PASSIVE HOUSES IN NEW ZEALAND: a comparison between predicted and real performance through post-occupancy evaluation

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RESEARCH PROCESS
Master of Architecture in Sustainable Design

Overview of NZ housing stock performance
Analysis of existing building certification schemes in NZ
Overview of Passive House worldwide & in NZ
Analysis of all certified Passive Houses in NZ

Post-occupancy evaluation of two completed Passive Houses
Quantitative Assessment
Comparison with NZBC code-complying houses
Conclusions, finding gaps and improvements for the future

Qualitative Assessment
Post Occupancy Evaluation (POE)

“The process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time. POEs focus on building occupants and their needs, and thus they provide insights into the consequences of past design decisions and the resulting building performance. This knowledge forms a sound basis for creating better buildings in the future.”

Preiser, Rabinowitz, & White, 1988
Auckland

Completed in 2014

Construction: Timber framing with double layer of insulation

8kW Photovoltaic Panels

Passive House certification: In progress

Homestar: 8/10 rating granted

Whanganui

Completed in 2014

Construction: Insulated Concrete Forms (ICF)

3kW Photovoltaic Panels

Passive House certification: Granted
A

- TFA: 216m²
- A/V ratio: 0.72
- A/TFA: 3.1
- 4 x 4
- 4 x 2
- 2 x 2

B

- TFA: 138m²
- A/V Ratio: 0.79
- A/TFA: 2.7
- 5 x 4
- 4 x 2
- 1 x 1
Orientation
Orientation
## Comparison: Insulation

<table>
<thead>
<tr>
<th>Component</th>
<th>House A</th>
<th></th>
<th>House B</th>
<th></th>
<th>NZBC Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U-Value</td>
<td>R-Value</td>
<td>U-Value</td>
<td>R-Value</td>
<td>R-Value</td>
</tr>
<tr>
<td>Floor Slab</td>
<td>0.433</td>
<td>2.309</td>
<td>0.240</td>
<td>4.167</td>
<td>1.3</td>
</tr>
<tr>
<td>Walls</td>
<td>0.282</td>
<td>3.546</td>
<td>0.261</td>
<td>3.831</td>
<td>1.9</td>
</tr>
<tr>
<td>Roof</td>
<td>0.183</td>
<td>5.464</td>
<td>0.145</td>
<td>6.896</td>
<td>2.9</td>
</tr>
<tr>
<td>Glazing - Uw</td>
<td>0.900</td>
<td>1.11</td>
<td>1.870</td>
<td>0.535</td>
<td>0.26</td>
</tr>
<tr>
<td>Glazing - Ug</td>
<td>0.690</td>
<td>1.449</td>
<td>1.100</td>
<td>0.909</td>
<td></td>
</tr>
</tbody>
</table>
## Comparison: Window-to-wall Ratio

<table>
<thead>
<tr>
<th>Façade</th>
<th>Value</th>
<th>House A (Auckland)</th>
<th>House B (Whanganui)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>Window Area</td>
<td>23 m²</td>
<td>26 m²</td>
</tr>
<tr>
<td></td>
<td>Window-to-wall ratio</td>
<td>45%</td>
<td>39%</td>
</tr>
<tr>
<td>South</td>
<td>Window Area</td>
<td>3 m²</td>
<td>0 m² *</td>
</tr>
<tr>
<td></td>
<td>Window-to-wall ratio</td>
<td>9%</td>
<td>0% *</td>
</tr>
<tr>
<td>East</td>
<td>Window Area</td>
<td>20 m²</td>
<td>3.2 m²</td>
</tr>
<tr>
<td></td>
<td>Window-to-wall ratio</td>
<td>16%</td>
<td>8%</td>
</tr>
<tr>
<td>West</td>
<td>Window Area</td>
<td>36 m²</td>
<td>2.5 m²</td>
</tr>
<tr>
<td></td>
<td>Window-to-wall ratio</td>
<td>31%</td>
<td>6%</td>
</tr>
</tbody>
</table>

*There are no windows in the South façade of House B.*
Quantitative Data

Monitoring System

Sensors installed in different rooms
Data transmission bridge

Data:

- Ambient temperature
- Relative humidity
- Wall heat flow
- CO₂ concentration
- Luminance
- Energy consumption and production

- Data gathered every 15 minutes
- Available online for homeowners and researchers

- Measurement procedures according to ISO 7726 (1998)
- All sensors positioned away from windows to avoid direct sunlight
Quantitative Data

Ground Floor Plan

Upper Floor Plan

Position of sensors

1. Outside
2. Garage
3. Living Room
4. Laundry - Air Exhaust
5. Bedroom East - Air Supply
6. Guest Bedroom
7. Guest Bedroom
8. Bedroom West
9. Upstairs Bedroom
10. Upstairs Bathroom
Winter Peak Temperature

Temperature (°C)

- 1_Outside
- 2_Garage
- 3_LivingRoom
- 4_Laundry
- 5_Bedroom_East
- 8_Bedroom_West
- 9_Upstairs_Bedroom
- 10_Upstairs_Bathroom
Summer Peak Temperature

Graph showing temperature changes over time for various locations:
- 1_Outside
- 2_Garage
- 3_LivingRoom
- 4_Laundry
- 5_Bedroom_East
- 8_Bedroom_West
- 9_Upstairs_Bedroom
- 10_Upstairs_Bathroom
Winter Peak Temperature

![Graph showing temperature trends over time for different locations: 1_Outsidae, 2_Media, 3_UpperHallway, 4_Stairs, 5_MasterBedroom. The graph demonstrates fluctuations in temperature across various times and locations, with some areas maintaining a relatively steady temperature while others show more variability.](image-url)
Summer Peak Temperature
Humidity - full period
## Qualitative Assessment

### Interviews based on ISO 7730

Thermal sensation assessed retrospectively

### Thermal Comfort

<table>
<thead>
<tr>
<th></th>
<th>Occupant #1</th>
<th>Occupant #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How would you evaluate the overall environmental comfort experienced in the building?</strong></td>
<td>In a scale where -3 is cold, 0 is neutral/comfortable and +3 is hot, how would you rate the house overall?</td>
<td>In a scale where -3 is cold, 0 is neutral/comfortable and +3 is hot, how would you rate the house in winter?</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td><strong>How would you evaluate the indoor thermal comfort of the house in winter?</strong></td>
<td>In a scale where -3 is cold, 0 is neutral/comfortable and +3 is hot, how would you rate the house in winter?</td>
<td>What is the coldest part of the house in winter?</td>
</tr>
<tr>
<td>It’s comfortable, so I would say 0.</td>
<td></td>
<td>Between -1 and 0</td>
</tr>
<tr>
<td>Coldest parts of the house are the two southern bedrooms, just a fraction colder than the rest of the house</td>
<td></td>
<td>Coldest part is the back of the house— the two bedrooms facing South, they don’t get as much thermal gains, no direct sun</td>
</tr>
<tr>
<td><strong>How many layers of clothing do you usually have to wear at home in winter?</strong></td>
<td>One: just pants and T-shirts</td>
<td>Usually one</td>
</tr>
<tr>
<td><strong>How would you evaluate the indoor thermal comfort of the house in summer?</strong></td>
<td>In a scale where -3 is cold, 0 is neutral/comfortable and +3 is hot, how would you rate the house in summer?</td>
<td>What is the warmest part of the house in summer?</td>
</tr>
<tr>
<td>+1</td>
<td>The warmest room of the house used to be the TV room upstairs. But we had the windows tinted, which made a huge difference. So, now the warmest room is probably the master bedroom. The living room does not feel warmer than the rest of the house— it has a high ceiling, so the heat moves up.</td>
<td>From 0 to +1</td>
</tr>
<tr>
<td><strong>How would you describe moisture in the house — especially kitchen and bathroom areas?</strong></td>
<td>No at all. As indicated in the measurements</td>
<td>No issue with moisture, we don’t have any</td>
</tr>
</tbody>
</table>
Qualitative Assessment

Key findings:

- Occupants felt comfortable in all seasons
- Health benefits - especially for children
- Superior indoor environment compared to their workplaces, previous houses and other buildings
- Occupants would like to have additional shading in summer
Energy consumption and production

Annual Primary Energy Demand (total)

Annual Primary Energy Demand per square metre

Percentage of energy provided by solar panels

Passive House
Limit: 120kWh/m²a

[kwh] | [kwh/m²a] | [Percentage]
---|---|---
House A | House B | House A | House B

A | B
Comparison: Energy consumption

Housing stock energy consumption from HEEP (BRANZ): http://www.branz.co.nz/HEEP-energy-graphs/graphs.aspx
Comparison with New Zealand dwellings built after 1978

Daily Temperature Profile - Bedrooms - Winter

Comparison: Temperature A B

Housing stock temperatures from HEEP (BRANZ): http://www.branz.co.nz/HEEP-energy-graphs/graphs.aspx
Comparison with New Zealand code-compliant houses built after the year 2000

Time-weighted temperature ranges for living rooms: Comparison between 15 code-compliant houses (left) and two Passive Houses (right). Based on Rosemeier (2014): Healthy and affordable housing in New Zealand: the role of ventilation.
CONCLUSIONS

Real performance is very similar to simulation predictions;

**Design choices and occupants’ behaviour** have significant impact on performance;

Passive House performance is confirmed to be **highly superior in terms of energy and comfort when compared to housing stock**;

There is still scope for improving design and technical solutions;

Health benefits are evident;

**Sun shading** is key for achieving comfortable conditions indoors during summer;

Next challenges are no longer to confirm that Passive Houses work well, but to investigate how to increase the number of houses built this way.
FUTURE RESEARCH FOR PH IN NZ

- Group builders
- Prefabrication
- Retrofitting existing housing stock
- Affordability
- Multi unit Passive Houses
- Life cycle assessment
Thank You!

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