Building Envelope Design for Thermal Resiliency
Foundation, Wall, and Roof assemblies are SYSTEMS of materials that must work together to provide a continuous barrier of thermal, air, and water control layers that separate the outside climate from the inside climate.

The fourth control layer is vapor diffusion, but it does not necessarily need to be a “barrier”.

Providing drying potential (low vapor diffusion resistance) is much more important than attempting to prevent vapor diffusion.
Recommended Insulation Levels
Thermal Barrier Continuity

Thermal Barrier
High-Performance Thermal Standards

- varies by climate, construction typology, economic and societal parameters.
- Does not address thermal resiliency
- Higher standards prolong habitability of building during outage

<table>
<thead>
<tr>
<th>Country/Climate Zone</th>
<th>Standard</th>
<th>Walk Minimum Insulation Value</th>
<th>Roof Minimum Insulation Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Northwest Good Building Practices</td>
<td>R-28</td>
<td>R-40</td>
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<tr>
<td></td>
<td>Northeast Territories Good Building Practices</td>
<td>R-32</td>
<td>R-50</td>
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<td></td>
<td>Yellowknife - Existing Buildings</td>
<td>R-50</td>
<td>R-40</td>
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<td></td>
<td>Yukon Housing Corporation</td>
<td>R-28 Whitehorse R-21 Thelonian</td>
<td>R-50</td>
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<td></td>
<td>General Passive House Guidelines</td>
<td>R-40 TO R-60+</td>
<td>R-60 TO R-100H</td>
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<td>National Energy Code of Canada for Buildings 2017 - Climate Zone 7</td>
<td>R-27</td>
<td>R-41</td>
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<tr>
<td>Alaska</td>
<td>Deep Energy Retrofit Climate Zone 7</td>
<td>R-50</td>
<td>R-65</td>
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<td>Deep Energy Retrofit Climate Zone 8</td>
<td>R-50</td>
<td>R-75</td>
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<td></td>
<td>Alaska Building Energy Efficiency Standard Climate Zone 7</td>
<td>R-25</td>
<td>R-54 or 48*</td>
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<td></td>
<td>Alaska Building Energy Efficiency Standard Climate Zone 8</td>
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<td>R-59 or 48*</td>
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<td>MILCON Initial Compliant Standards</td>
<td>R-45</td>
<td>R-60</td>
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</table>

* The smaller value may be used with a properly sized, energy-heat transfer.
High-Performance Thermal Envelope

- In U.S., current high-performance standards for most federal new construction projects requires a 30% energy reduction compared to the ASHRAE 90.1-2013 baseline building.
- The most effective strategy to reach this goal is to focus on reducing HVAC loads with a high-performance building envelope.
- This will reduce energy costs, improve thermal comfort, and prolong the habitability of the building during disruptions to heat supply.

<table>
<thead>
<tr>
<th>ASHRAE Climate Zone</th>
<th>Insulation Entirely above Deck</th>
<th>Metal Building</th>
<th>Attic</th>
<th>Mass Wall</th>
<th>Metal Building</th>
<th>Steel Framed</th>
<th>Wood Framed &amp; Other</th>
<th>Unheated (Vertical Insulation for 48&quot;)</th>
<th>Heated (Vertical Insulation for 48&quot;)</th>
<th>Entrance Doors</th>
<th>Metal Windows (Fixed/Operable)</th>
<th>Nonmetal Windows</th>
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<tbody>
<tr>
<td>Zone 8 (Fairbanks)</td>
<td>46.4</td>
<td>50</td>
<td>76.5</td>
<td>27.1</td>
<td>33.3</td>
<td>35.1</td>
<td>40.6</td>
<td>26</td>
<td>32.5</td>
<td>1.7</td>
<td>3.4 / 3.3</td>
<td>4.1</td>
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<tr>
<td>Zone 7 (Anchorage)</td>
<td>46.4</td>
<td>44.8</td>
<td>76.5</td>
<td>18.3</td>
<td>29.5</td>
<td>26.5</td>
<td>25.5</td>
<td>9.8</td>
<td>32.5</td>
<td>1.7</td>
<td>3.4 / 3.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Zone 6 (Minneapolis)</td>
<td>40.6</td>
<td>41.9</td>
<td>61.9</td>
<td>16.3</td>
<td>26.0</td>
<td>26.5</td>
<td>25.5</td>
<td>9.8</td>
<td>26</td>
<td>1.7</td>
<td>3.1 / 2.6</td>
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</table>
Thermal Bridging

- Energy Loss
- Condensation
Energy / Heat loss impacts
Recommended Airtightness Levels
Air Barrier Continuity – localized damage

Air Barrier
Energy Savings

Air Leakage

• Energy Loss
• Condensation
Energy / Heat loss impacts
IAQ / Durability impacts

Water Barrier
R-value is dependent on moisture content

Image Credit: Connor, AUTC / UAF 2019

Data Source: WUFI material database, Fraunhofer Institute for Building Physics
Water Barrier Failure impacts Thermal Barrier

No kickout flashing causes staining...  ... rot, and poor thermal performance
Air and Thermal Barrier Failure impacts Water Barrier

Hot Roof in Winter...

... causes leaks in Summer

Image Credit: Design Alaska
80% of construction defect litigation is due to moisture-related failures

>$7 Billion annually to correct moisture-related construction defects

$3.5 Billion spent annually on asthma-related medical costs attributable to exposures to dampness and mold (Berkeley Lab estimate)


Wetting / Storage / Drying
Type & Location of Insulation matters
Hygrothermal modeling – ASHRAE 160

Vapor Profile
The diagram illustrates various moisture-related processes and their corresponding phases, moisture sources, transport processes, moisture storage, drying processes, transport processes, and moisture sinks. Each process is connected to others through arrows, indicating the flow of moisture from one phase to another. The diagram is a comprehensive representation of how moisture behaves in different environmental conditions and materials.
Vapor Diffusion

Drying >> Wetting

LOW-PERMEANCE EXTERIOR INSULATION
4” Faced EPS Exterior Insulation

HIGH-PERMEANCE EXTERIOR INSULATION
4” Mineral Wool Exterior Insulation
Hygrothermal Modeling – Split Insulated Wood Wall with Interior Vapor Barrier and **Low Perm** Exterior Insulation

- Large Amounts of Moisture (Blue) accumulate in the OSB during Winter
- Low-Perm materials on both sides of OSB retard the drying process during Summer
- Classic “Double Vapor Barrier” problem
Hygrothermal Modeling – Split Insulated Wood Wall with Interior Vapor Barrier and High Perm Exterior Insulation

- Some Moisture (Blue) accumulates in the OSB during Winter
- High-Perm Mineral Wool exterior insulation expedites the drying process during Summer
- “Dry to the Exterior” – works great in cold, dry climates (Fairbanks)
Hygrothermal Modeling – Split Insulated Wood Walls with Interior Vapor Barrier
Putting It All Together

High Performance
Barrier Continuity
Balanced Vapor Profile
Wall Assembly

- Exterior Insulated Wall
- Split-Insulated Wall

- Thermal Barrier Continuity
- Air Barrier Continuity
- Water Barrier Continuity
- Balanced Vapor Profile
Devil in the Details

- High Performance
- Barrier Continuity
- Balanced Vapor Profile

Thermal Barrier Continuity
Air Barrier Continuity
Water Barrier Continuity
Balanced Vapor Profile
Building Envelope Design for Thermal Resiliency

Lyle Axelarris, PE, LEED AP
Building Enclosures | Design Alaska

Thank You