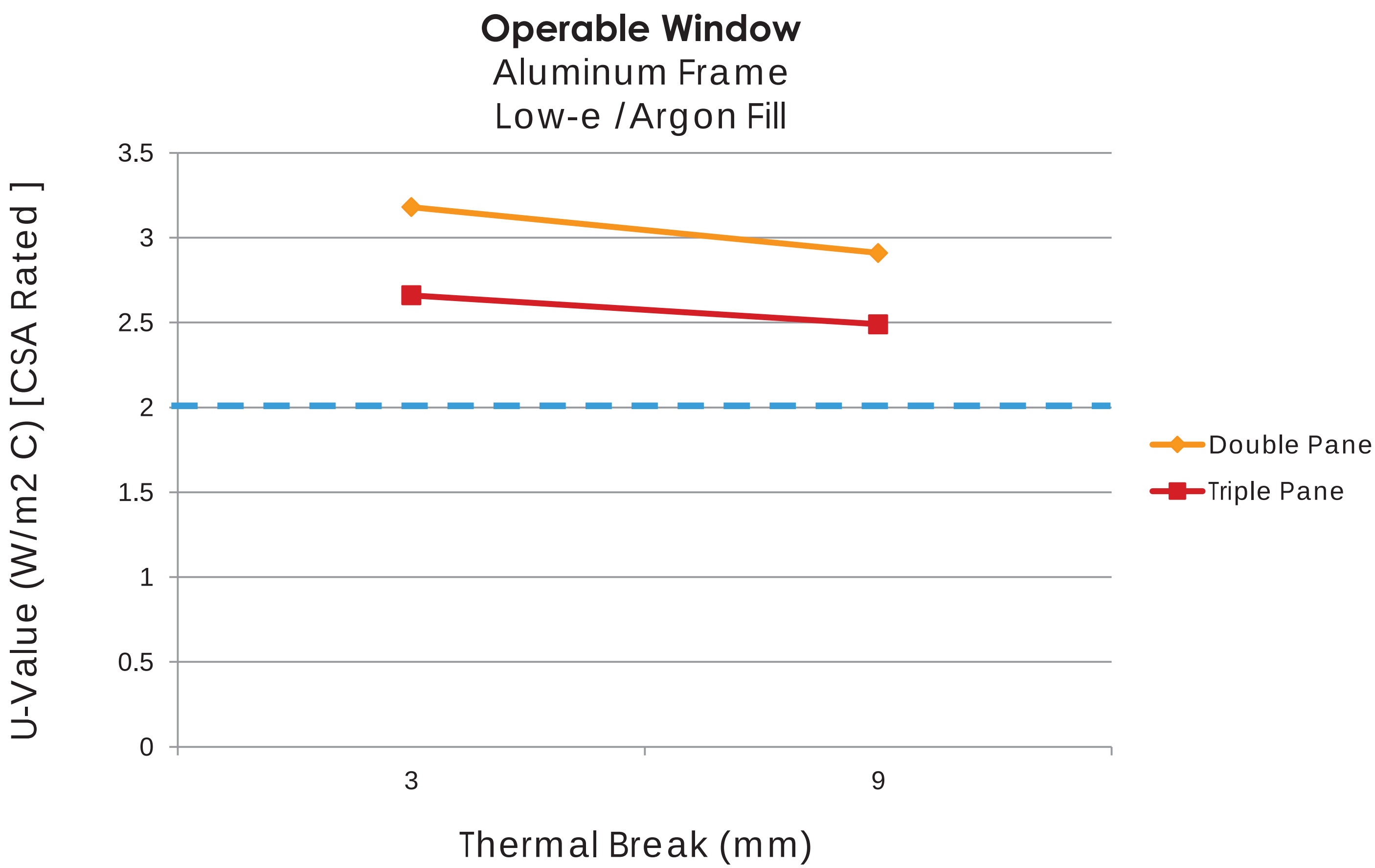
Example Windows



Ref: Frameplus Online

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Fenestration-and-Door-to-Wall Ratio:

Table A-3.2.1.4.(1)
Maximum Allowable FDWR for Various HDD

HDD	Max. FDWR
< 4000	0.40
4000	0.40
4250	0.38
4500	0.37
4750	0.35
5000	0.33
5250	0.32
5500	0.30
5750	0.28
6000	0.27
6250	0.25
6500	0.23
6750	0.22
7000	0.20
> 7000	0.20

Winnipeg ~ 29%

Prescriptive Summary

City	HDD	Zone	Roof-U	Roof-R	Wall-U	Wall-R	Max FDWR
Vancouver	2825	4	0.227	R-25	0.315	R-18	40%
Calgary	5000	7A	0.162	R-35	0.21	R-27	33%
Edmonton	5120	7A	0.162	R-35	0.21	R-27	32%
Fort McMurray	6250	7B	0.162	R-35	0.21	R-27	25%
Winnipeg	**5670**	**7A**	**0.162**	**R-35**	**0.21**	**R-27**	**29%**
Toronto	3520	5	0.183	R-31	0.278	R-20	40%
Halifax	4000	6	0.183	R-31	0.247	R-23	40%
St. John	4570	6	0.183	R-31	0.247	R-23	37%
St. John's	4800	6	0.183	R-31	0.247	R-23	35%

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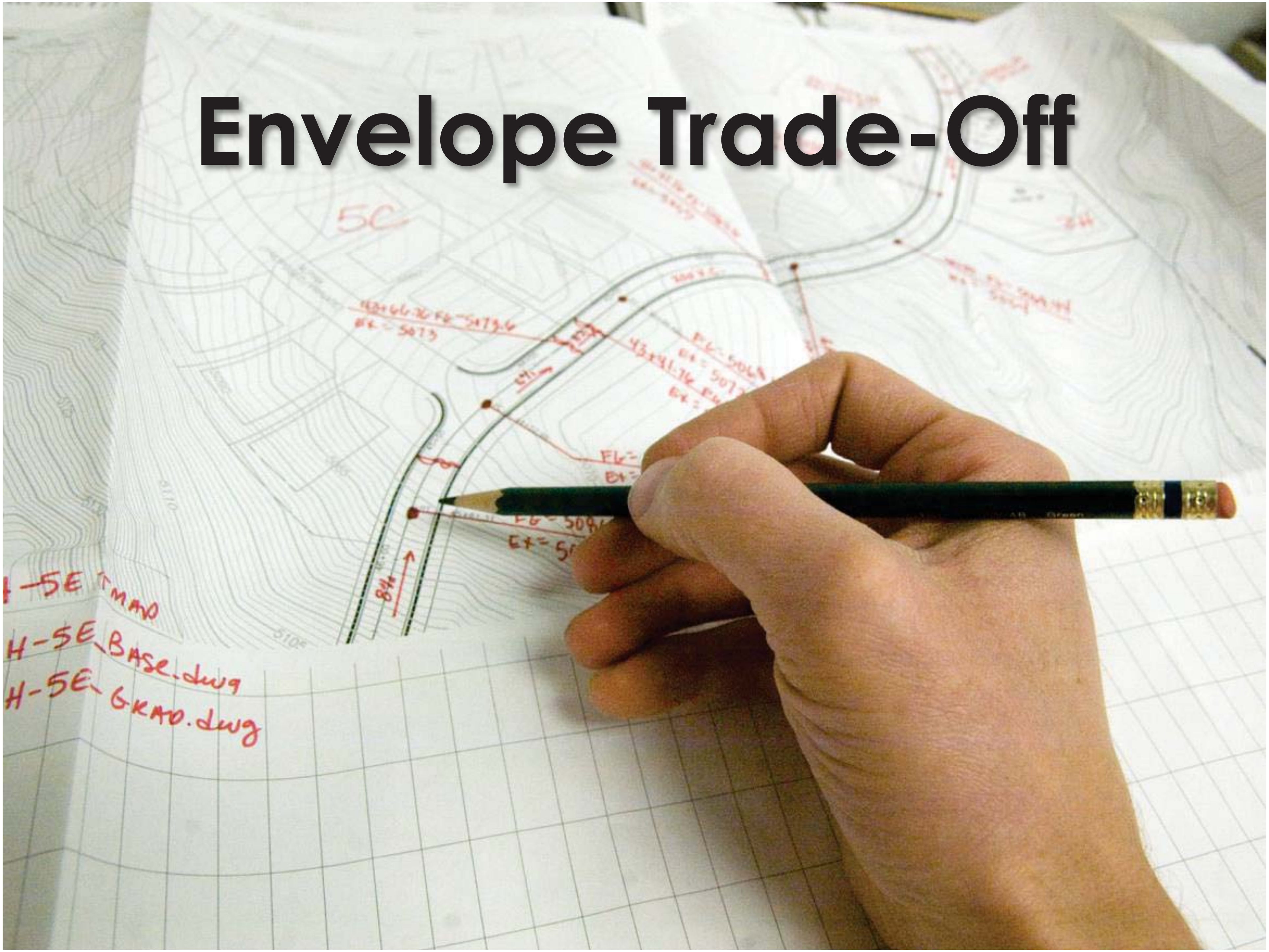
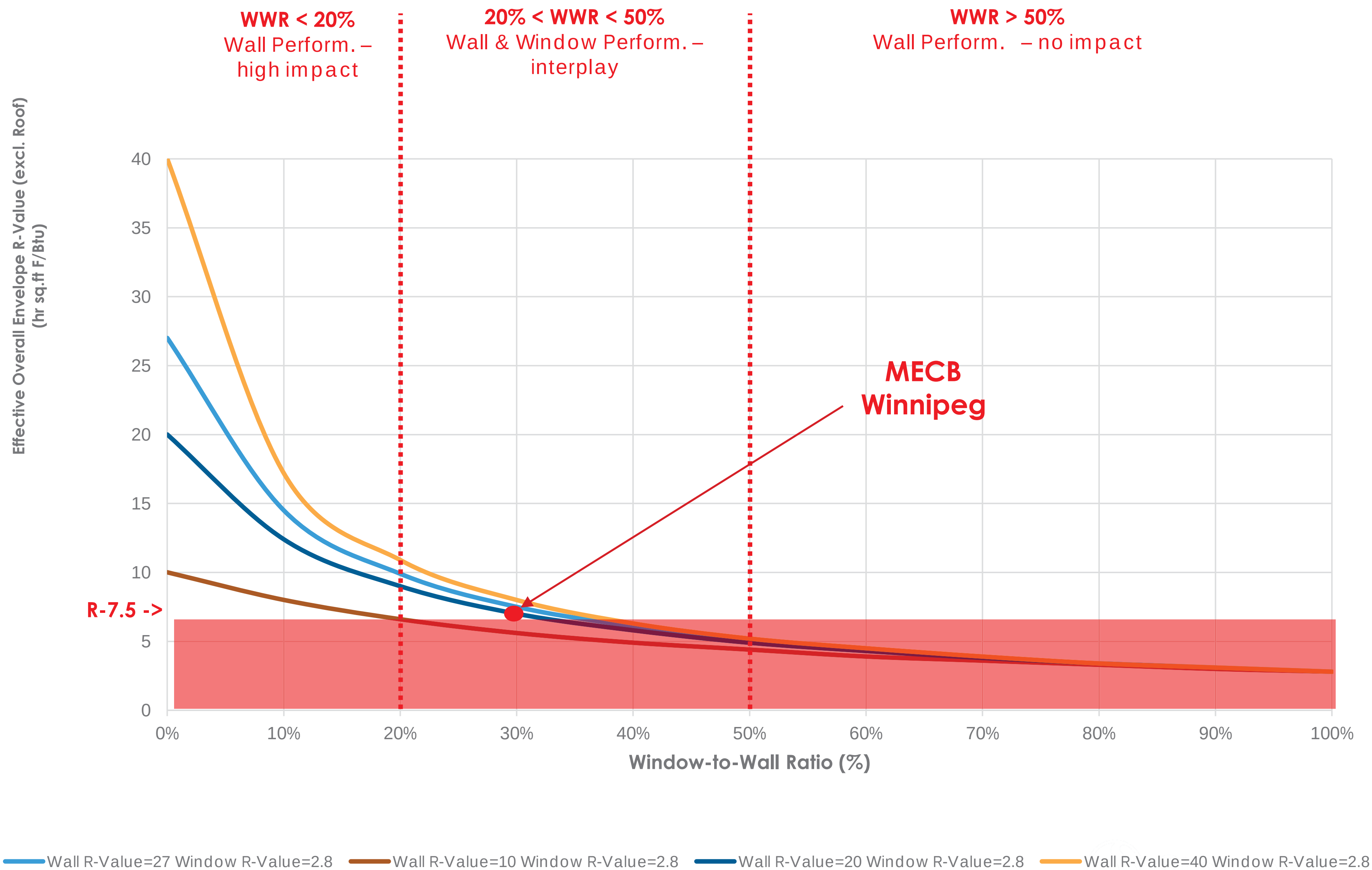
Envelope Trade-Off



Envelope Simple Trade-Off:

$$\sum_{i=1}^{n} U_{ip}A_{ip} \leq \sum_{i=1}^{n} U_{ir}A_{ir}$$

- Vertical can only be traded off against vertical
- Same for horizontal
- Reference assumes prescriptive targets
- For Winnipeg:
  - R27 wall insulation / R35 Roof
  - U=2.0 windows
  - 29% FDWR
  - Even 5% skylights


WWR < 20%
Wall Perform. – high impact
20% < WWR < 50%
Wall & Window Perform. – interplay
WWR > 50%
Wall Perform. – no impact
MECB Winnipeg
R-7.5 ->
Effective Overall Envelope R-Value (excl. Roof) (hr sq.ft F/Btu)
0
5
10
15
20
25
30
35
40
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Window-to-Wall Ratio (%)
Wall R-Value=27 Window R-Value=2.8
Wall R-Value=10 Window R-Value=2.8
Wall R-Value=20 Window R-Value=2.8
Wall R-Value=40 Window R-Value=2.8

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CASE STUDY - WAREHOUSE

<u>Prescriptive Targets – Wall Construction</u>

- FDWR = 29%
- Windows U = 2.0 W/m2K
- Doors U = 2.2 W/m2K
- Walls U = 0.210 W/m2K (R27)

<u>Warehouse – Wall Construction</u>

- FDWR = 5% (only doors, no windows)
- Doors U = 2.2 W/m2K
- Walls = ??

Wall Area = 10,000 sf

Proposed Heat Transfer Coefficient ≤ Baseline Heat Transfer Coefficient

$$\sum_{i=1}^{n} U_{ip}A_{ip} \leq \sum_{i=1}^{n} U_{ir}A_{ir}$$

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CASE STUDY - WAREHOUSE

Prescriptive Targets – Wall Construction

- FDWR = 29%
- Windows U = 2.0 W/m2K
- Doors U = 2.2 W/m2K
- Walls U = 0.210 W/m2K (R27)

Warehouse – Wall Construction

- FDWR = 5% (only doors, no windows)
- Doors U = 2.2 W/m2K

-> $U_{Walls} \leq 0.64\ W/m^2K$ (R8.8)

Wall Area = 10,000 sf

Proposed Heat Transfer Coefficient ≤ Baseline Heat Transfer Coefficient

$$\sum_{i=1}^{n} U_{ip} A_{ip} \leq \sum_{i=1}^{n} U_{ir} A_{ir}$$

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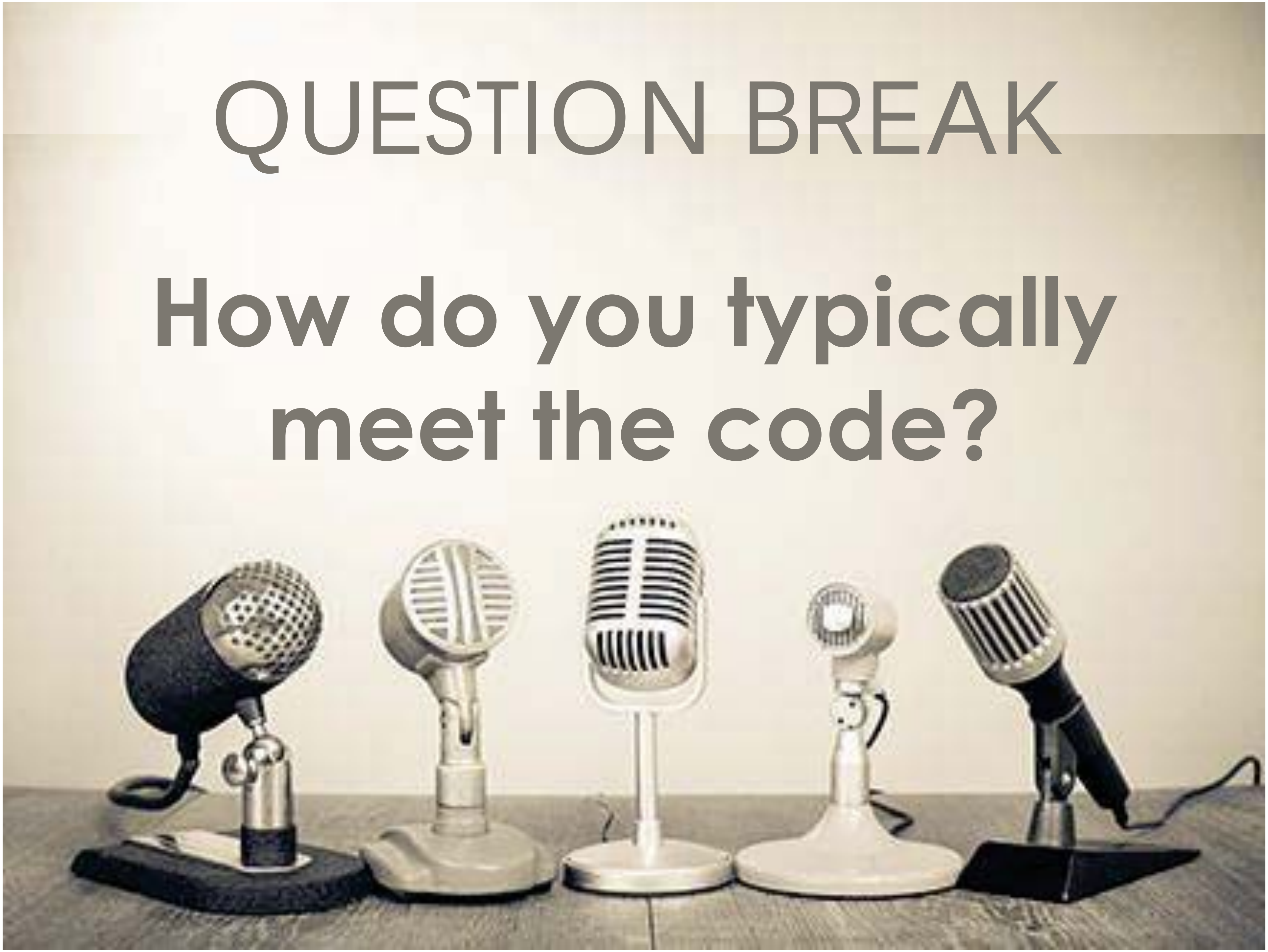
Trade-off path

HVAC, SHW & Lighting:

– Use trade-off to calculate annual interior HVAC trade-off index and service water trade-off index

– Use trade-off to calculate annual interior lighting energy consumption
– Includes impacts of daylighting and occupancy controls

– Use spreadsheet tools available from NRCan


QUESTION BREAK
How do you typically meet the code?


Performance Path

Why Use Performance Path?

- It offers the greatest flexibility for demonstrating compliance
- It is often the only alternative when the design is non-compliant due to:
  - high FWDR values
  - predominantly curtain-wall or window-wall envelope
  - lighting requirements
  - HVAC limitations
- May be required for other project goals (LEED, Power Smart)
- **Different buildings have different energy profiles**
  - **Modeling allows for the most optimum design**

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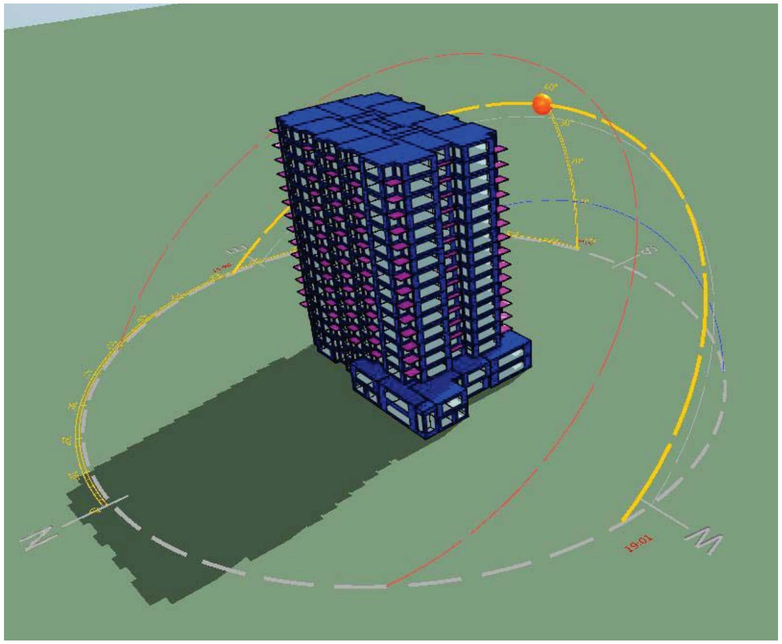
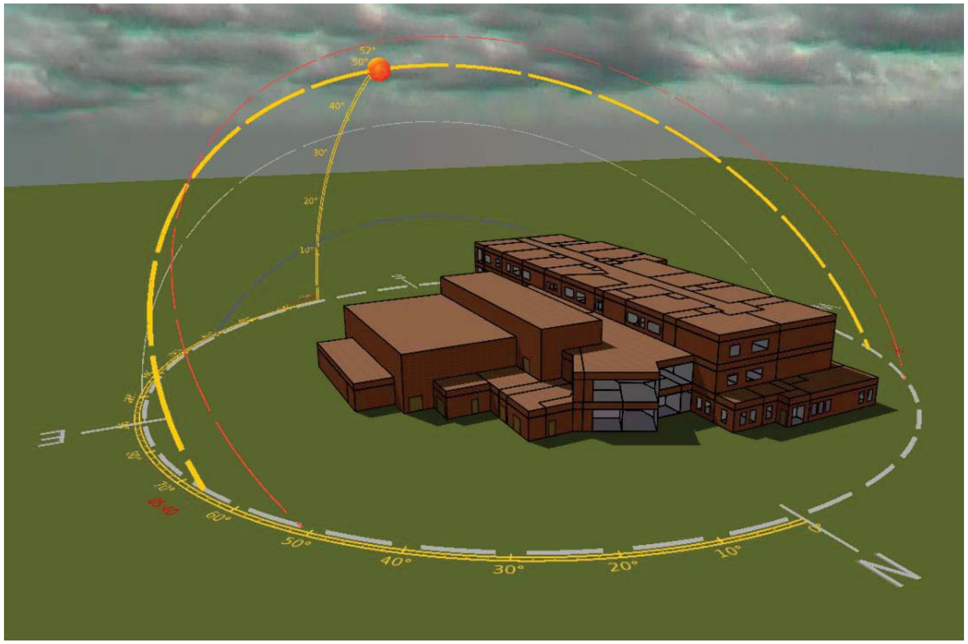
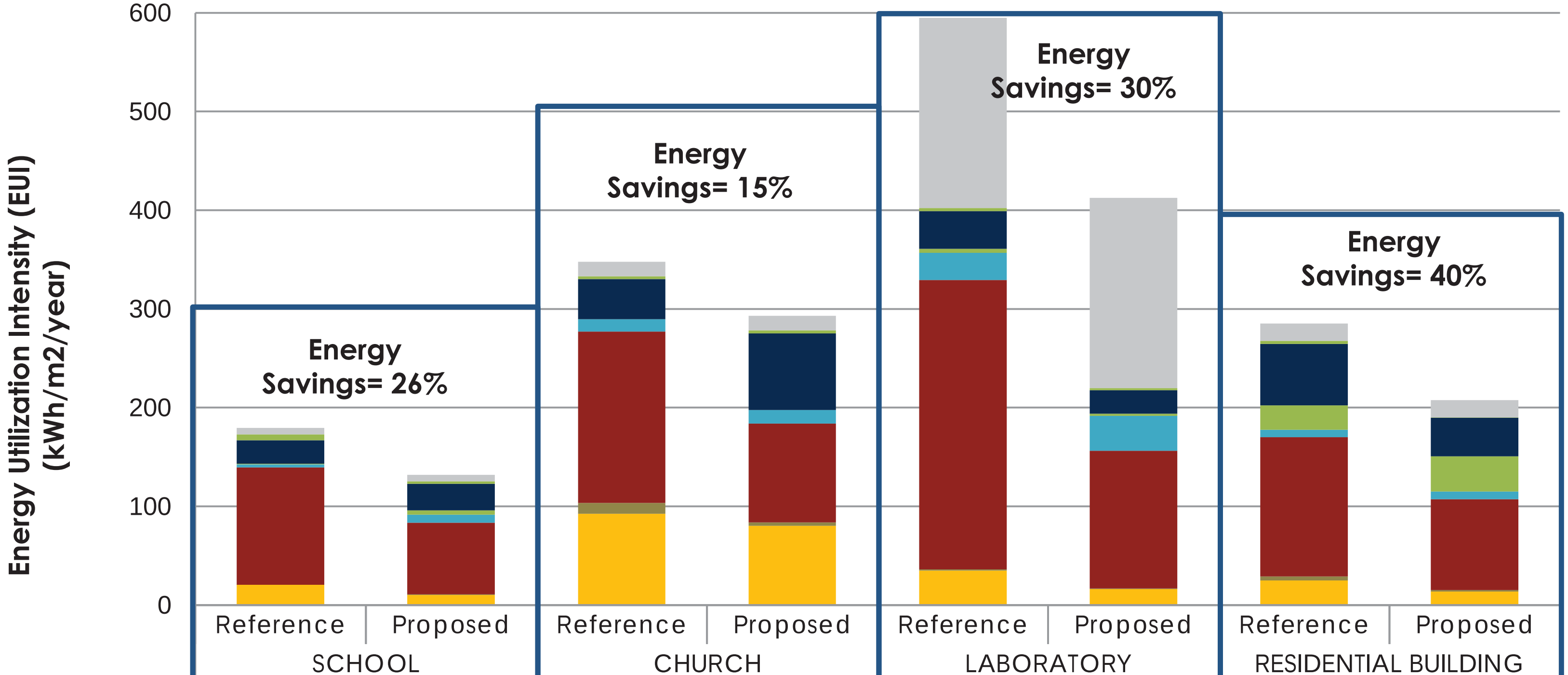
Can you guess the function?



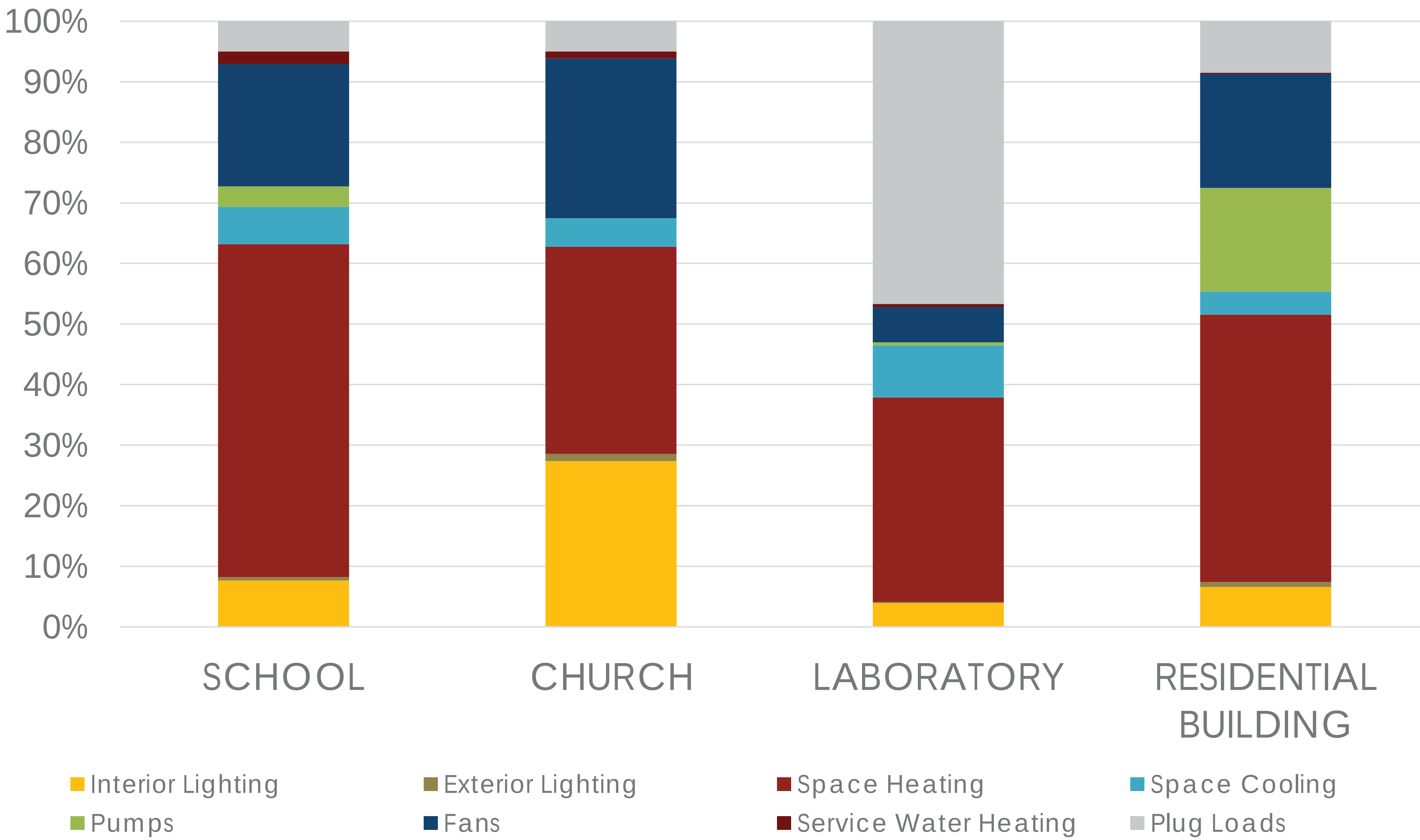


Different Building Types = Different Energy Utilization Intensity (EUI)

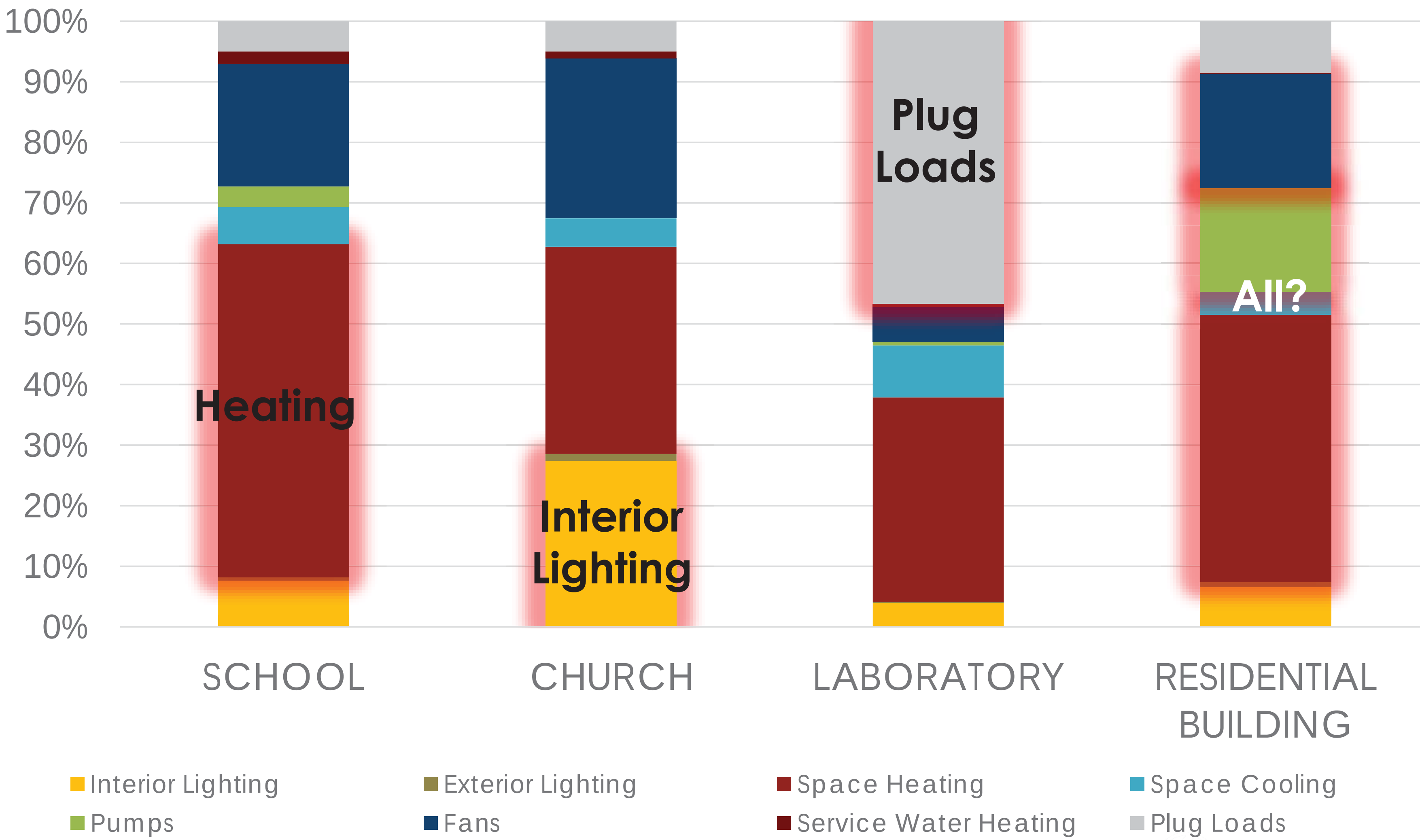


	SCHOOL Reference	SCHOOL Proposed	CHURCH Reference	CHURCH Proposed	LABORATORY Reference	LABORATORY Proposed	RESIDENTIAL BUILDING Reference	RESIDENTIAL BUILDING Proposed
Total	180	132	347.7	293.1	594.8	412.6	285.3	207.8
Plug Loads	7	7	14.7	14.7	192.7	192.7	17.7	17.7
Service Water Heating	6	3	2.7	3.4	3.1	2.1	3.2	0.4
Fans	24	27	40.7	77.3	38.0	24.0	62.1	39.1
Pumps	1	4	0.0	0.0	4.1	2.0	24.7	35.6
Space Cooling	3	8	12.5	13.8	27.7	35.5	7.4	7.9
Space Heating	119	73	173.6	100.3	293.0	139.5	141.2	91.8
Exterior Lighting	0	1	11.1	3.4	1.3	0.7	4.0	1.6
Interior Lighting	20	10	92.4	80.2	34.9	16.1	25.0	13.7

Different Building Types = Different Weight of Energy End-Use
(DIFFERENT OPTIMIZATION STRATEGIES)



Different Building Types = Different Weight of Energy End-Use
(DIFFERENT OPTIMIZATION STRATEGIES)



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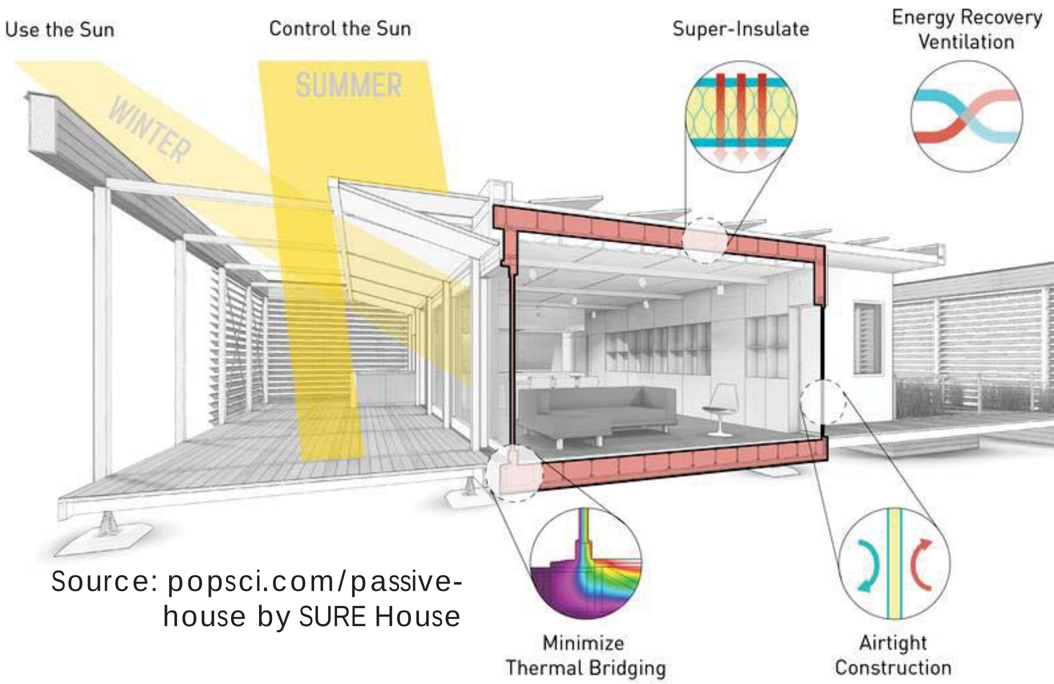
Why Use Performance Path?

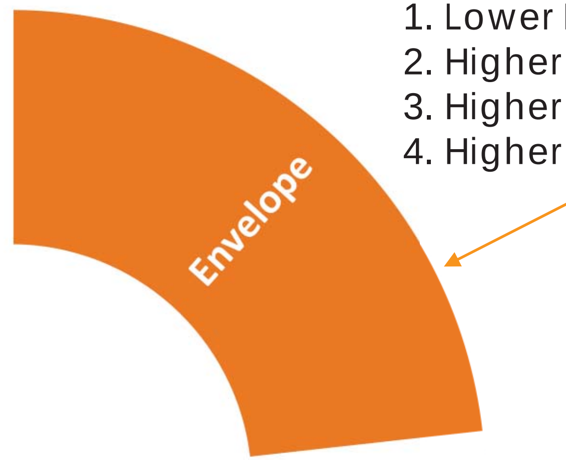
- Energy modeling allows for the quantification of Energy Conservation Measures (ECMs)



Source: popsci.com/passive-house by SURE House

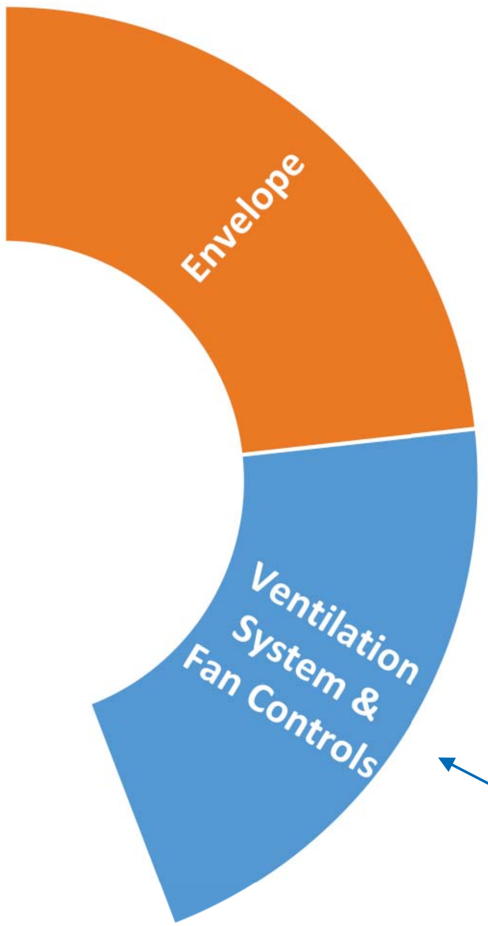
Source: Chum Creek Outdoor Education Centre FMSA Architects

Energy Conservation Measures (ECMs)



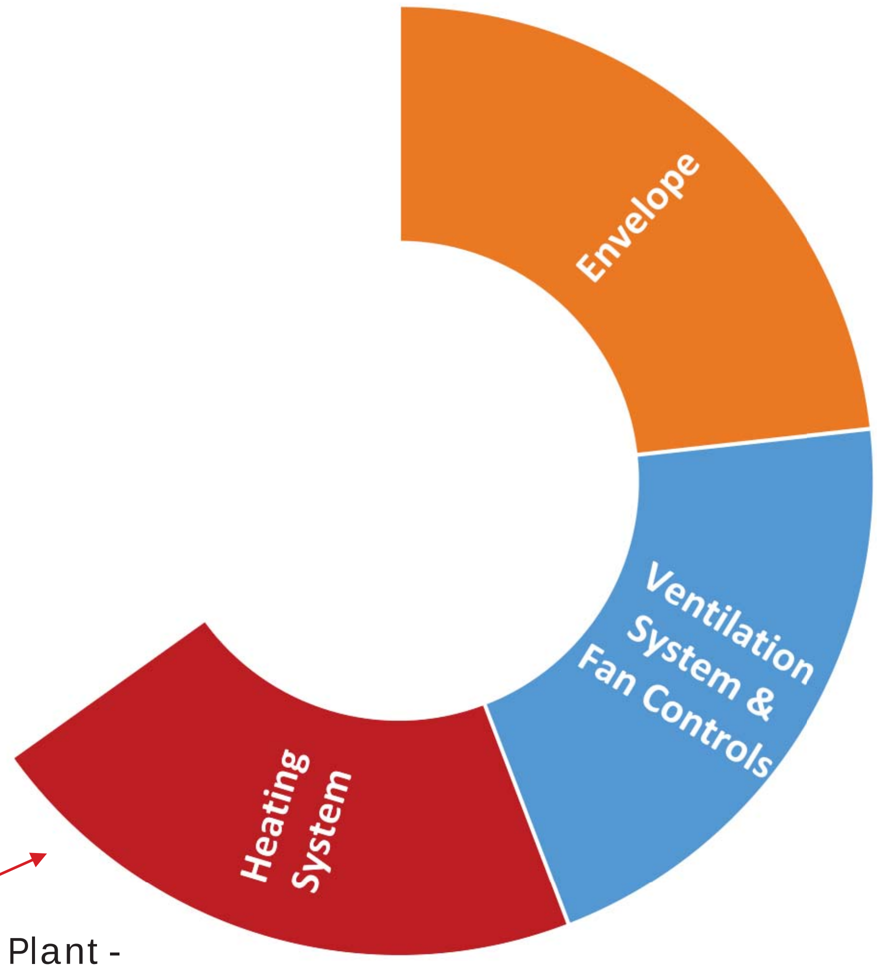
1. Lower FDWR
2. Higher Wall R-Value
3. Higher Window R-Value
4. Higher Roof R-Value

Energy Conservation Measures (ECMs)



1. DOAS
2. DCV
3. Displacement Ventilation
4. Active Chilled Beams

Energy Conservation Measures (ECMs)



1. High Efficiency Heating Plant - Condensing Gas Boiler 96%
2. Ground-/Water-Source Heat Pump
3. Air Source Heat Pump etc.

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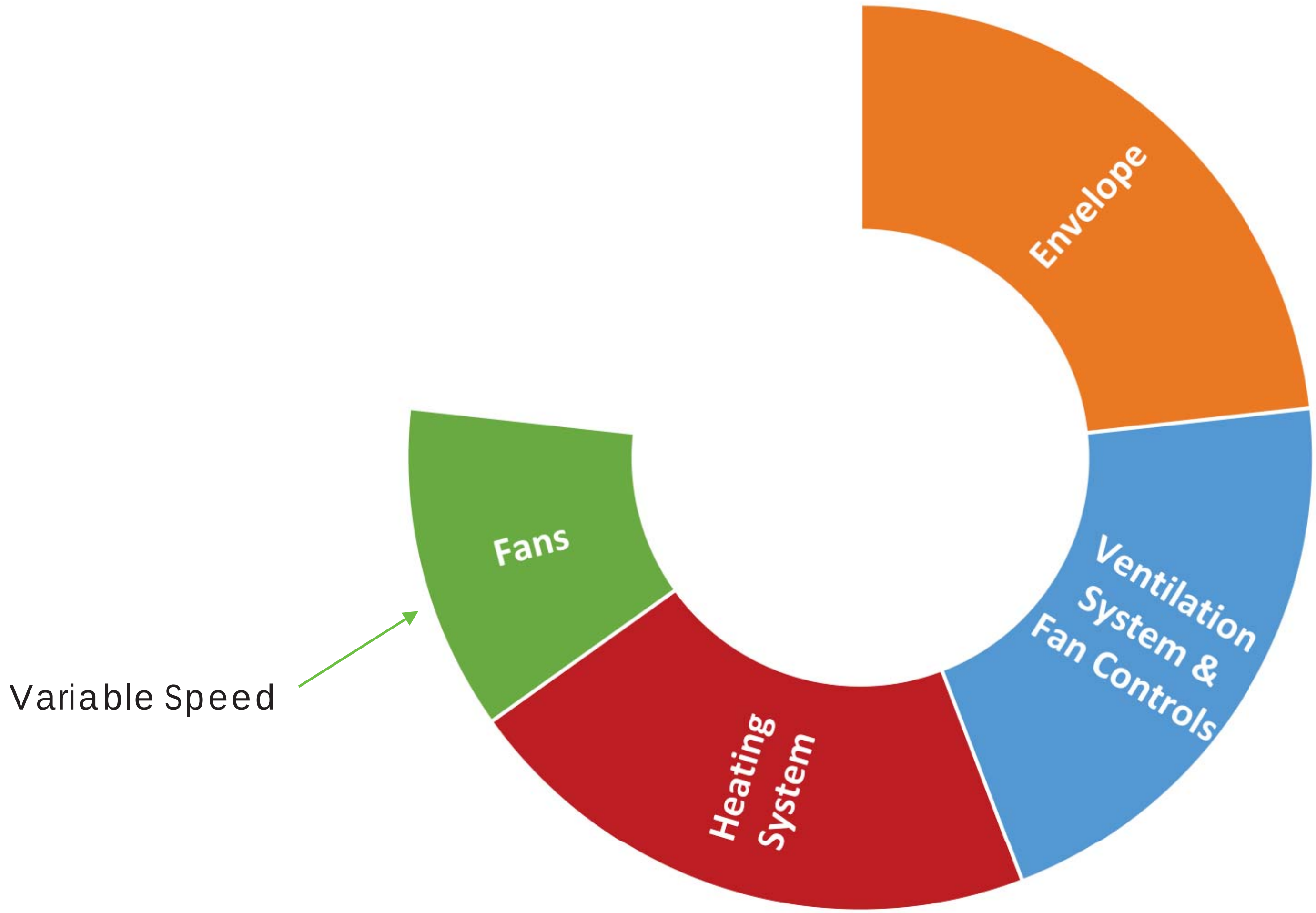
Energy Conservation Measures (ECMs)

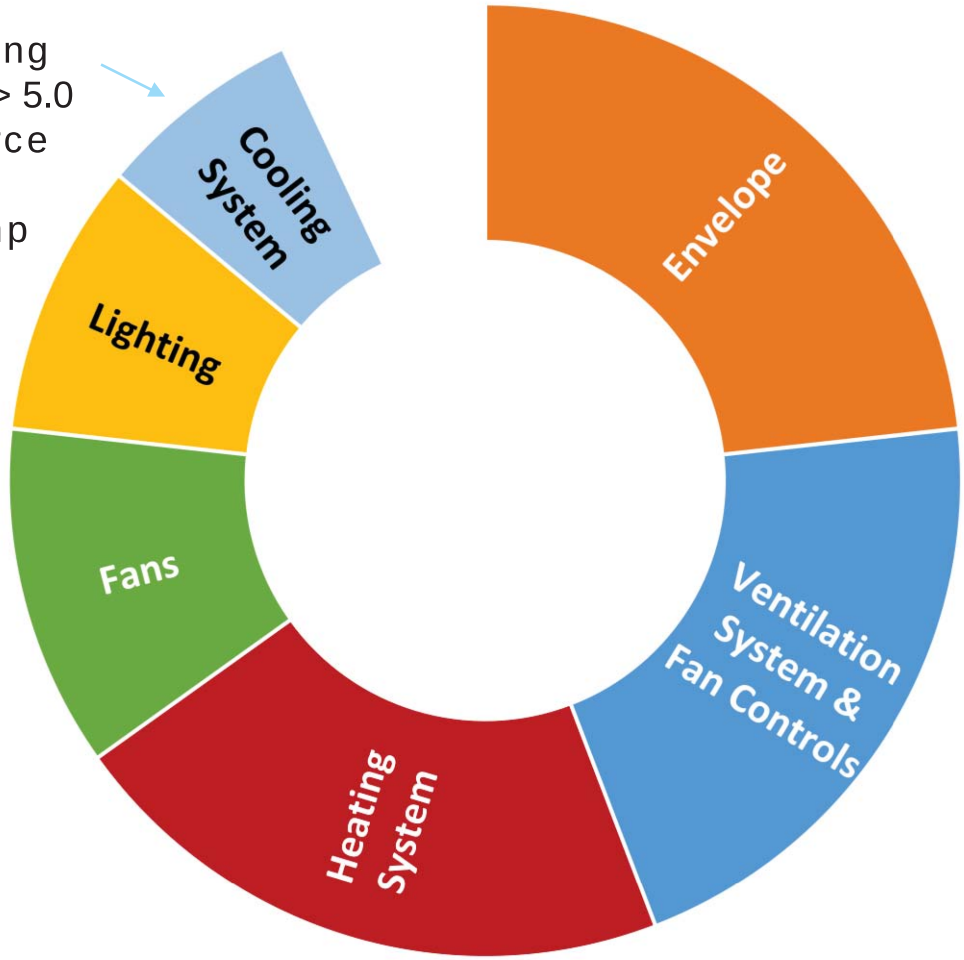


Energy Conservation Measures (ECMs)

1. Occupancy Sensors
2. Daylight Sensors
3. LED Lighting

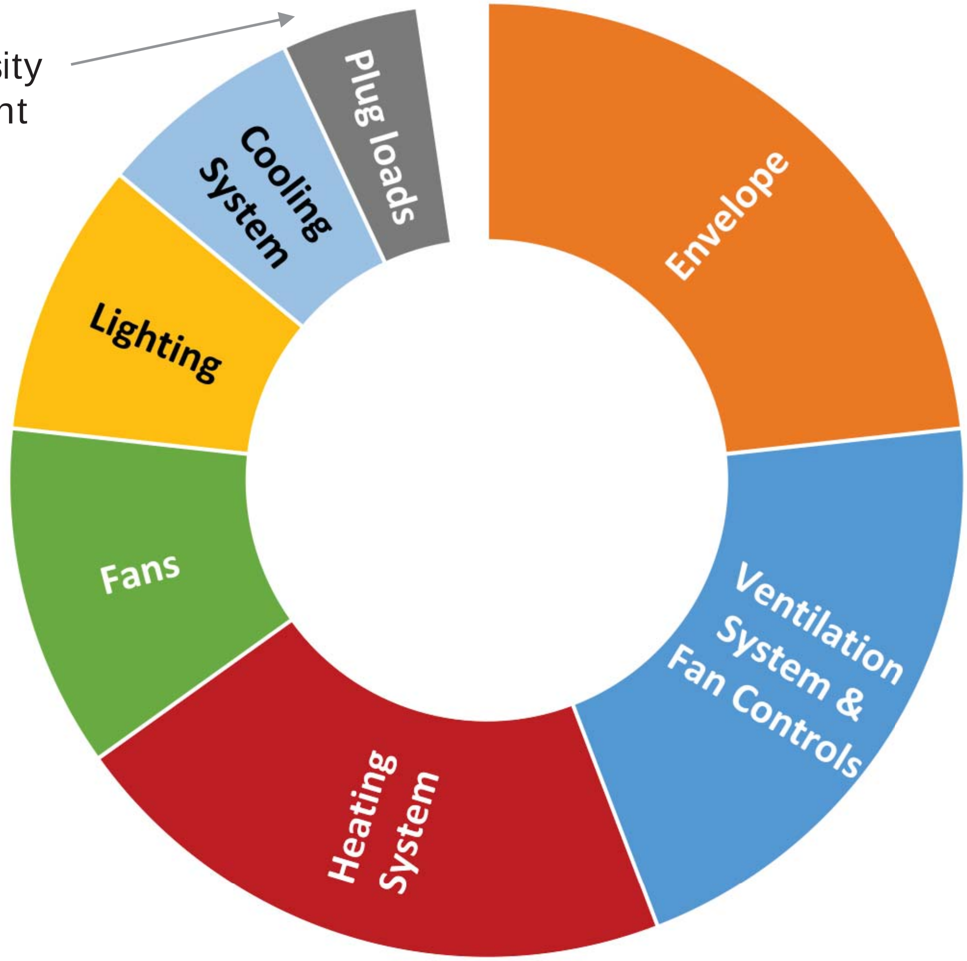
Energy Conservation Measures (ECMs)

1. High Efficiency Cooling Plant - Chiller w/ COP > 5.0
2. Ground-/Water-Source Heat Pump
3. Air Source Heat Pump



Energy Conservation Measures (ECMs)

Reduced Power Density of Specialty Equipment



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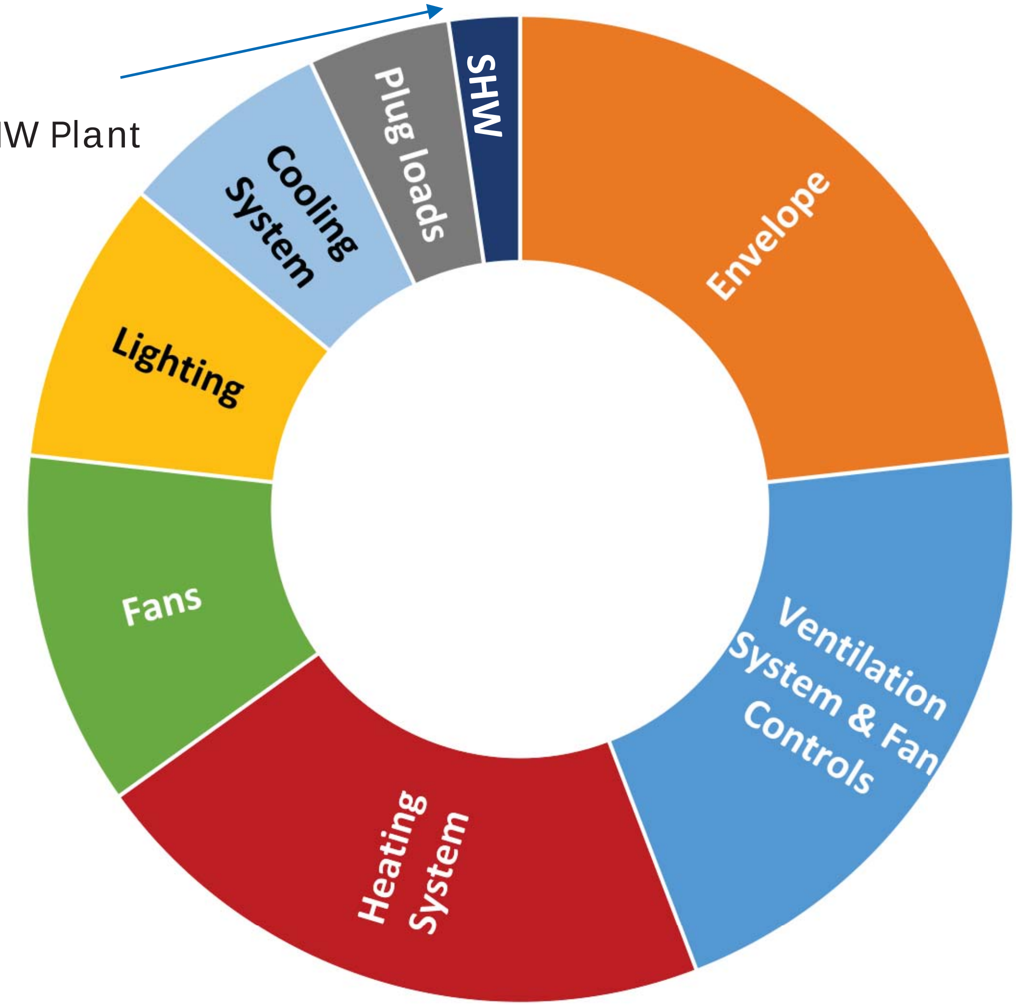
Energy Conservation Measures (ECMs)

1. Low-Flow Fixtures
2. High Efficiency SHW Plant



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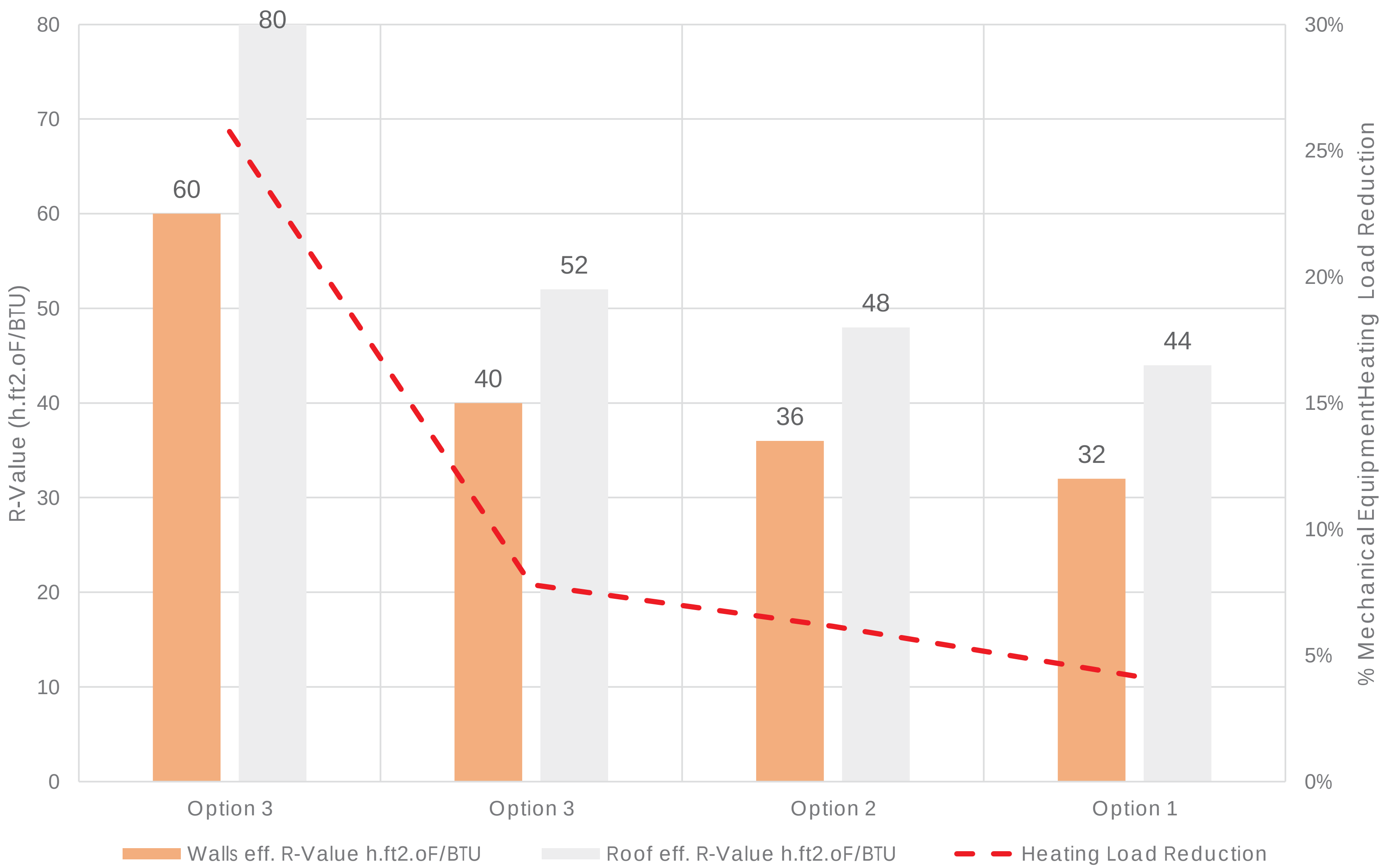
ECMs quantified: **Envelope Thermal Performance vs. Mechanical Load Reduction**



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Why Else Conduct Energy Simulations?

- Loads calculations
- Design flexibility
- Project-specific resource allocation – i.e. where to put your money
- Integrated design facilitation – early-stage design optimization across disciplines

- Financial incentives: Manitoba Hydro Power Smart
  - Energy Modeling Assistance Incentive
  - Performance Path Incentive – you cannot receive financial incentives w/o energy modeling, commissioning, integrated design etc.

- Responding to other sustainability requirements (oftentimes dictated in the RFP):
  - MB Hydro Power Smart
  - LEED – you cannot earn credits w/o energy modeling

Why Else Conduct Energy Simulations?

- **Power Smart New Buildings Program:**
  - Energy Modeling Assistance Incentive:
    - **Max. $10,000**
  - Performance Path Incentive:
    - **Incentive per project area**
    - **(Max. $2.00/ft²)**
- What do you need to do to get it?
  - **Power Smart designation, if Proposed Energy Consumption < 10% than MECB Baseline Energy Consumption**
- Why do it?
  - Your building has to qualify for MECB anyways
  - Power Smart incentives are modelled to the same baseline (no extra work)
  - Financial incentive back to the client

Building energy target (% better than MECB)	Incentive factor ($/sq. ft)
5	0.50
6	0.60
7	0.70
8	0.80
9	0.90
Power Smart designation levels (10 to 20%)	
10	1.00
11	1.10
12	1.20
13	1.30
14	1.40
15	1.50
16	1.60
17	1.70
18	1.80
19	1.90
20	2.00

https://www.hydro.mb.ca/your_business/new_building/incentives.shtml

Why Else Conduct Energy Simulations?

- LEED Energy and Atmosphere:
- **Energy optimization alone can contribute to 25 – 50% of your LEED certification**
  - Prerequisite: Minimum Energy Performance
  - Credit: Optimize Energy Performance

	LEED v4
LEED Certified LEED Silver LEED Gold LEED Platinum	40 – 49 points 50 – 59 points 60 – 79 points 80 – 110 points

If you go **performance path**, you get	up to **18 points** for all buildings, except up to 16 points for schools up to 20 points for healthcare
Compliance Paths	either NECB 2011 or ASHRAE 90.1:2010 **Proposed Energy Cost < 5% than Baseline Energy Cost**

What to expect of Part 2 of this series?

- Today we focused on **COMPLIANCE**
- Next time we will focus on how powerful energy modeling can be, when used as a **DESIGN OPTIMIZATION TOOL**

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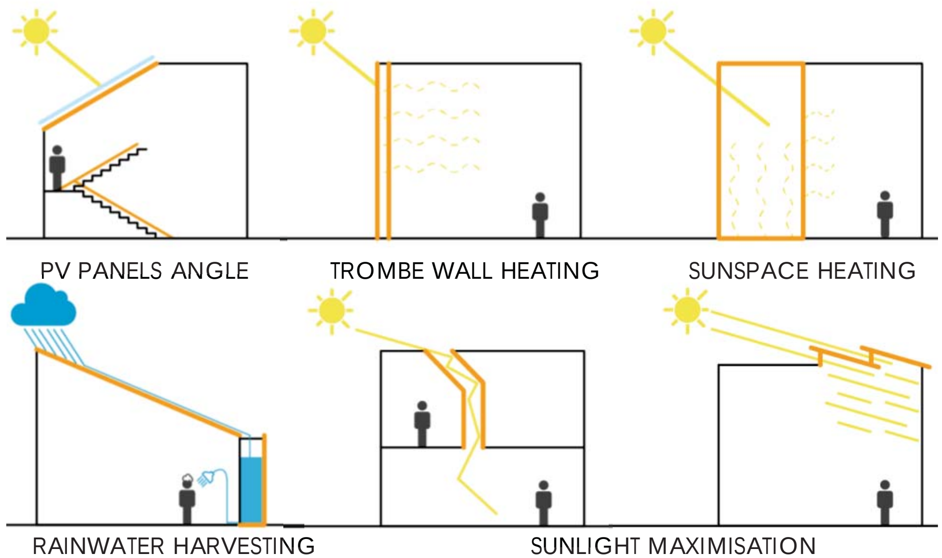
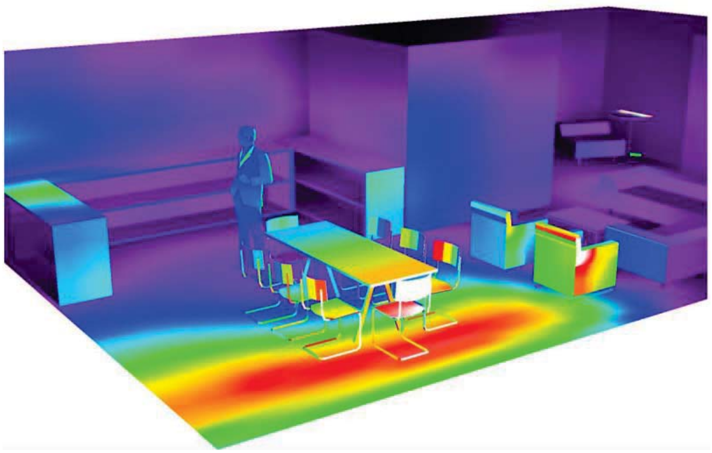
What to expect of Part 2 of this series?





- Energy modeling – sensitivity analyses
- Parametric design optimizations
- Daylight analyses
- Life cycle assessments
- Thermal comfort analyses
- Heat transfer analyses etc. – Thermal bridging calcs

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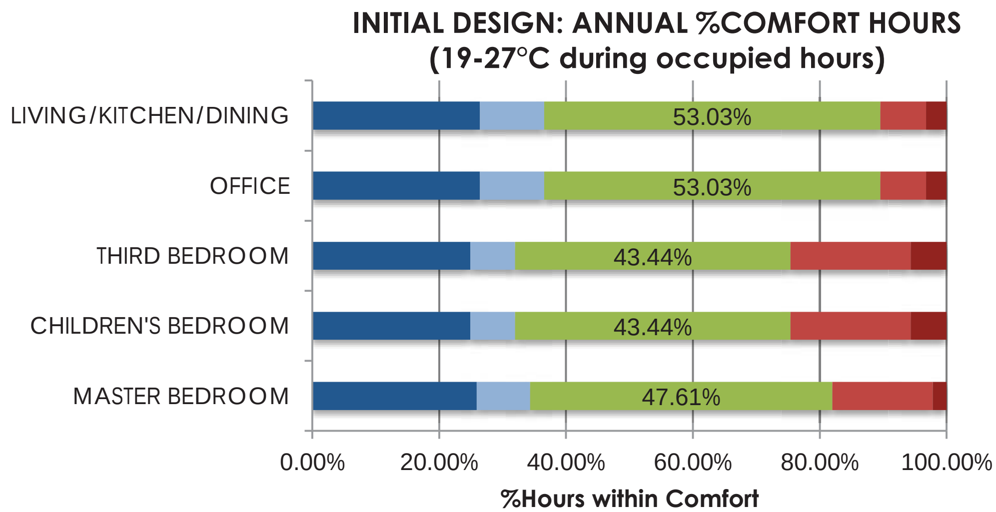
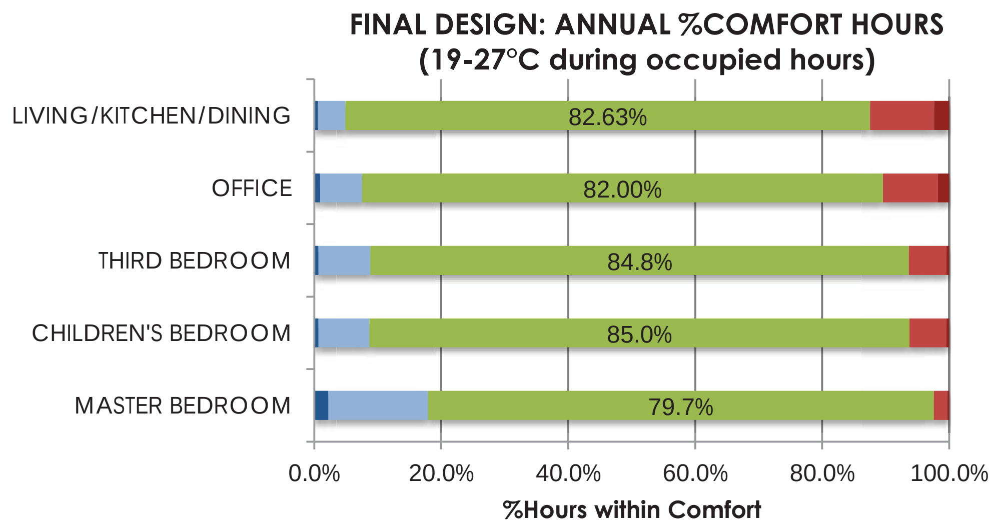
What to expect of Part 2 of this series?





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Conclusions

1 MECB will initiate a trend in building energy savings

2 Prescriptive targets aren't always optimal

3 Trade-off between targets is a powerful tool

4 Different buildings need different optimization strategies

5 Performance path offers ultimate design flexibility

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Thank You

Jordan Lanoway, *P.Eng., PMP, LEED AP*

Senior Project Manager
jordan.lanoway@stantec.com

Afaf Azzouz, *E.I.T., M.Sc., LEED Green Associate*

Buildings Energy Analyst
afaf.azzouz@stantec.com

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