AFFORDABLE (PASSIVE) HOUSING AND THE CLIMATE ADJUSTED STANDARD: A CASE STUDY

Mike Anderson, BSc, March. Passive House E-Design
Learning Objectives

- Understand the design and cost implications of the climate adjusted standard in the affordable housing model.
- Learn possible strategies for cost effective construction to Passive House standard.
- Understand the different processes required to design and construct a Passive House within the affordable housing model.
- Learn about the Housing Nova Scotia project experience, the choices made and lessons learned.
Housing Nova Scotia

- Housing Nova Scotia (HNS) owns 12,000 seniors and family residential units.
- HNS has a mandate to make those properties both affordable and safe: “To ensure all Nova Scotians can find a home that’s right for them, at a price they can afford, in a healthy, vibrant community that offers the services, supports and opportunities they need.”
Affordable Housing: Opportunities

- These buildings are owned for their entire life-cycle, which can help justify higher capital costs.
- Heat is included in the rent.
- Most units are for seniors.
- The focus of Passive House on simple conservation aligns with the needs of affordable housing.
Affordable Housing: Challenges

- Residents do not receive financial benefit from energy saving.
- Maintenance staff not necessarily familiar with PH assemblies.
- Sites may have few orientation options and limited solar access.
- Modest design and construction budgets.
Passive House: the Old Standard

- Thermal Performance of Envelope: \( \leq 15 \text{ kWh/m}^2 \)
- Total Energy Consumption: \( \leq 120 \text{ kWh/m}^2 \)
- Airtightness: \( \leq 0.6 \text{ ACH @ 50 Pa} \)
Challenges with one target fits all

- **Annual Heat/Cooling Demand**
  - Huge range of climate zones in North America.
  - NS has longer winters, more HDD and more solar radiation.
  - Annual Heat Demand does not ensure comfort.
  - NS requires a tiny cooling demand.
  - Based on German TFA.
Challenges with one target fits all

- **Response to 15kWh/m²**
  - Rely heavily on solar.
  - Over glazing on the south leading to over heating.
  - Using strategies that are not always cost effective.
  - Reducing north glazing – impacting the building aesthetic.

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Challenges to Primary Energy target

- North America grid not as efficient as Europe.
- North America plug loads proving much higher.
- Normalizing by area penalizes small buildings and density.

- Response to 120 kWh/m²
  - Not accurate.
  - Relying on waste heat for annual heat demand target.
  - Big buildings/lower density are reaching certification – not fundamentally green.
Challenges to Air Tightness

- 0.6 ACH based on volume.
- Favors large buildings.
- Not NA standard for calculating volume.
- Focusing on air tightness rather than building science.

- Larger buildings much easier to certify.
PHIUS Method of Developing Climate Adjusted Standard

“This study’s main objective is to validate (in a theoretical sense) verifiable, climate-specific passive standards and space conditioning criteria that retain ambitious, environmentally-necessary energy reduction targets and are economically feasible. Such standards provide designers an ambitious but achievable performance target on the path to zero.”

The second objective: “Develop simplified formulas for inclusion in a design and verification software tool that allow the generation of custom criteria based on specific climate and energy cost parameters for any particular location.”

Credit: Climate Specific Passive Building Standard, Building America Report 1405
Cost Optimization

Credit: Climate Specific Passive Building Standard, Building America Report 1405
Passive House: Climate Adjusted Standard

- Thermal Performance of Envelope: varies by climate
  (≤ 7.1KBTU/sqft/yr in NS)

- Total Energy Consumption: ≤ 6000 kWh/person/yr

- Airtightness: + ≤ 0.05 cfm/sqft @ 50 Pa

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Climate Adjusted Standard: Thermal Performance

**Annual Heat/Cooling Demand**
- Heating/cooling targets adjust by HDD/CDD and other climate factors.
- Total of heating and cooling targets less than in old standard.
- Normalized by area, but using iCFA, more standard than old TFA.
- Based on cost optimization using Beopt.

**Design Heat/Cooling Load**
- Targets set to minimize mechanicals and ensure comfort.
- Not based on arbitrary ability to distribute heat through HRV ducts in German climate.
- Also normalized by iCFA area.
- Currently being fine-tuned.
Climate Adjusted Standard: Total Primary Energy

- Higher plug loads mean more internal gains, but also higher baseline total energy.
- Less efficient grid so higher source energy factor to calculate electricity PE = 3.1
- Normalized by # people, not area.
- Occupancy based on # bedrooms + 1.
- Encourages small houses with more density.
- Domestic hot water as important to PE as heat demand.
- Allowed to count PV to offset PE.
- In our experience: Heat pumps, solar thermal, or PV required to hit PE number.
Climate Adjusted Standard: Air-tightness

- Air leaks out through envelope area, so normalizing for area will more accurately measure actual air-tightness across building scale.
- New standard reflects building science requirements of air-tightness.
The Alice St. Pilot: Initial Conditions

- Site selected in Truro, NS.
- Alice St. has defined building scale and typology.
- Two 3-bedroom units required.
- Schematic plans and elevations completed when we joined team.
- Proposed plan area close to maximum buildable area.
- Very poor solar access – dense maples uphill in adjacent schoolyard.
Alice St. Project: Initial Conditions

Site selected in Truro, NS, with a defined building scale and typology
Poor solar access and proposed design filled allowable building footprint
Elevations respond to street context and building vernacular
Two 3-bedroom units required, so symmetrical duplex plan
• Apply PH principles: thick walls, centralize plumbing, prioritize south windows, maximize iCFA.

• Thick walls required redesign and filled remaining space in allowable footprint.

• Public tender: use tested and reliable assemblies.

• Shift some rooms and walls for more usable space.

• Significant shading made south windows energy neutral, so passive-solar principles not helping us achieve PH in this case.
Thicker walls requires enlarged footprint to achieve same indoor area
Reworked plan for thicker walls and to maximize iCFA
Public Tender:
Use reliable assemblies and details
Alice St. Project: Design Response

Large amount of shading makes south glazing ineffective as heat source
The Alice St. Pilot: the Old Standard

- Energy model showed that achieving heat demand using old standard would not be cost-effective.
- Wall thickness constrained by building site and setbacks, so could only add insulation to slab and roof.
- Building shape and orientation already optimized.
- Reducing shading and adding south glazing required to hit old annual heat demand targets.
### Alice St. Project: the Old Standard

Energy model analysis sheet showing strategies required to hit old standard

<table>
<thead>
<tr>
<th>BTU/sqft/yr</th>
<th>% improvement</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original file</td>
<td>21.21</td>
<td>Assume 3 ACH, lifebreath 2&quot; ICF 60% shading etc.</td>
</tr>
<tr>
<td>PH assemblies</td>
<td>15</td>
<td>29%</td>
</tr>
<tr>
<td>airtightness</td>
<td>9.82</td>
<td>35%</td>
</tr>
<tr>
<td>good glazing</td>
<td>7.45</td>
<td>24%</td>
</tr>
<tr>
<td>Top Quality HRV</td>
<td>6.19</td>
<td>17% Almost 75% less energy consumption, limited design changes</td>
</tr>
<tr>
<td>Ground loop</td>
<td>5.96</td>
<td>4% Move dining window to south wall, flip north and south window sizes</td>
</tr>
<tr>
<td>Shift Kitchen/dining</td>
<td>5.46</td>
<td>8% Only single windows on north</td>
</tr>
<tr>
<td>Reduce north windows</td>
<td>4.98</td>
<td>9%</td>
</tr>
<tr>
<td>Move Bed 3 to south</td>
<td>4.84</td>
<td>3% Change grading for sunken patio</td>
</tr>
<tr>
<td>Cut trees to 30% shading</td>
<td>4.66</td>
<td>4% Reduce Shading</td>
</tr>
</tbody>
</table>
Alice St. Project: the Old Standard

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<td>7.45</td>
<td>24%</td>
</tr>
<tr>
<td>40&quot; roof</td>
<td>7.36</td>
<td>1%</td>
</tr>
<tr>
<td>100&quot; roof</td>
<td>7.02</td>
<td>5%</td>
</tr>
<tr>
<td>20&quot; slab</td>
<td>6.55</td>
<td>7%</td>
</tr>
<tr>
<td>40&quot; slab</td>
<td>6.27</td>
<td>4%</td>
</tr>
<tr>
<td>best airtightness ever</td>
<td>5.86</td>
<td>11% .3 ACH</td>
</tr>
<tr>
<td>11 7/8 TJI</td>
<td>5.31</td>
<td>15%</td>
</tr>
<tr>
<td>16&quot; custom truss</td>
<td>4.65</td>
<td>21%</td>
</tr>
</tbody>
</table>

Assume 3 ACH, lifebreath 2" ICF 60% shading etc.

Using assemblies and components only to meet standard
The Alice St. Pilot:  
the Climate Adjusted Standard

- Adjusted annual heat demand target achievable with ‘standard’ PH assemblies and components, improved solar access not required.

- Small, high occupancy building meant higher targets for PE and airtightness than old standard.

- No natural gas available, so all-electric house.

- To hit PE target, some mechanical systems had to be upgraded from the cheapest, simplest options.
The Alice St. Pilot: the Climate Adjusted Standard

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<tr>
<td>good glazing</td>
<td>7.45</td>
<td>24%</td>
</tr>
<tr>
<td>Shift Kitchen/dining window areas</td>
<td>6.85</td>
<td>8%</td>
</tr>
</tbody>
</table>

Almost 70% less energy consumption

Only the most cost-effective strategies are needed to hit climate adjusted standard
The Alice St. Pilot: Climate Adjusted Standard Heat Load

- Heat load target could not be achieved using the same strategies as annual heat demand - still 5-10% over.
- Heat load as a part of the standard helps reduce over-reliance on passive solar techniques, so this site should be a good study of this target.
- Manual J calculation may be a better measure right now - these calculations are still being performed in this project.
- We could not guarantee heat load target on this project, allowed to miss this target in this case.
Alice St. Project:
Climate Adjusted Standard Heat Load

<table>
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<tr>
<th>Strategy</th>
<th>BTU/sqft</th>
<th>% improvement</th>
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<tr>
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<tr>
<td>PH assemblies</td>
<td>9.32</td>
<td>19%</td>
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<tr>
<td>airtightness</td>
<td>5.09</td>
<td>45%</td>
</tr>
<tr>
<td>good glazing</td>
<td>4.57</td>
<td>10%</td>
</tr>
<tr>
<td>Top Quality HRV</td>
<td>4.11</td>
<td>10%</td>
</tr>
<tr>
<td>Ground loop</td>
<td>3.83</td>
<td>7%</td>
</tr>
<tr>
<td>Best air-tightness ever</td>
<td>3.74</td>
<td>2%</td>
</tr>
<tr>
<td>Reduce north windows</td>
<td>4.32</td>
<td>-16%</td>
</tr>
<tr>
<td>40&quot; roof, 16&quot; truss, 20&quot; under slab</td>
<td>3.93</td>
<td>9%</td>
</tr>
<tr>
<td>Cut trees to 30% shading</td>
<td>3.85</td>
<td>2%</td>
</tr>
</tbody>
</table>

Assume 3 ACH, lifebreath 2" ICF 60% shading etc.

Must use Canadian HRV, no can do

Not usually cost effective

3 ACH, new builder

Ugly, but doable

Change grading for sunken patio

Reduce Shading

Strategies to hit Climate Adjusted Standard heat load target

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The Alice St. Pilot: Mechanical Choices

- Simple mechanicals not enough to hit PE target.
- Ductless mini-split instead of baseboards: expensive and high maintenance.
- Upgrade to German HRV: made-in-Canada/CSA approval was a requirement and upgraded unit is expensive.
- Added PV: poor solar access and expensive.
- Solar thermal for DHW: poor solar access and high maintenance.
- DHW heat pump: some maintenance but OK.
Alice St. Project: Climate Adjusted Standard P.E.

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<td>91</td>
<td>Assume 3 ACH, lifebreath 2&quot; ICF 60% shading etc.</td>
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<tr>
<td>PH assemblies</td>
<td>70.5</td>
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<td>airtightness</td>
<td>57.7</td>
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<tr>
<td>good glazing</td>
<td>54.1</td>
<td>6%</td>
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<tr>
<td>Top Quality HRV</td>
<td>49.8</td>
<td>Must use Canadian HRV, no can do</td>
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<tr>
<td>Ductless mini-split</td>
<td>40.6</td>
<td>&quot;Too much maintainance&quot;</td>
</tr>
<tr>
<td>Hot water heat pump</td>
<td>43.4</td>
<td>OK</td>
</tr>
</tbody>
</table>

Strategies to hit Climate Adjusted Standard primary energy
The Alice St. Pilot: Public Tender

- HNS required to tender all projects.
- Tender was chosen based on price, plus mandatory criteria related to safety and insurance.
- Mandatory criteria for safety and insurances results in no bids from residential builders with PH or R-2000 experience.
- Project management is regional, so not part of design process.
- PH expertise contracted to provide training and construction support.
The Alice St. Pilot: Construction Support

- Onsite training in PH critical tasks.
- Air-sealing instruction sub-slab, walls and ceiling, at windows and doors.
- Window and door installation support.
- Instruction to mechanical and electrical trades during rough-in.
- Perform blower door tests throughout construction.
- Check cellulose density.
- Alice St. being used as PH example for Housing NS and other builders, through production of project videos.
The Alice St. Pilot: Construction Lessons

• New window labeling rules in National Building Code of Canada recently.

• Difficult for smaller manufacturers to keep up with lab testing.

• Good example of third aspect of building with Housing Authority, beyond cost effectiveness and energy efficiency.
The Alice St. Pilot: Construction Lessons

- Excavation revealed a very high water table on this site – above the design elevation for underside of foam.
- We chose to raise the foundation a couple feet on good fill, but had ~ 2% energy penalty to heat demand and PE.
- Always design with a cushion!
Conclusions

- Public Housing and Passive House are a good fit.
- Public Housing makes decisions based on cost optimization and energy efficiency.
- Compact 3-storey duplex with good design should be able to reach PH standard without solar.
- Climate adjusted standard made certification possible for this client and site.
Further Information

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