PASSIVEHOUSE

Introduction to Passive House
High Performance Buildings

Presenter: Larry Ferreira (Canadian Sales Manager)
Company: 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

90% less space heating energy
15 kWh/m² required

What do I need to know to build to the Passive House Standard?
Space Heating Energy Balance
EN ISO 13790

Transmission [Windows]
Transmission [Opaque]

Air leakage, Ventilation

Solar Gain
Internal Heat Gains
15 kWh/m²a
Space Heating System

Losses Gains
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

MECHANICAL VENTILATION
WITH ≥ 75 % HEAT RECOVERY
[ELECTRICITY DEMAND ≤ 0.45 W/(m²/h)]

LOW U-VALUES
U ≤ 0.15 W/m².K

AIRtightness
n₅₀ ≤ 0.6 ACH@50

THERMAL BRIDGE FREE

TRIPLE GLAZING
$U_W \leq 0.8 \text{ W/m}^2\text{K (R7)}$
$g$-value/SHGC: 0.50-0.60
Finally, just a bit of heat

- Heating / cooling generation by various means
- Air based or hydronic distribution

1. LOW U-VALUES
   \[ U \leq 0.15 \text{ W/m}^2\text{K} \]

2. AIRTIGHTNESS
   \[ n_{50} \leq 0.6 \text{ ACH@50} \]

3. THERMAL BRIDGE FREE

4. TRIPLE GLAZING
   \[ U_w \leq 0.8 \text{ W/m}^2\text{K} \ (R7) \]
   \[ g-value/SHGC: 0.50-0.60 \]
Finally, just a bit of heat

Air source heat pump
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

<table>
<thead>
<tr>
<th>Number of Stories</th>
<th>A/V Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 story</td>
<td>A/V = 1.33</td>
</tr>
<tr>
<td>1 story</td>
<td>A/V = 1.18</td>
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<tr>
<td>1 story</td>
<td>A/V = 1.04</td>
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<tr>
<td>2 story</td>
<td>A/V = 0.70</td>
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<tr>
<td>4 story</td>
<td>A/V = 0.34</td>
</tr>
<tr>
<td>8 story</td>
<td>A/V = 0.28</td>
</tr>
</tbody>
</table>
Non-optimal form :)

![Image of a non-optimal building design](image-url)
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

- Superinsulated – R40
- Airtight - 0.8 ACH @ 50 Pa
- Innovative HRV
- Compact shape
- Minimal N, W, E glass
- Good S orientation

One of the most important Passive House prototypes
Still Saving Energy 40 Years Later
Requirements & Criteria of the Passive House Standard
Annual Space Heating / Cooling Demand

15 kWh/(m²a) square meter (treated floor area) year (annum)

4.75 kBTU/(ft²a)

Must Criteria (either or with Heating Load)
Heating/Cooling Load

10 W/m²

10 W/m² = 3.17 BTU/h/ft²

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

Opaque Assemblies: Walls, Roof, Floor

\[ U \leq 0.15 \text{ W/(m}^2\text{K)} \]

Recommendation to meet standard – not *must* criteria.

*U*-value – heat transfer coefficient, heat lost over a given surface area and temperature difference

(\text{change of 1}^\circ\text{C} = \text{change of 1 Kelvin, K})

*R*-value – thermal resistance [\text{\sim R}40]

\[ \Delta T = 1 \text{ K} \]
# Thermal Performance

Opaque Assemblies: Walls, Roof, Floor

## U-value - R-value Conversion Table

Heat transfer coefficient vs thermal resistance

\[
U = \frac{1}{R}
\]

\[
RSI \times 5.678 = R_{\text{imperial}}
\]

<table>
<thead>
<tr>
<th>U-value (W/m²K)</th>
<th>R-value, RSI (m²K/W)</th>
<th>U-value (BTU/ft²Fh)</th>
<th>R-value (ft²Fh/BTU)</th>
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</thead>
<tbody>
<tr>
<td>0.06</td>
<td>16.7</td>
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<td>0.023</td>
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<td>0.14</td>
<td>7.1</td>
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<td>0.25</td>
<td>4.0</td>
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<tr>
<td>0.30</td>
<td>3.3</td>
<td>0.053</td>
<td>19</td>
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</tbody>
</table>

\[ R_{\text{imperial}} = \frac{5.678}{U_{\text{metric}}} \]

\[ U_{\text{metric}} = \frac{5.678}{R_{\text{imperial}}} \]
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

- 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

Service cavity created by moving the air / vapour barrier just outside the interior wall.
Walls – Double Stud Wood Framed w/ Service Cavity
Prefab Deep Stud Walls

Wall Panels (RSZ)
Structural Wall (R18)
1. Siding (Net Shown)
2. Rainscreen (1.5”) (Not Shown)
3. Diffusion Board
4. Z10 Studs
5. Cellulose Blown Insulation
6. OSB Sheathing
7. Rock Wool Batt Insulation
8. Gypsum Board
9. Certified Passive House Window
1. Triple-Pane with Insulated Glazing
2. Argon Filled Insulating Glass
3. Low Emissivity Coating
4. U-Value: Less than 0.8
5. Thermal Bridge Free Window Frames

Floor Panels (R65+)
Structural Component
1. Diffusion Board
2. TJI Joists
3. Cellulose Blown Insulation
4. OSB Sheathing
5. Service Space Framing
6. Z6 Studs
7. Rock Wool Batt Insulation
8. OSB Sheathing
9. Gypsum Board
10. Flooring

NB: All panels are described from the exterior inward.
Study: Labour & Material Costs – R40 Walls in Yellowknife
**Thermal Bridge Free Design**

\[ \Psi \text{ (Psi)} \leq 0.01 \text{ W/(mK)} \]

- 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)

\[ \Delta T = 1 \text{ K} \]

\[ 0.01 \text{ watts} \]
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

$T_{\text{out}} = 0^\circ \text{C}$

$T_{\text{in}} = 20^\circ \text{C}$
Details Are Vital  
(e.g. Basement Wall)

Typical Installation

$\Psi_{\text{Einbau}} = 0.15 \text{ W/(mK)}$
Details Are Vital (e.g. Basement Wall)

Recommended Installation

$\Psi_{\text{Einbau}} = 0.005 \, \text{W/(mK)}$
Identifying Thermal Bridges
Identifying Thermal Bridges

- Ridge
- Int Wall - Ceiling
- Eaves
- Floor Junction
- Window Fitting
- Internal Wall
- Footing
A raised heel truss reduces the thermal bridge at the eave by ensuring a thick wrap of insulation.
Windows

\[ U \leq 0.8 \text{ W}/(\text{m}^2\text{K}) \]

- High solar heat gain coefficient: \( \text{SHGC, } g > 50\% \)
- 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

<table>
<thead>
<tr>
<th>Metric</th>
<th>Imperial</th>
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</thead>
<tbody>
<tr>
<td>U-value [W/m²K]</td>
<td>RSI [m²K/W]</td>
</tr>
<tr>
<td>0.40</td>
<td>2.50</td>
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<tr>
<td>0.45</td>
<td>2.22</td>
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<tr>
<td>0.50</td>
<td>2.00</td>
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<tr>
<td>0.55</td>
<td>1.82</td>
</tr>
<tr>
<td>0.60</td>
<td>1.67</td>
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<tr>
<td>0.65</td>
<td>1.54</td>
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<tr>
<td>0.70</td>
<td>1.43</td>
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<td>0.71</td>
</tr>
<tr>
<td>1.50</td>
<td>0.67</td>
</tr>
<tr>
<td>1.60</td>
<td>0.63</td>
</tr>
</tbody>
</table>

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

- Energystar Zone 3
- Vancouver Code
- Energystar Zone 1
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/(m$^2$·K)
glazing $U_g$: 0.55 W/(m$^2$·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

- Summer Bypass Mechanical Ventilation
- Insulation
- Air-seal to reduce latent loads
- Low Internal Gains
- Shade Solar Gains
- Nighttime Window Ventilation (if humidity is not too high!)
Shade windows to prevent overheating
Air Tightness

\[ n_{50} \leq 0.6 \text{/h} \]

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

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

Diagram showing negative and positive pressure tests.
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)
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 activated by manual switch on hood or automatic pressure switch sensor

Range Hood → Damper → Make-up Air Damper

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/m²)
When the peak load is 10 W/m²

2,200 sqft home
= 180 m² TFA

@ 10 W/m²
= 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

MECHANICAL VENTILATION WITH ≥ 75% HEAT RECOVERY
[ELECTRICITY DEMAND ≤ 0.45 W/(m²h)]

NOTE: For cooling, there is an additional energy allowance for latent loads which varies by climate

1. LOW U-VALUES
   \[ U \leq 0.15 \text{ W/m}^2\text{K} \]

2. AIRTIGHTNESS
   \[ n_{50} \leq 0.6 \text{ ACH@50} \]

3. THERMAL BRIDGE FREE

4. TRIPLE GLAZING
   \[ R_w \geq 7.1 \text{ (hr-ft}^2\text{-°F)/Btu} \]
   \[ \text{SHGC 0.5 – 0.62} \]

Yearly Heating Demand
≤ 15 kWh/(m²-yr)

or Peak Heat Load
≤ 10 W/m²

Yearly Cooling Demand
≤ 15 kWh/(m²-yr)

Primary Energy Demand
≤ 60 kWh/(m²-yr)

Building Airtightness
≤ 0.6 ACH@50

Excess Temp Frequency
≤ 10%
Economics
Passive House Economics

Additional costs $/m²

Specific heating energy demand kWh/(m²a)

Investment
Passive House Economics

- Simplified heating system
- Investment

Additional costs \( \$/m^2 \)

Specific heating energy demand \( kWh/(m^2a) \)
Passive House Economics

$< 10 \text{ W/m}^2 = \text{Ventilation air only heating system}$

Investment

$15 \text{ kWh/}(\text{m}^2\text{a})$

Specific heating energy demand $\text{kWh/}(\text{m}^2\text{a})$
Additional Costs

ADDITIONAL INVESTMENT COSTS ON AVERAGE: 8%
What Is It Like to Live In?

- Comfortable
- Comfortable
- Comfortable
- Silent
- Air quality is excellent
## Owners Cost

<table>
<thead>
<tr>
<th></th>
<th>Passive Construction Costs</th>
<th>Conventional Construction Costs</th>
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</thead>
<tbody>
<tr>
<td>Cost of Energy Per month</td>
<td>$65.00</td>
<td>$210.00</td>
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<tr>
<td>Extra mortgage costs</td>
<td>$134.00</td>
<td>0.00</td>
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<tr>
<td>Mechanical Maintenance costs</td>
<td>$10</td>
<td>$50</td>
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<tr>
<td>Total Cost of living per month</td>
<td>$209.00</td>
<td>$260.00</td>
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## Comparison Of Canadian PH v Normal Costs


<table>
<thead>
<tr>
<th>3864 ft² Single Family Home with Suite &amp; Garage</th>
<th>Passive House</th>
<th>Conventional</th>
<th>Difference</th>
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</thead>
<tbody>
<tr>
<td>Construction Costs - Site and Building</td>
<td>$619.0</td>
<td>$601.7</td>
<td>$4.5</td>
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<tr>
<td>Soft Costs and Construction</td>
<td>$740.5</td>
<td>$707.7</td>
<td>$8.5</td>
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<tr>
<td>Total: Construction, Soft Costs, Land and Financing</td>
<td>$1,284.8</td>
<td>$1,251.4</td>
<td>$33.4</td>
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</tbody>
</table>

*Square Foot floor areas measured to the outer face of exterior walls.*
THANK YOU!