PASSIVEHOUSE

Introduction to Passive House
High Performance Buildings

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Company: Systemair

systemair

Why build to the Passive House Standard?

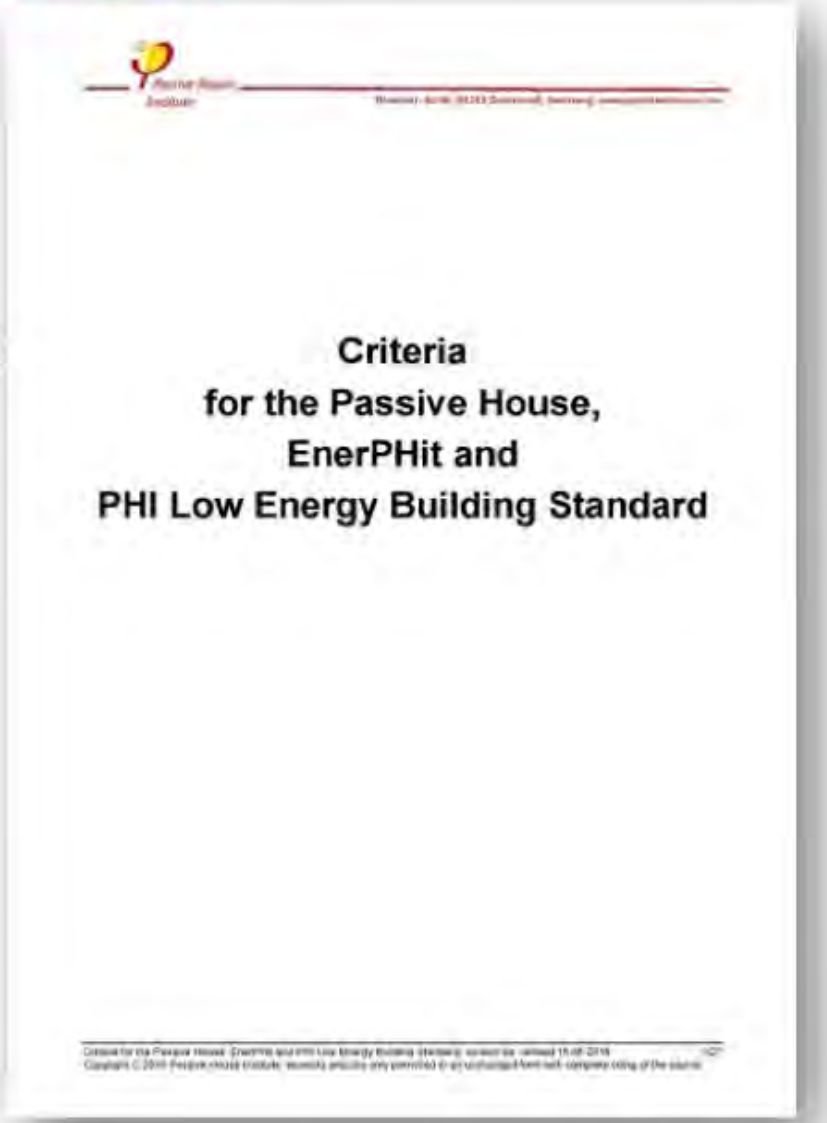
- energy efficiency
- savings
- indoor air quality
- comfort
- GHG reduction
- durability

The Passive House (Passivhaus) Standard

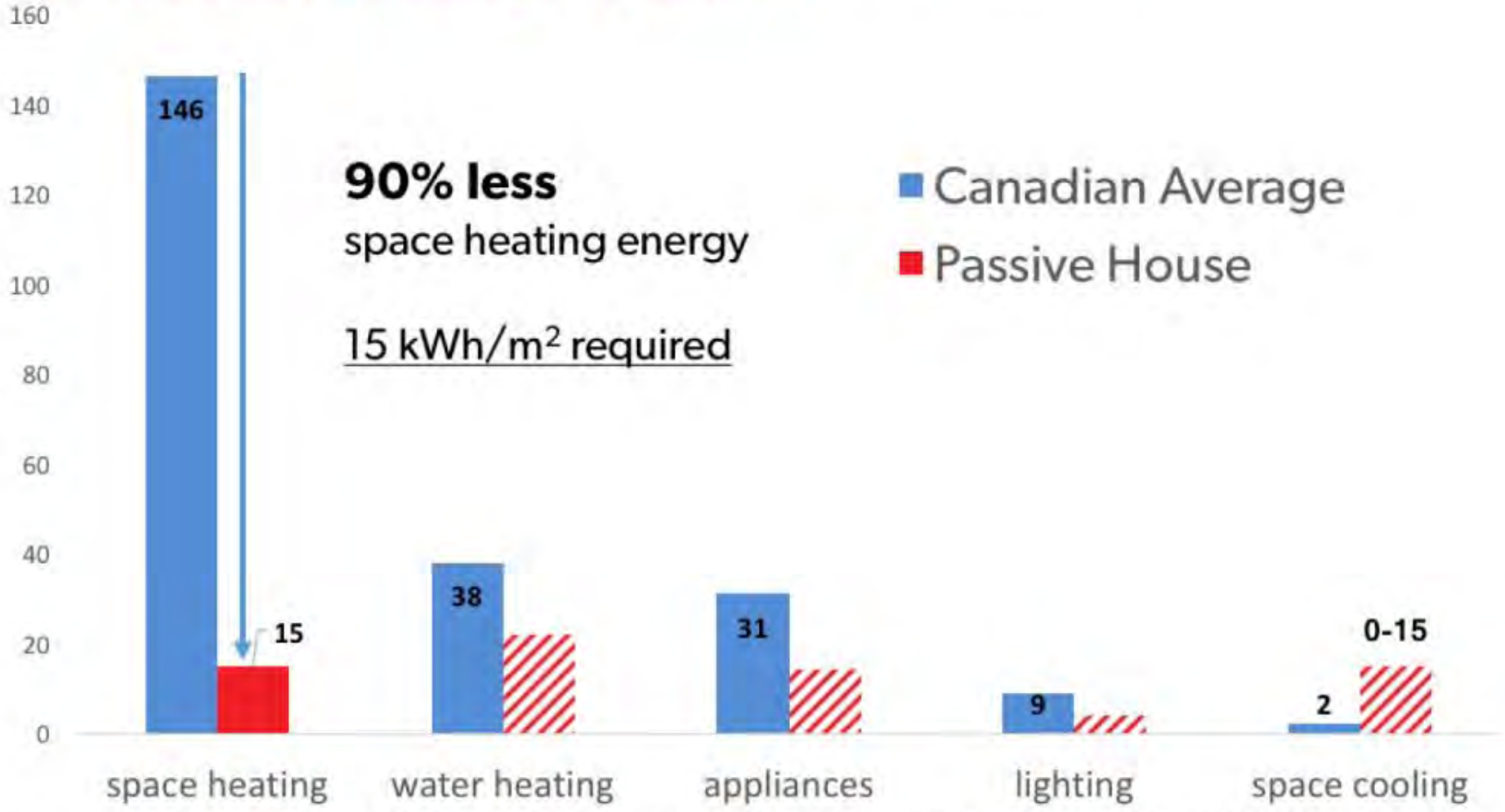
- **15 kWh/(m²a)** – Space heating energy
- 0.6 ACH @ 50 Pa – Airtightness
- 60 kWh/(m²a) – Primary energy (PER method)

As calculated by the PHPP energy model.

An international climate-independent low energy building standard for all building types.



Energy Use Intensity (kWh Per m² Per Year) For Residential Buildings In Canada



source: NRCan Energy Use Data Handbook 2010 and Energy Efficiency Trends in Canada 1990-2009, graphic: Nem


201
302
860
301
202

Passive House – All Building Types

School Retrofit

Industrial / Manufacturing

HRV Manufacturer

Office Building

Office Retrofit

Passive House Office Tower

Passive House – All Building Types

Modular Staff Housing

Student Residences

Affordable Housing

Passive House – All Building Types

Research Lab

Brownstone Retrofit

Archive

Assisted Living

Pool Complex

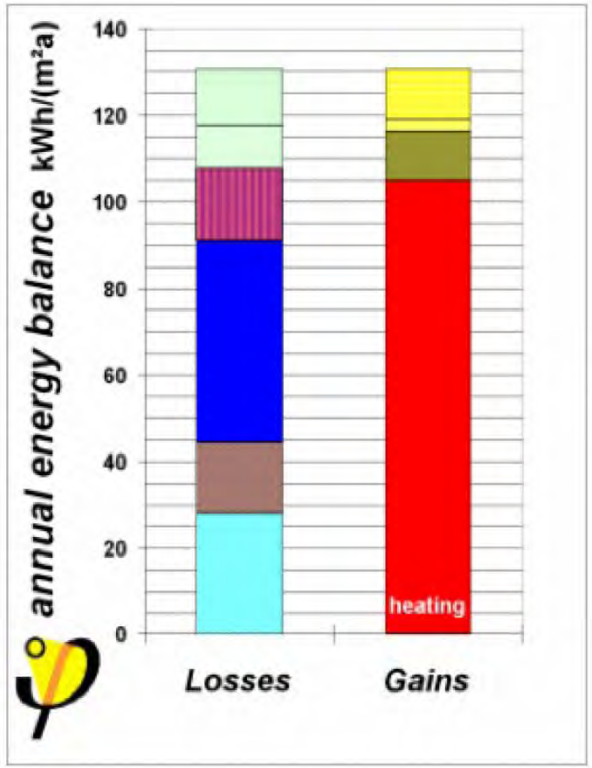
Fire Hall

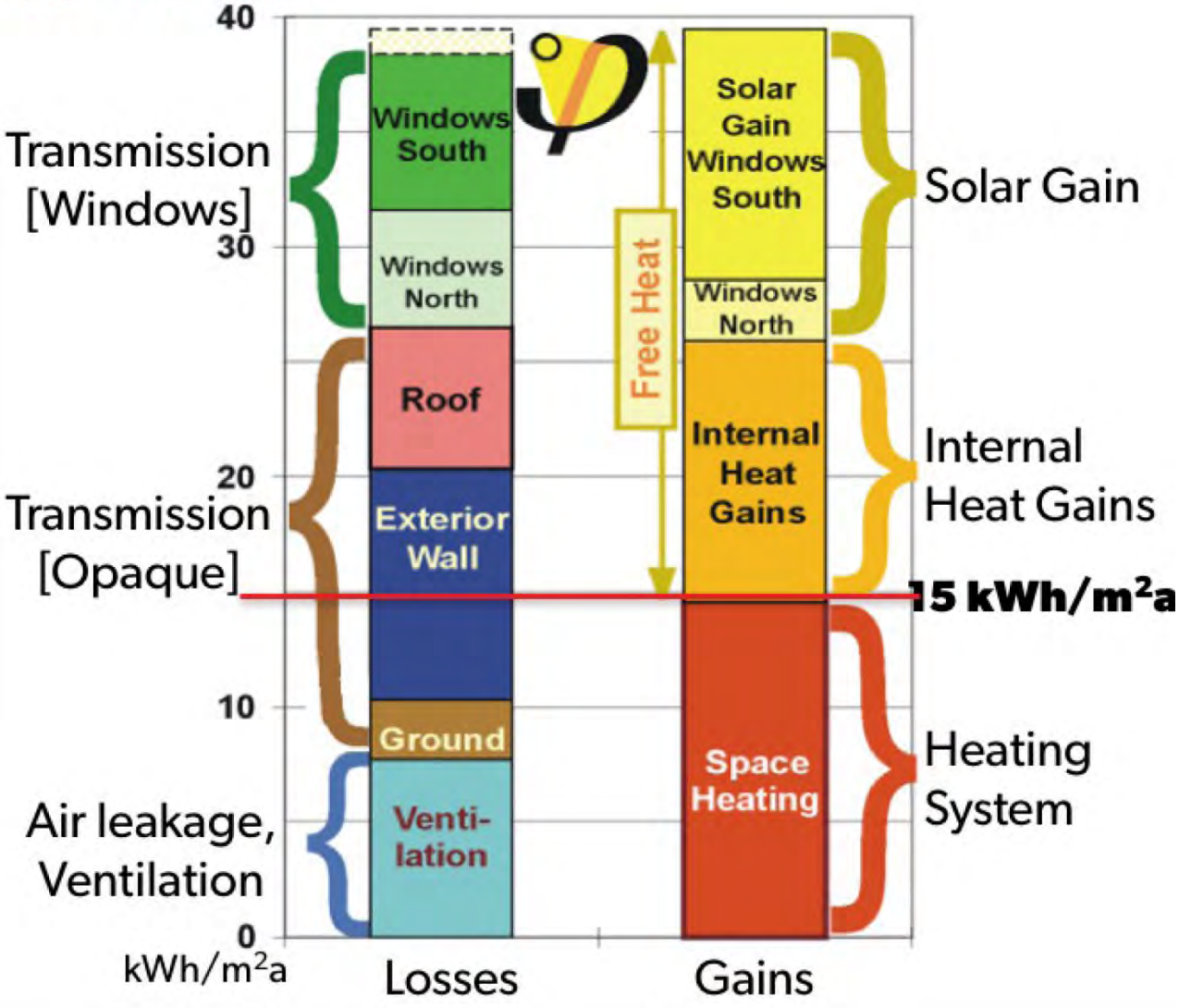
Church

Supermarket

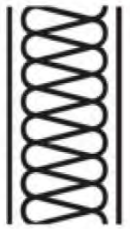
What do I need to know to build to the Passive House Standard?

Space Heating Energy Balance
EN ISO 13790

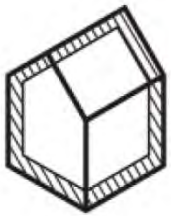




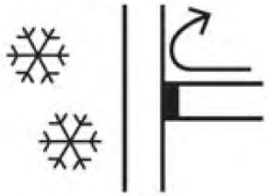
Five Principles of Passive House Design



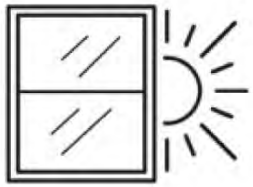
1. Super-insulation



2. Airtight construction



3. Thermal bridge free

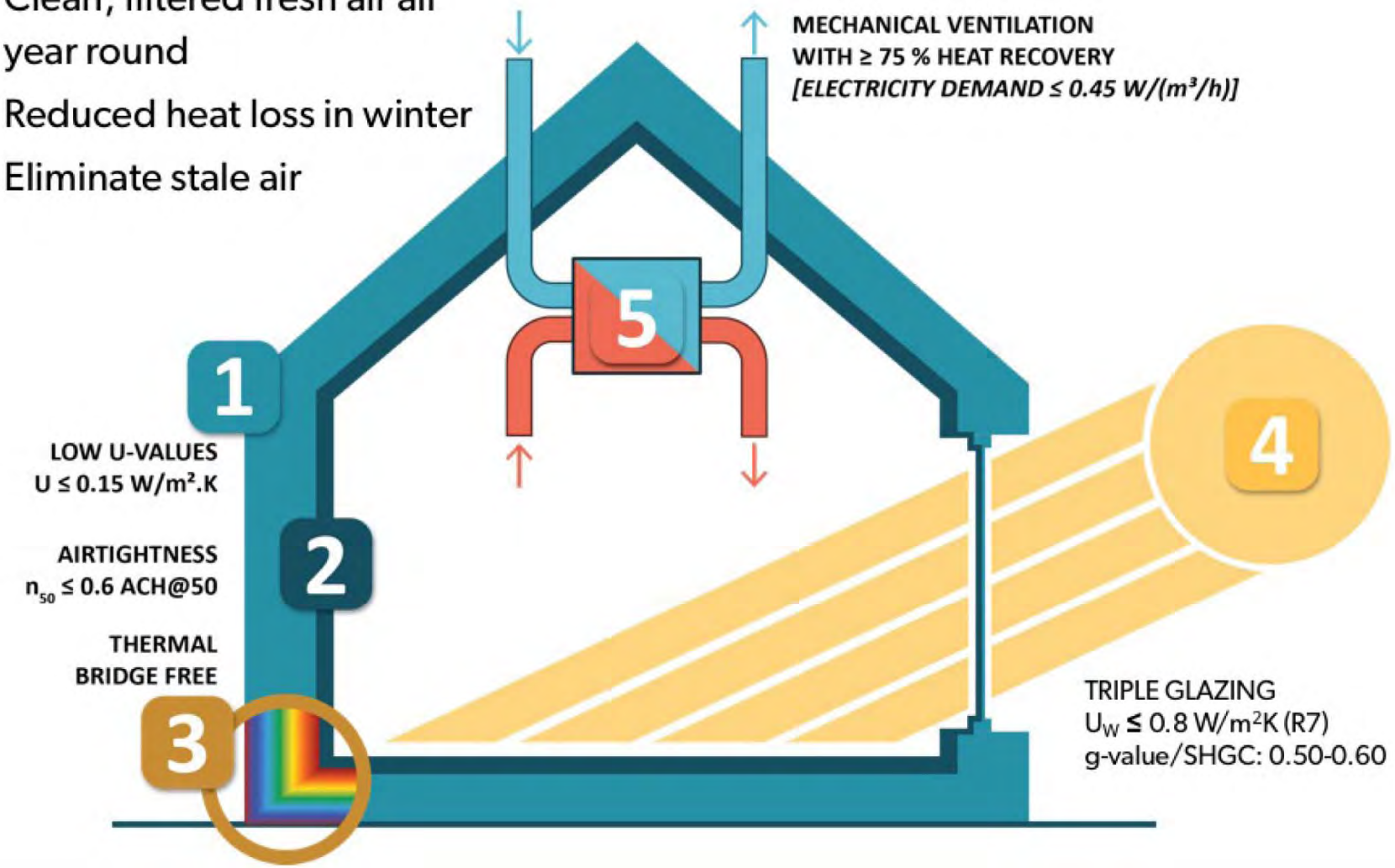


4. High quality windows with solar orientation

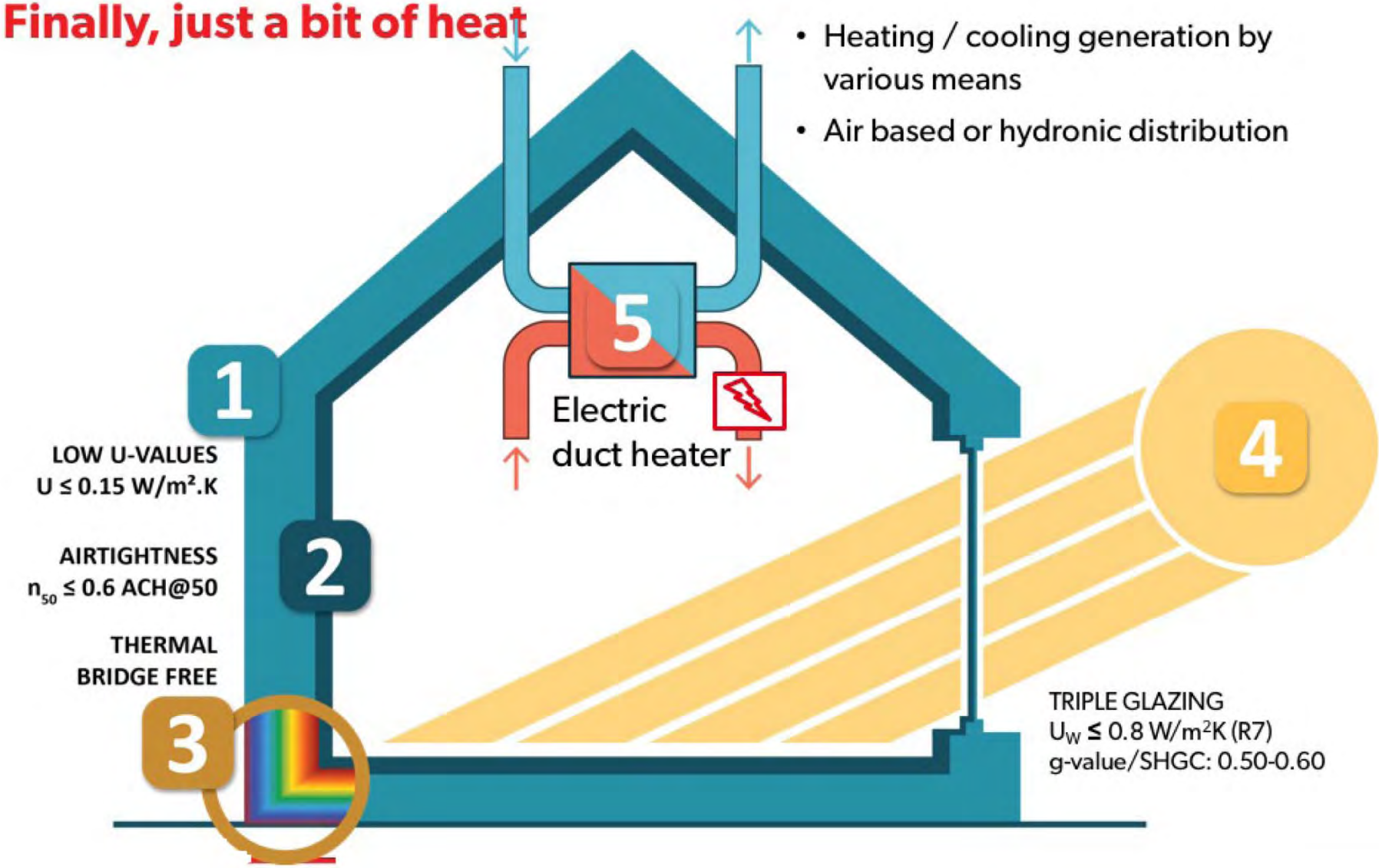
5. Ventilation system with heat recovery

Mechanical Ventilation with Heat Recovery

- Clean, filtered fresh air all year round
- Reduced heat loss in winter
- Eliminate stale air



Finally, just a bit of heat



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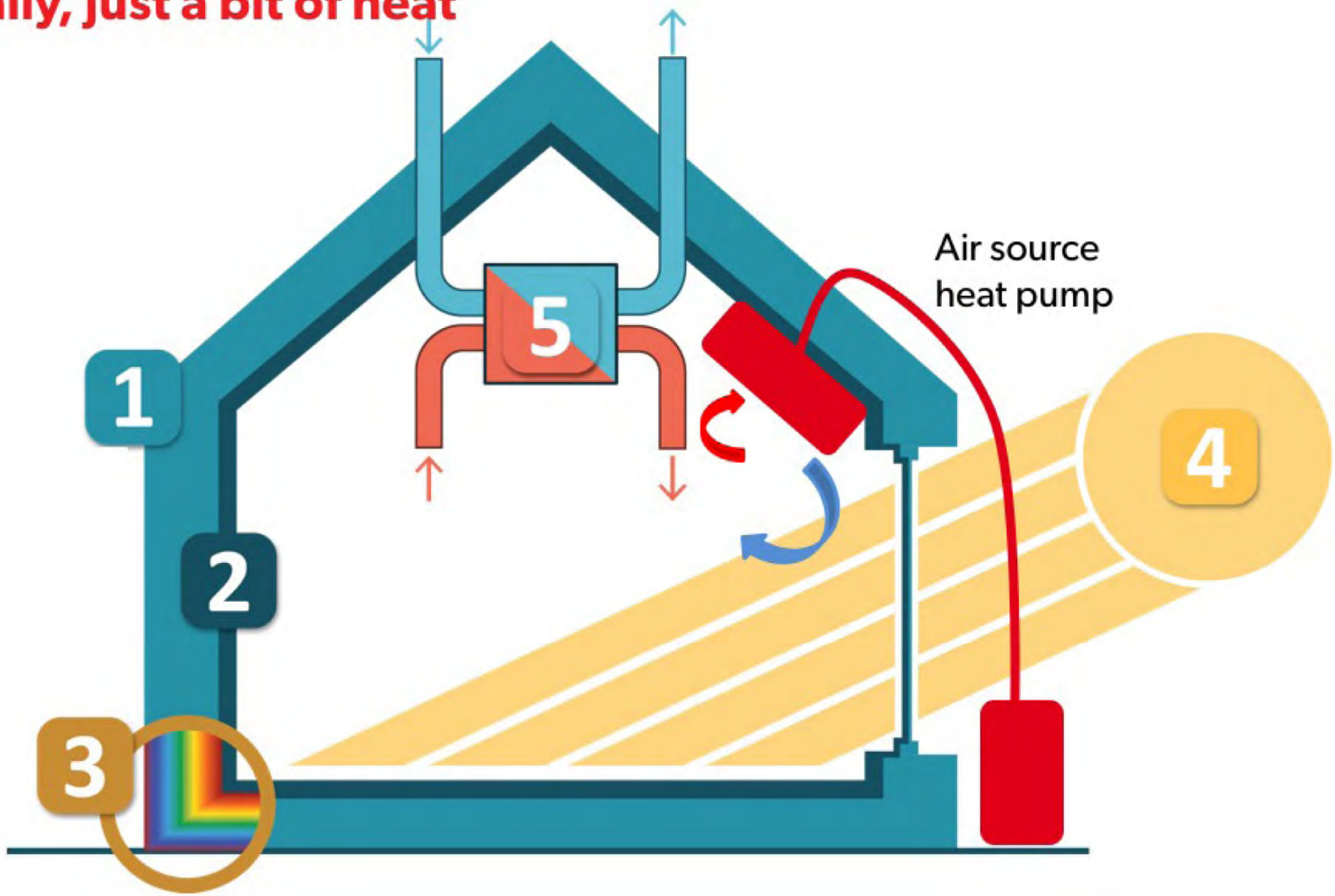
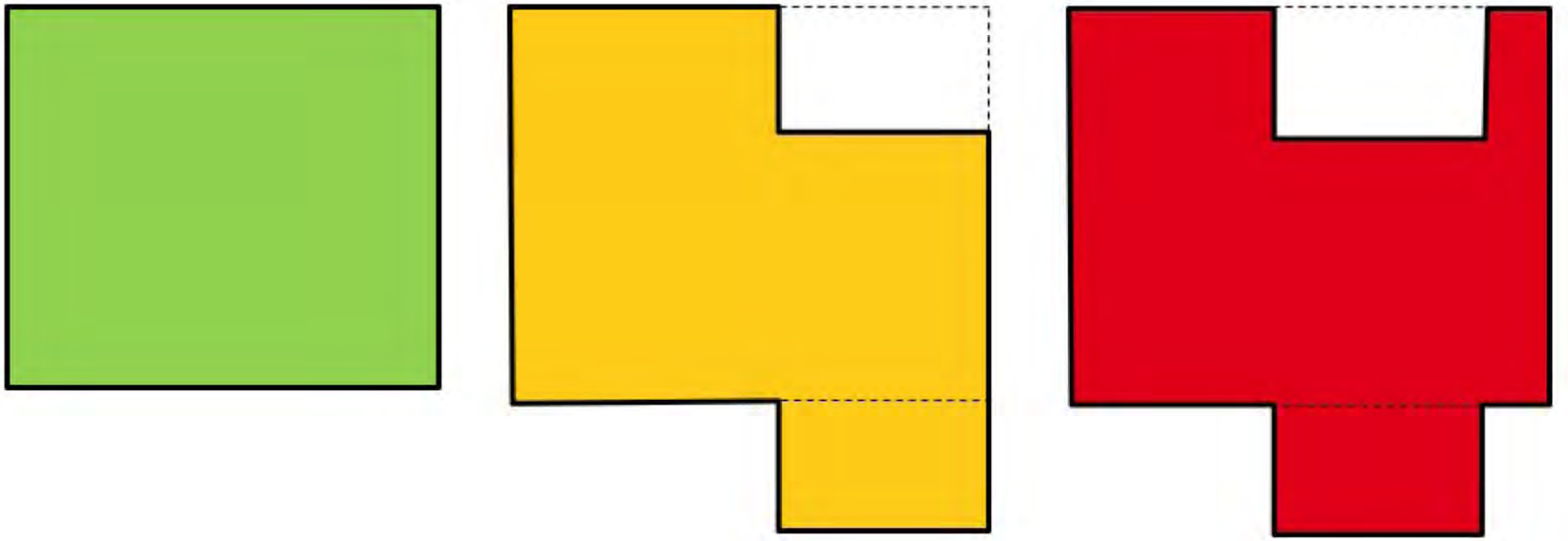


Compactness

Influence of an increased perimeter for the same floor area



Compact shape

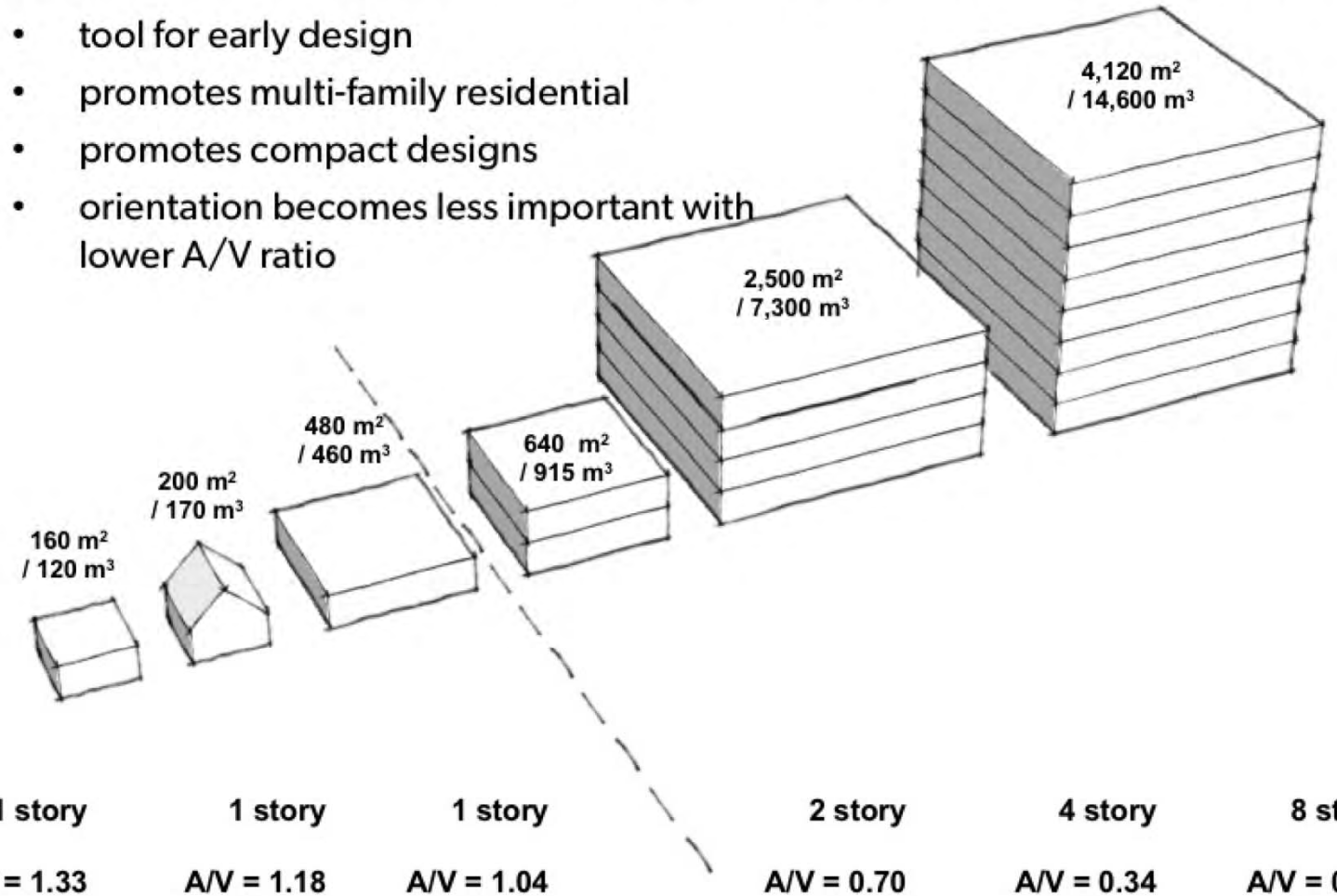
Increase of wall area 10 %
Insulation + 20mm

Increase of wall area 20 %
Insulation + 40mm

Area To Volume Ratio (A/V)

A/V Ratio = Total of all exterior envelope areas (floor, walls, windows and roof) / total volume

- tool for early design
- promotes multi-family residential
- promotes compact designs
- orientation becomes less important with lower A/V ratio



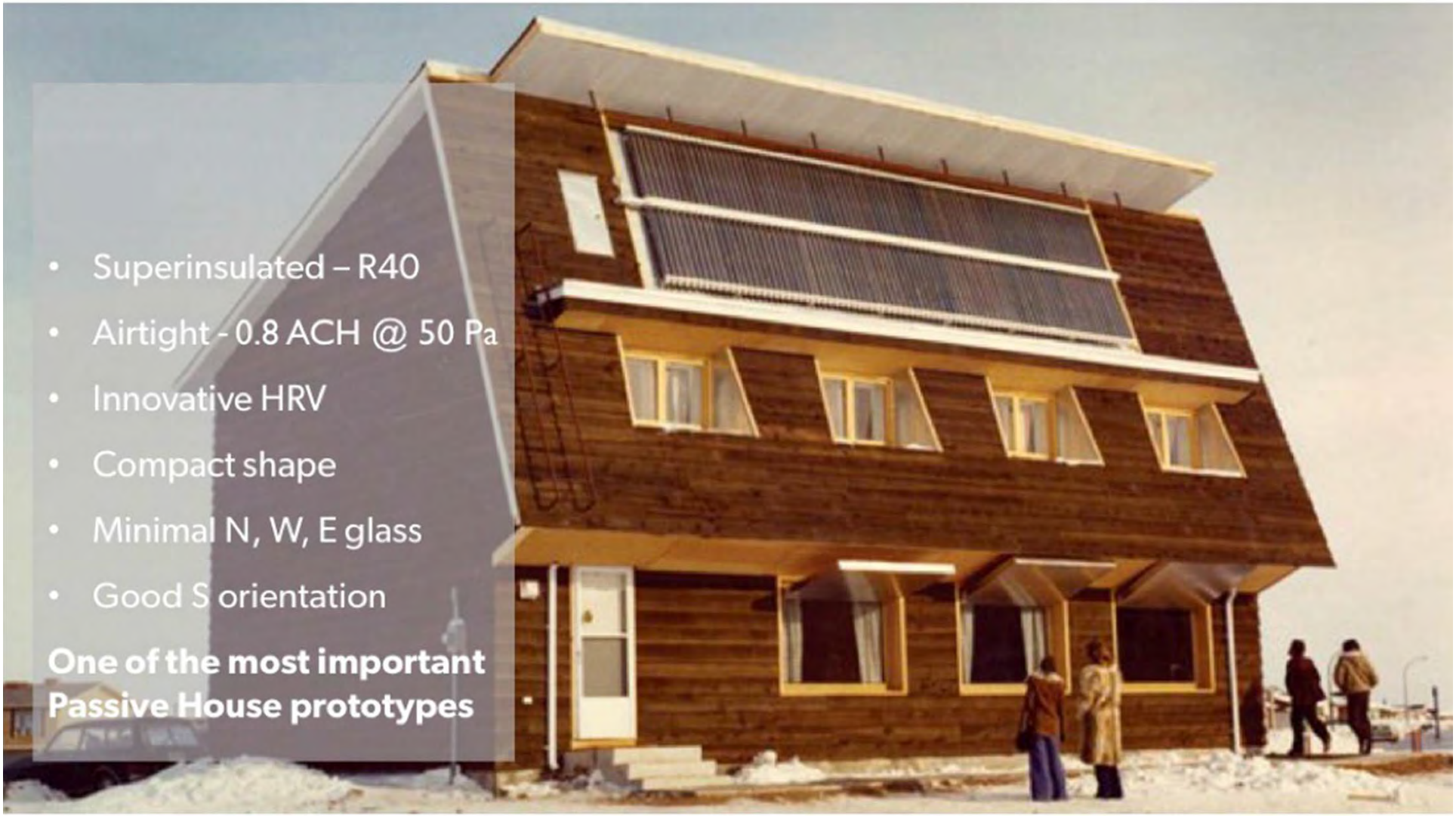
1 story	1 story	1 story	2 story	4 story	8 story
A/V = 1.33	A/V = 1.18	A/V = 1.04	A/V = 0.70	A/V = 0.34	A/V = 0.28

Non-optimal form :)

Form Factor and Defining the Thermal Envelope

- Home on the left has a more favourable form factor
- In both cases, garage is external to thermal envelope

A History Of Getting It Right - 1977 Pioneers In Canada



Still Saving Energy 40 Years Later

Requirements & Criteria of the Passive House Standard

Annual Space Heating / Cooling Demand

kilowatt-hours / square meter (treated floor area) / year (annum)

15 kWh/(m²a)

4.75 kBTU/(ft²a)

Must Criteria (*either or* with Heating Load)

Heating/Cooling Load

$$10\ \frac{\text{watts}}{\text{square meter (treated floor area)}} = 10\ W/m^2$$

$10\ W/m^2 = 3.17\ BTU/h/ft^2$

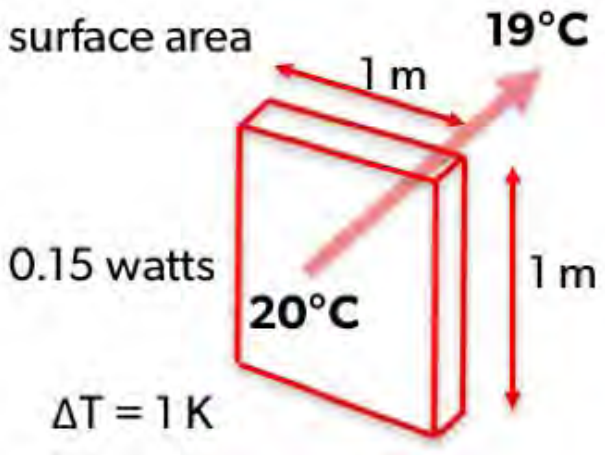
Must Criteria (*either or* with Annual Space Heating Demand)

Thermal Performance
Opaque Assemblies: Walls, Roof, Floor

$U \leq 0.15\ W/(m^2K)$

Recommendation to meet standard – not *must criteria*.

U-value – heat transfer coefficient, heat lost over a given surface area and temperature difference
(change of 1°C = change of 1 Kelvin, K)
R-value – thermal resistance [~**R40**]



Thermal Performance

Opaque Assemblies: Walls, Roof, Floor

U-value - R-value Conversion Table

Heat transfer coefficient vs thermal resistance

$U = \frac{1}{R}$ $\qquad$ $RSI \times 5.678 = R_{imperial}$

Passive House Walls / Roof

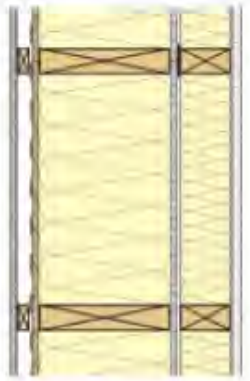
metric		imperial		
U-value (W/m^2K)	R-value, RSI (m^2K/W)	U-value ($BTU/ft^{2\circ}Fh$)	R-value ($ft^{2\circ}Fh/BTU$)	
0.06	16.7	0.011	95	**~R100**
0.07	14.3	0.012	81	
0.08	12.5	0.014	71	
0.09	11.1	0.016	63	
0.10	10.0	0.018	57	**~R60**
0.11	9.1	0.019	52	
0.12	8.3	0.021	47	
0.13	7.7	0.023	44	
0.14	7.1	0.025	41	
0.15	6.7	0.026	38	**~R40**
0.20	5.0	0.035	28	
0.25	4.0	0.044	23	
0.30	3.3	0.053	19	**~R20**

$$R_{imperial} = \frac{5.678}{U_{metric}}$$

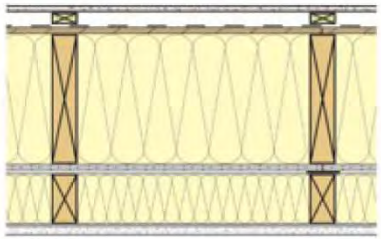
$$U_{metric} = \frac{5.678}{R_{imperial}}$$

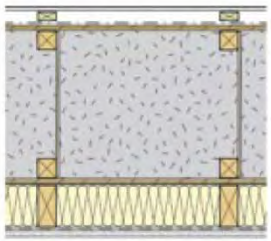
Considerations for Highly Insulated Walls

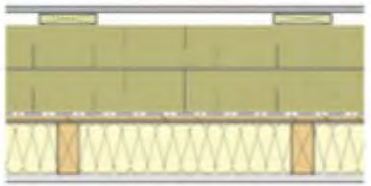
- Durability & Longevity
- Material & Labour Cost
- Material Availability
- Ease of Construction
- Pre-fabrication vs Site-Built
- Thickness
- Weight (shipping and/or site handling)
- Environmental aspects (insulation type)
- Air Barrier System & Detailing
- Water & Vapour control (wetting & drying)
- Cladding Attachment, Finishes



Leading Super-insulated Wall Types



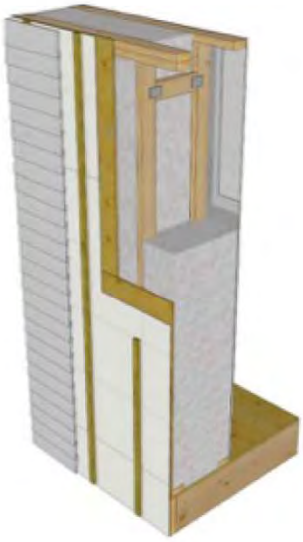




Interior Insulated

Exterior Wall Loadbearing

(Double Stud, Deep Stud)

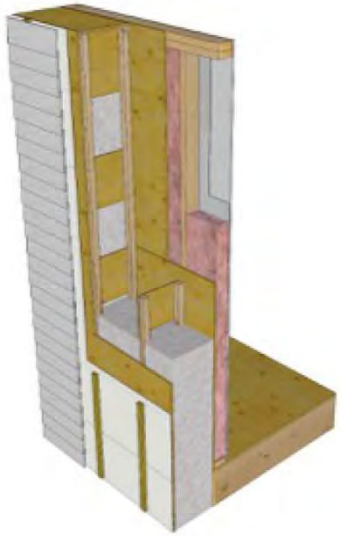


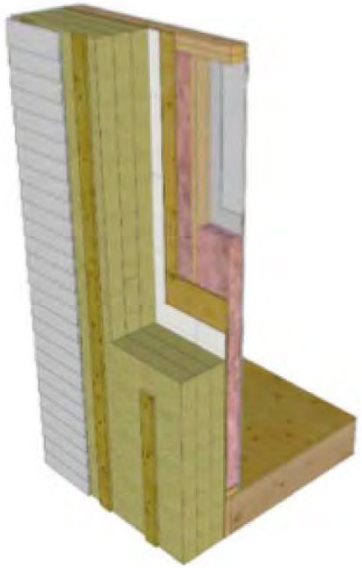
Exterior Insulated

Interior Wall Loadbearing

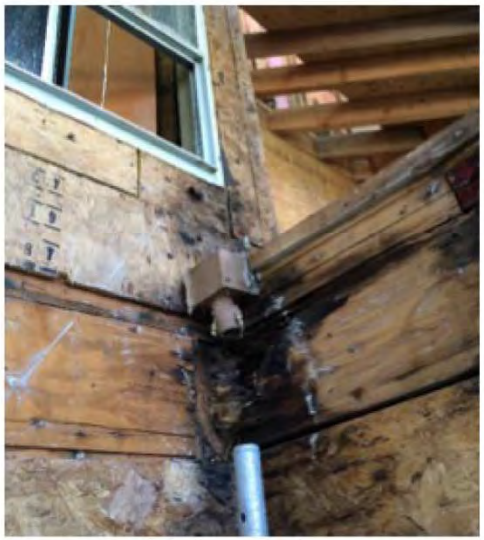
(Larsen Truss, REMOTE Wall)

Best for Retrofits





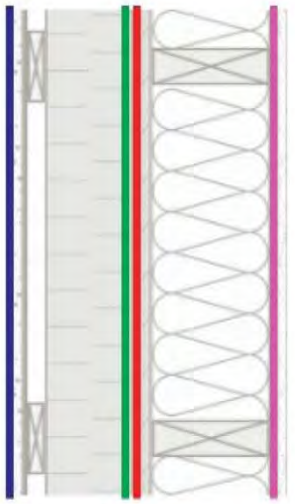
Many Lessons Learned From Wood-frame Buildings

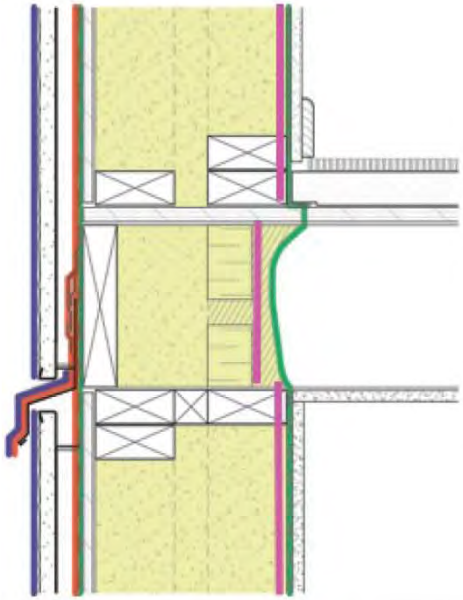


Location of Critical Barriers

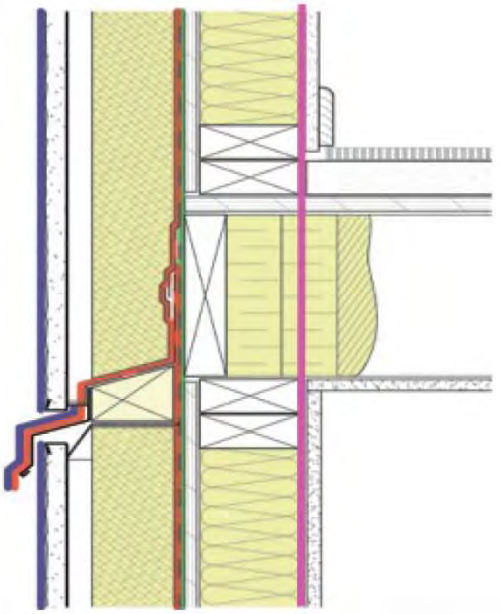
Water Shedding Surface **(WSS)**
Water Resistive Barrier **(WRB)**
Air Barrier **(AB)**
Vapour Barrier **(VB)**

Thermal Barrier **(Insulating Materials)**



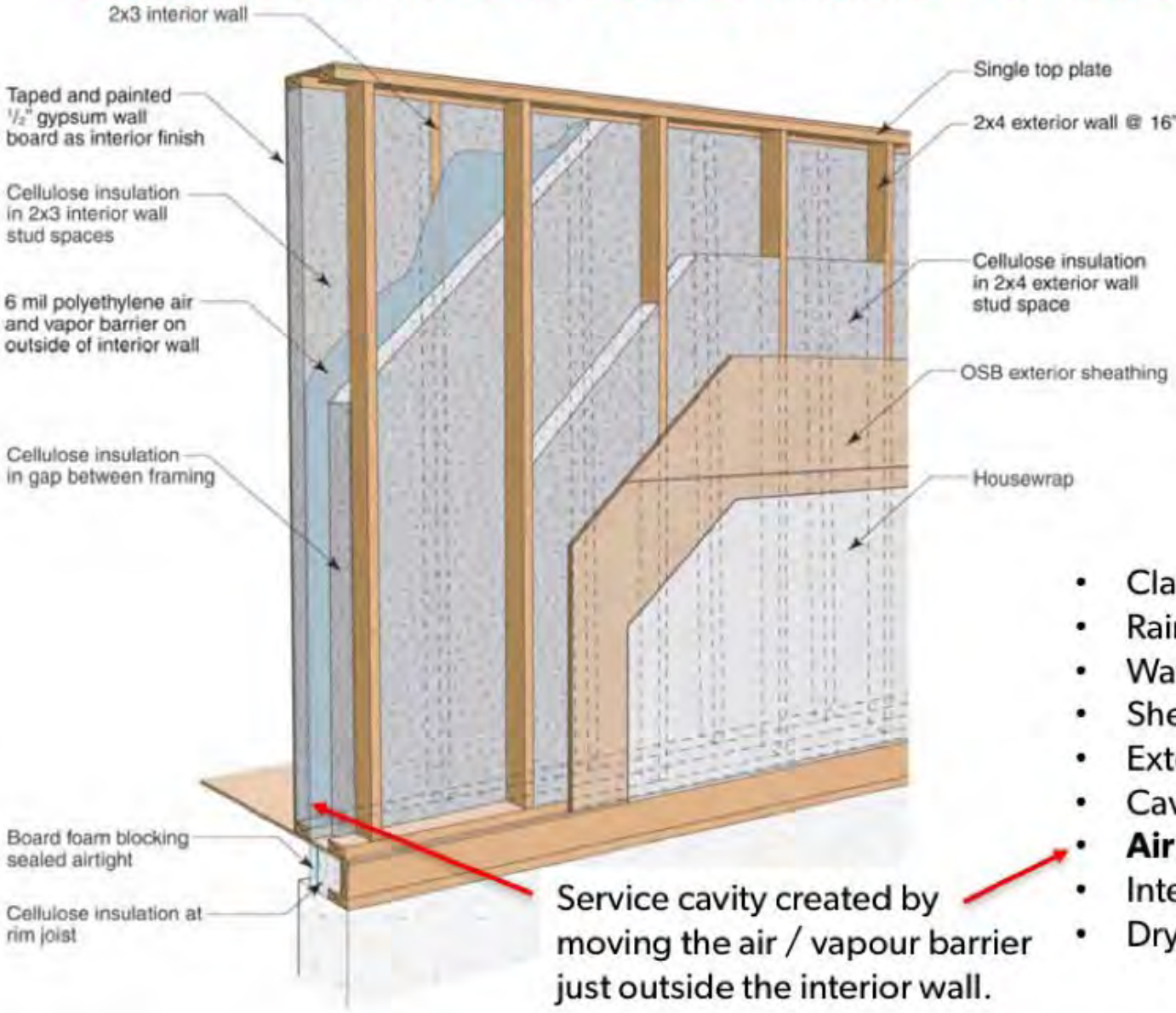


- The vapour barrier must be within the inner 1/3rd of R-value.
- The water resistive barrier must be on the outside.
- Air barrier can be either.



Interior Insulated Walls – Double Stud Wood Framed

Walls – Double Stud Wood Framed – w/ Service Cavity

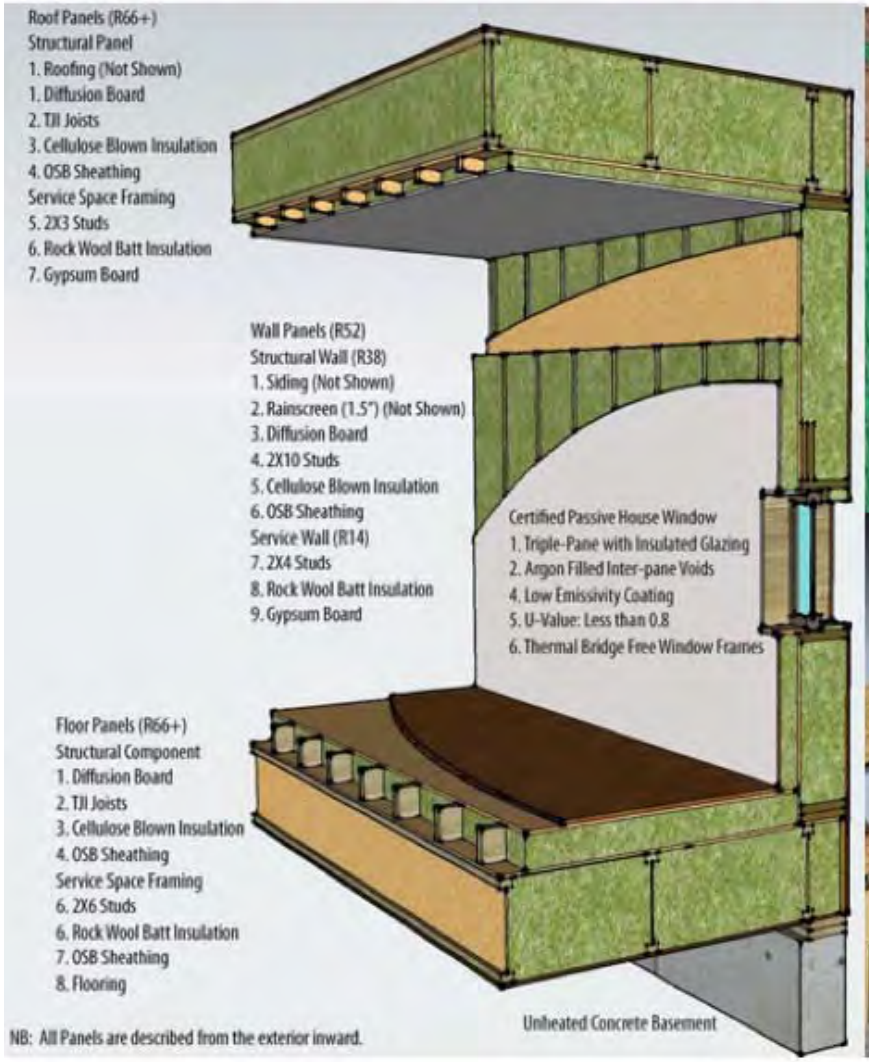


Service cavity created by moving the air / vapour barrier just outside the interior wall.

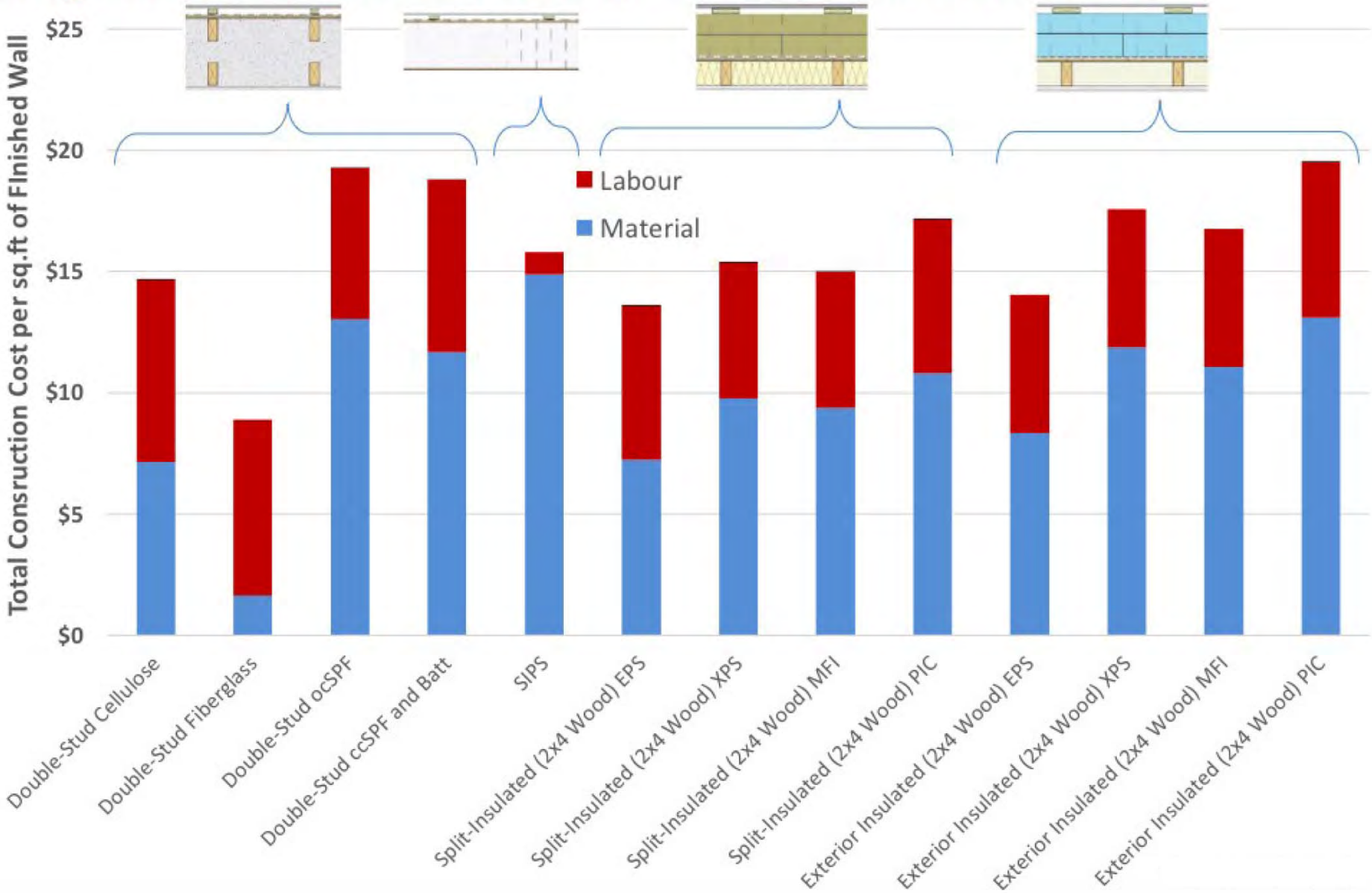
- Cladding
- Rainscreen
- Water Resistive Barrier
- Sheathing (plywood or OSB)
- Exterior 2x4 wall
- Cavity filled with insulation
- **Air / Vapour Barrier**
- Interior 2x4 wall (also insulated)
- Drywall

Walls – Double Stud Wood Framed w/ Service Cavity

Prefab Deep Stud Walls



Study: Labour & Material Costs – R40 Walls in Yellowknife



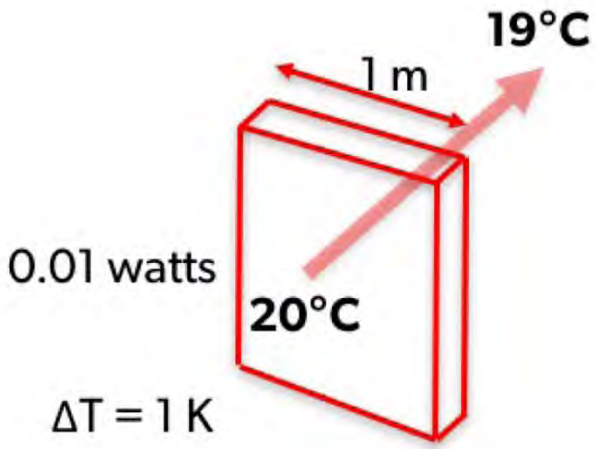
Thermal Bridge Free Design

Ψ (Psi) $\leq$ 0.01 W/(mK)

- Thermal bridging coefficients measure heat loss along a linear element (instead of an area).
- Thermal bridges exceeding 0.01 W/(mK) must be accounted for in the PHPP – some thermal bridging is allowed.

Thermal bridging may be determined from:

- Qualitative assessment
- Reference literature
- Thermal bridge calculation
  using heat transfer software (e.g. THERM)



What is a thermal bridge?

Part of the building envelope where the otherwise uniform thermal resistance is significantly reduced by:

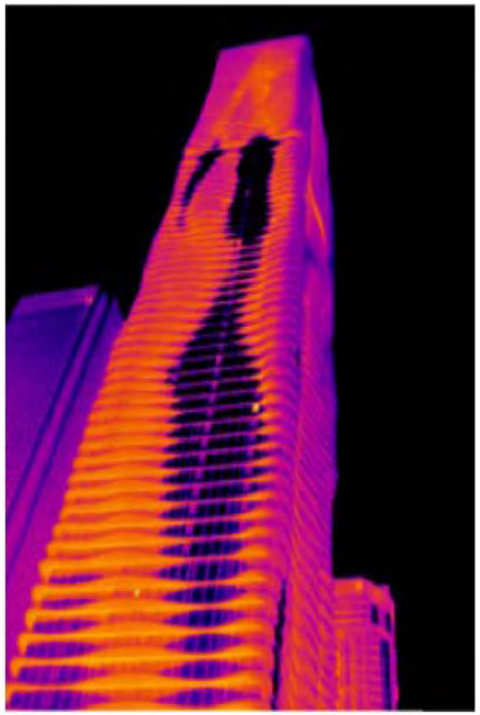
a) full or partial interruption of the insulating layers by materials with a different thermal conductivity (e.g. balconies)

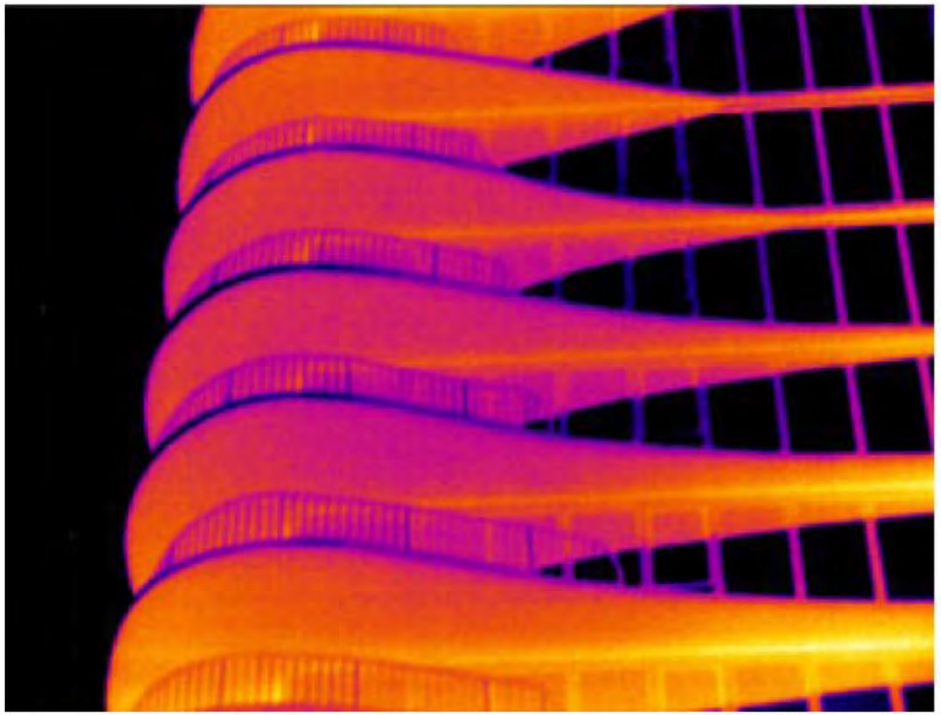
b) a change in thickness of the insulating layers

c) a difference between internal and external areas, such as occurs at wall/floor/ceiling junctions (geometric)

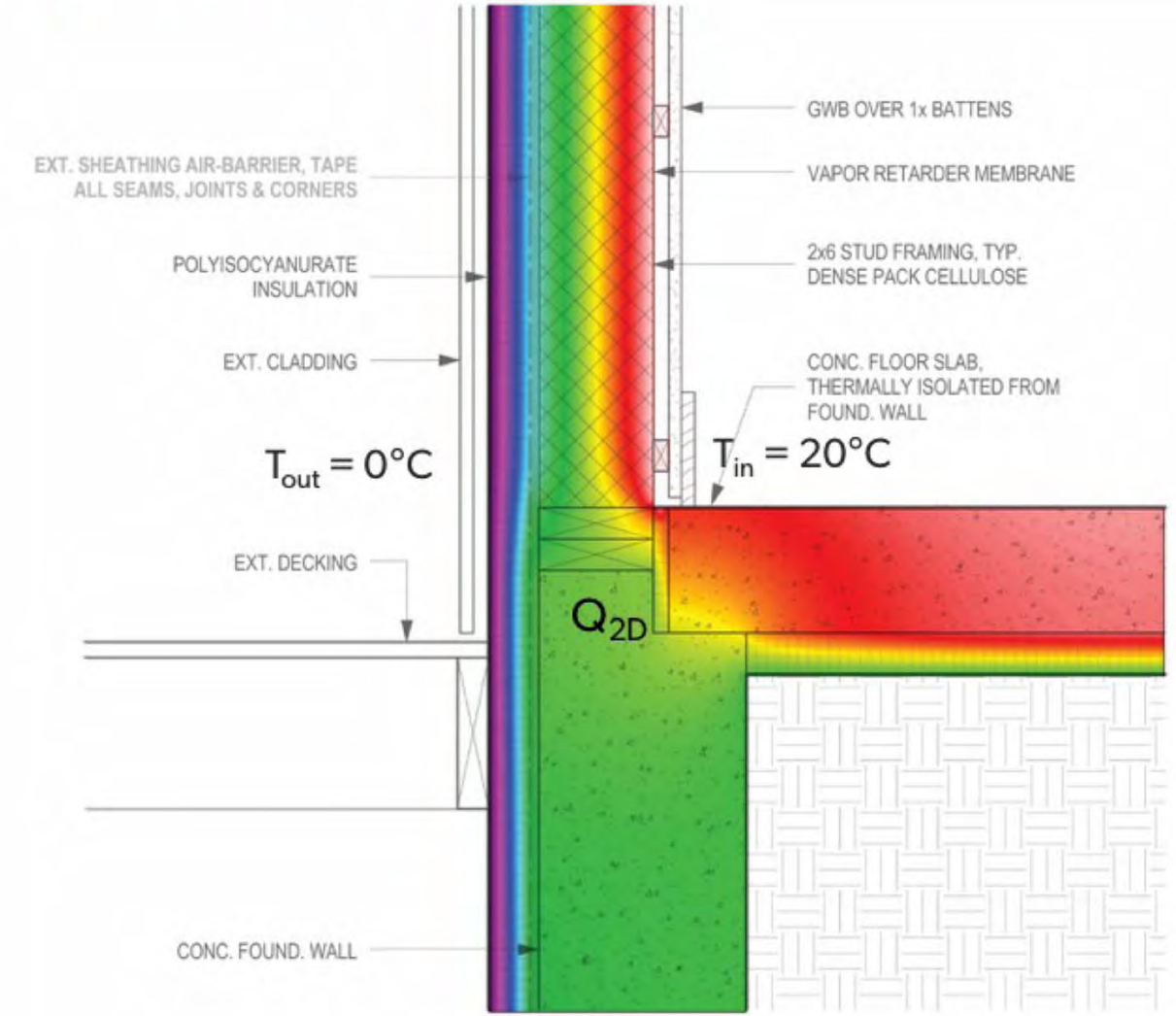
Thermal *Shortcuts* Through The Envelope

Concrete balconies are thermal bridges



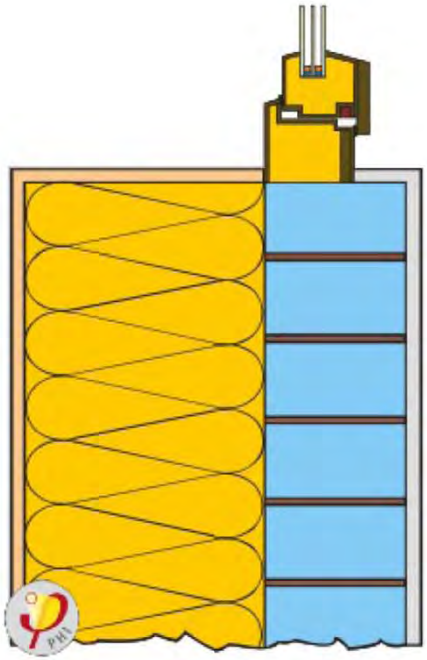


Simulating thermal bridges

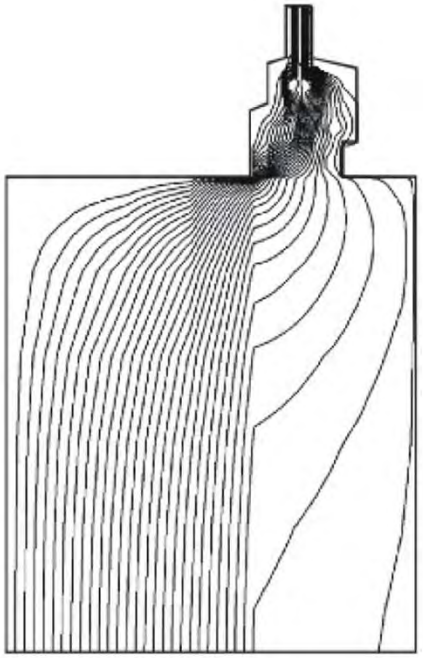


Details Are Vital
(e.g. Basement Wall)

Typical
Installation

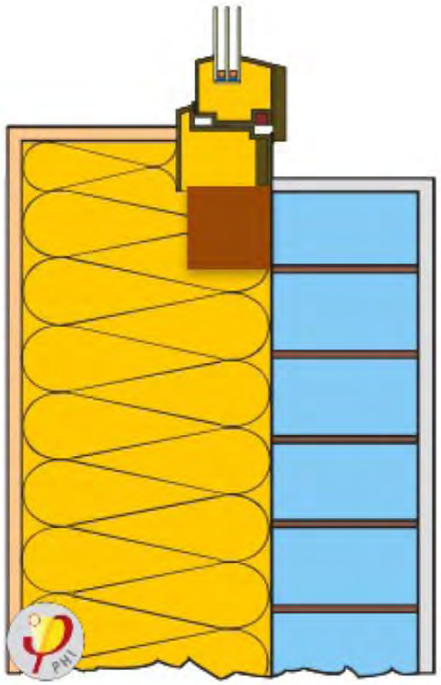


Ψ_{Einbau} = 0,15 W/(mK)

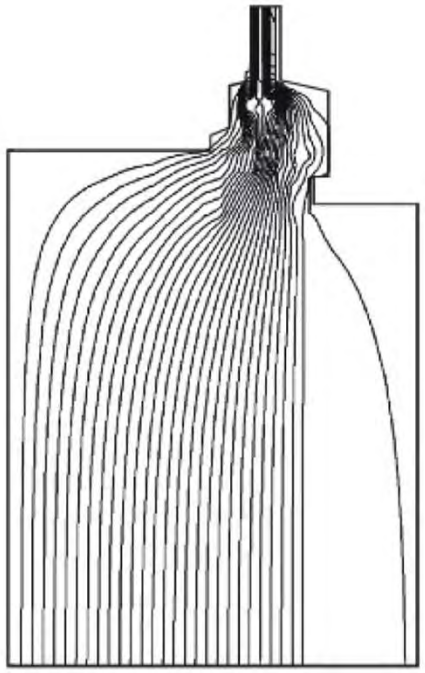


Details Are Vital
(e.g. Basement Wall)

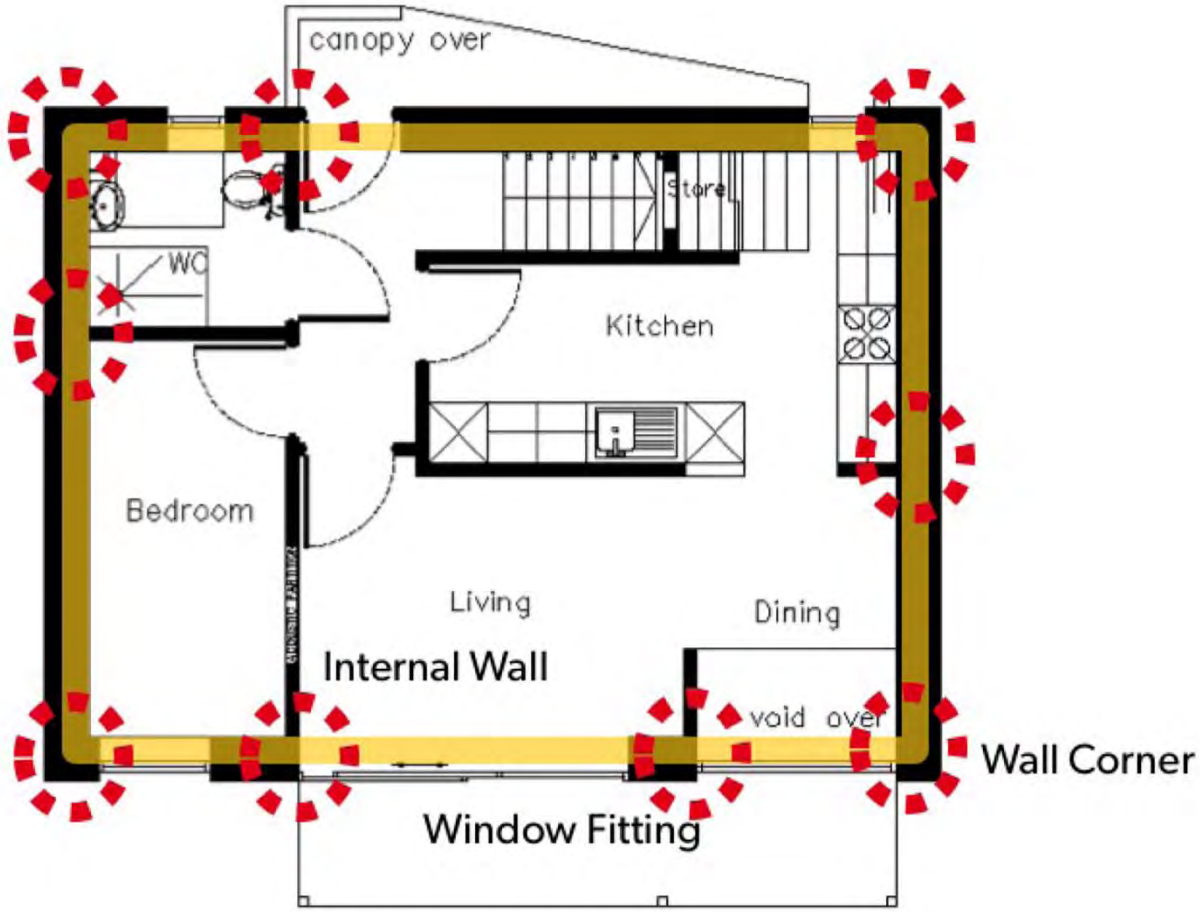
Recommended Installation



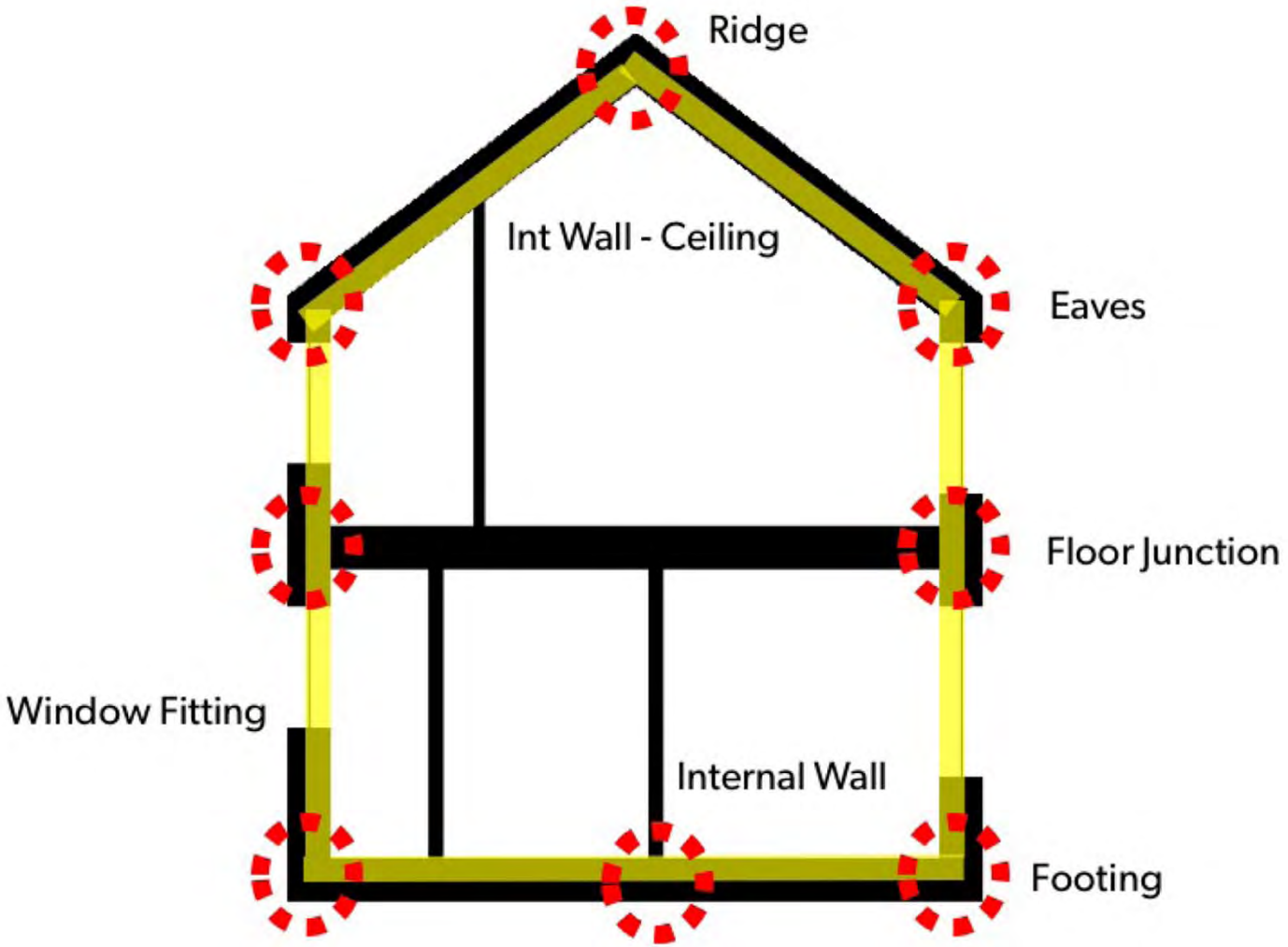
Ψ_{Einbau} = 0,005 W/(mK)



Identifying Thermal Bridges

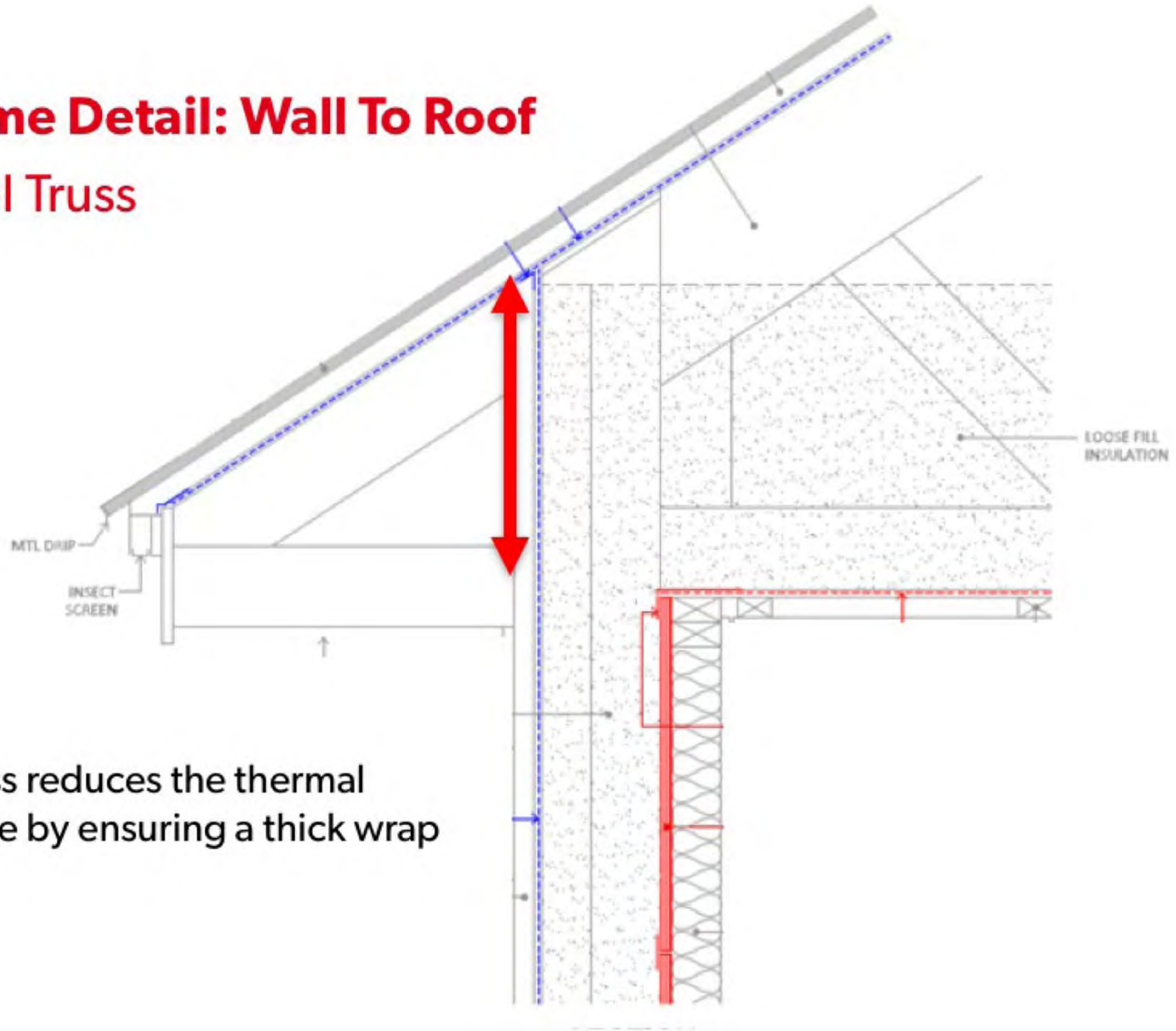


Identifying Thermal Bridges



Wood Frame Detail: Wall To Roof

Raised Heel Truss



A raised heel truss reduces the thermal bridge at the eave by ensuring a thick wrap of insulation

Windows

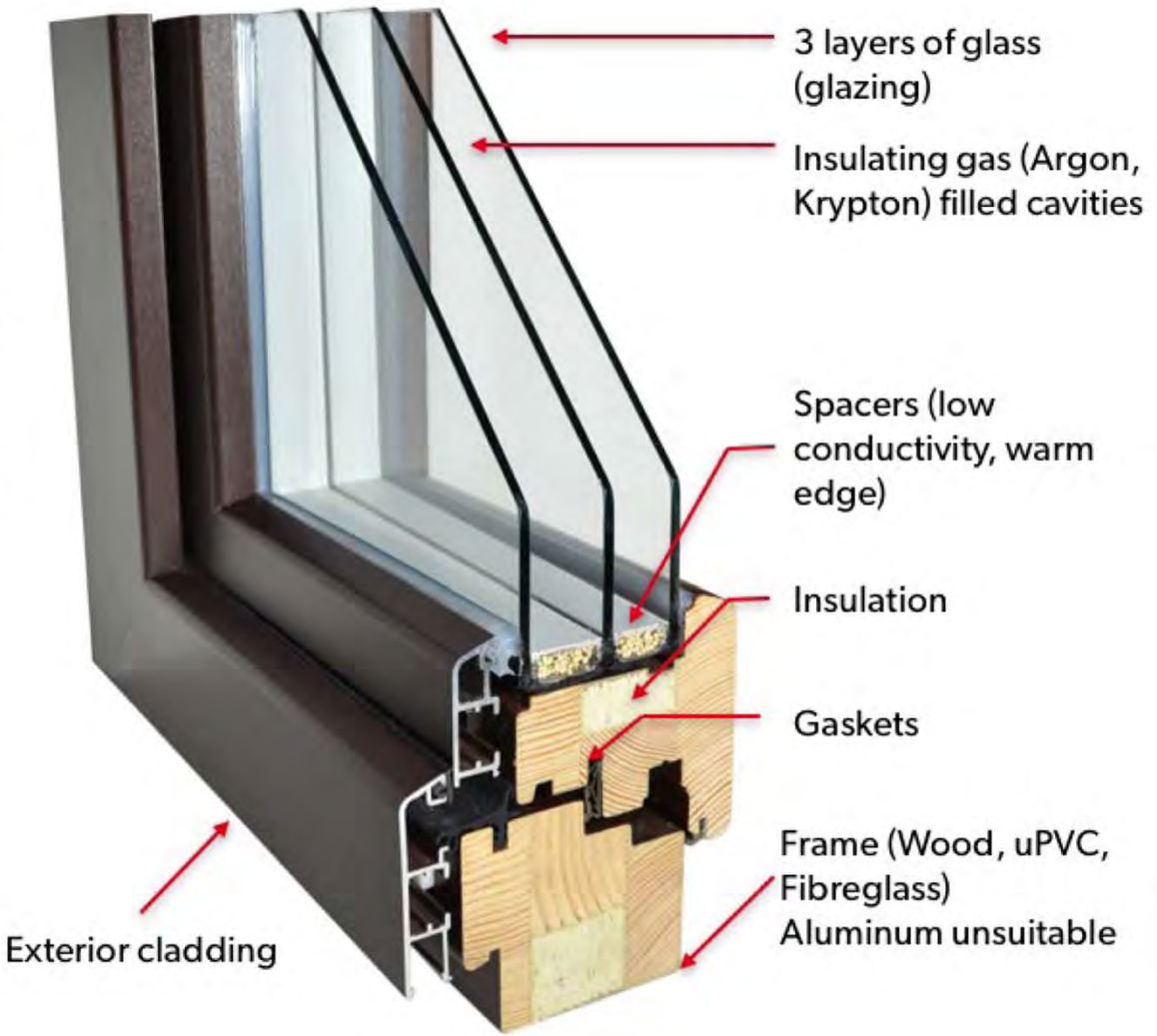
$U \leq 0.8\ W/(m^2K)$

- High solar heat gain coefficient: SHGC, g > 50%
- Must meet climate's comfort and hygiene criteria
  or be provided with heat
- Recommendation to meet standard
- Equivalent to R7

Window Elements

Excellent windows are needed because:

- Windows are a building's highest energy loss (lowest R-value)
- Inadequate performance can lead to cold interior surface temperatures
- Windows are prone to air leakage if their gaskets fail
- Windows are the only building component which can (passively) generate energy
- Consider (south facing) windows as solar thermal collectors!



Window U-values

U-values appropriate for Passive House (overall value, not centre-of-glass)

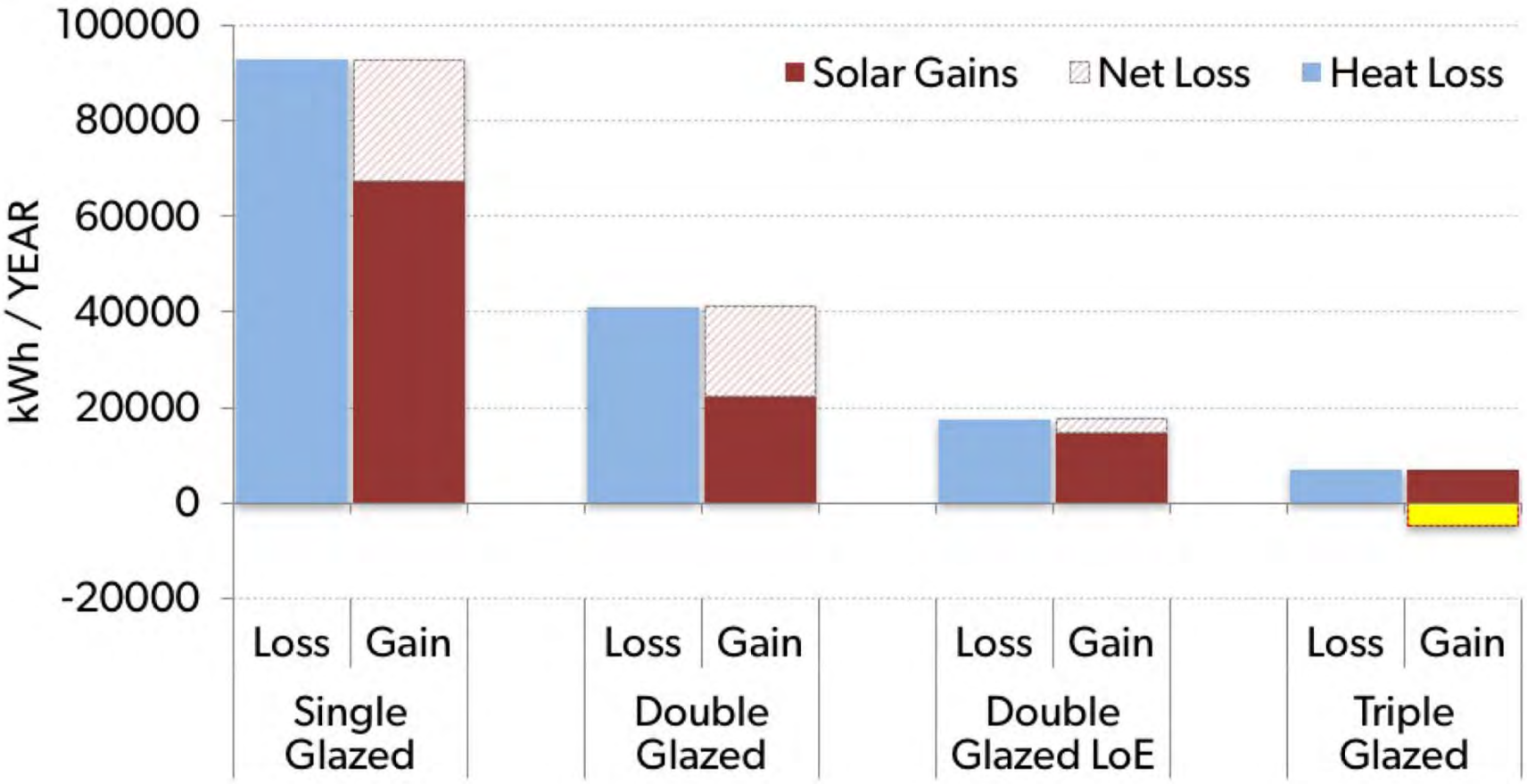
Energystar Zone 3

Vancouver Code

Energystar Zone 1

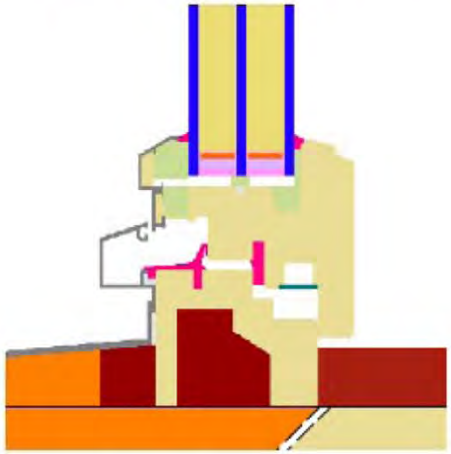
metric		imperial	
U-value [W/m²K]	RSI [m²K/W]	U-value [BTU/ft²Fh]	R-value [ft²Fh/BTU]
0.40	2.50	0.070	14.20
0.45	2.22	0.079	12.62
0.50	2.00	0.088	11.36
0.55	1.82	0.097	10.32
0.60	1.67	0.106	9.46
0.65	1.54	0.114	8.74
0.70	1.43	0.123	8.11
0.75	1.33	0.132	7.57
0.80	1.25	0.141	7.10
0.85	1.18	0.15	6.68
0.90	1.11	0.16	6.31
0.95	1.05	0.17	5.98
1.00	1.00	0.18	5.68
1.10	0.91	0.19	5.16
1.20	0.83	0.21	4.73
1.30	0.77	0.23	4.37
1.40	0.71	0.25	4.06
1.50	0.67	0.26	3.79
1.60	0.63	0.28	3.55

South-facing window energy balance



Example:

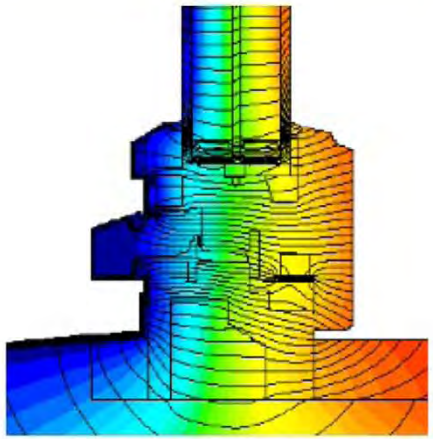
Single Family Home Window Energy Balance



Scenario 1 – conventional window

Energy demand **31 kWh/m² year**

Window is a loss-factor



Scenario 2 – Passive House window

Energy demand **14 kWh/m² year**

Window generates energy

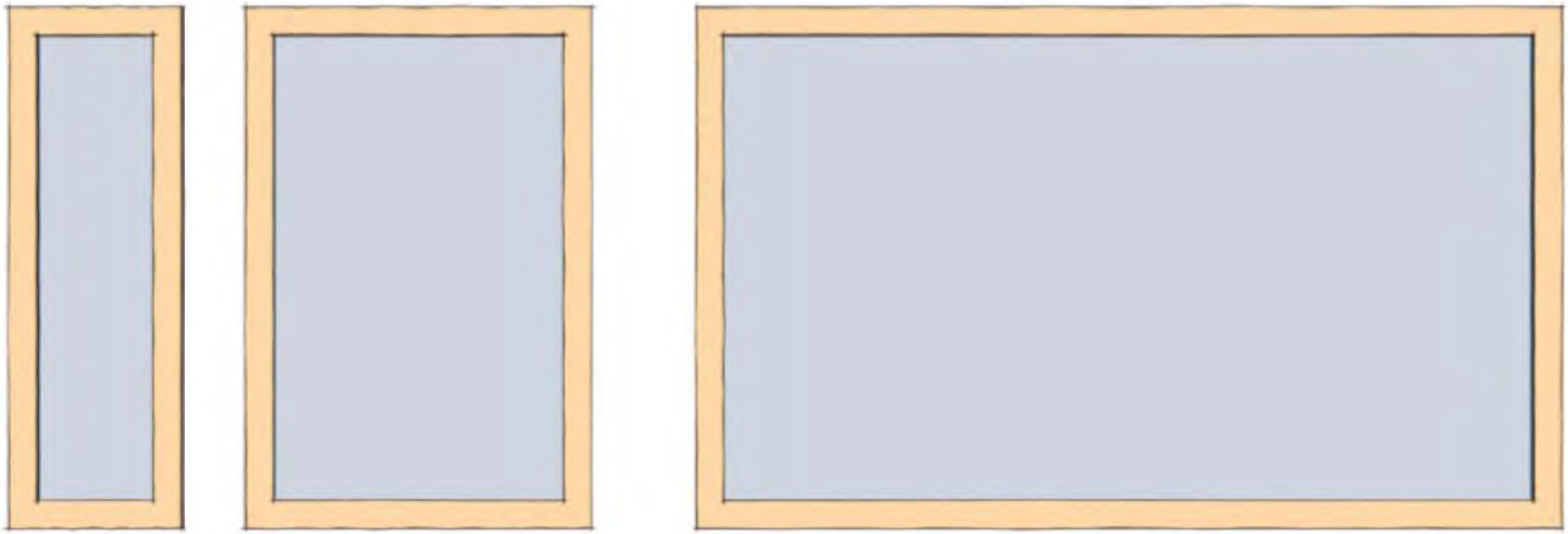
Conclusion

High performance south facing windows
are solar thermal collectors

Window size affects overall U-value

frame U_f: 0.80 W/(m²·K)

glazing U_g: 0.55 W/(m²·K)



0.6 x 1.8 m

U_w 0.82

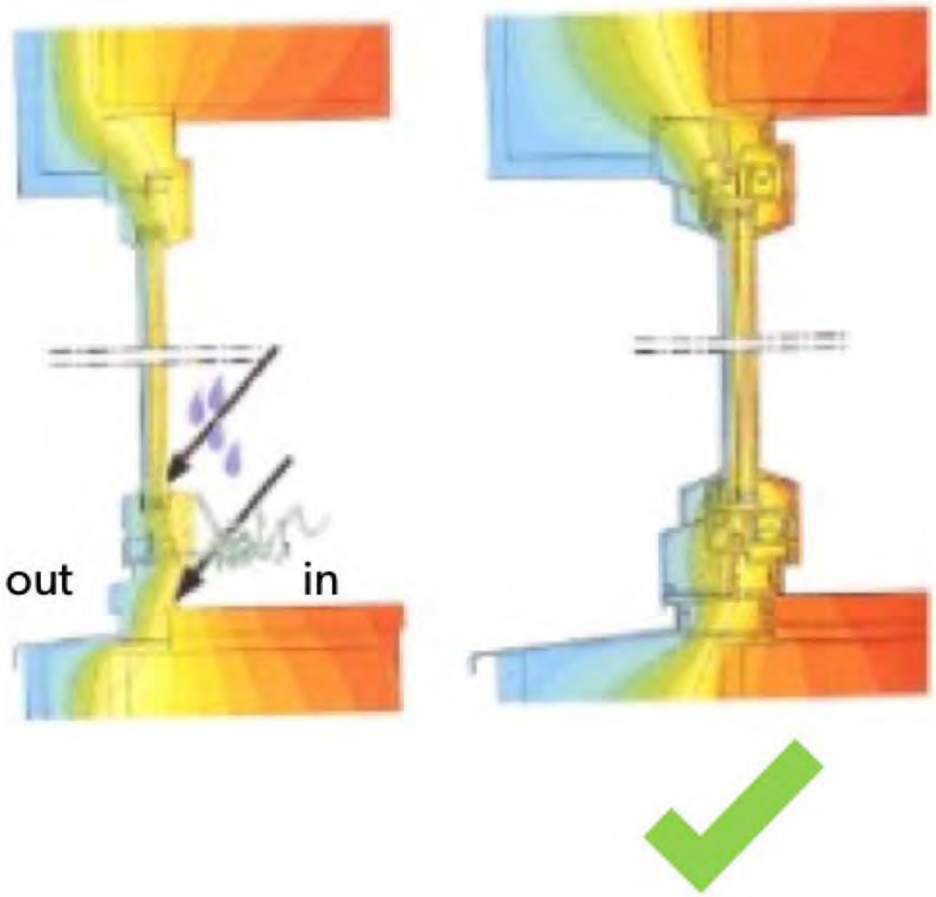
1.2 x 1.8 m

U_w 0.67

3.0 x 1.8 m

U_w 0.62

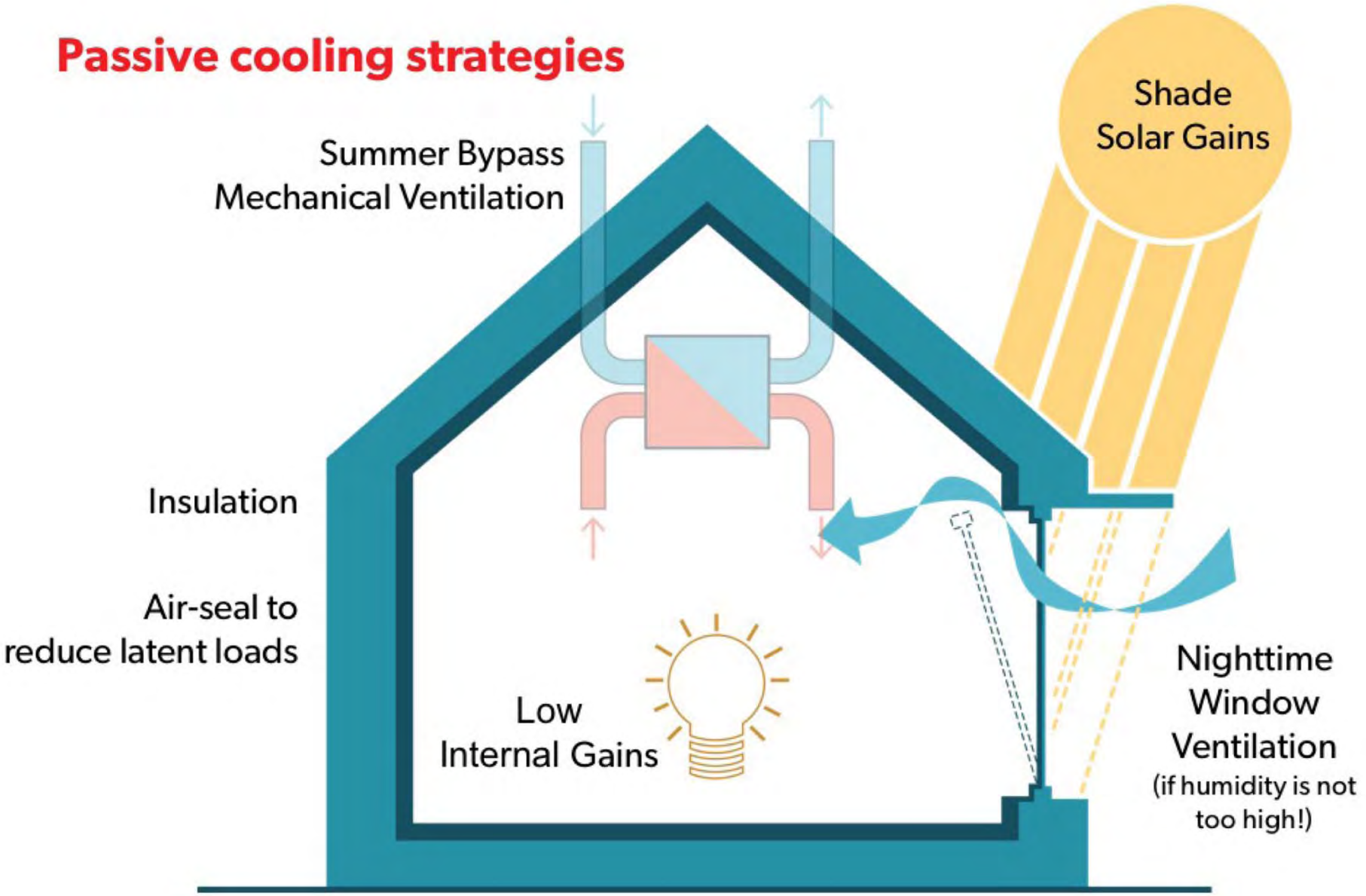
Ideal Position Of Windows



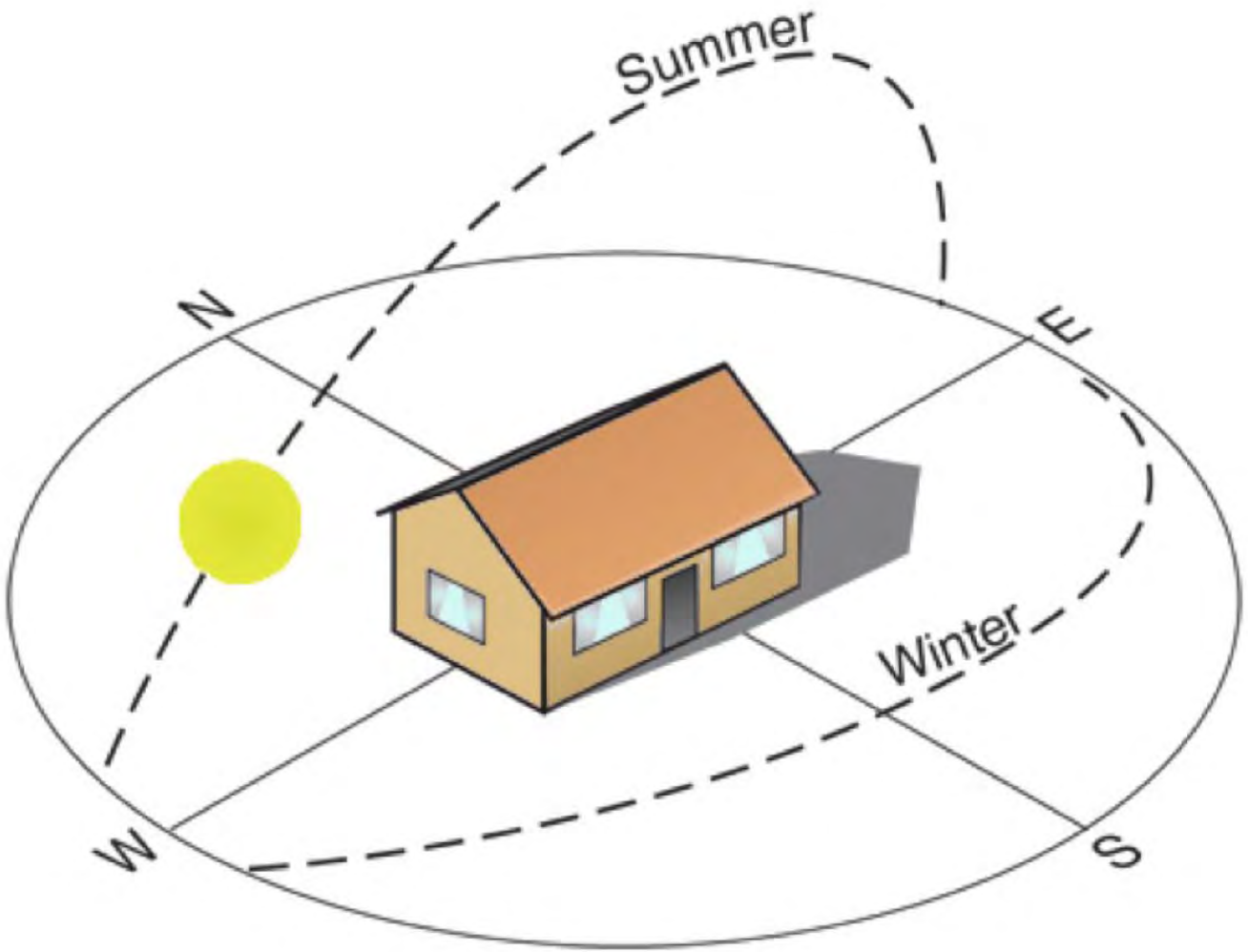
Windows should be installed:

- **towards the centre of the insulation**
  - to **reduce thermal bridging** effects
  - improve internal surface temperature
  - **avoid condensation** and uncomfortable temperatures

Passive cooling strategies



Shade windows to prevent overheating



Air Tightness

$n_{50} \leq 0.6\ /h$

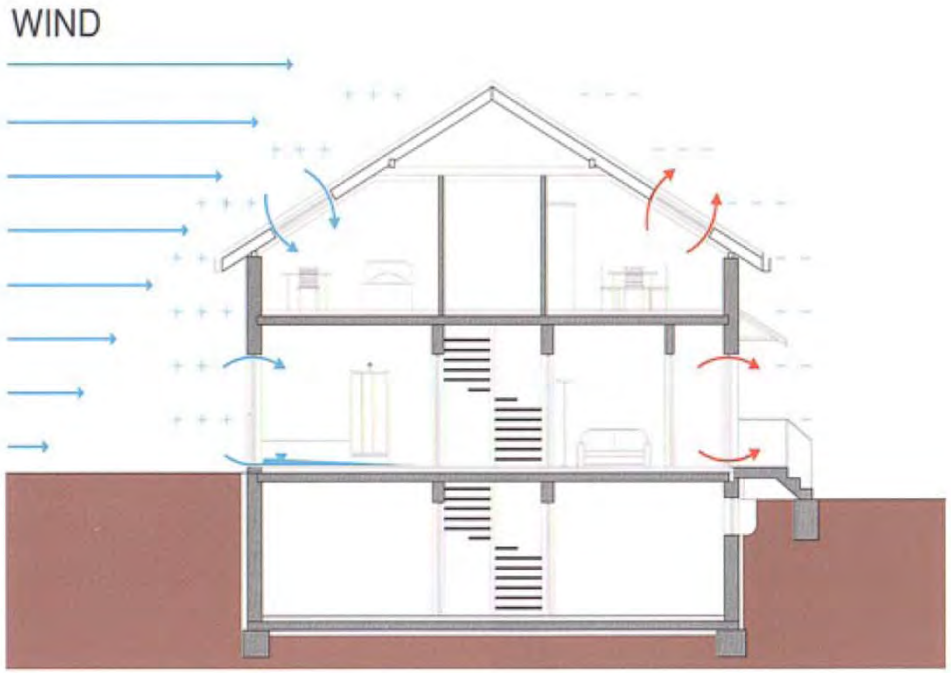
Must criteria

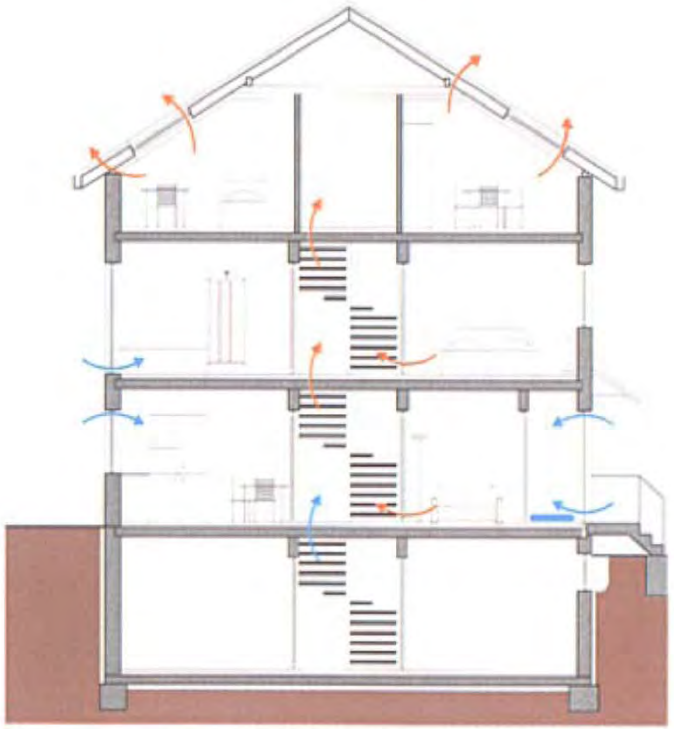
/h or h^{-1} = Air Changes *per Hour* (ACH)
at 50 Pa pressure difference

Infiltration And Exfiltration

Where air leaks out, heat leaks out.

Where air leaks out, water leaks out.





30 litres in one winter

- A hole the size of a Loonie can pump 30 litres of water into a wall.

=

Why Is Air Tightness Important?

Air-tightness:

- Avoid condensation in assemblies
- Avoid mold growth and structural damage
- Minimize heat loss
- Minimize sound transmission
- Improve air quality

Critical Barriers

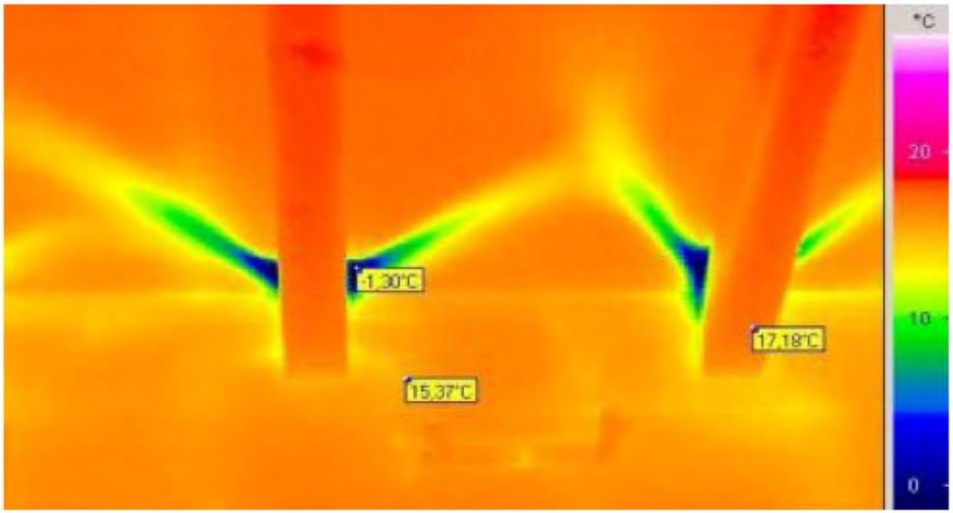
The **vapour barrier** must be on the **warm side of insulation**.

The **water resistive barrier** (WRB) must be on the **outside**.

The **air barrier** can be anywhere, but must be **continuous**!

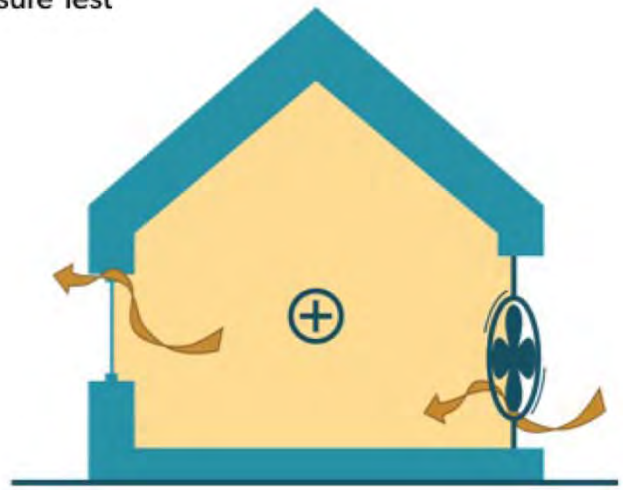
*Walls **do not** need to breathe.* ***Walls need to dry.***

Blower Door Test



Blower Door Test Required In Both Directions

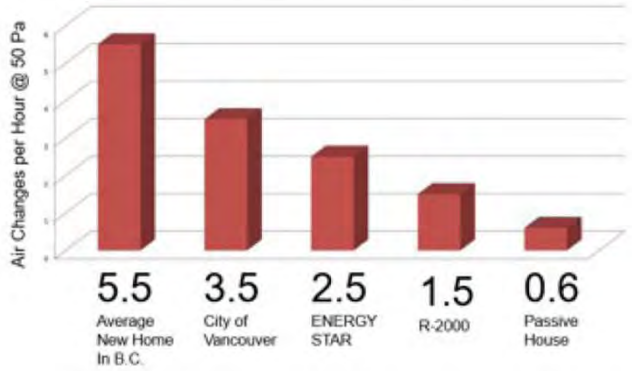
Negative Pressure Test



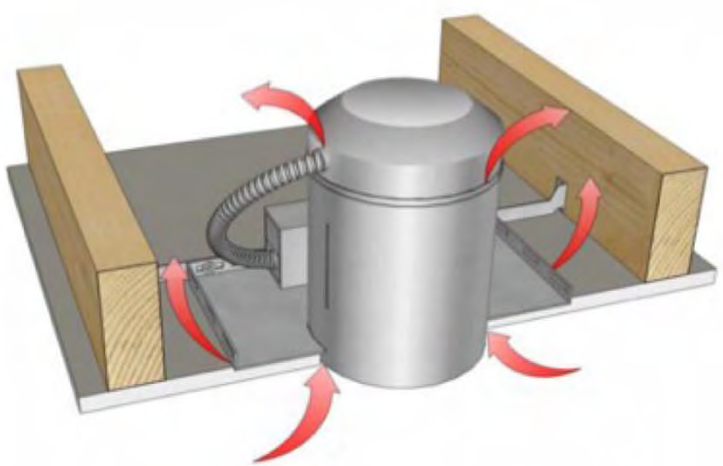
Positive Pressure Test

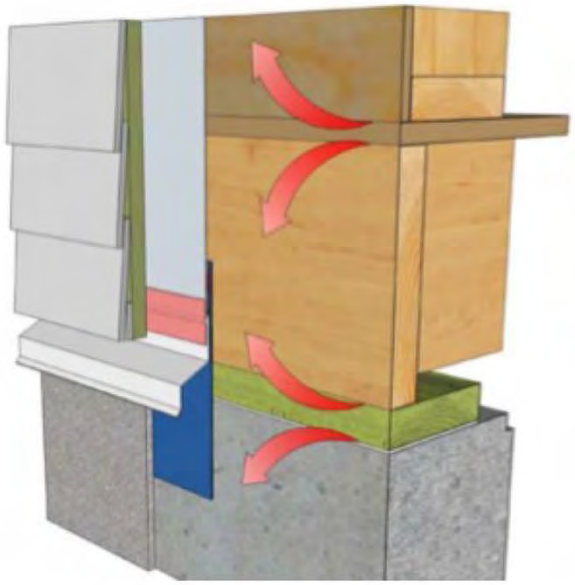
Limits:

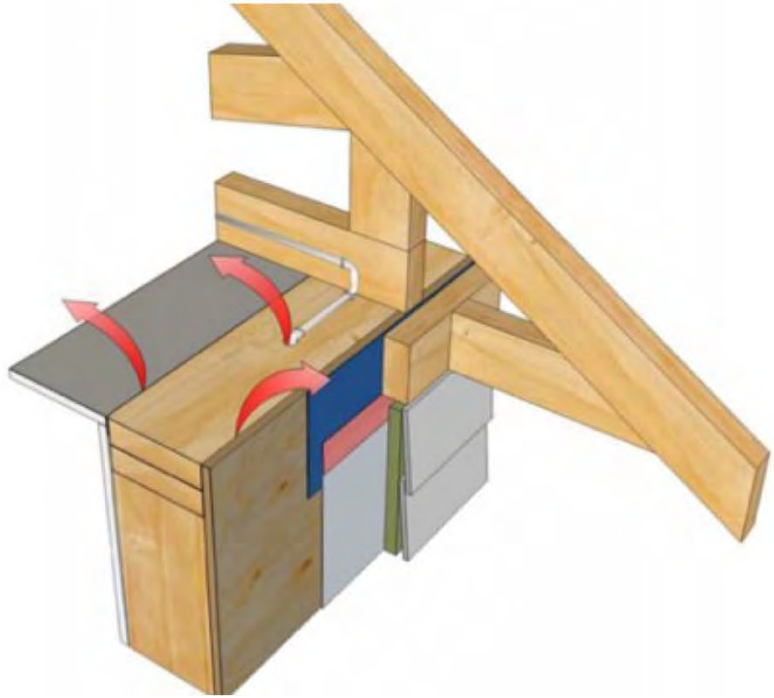
Passive House:	0.6 h^{-1}
R2000	0.6 h^{-1}
OBC (2017)	2.5 h^{-1}
VBBL (2012)	3.5 h^{-1}
Typical practice:	5.5 h^{-1}



Sources of leaks







Heat Recovery Ventilation, HRV

Ventilation with heat recovery efficiency ≥ 75%

Recommendation

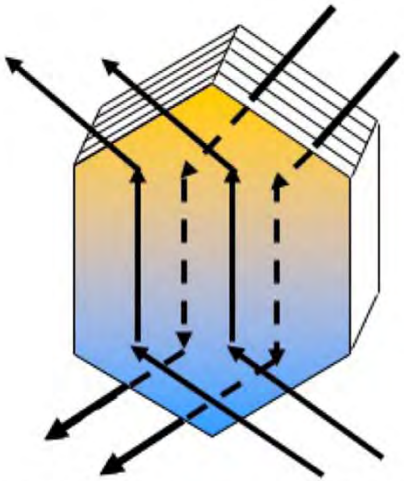
Components Of Central Units (HRV)

- Air to air heat exchanger with HR >75%
- DC motors
- Control: operating levels and air flow balancing
- Thermal insulation and airtightness
- Condensate drain

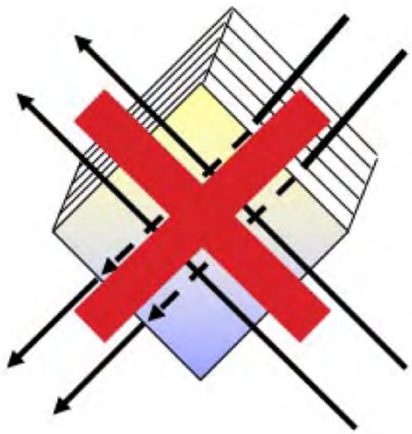
- Filter: Extract air + outdoor air
- Frost protection
- Summer bypass

HRV Core

- Overall heat recovery efficiency must be > 75%
- Electric efficiency has to be < 0.45Wh/m³
- Simple cross flow heat exchangers are not appropriate because they do not achieve 75% (according to PHI)

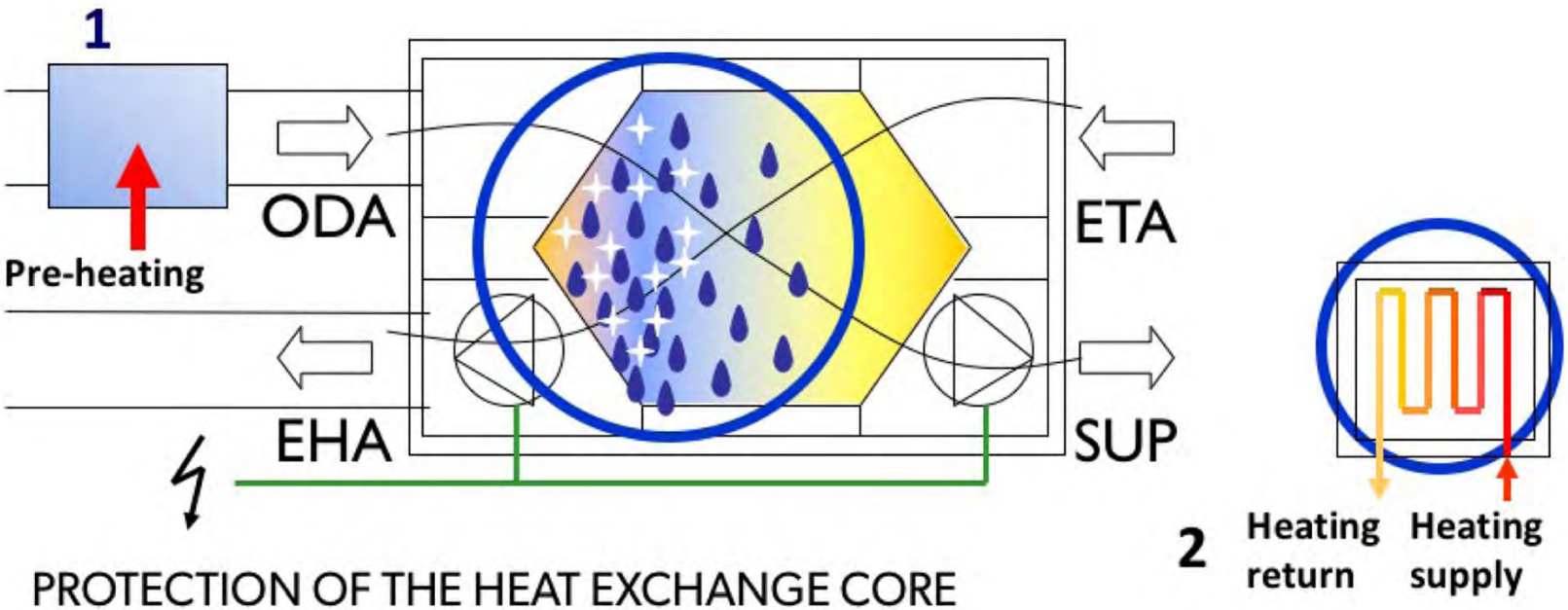


COUNTER FLOW/CROSS COUNTER FLOW



CROSS FLOW

Ventilation System Frost Protection



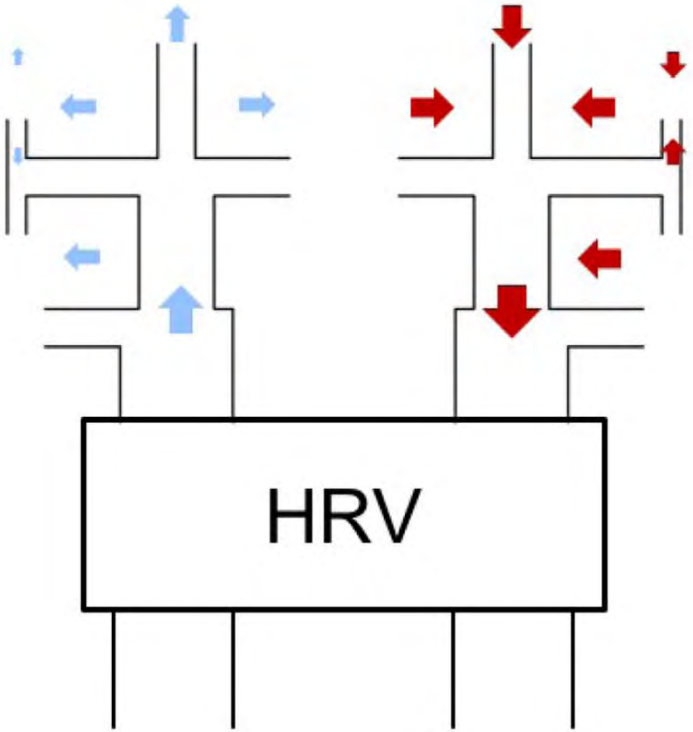
PROTECTION OF THE HEAT EXCHANGE CORE

Suitable systems:

- Air subsoil HX
- Glycol subsoil HX
- Electric air preheat unit
- Hydronic air preheat unit

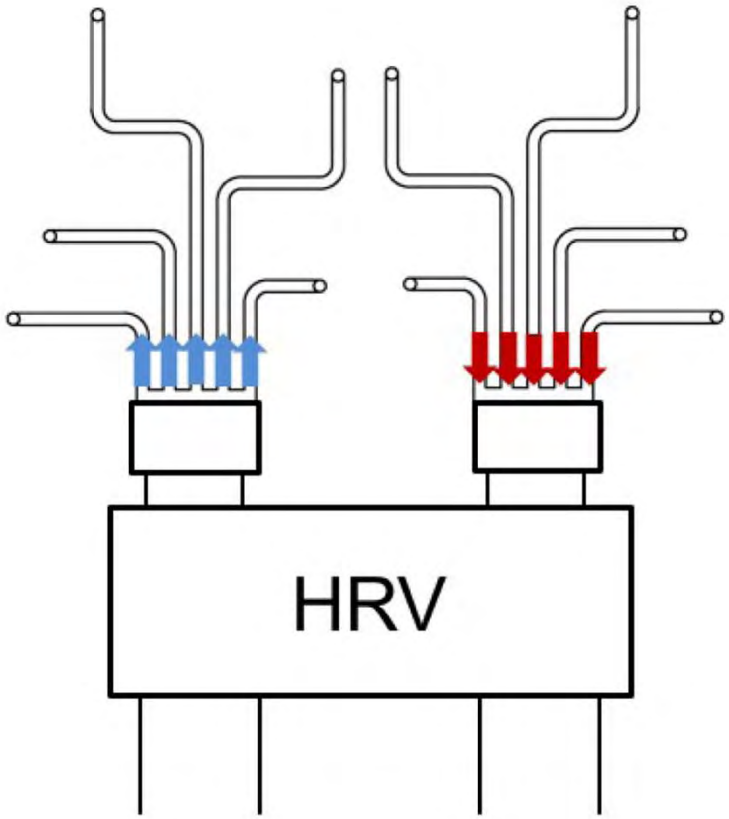
Trunk and branch ducts

- Two large ducts leave the H/ERV, one for supply and one for extract, and along each one branches tap off for each room, and the duct gets smaller at each branch.

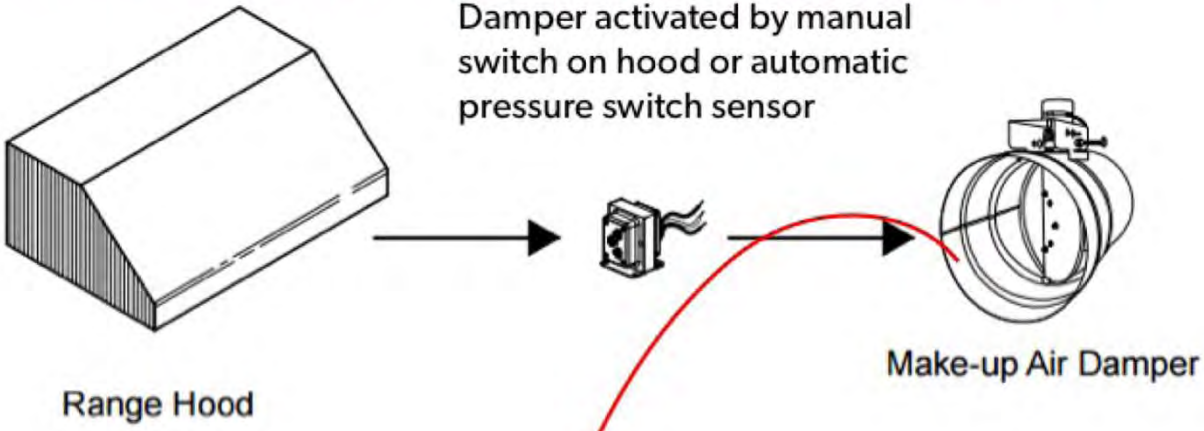


Manifold ducts (home run)

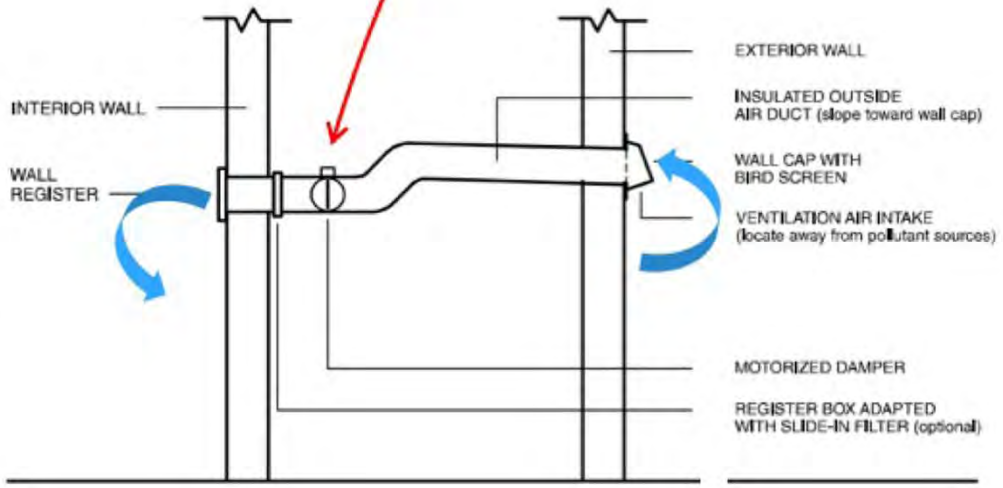
- A manifold divides up all the air at one point, and smaller individual ducts run to and from each space.



Automatic make-up air dampers for kitchens



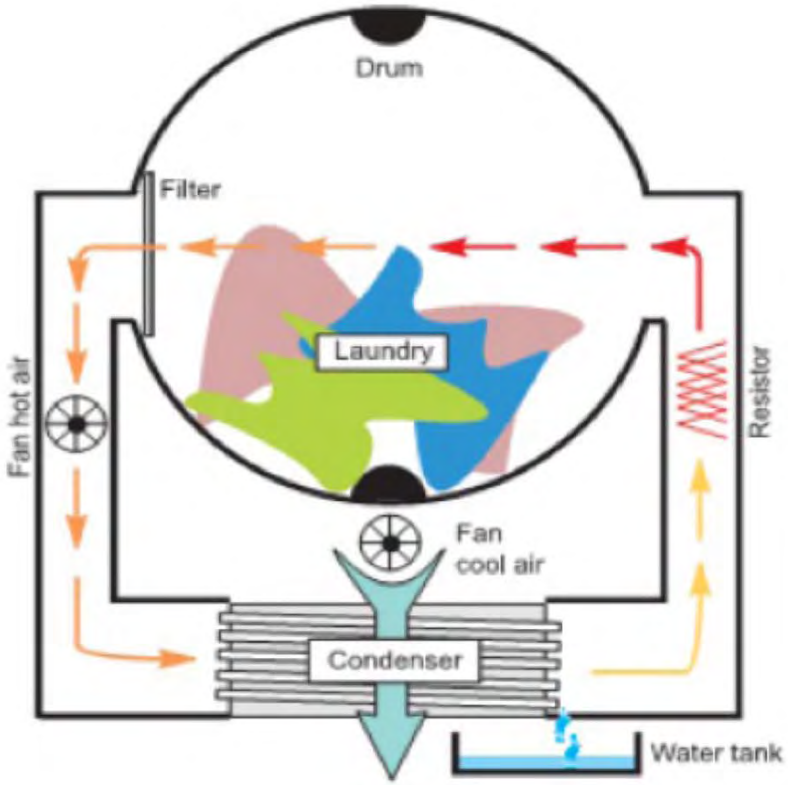
Damper and outdoor air duct connected to a ceiling, wall or floor register



Induction cooking

- Emissions from gas ranges may degrade indoor air quality.
- Induction is safer and provides comparable experience to gas.

Condensing dryer



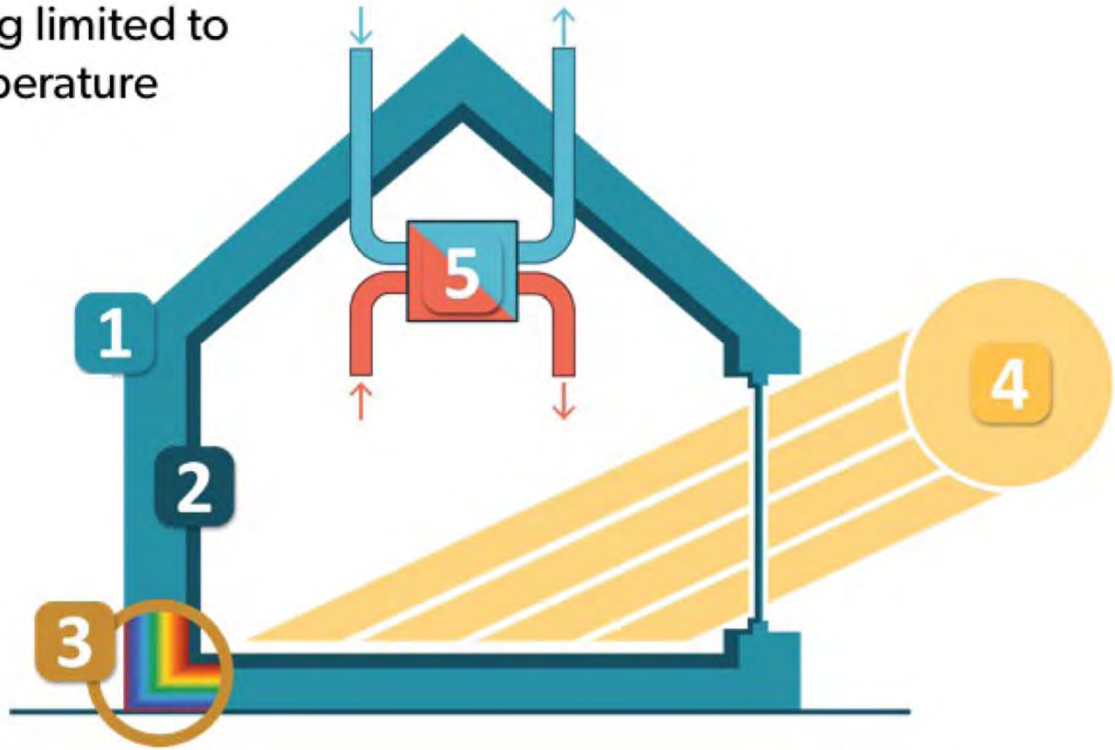
Passive House Mechanical System

- Requirements
  - Space heating
  - Space cooling
  - Domestic hot water

- Many options
  - Electric resistance (duct heater, infloor heat, radiator, baseboard…)
  - Air source heat pump
  - Gas boiler / furnace
  - Biomass boiler (carbon-neutral)
    - Pellet
    - Woodchip
  - Ground source heat pump
  - Solar thermal
  - Compact Unit (n/a in Can.)

Passive House Mechanical System

- Point-source heating is now acceptable
- Perimeter heating is not required
- Keep it simple
- Reduce installed cost
- Ventilation air heating limited to 52°C supply air temperature
  (10 W/m^2)



When the peak load is 10 W/m^2

2,200 sqft home

= 180 m^2 TFA

@ 10 W/m^2

= 1800 watts

Why not put the hair dryer in the HRV supply duct?

- For low peak loads (and low annual demand), an electric duct heater as a post-heater in the ventilation system may be the most cost-effective.

- May also be useful to add supplement heat to critical rooms.

Electric duct heater – Post heater

Heating system efficiency – Electric resistance

100%

1 kW = 1 kW

100%

1 kW = 1 kW

100%

1 kW = 1 kW

Heating system efficiency - Combustion

10%

Most of heat goes
up chimney

60-70%

Two appliances
Two pilot lights

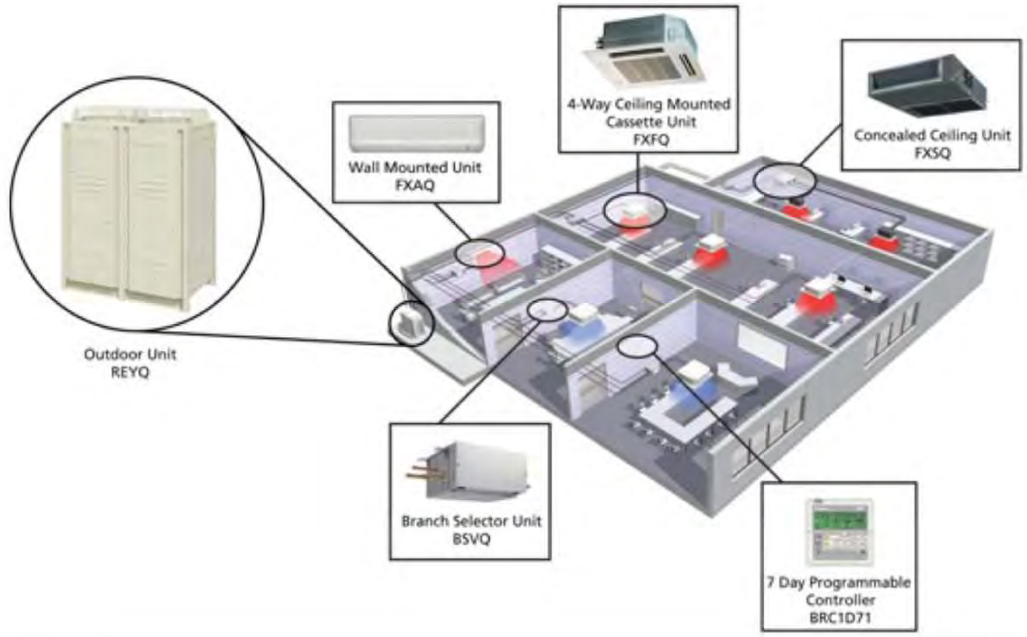
90-95%

Direct Vent
Combo: Heat & DHW

Air Source Heat Pumps

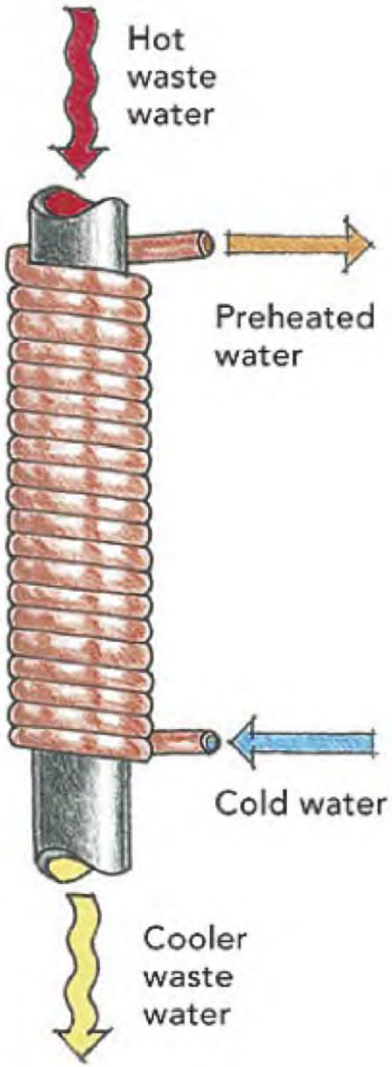
Coefficient of performance (COP) of 3+ (uses 1 W electricity per 3 W heating)

- Low installed cost, perk of A/C
- Performance degrades with cold outside temperatures
- Requires electric resistance back-up for coldest days, but average annual COP is still >2 on Canadian Prairies
- Commercial can use Variable Refrigerant Flow (VRF) technologies

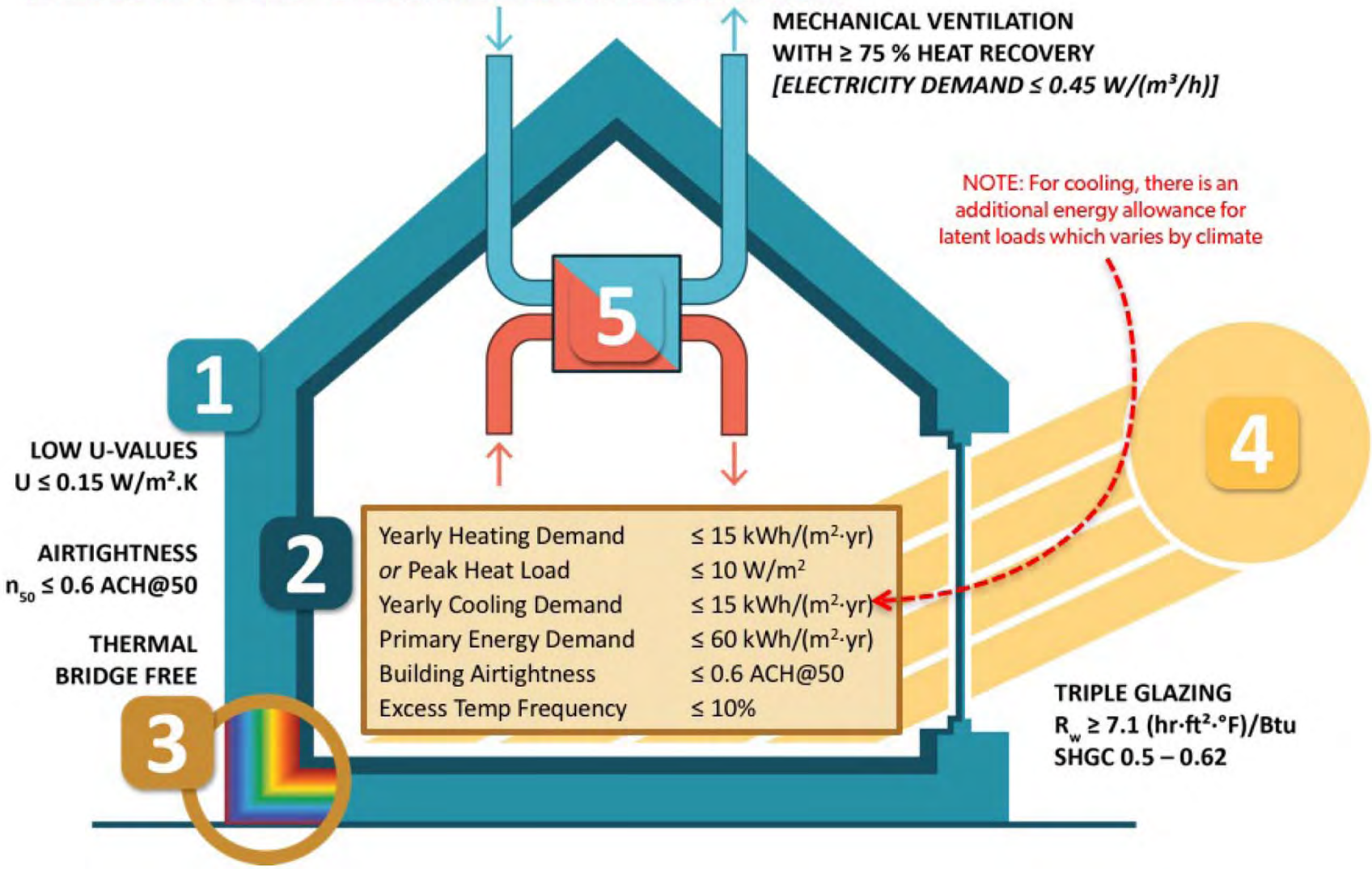


Drain Water Heat Recovery

- Can offer large domestic hot water energy savings
- No moving parts
- DHW has a large effect on Primary Energy demand
  - Larger than space heating for a Passive House

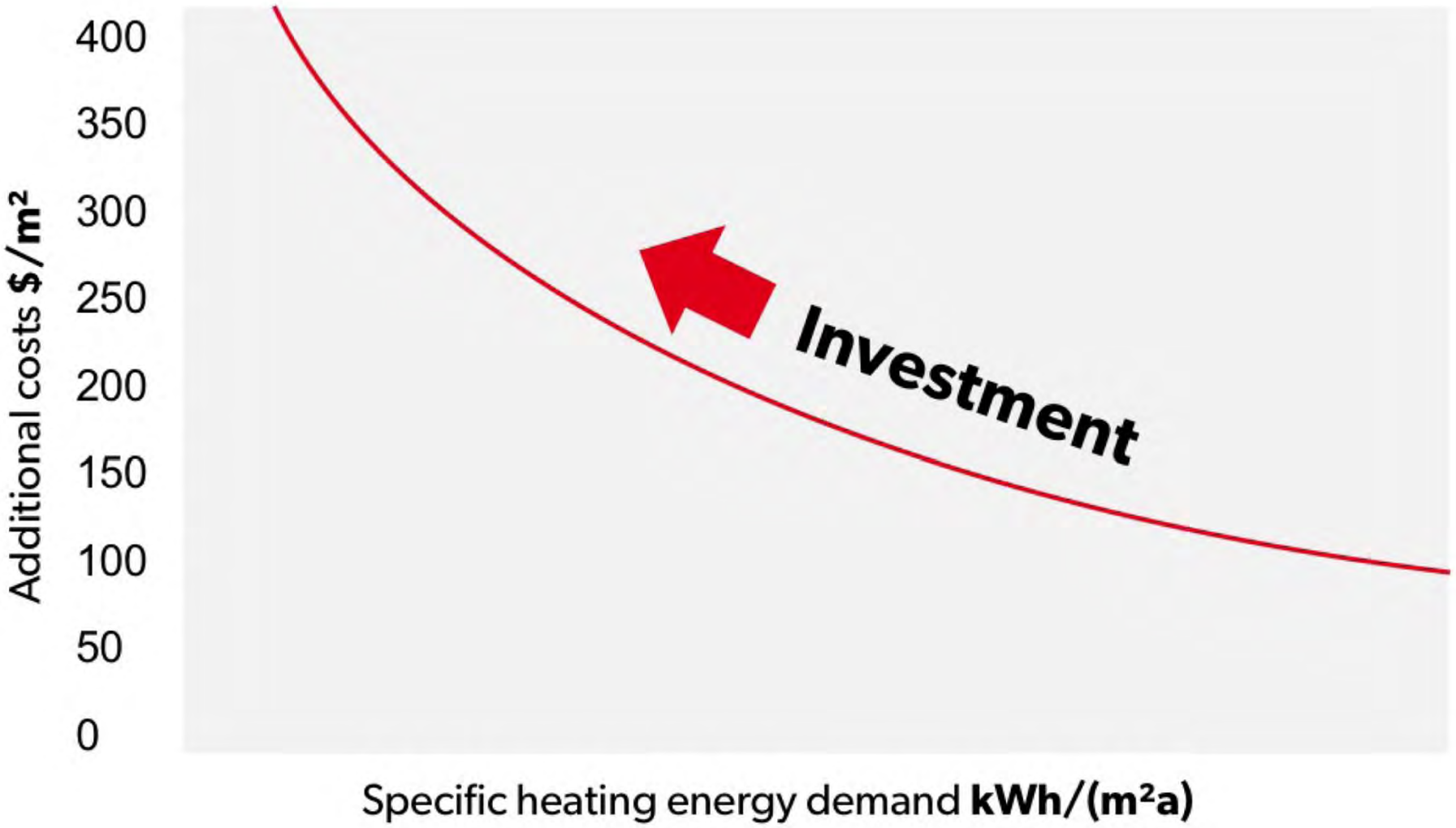


Review: The Certification Standard

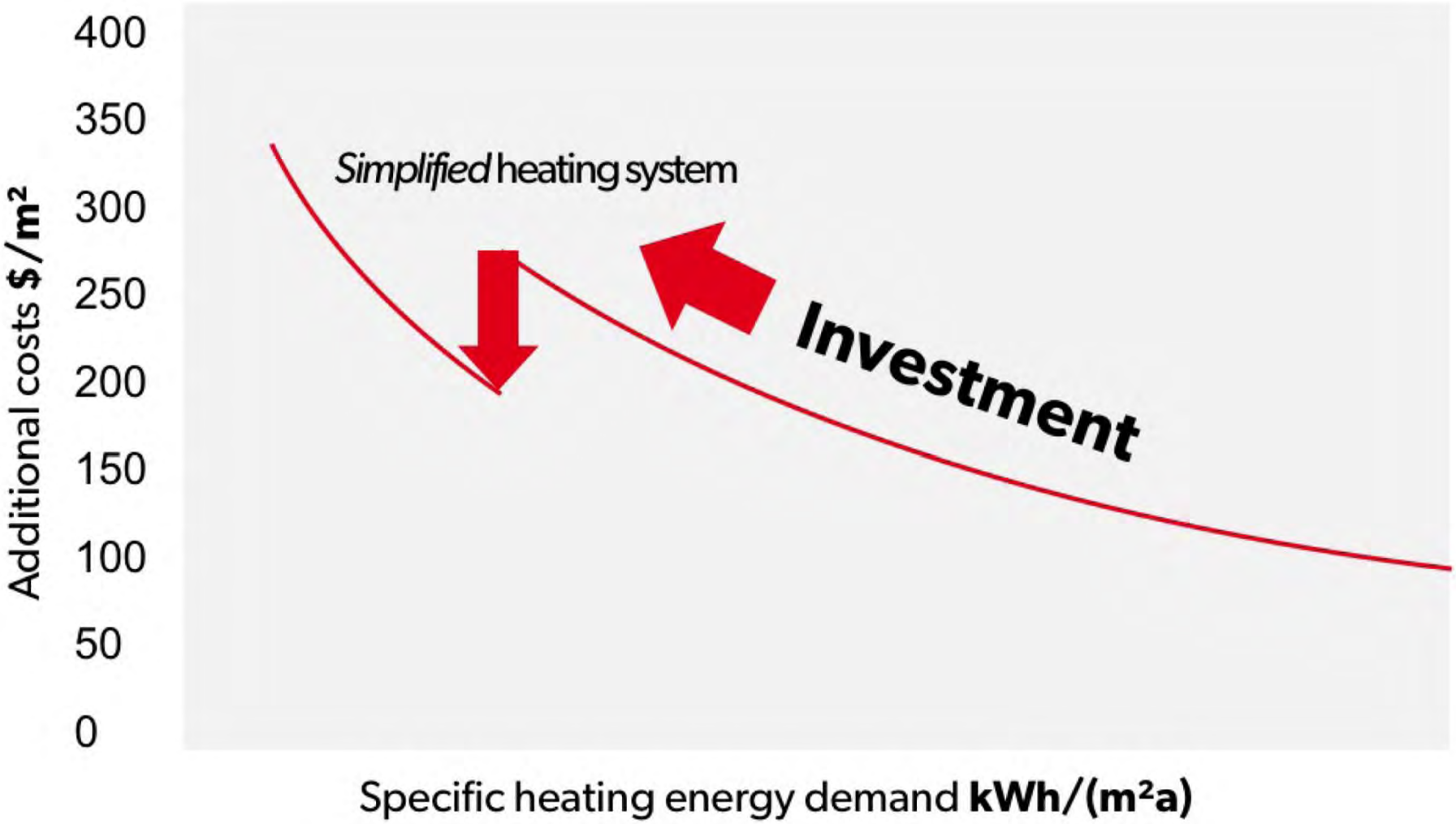


Economics

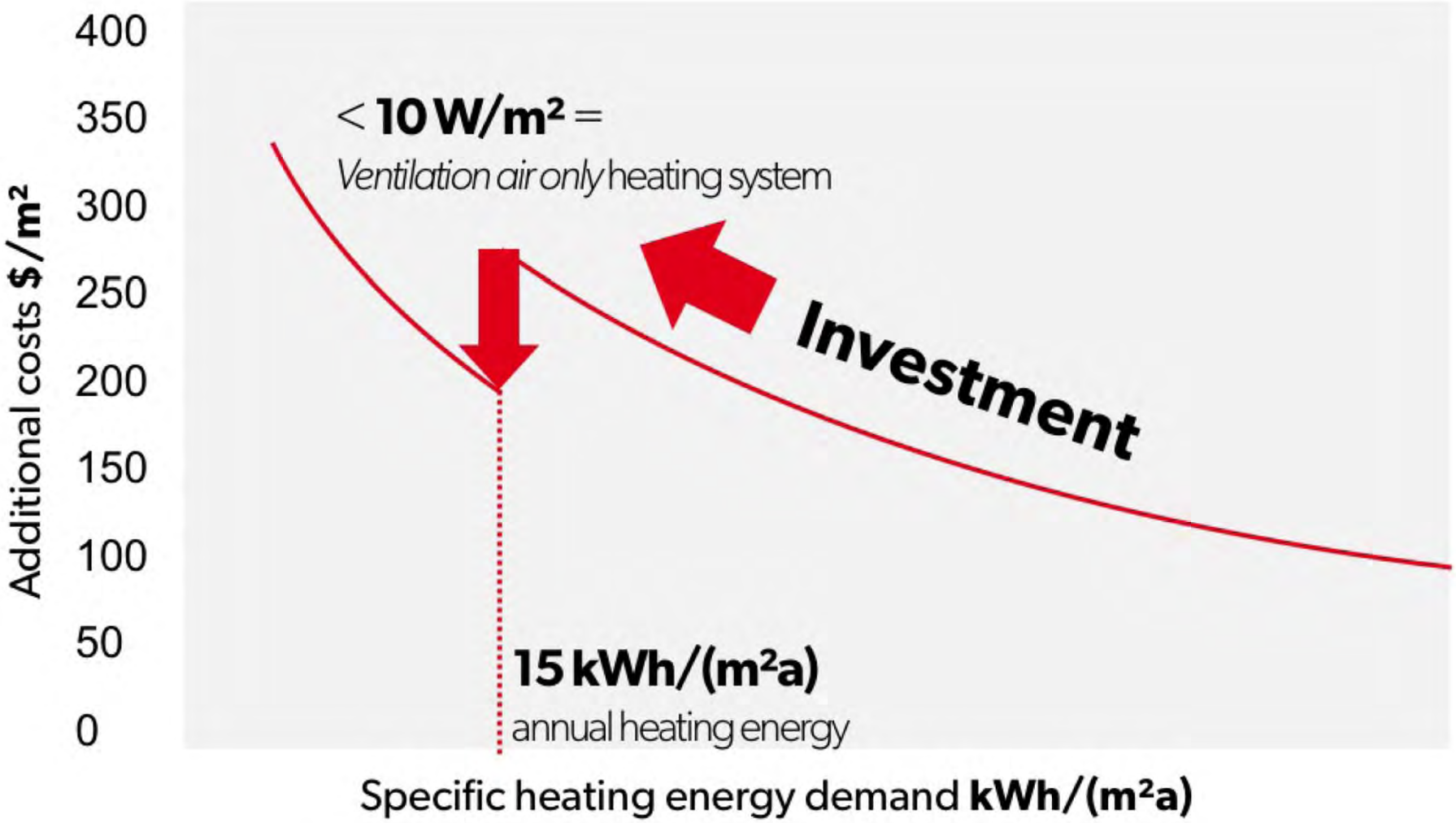
Passive House Economics

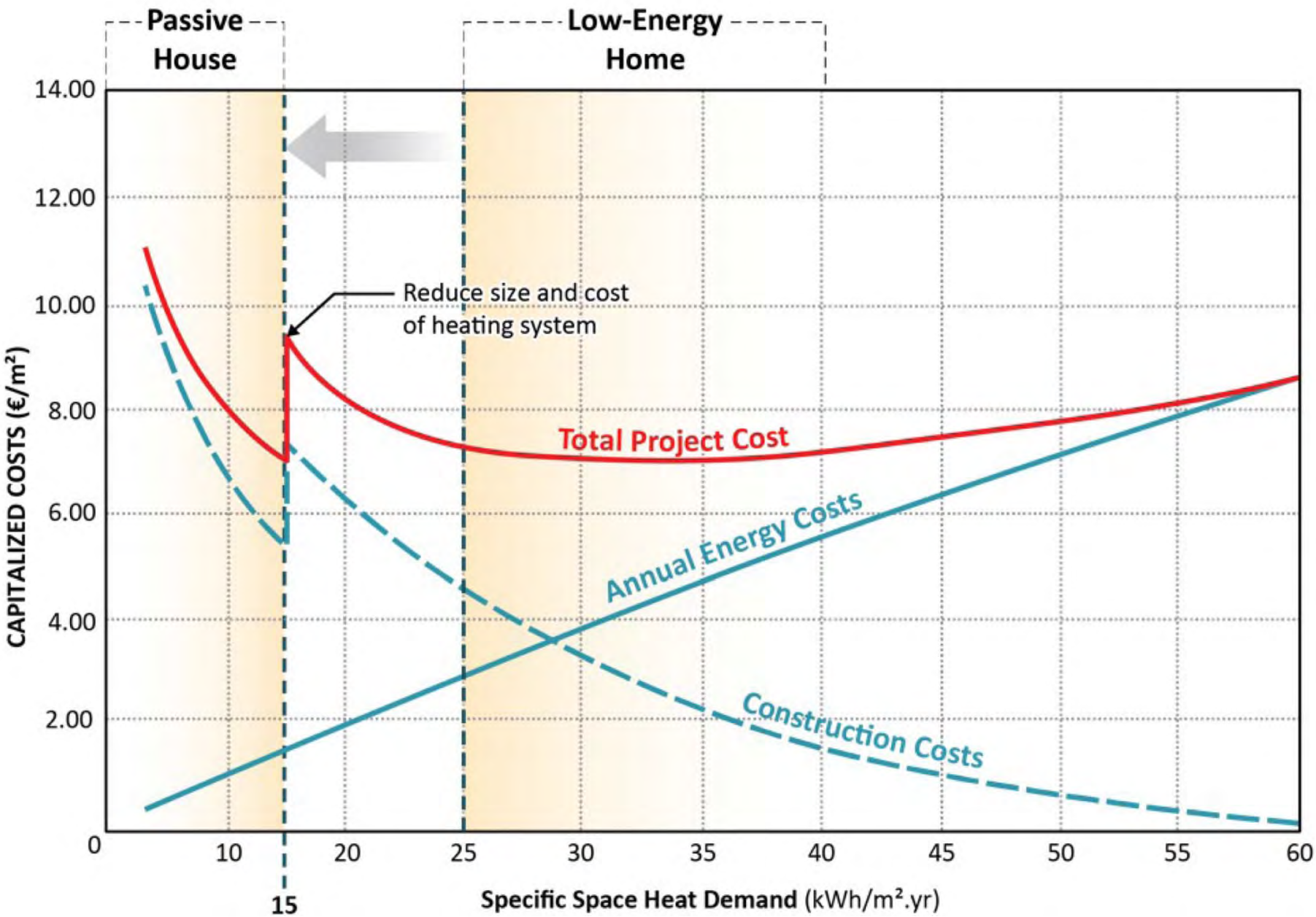


Passive House Economics

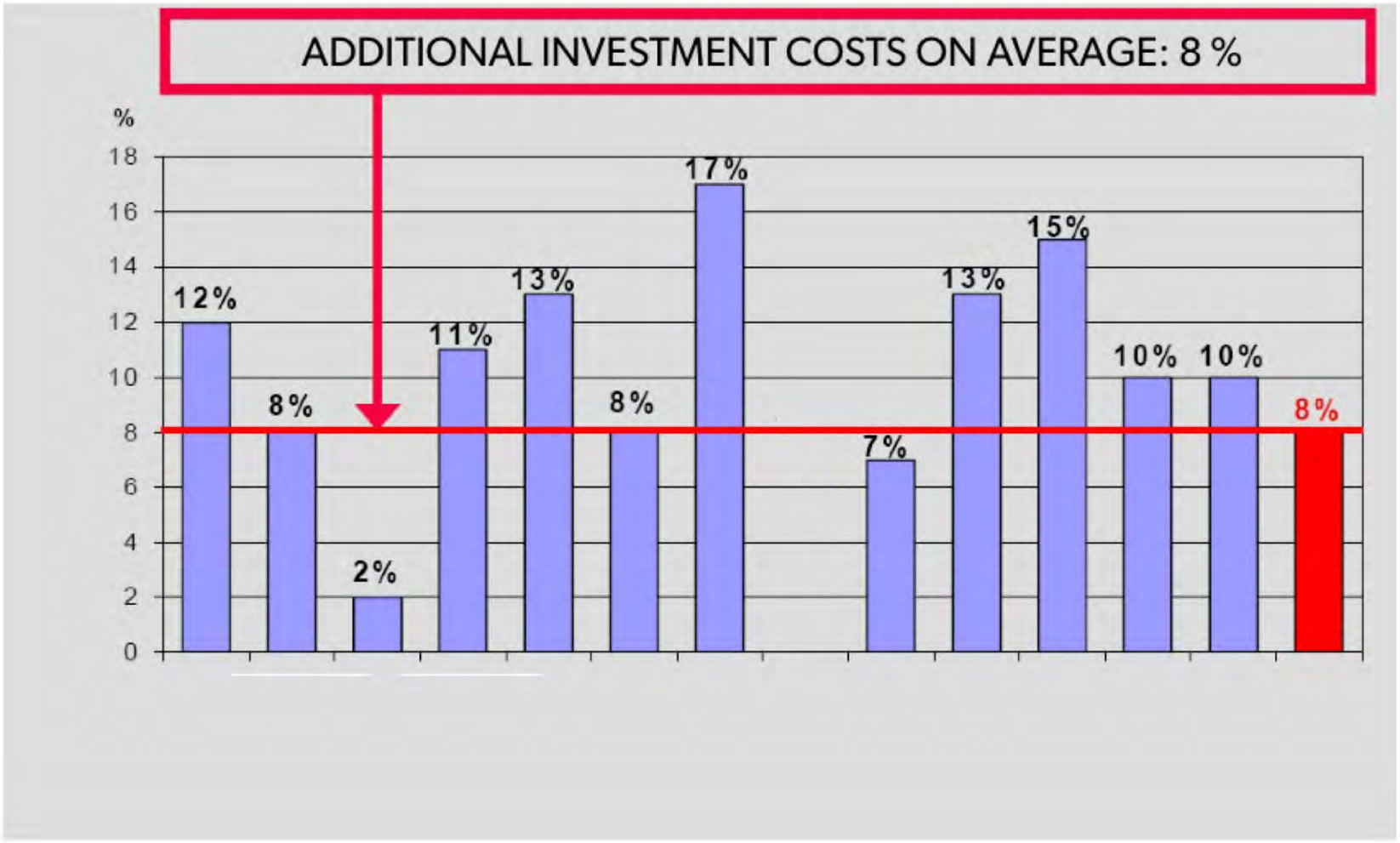


Passive House Economics




Passive House
Low-Energy Home
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0
CAPITALIZED COSTS (€/m²)
Reduce size and cost of heating system
Total Project Cost
Annual Energy Costs
Construction Costs
10
15
20
25
30
35
40
45
50
55
60
Specific Space Heat Demand (kWh/m².yr)

Additional Costs



What Is It Like to Live In?

- Comfortable
- Comfortable
- Comfortable
- Silent
- Air quality is excellent

Owners Cost

	Passive Construction Costs	Conventional Construction Costs
Cost of Energy Per month	~$65.00	~$210.00
Extra mortgage costs	~$134.00	0.00
Mechanical Maintenance costs	$10	$50
Total Cost of living per month	$209.00	$260.00

Comparison Of Canadian PH v Normal Costs

TABLE 2: Cost comparison of the Bernhardt Passive House vs. Bernhardt Conventional.

3864 ft² Single Family Home with Suite & Garage		Passive House		Conventional		Difference	
	$ (1000s)	$ Per ft²*	$ (1000s)	$ Per ft²*	$ (1000s)	$ Per ft²*	%
Construction Costs - Site and Building	619.0	160.2	601.7	155.7	17.3	4.5	2.88
Soft Costs and Construction	740.5	191.6	707.7	183.2	32.8	8.5	4.64
Total: Construction, Soft Costs, Land and Financing	1,284.8	n/a	1,251.4	n/a	33.4	n/a	2.66
*Square Foot floor areas measured to the outer face of exterior walls.							

THANK YOU!