Integral Group

Large, Complex, & Non-Residential Buildings

ILFI: Net Positive Symposium

Stuart Hood – Managing Principal, PEng, CEng, CPHD, LEED AP
Scott Ghomeshi – Senior Mechanical Designer, PEng, CPHD, LEED AP BD+C
Andy Chong – Principal, PEng, LEED AP
I N T E G R A L
Revolutionary Engineering
imagine | perform | accelerate | sustain

TORONTO
VICTORIA
CALGARY
SAN JOSE
OAKLAND
LOS ANGELES
AUSTIN
ATLANTA
LONDON
OXFORD
WASHINGON DC
ALEXANDRIA
AUSTIN
WASHINGTON DC
ATLANTA
OXFORD
LONDON
SEATTLE
VANCOUVER
SYDNEY

15 OFFICES
30 STAFF TRAINED IN PH
15 CERTIFIED PASSIVE HOUSE DESIGNERS
Vancouver Passive House Projects

- Clayton Heights Community Hub – HCMA Architecture + Design
- Vancouver Fire Hall No.17 Redevelopment – HCMA Architecture + Design
- Vancouver Art Galley – Herzog & de Meuron + Perkins+Will
- 388 Skeena Ave – Cornerstone Architecture
Passive House for Your Climate

Criteria & algorithms for Certified Passive House Components: Transparent Building Components
Packard Foundation – Net Zero Office

David & Lucile Packard Foundation Headquarters – EHDD Architects, Los Altos, CA
Idea’s Net Zero Office - San Jose, California
Current Code vs. Passive House

Energy Step Code

- **Step 1**: Enhanced compliance
  - BC Building Code - minimum acceptable standard

- **Step 2**: Tools
  - Voluntary measures
  - Incentives
  - Requirements

- **Step 3**: Adopted in future BC Code

- **Step 4**: Adopted in future BC Code

2017 - 2032
# Current Code vs. Passive House

**BCBC Part 10**

## Table 10.2.3.3.A
Energy Performance Requirements for Residential Occupancies
Forming Part of Sentences 10.2.3.3.(1) and (2)

<table>
<thead>
<tr>
<th>Step</th>
<th>Equipment and Systems – Maximum Total Energy Use Intensity (kWh/m²·year)</th>
<th>Building Envelope – Maximum Thermal Energy Demand Intensity (kWh/m²·year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conform to Part 8 of the NECB</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

## GREEN BUILDINGS POLICY FOR REZONING - PROCESS AND REQUIREMENTS

**Table B.1.2a: Performance Limits - Buildings Not Connected to a City-Renowned Low Carbon Energy System**

<table>
<thead>
<tr>
<th>Building Type</th>
<th>TEUI (kWh/m²)</th>
<th>TEDI (kWh/m²)</th>
<th>GHGI (kgCO₂/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Low-Rise (&lt; 7 storeys)</td>
<td>100</td>
<td><strong>15</strong></td>
<td>5</td>
</tr>
<tr>
<td>Residential High-Rise (7+ storeys)</td>
<td>120</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>Office</td>
<td>100</td>
<td>27</td>
<td>3</td>
</tr>
<tr>
<td>Retail</td>
<td>170</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>Hotel</td>
<td>170</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>All Other Buildings</td>
<td>EUI 35% below 90.1-2010</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Passive House Case Study Projects

Charter Telecom – Waymark Architecture

Hornby Island Fire Hall – Simcic + Uhrich Architects

Clayton Heights Community Hub – HCMA Architecture + Design

Vancouver Fire Hall 17 – HCMA Architecture + Design
Case Study: Charter Telecom Headquarters

**Developer/Owner:** Charter Telecom
**Architect:** Waymark Architecture
**MEP Engineer:** Integral Group
**Status:** In Design

**Green Building Ratings:**
Targeting Passive House Classic

**Description:**
- 1 storey covered parking
- 2 stories offices & tech lab
- 1 storey amenity & private residence
- total area approx 15,000 sqft

**Unique Mechanical Features:**
- Variable Refrigerant Volume (VRV) Heat Recovery System for Heating & Cooling
- Variety of Plate-Type HRVs for Ventilation & Exhaust
- Domestic Water Heating (DHW) by Air-Source Heat Pump
Case Study: Charter Telecom Headquarters

Lessons from Charter:
1. Ventilation Design
2. Domestic Hot Water
3. Cooling and Overheating Risk

High Performance Office Buildings:
1. Innovative Ventilation Strategies
2. Radiant Heating and Cooling
3. Energy Modeling
High Performance Commercial Buildings (Vancouver Island)

1515 Douglas & 750 Pandora
Victoria, BC

Capital Park
Victoria, BC

Reliable Controls Headquarters
View Royal, BC

Charter Telecom Headquarters
Langford, BC

Passive House Institute
High Performance Commercial Buildings (Vancouver Island)

- In Construction
  TEUI ~ 100 kWh/m²-yr (energy model)

- Completed Fall 2012
  TEUI = 56 kWh/m²-yr (actual figures 2016)

- In Design
  TEUI < 60 kWh/m²-yr
  TEDI < 15 kWh/m²-yr (TBC in PHPP)

- Phase 1 Completed
  Fall 2017
  TEUI est. 110 kWh/m²-yr (energy model underway)
Common Requirements

• “Speculative” Development – uncertain tenant requirements and tenant churn. Requires flexibility, assumptions, future capacity
• Commonly Owner/Operator Build & Hold
• Potential for Mixed Use – Coffee, Retail
• Relatively High Ventilation Requirements
• Relatively Low DHW Demands
• Relatively High Internal Gains
  – Cooling Dominant by Installed Capacity
  – Heating Dominant by Annual Energy
Recommended Design Considerations

• Control & Reduce Internal Gains – for sake of cooling and TEUI
• Control & Reduce Solar Gains
• Apply Heat Recovery to Remaining Heating/Cooling Load
• Careful Planning of Ventilation Strategy
• Energy Modeling as a Design Tool (not just compliance)
• Work Closely with Developer to Anticipate Future Tenant Requirements
Ventilation for Commercial Office Buildings

Basic Ventilation Requirements

- Mandatory BC Building Code Requirements for Ventilation Supply
- Passive House Criteria for Ventilation Rates
- Other Green Building Frameworks e.g. LEED?
- Owner Specific Requirements, Leasing Flexibility?

- Common Washroom Exhaust
- Parkade Ventilation
Ventilation for Commercial Office Buildings

Other Considerations...

- Janitor Areas & Chemical Storage
- M&E Service Rooms
- Lunchroom/Lounge Exhaust
- Commercial Kitchens

- Smoke Control Requirements
- Stairwell Pressurization
- Vestibule Pressurization
- Elevator Cooling & Hoistway Ventilation
Ventilation for Commercial Office Buildings

- Balance of Codes and Standards

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Standard</th>
<th>Resulting Design Ventilation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC Building Code 2012 for Part 3 Buildings</td>
<td>ASHRAE 62.1-2001</td>
<td>0.14 – 0.31 CFM/sqft</td>
</tr>
<tr>
<td>LEED IEQp1 Minimum Ventilation</td>
<td>ASHRAE 62.1-2007</td>
<td>0.11 – 0.125 CFM/sqft</td>
</tr>
<tr>
<td>LEED IEQc2 Increased Ventilation</td>
<td>ASHRAE 62.1-2007 + 30%</td>
<td>0.1625 CFM/sqft</td>
</tr>
<tr>
<td>Passive House Certification</td>
<td>PH Criteria 1: 30 m³/h pp PH Criteria 2: match exhaust PH Criteria 3: 0.3 ACH</td>
<td>0.23 CFM/sqft -- 0.045 CFM/sqft</td>
</tr>
<tr>
<td>Leasing Requirements/Future Flexibility</td>
<td>ASHRAE with flexibility for tenant design??</td>
<td>typically 0.3 CFM/sqft</td>
</tr>
<tr>
<td>BCBC Smoke Exhaust for High Buildings</td>
<td>Sentence 3.2.6.6. = 6 ACH</td>
<td>approx 0.9 CFM/sqft</td>
</tr>
</tbody>
</table>
## Ventilation for Commercial Office Buildings

- **Typical 5,000 sqft Office Floor**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Standard</th>
<th>Resulting Design Ventilation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEED IEQp1 Minimum Ventilation</td>
<td>ASHRAE 62.1-2007</td>
<td>625 CFM</td>
</tr>
<tr>
<td>LEED IEQc2 Increased Ventilation</td>
<td>ASHRAE 62.1-2007 + 30%</td>
<td>813 CFM</td>
</tr>
<tr>
<td>Passive House Certification</td>
<td>PH Criteria 1: 30 m³/h pp</td>
<td>1150 CFM</td>
</tr>
<tr>
<td></td>
<td>PH Criteria 2: match exhaust</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PH Criteria 3: 0.3 ACH</td>
<td></td>
</tr>
<tr>
<td>Leasing Requirements/Future Flexibility</td>
<td>ASHRAE with flexibility for tenant design???</td>
<td>1500 CFM</td>
</tr>
<tr>
<td>BCBC Smoke Exhaust for High Buildings</td>
<td>Sentence 3.2.6.6. = 6 ACH</td>
<td>4500 CFM</td>
</tr>
</tbody>
</table>
Ventilation for Commercial Office Buildings

Challenge 1: Product Availability
Common Design Themes – High Capacity HRV Systems
Common Design Themes – High Capacity HRV Systems

- 2 units x 15,000 CFM each
- Changeover type damper with dual cores
Ventilation for Commercial Office Buildings

Challenge 1: Product Availability

• Passive House Certified or 12% Penalty!
• Largest Units available... 9000 m³/hr = 5300 CFM, not bad?
• At ASHRAE 62.1-2001 rates, this serves 17,000 sqft +/-
• What about larger buildings?
Ventilation for Commercial Office Buildings

Challenge 2: How to reconcile higher ventilation rates with maximum energy thresholds?
• Natural or Mixed-Mode Ventilation
Ventilation for Commercial Office Buildings

Challenge 2: How to reconcile higher ventilation rates with maximum energy thresholds?

- DOAS and CO2 Demand Control
Ventilation for Commercial Office Buildings

Challenge 2: How to reconcile higher ventilation rates with maximum energy thresholds?

• Increased Ventilation Effectiveness
Case Study: Charter Telecom Headquarters

Ventilation Design Approach

1. **Open Parkade – No Fans!**
2. **Mid-Capacity Ventacity HRVs**
   - 2000 CFM Office Level 2
   - 2000 CFM Office Level 3
3. **Small-Capacity Zehnder HRVs**
   - 650 CFM Amenity Level 4
   - 200 CFM Residence/Hospitality Level 4

**Equipment Budget = $80,000 +/- Supply Only**
Domestic Hot Water for Commercial Office

General Characteristics and Design Criteria:

- BC Building Code – “in accordance with good engineering practice, such as that described in the ASHRAE Handbooks and ASPE Data Books.”
- Generally low demands and intermittent use – kitchenettes, coffee stations, and washroom lavatories
- Low storage, low recovery requirements
- BCBC Part 10 Water Efficiency
  - Max 2.2 GPM for lavatories
- LEED WEp1 & WEc3
  - Typically 0.5 GPM for lavatories
## Domestic Hot Water for Commercial Office

### System Options - Electric

<table>
<thead>
<tr>
<th>Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| Electric Tank   | • Conventional approach  
                  • Wide variety of capacities  
                  • Silent                      | • COP ~ 1  
                  • Space requirement  
                  • Requires drain  
                  • Standby losses |
| Electric Demand | • Small form factor  
                  • No drain  
                  • No standby losses | • COP ~ 1  
                  • Huge electrical service  
                                (2.2 GPM → 32 kW!) |
## Domestic Hot Water for Commercial Office

### System Options - Gas

<table>
<thead>
<tr>
<th>Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| **Gas Tank**  | • Conventional approach  
                 • Wide variety of capacities  
                 • Balance of Storage vs. Recovery | • COP < 1  
                 • Requires space, drain  
                 • Standby losses  
                 • Venting to outdoors  
                 • Fossil fuel dependency |
| **Gas Demand**| • Small form factor  
                • Lower standby losses                                                  | • COP < 1  
                • Not ideal for fixtures located far away  
                • Venting, fossil fuels  |
# Domestic Hot Water for Commercial Office

## System Options - Other

<table>
<thead>
<tr>
<th>Type</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Thermal</td>
<td>• Low utility consumption</td>
<td>• Weather dependent</td>
</tr>
<tr>
<td></td>
<td>• Great optics!</td>
<td>• Must manage freezing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cost and complexity not ideal for office application with low loads</td>
</tr>
<tr>
<td>Indirect Hot Water</td>
<td>• Can couple with an efficient source of heating if available e.g. central boiler or heat pump system; COP &gt;&gt; 1</td>
<td>• Double-wall HX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cost and complexity not ideal for office application with low loads</td>
</tr>
<tr>
<td>Heat Pump and Hybrid</td>
<td>• COP &gt;&gt; 1</td>
<td>• Heat pump compressor noise</td>
</tr>
<tr>
<td></td>
<td>• Similar to conventional electric/gas tank approach</td>
<td>• Piped water to outdoor unit – penetrations, waterproofing, thermal bridge</td>
</tr>
<tr>
<td></td>
<td>• Some range in capacity options</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reasonable install cost</td>
<td></td>
</tr>
</tbody>
</table>
Domestic Hot Water for Commercial Office
Domestic Hot Water for Commercial Office

CO2 Air Source Heat Pump Water Heater

- **Benefits:**
  - Capacity is well matched to building size and application
  - Small form factor, works with recirculation system
  - Much lower electrical load than conventional elec resistance
  - No gas, no venting = reduced penetrations and shafts

- **Cautions:**
  - Water piped to outdoor unit requires freeze protection
  - No electric backup – consider auto drain valve to protect from power failure
  - Same cautions as with any heat pump system... defrost, compressor noise, snow protection
Cooling and Overheating Risk

Key Difference in Commercial Buildings vs. Smaller/Residential Passive House...
Internal Gains!
Cooling and Overheating Risk

Passive House Certification Criteria:
- Cooling + Dehumidification Demand < 15 kWh/m²-yr + dehumidification contribution
- Cooling Load < 10 W/m²

**10 W/m² criteria barely covers office lighting → unrealistic to this criteria for commercial buildings**

Typical Office Cooling Loads...
- Sedentary Office Occupant...
  - 245 BTU/h (71 W) per person
- Typical Lighting...
  - 0.7 to 1.1 W/sqft
- Typical Computers “Medium Density”...
  - 1.0 W/sqft
- Typical Photocopier...
  - 550 W
- Typical Coffee Machine...
  - 1200 BTU/h (350 W)
## Cooling and Overheating Risk

### Comparison of Cooling Figures...

<table>
<thead>
<tr>
<th></th>
<th>W/m²</th>
<th>W/sqft</th>
<th>sqft/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive House Criteria</td>
<td>10</td>
<td>0.93</td>
<td>3778</td>
</tr>
<tr>
<td>ASHRAE Internal Gains at:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 1.0 W/sqft lighting</td>
<td>25.4</td>
<td>2.36</td>
<td>1489</td>
</tr>
<tr>
<td>• 1.0 W/sqft equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 5 people/1000sqft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical Commercial Office Rule of Thumb</td>
<td>63</td>
<td>5.85</td>
<td>600</td>
</tr>
</tbody>
</table>
Cooling and Overheating Risk

Strategies used at Charter:

• Reduce solar heat gains through form factor and positioning of glazing
• Utilize LED lighting and occupancy sensor controls throughout
• HRV economizer bypass – don’t recover heat from office when it’s not needed

• For the cooling load that remains, use high-efficiency heat pump technology: Variable Refrigerant Volume (VRV aka VRF)
Cooling and Overheating Risk
VRV – How It Works
VRV – Cooling

ELECTRICAL COMPRESSOR WORK

imagine | perform | accelerate | sustain

INTEGRAL
Revolutionary Engineering
VRV – Heat Recovery
Common Design Themes – Radiant Heat Transfer
Common Design Themes – Energy Modeling
Common Design Themes – Heat Pumps & Heat Recovery
Common Design Themes – Building Automation
High Performance requires Methodical, Thoughtful Design!

• Anticipate Tenant Requirements and Future Flexibility
• Carefully Manage Internal Gains and Cooling Requirements
• Carefully Consider Innovative Ventilation Design
• HRV for Ventilation Heat Recovery
• Hydronic or Refrigerant Systems for Heating/Cooling Heat Recovery
• Radiant Heat Transfer
• Building Automation
• PLAN, PLAN, PLAN!
Hornby Island Fire Hall
The Trip To Hornby
Mechanical System Rooted in Resilience

• Keeping it Simple
• Low Cost
• Low Maintenance
• Limited Utilities
• Post Disaster

Hornby Island Fire Hall – Completed September 2017
Heating + Cooling

HIFH Lower Floor Plan
Heating + Cooling

HIFH Upper Floor Plan
Ventilation

Ground Floorplan

Second Floorplan

3 @ Zehnder Comfoair 550
Domestic Hot Water

Initial Domestic Hot Water Strategy

Final Domestic Hot Water Strategy
Airtightness

Final Test: **1.6 ACH**
Insulation
Apparatus Bays

- Passive House for Apparatus Bay?
- Standard Construction Heated to 10°C (50°F).
- Winter Design Temperature -6°C (21°F).
- Annual Heating Cost = $210

### Specific building characteristics with reference to the treated floor area

<table>
<thead>
<tr>
<th>Treated floor area m²</th>
<th>293.7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Space heating</strong></td>
<td></td>
</tr>
<tr>
<td>Heating demand kWh/(m²a)</td>
<td>6.1</td>
</tr>
<tr>
<td>Heating load W/m²</td>
<td>15.4</td>
</tr>
<tr>
<td><strong>Space cooling</strong></td>
<td></td>
</tr>
<tr>
<td>Cooling &amp; dehum. demand kWh/(m²a)</td>
<td>≤</td>
</tr>
<tr>
<td>Cooling load W/m²</td>
<td>≤</td>
</tr>
<tr>
<td>Frequency of overheating (&gt; 25 °C) %</td>
<td>0</td>
</tr>
<tr>
<td>Frequency excessively high humidity (&gt; 12 g/kg) %</td>
<td>0</td>
</tr>
<tr>
<td><strong>Airtightness</strong></td>
<td></td>
</tr>
<tr>
<td>Pressurization test result n₅₀ 1/h</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>Non-renewable Primary Energy (PE)</strong></td>
<td></td>
</tr>
<tr>
<td>PE demand kWh/(m²a)</td>
<td>140</td>
</tr>
<tr>
<td><strong>Primary Energy Renewable (PER)</strong></td>
<td></td>
</tr>
<tr>
<td>Generation of renewable energy kWh/(m²a)</td>
<td>64</td>
</tr>
</tbody>
</table>

2 Empty field: Data missing; '-' No requirement
In Our Own Backward - Fire Hall No.17
A Different Kind of Resilience

- Emphasis on Low Carbon Solutions
- Programming Requirements
- Client Requirements
- Post Disaster

Vancouver Fire Hall No.17 Redevelopment – HCMA Architecture + Design
Existing Fire Hall Energy Consumption

Existing FH 17

Goal
### Three Options to Consider

<table>
<thead>
<tr>
<th>SYSTEM TYPE</th>
<th>BENEFITS</th>
<th>CHALLENGES</th>
</tr>
</thead>
</table>
| GeoExchange (Water to Water) | • Superior Energy Savings  
• Flexibility  
• Equipment Availability  
• Defrost Cycle Mitigated  
• Isolated Refrigerant Gas  
• Equipment Indoors | • Cost  
• Site Limitations  
• Careful Design Considerations  
• Increased Maintenance |
| Air Source Heat Pump (Air to Water) | • Ability to Pre-Heat DHW  
• Flexibility  
• Isolated Refrigerant Gas | • Equipment Oudoors  
• Cost: Geo > ASHP > VRF  
• Careful Design Considerations  
• Increased Maintenance  
• Viable/reliable Equipment  
• Defrost Cycle |
| Variable Refrigerant Flow (Air to Refrigerant) | • Simple  
• Cost Effective Cooling  
• Minimal Maintenance | • Equipment Oudoors  
• Limited Controllability  
• Lack of Detailed Info  
• Large Amount of Refrigerant  
• Constrained to 1 vendor  
• Programming Requirements |
Heating + Cooling - GeoExchange

TEMPORARY FACILITIES
Ventilation

5 @ Swegon Gold RX
Ventilation
Kitchen Exhaust

- 10 Fire Fighters x 2 Shifts x 3 Meals
- Training Days
- What about the Thermal Bridge

<table>
<thead>
<tr>
<th></th>
<th>Baseline Design (Recirculating Extract)</th>
<th>Direct Kitchen Exhaust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Heating Demand</td>
<td>7.6</td>
<td>8.7 (+1.1)</td>
</tr>
<tr>
<td>(kWh/m²/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Cooling Demand</td>
<td>5</td>
<td>4.9 (-0.1)</td>
</tr>
<tr>
<td>(kWh/m²/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Energy Demand</td>
<td>99</td>
<td>100 (+1)</td>
</tr>
<tr>
<td>(kWh/m²/yr)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Domestic Hot Water

- Drain Heat Recovery via Power Pipe
- ASHP - Dual Benefit
- Direct Electric
Radcliffe Residence

Radcliffe Residence – Battersby Howat Architects
Radcliffe Residence

<table>
<thead>
<tr>
<th>Glazing Solar Heat Gain</th>
<th>Passes TM52 Vancouver</th>
<th>Passes TM52 Abbotsford</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master Bedroom</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Kid Bed 1</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Kid Bed 2</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Living/Dining</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Games/Media</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Clayton Heights - Community Hub
Dynamic Natural Modelling
# Dynamic Natural Ventilation Modelling

<table>
<thead>
<tr>
<th>WINDOW PROVISION</th>
<th>Passes TMS2 (no mech vent or cooling)</th>
<th>TMS2 Peak Temp (°C)</th>
<th>TMS2 Hrs &gt; 25°C</th>
<th>Peak Cooling Load* (kW) (thermostat &lt; 25°C)</th>
<th>Annual Cooling* (kWh/yr) (thermostat &lt; 25°C)</th>
<th>Annual Cooling with No Nat Vent** (kWh/yr) (thermostat &lt; 25°C)</th>
<th>Peak Cooling Load* (kW) (thermostat &lt; 22°C)</th>
<th>Annual Cooling* (kWh/yr) (thermostat &lt; 22°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular openings [24-7] - 16.0m² Pop-up Windows - 16.0m²</td>
<td>X</td>
<td>33.5</td>
<td>480</td>
<td>44.8</td>
<td>5900 (7.4 kWh/m².yr)</td>
<td>17100 (21.5 kWh/m².yr) + fan energy</td>
<td>56.9</td>
<td>18300 (23.8 kWh/m².yr)</td>
</tr>
<tr>
<td>Regular openings [24-7] - 24.0m² Pop-up Windows - 24.0m²</td>
<td>X</td>
<td>33.4</td>
<td>450</td>
<td>42.6</td>
<td>5400 (6.8 kWh/m².yr)</td>
<td>17000 (22.3 kWh/m².yr)</td>
<td>56.6</td>
<td>17000 (22.3 kWh/m².yr)</td>
</tr>
<tr>
<td>Regular openings [24-7] - 24.0m² Pop-up Windows - 24.0m² Lower openings (boost) - 12.0m²</td>
<td>X</td>
<td>33.0</td>
<td>420</td>
<td>43.2</td>
<td>5000 (6.3 kWh/m².yr)</td>
<td>16500 (20.8 kWh/m².yr)</td>
<td>56.4</td>
<td>16500 (20.8 kWh/m².yr)</td>
</tr>
<tr>
<td>Regular openings [24-7] - 16.0m² Pop-up Windows - 16.0m² 1.0m Tapering Shading on all Windows</td>
<td>X</td>
<td>33.3</td>
<td>460</td>
<td>43.0</td>
<td>5750 (7.2 kWh/m².yr)</td>
<td>16500 (20.8 kWh/m².yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular openings [24-7] - 16.0m² Pop-up Windows - 16.0m² 1.5m Tapering Shading on all Windows</td>
<td>X</td>
<td>32.8</td>
<td>430</td>
<td>41.1</td>
<td>5400 (6.8 kWh/m².yr)</td>
<td>16000 (20.1 kWh/m².yr)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Solar heat gain coefficient = 0.29, No Shading | | | | | | | | |

<table>
<thead>
<tr>
<th>WINDOW PROVISION</th>
<th>Passes TMS2 (no mech vent or cooling)</th>
<th>TMS2 Peak Temp (°C)</th>
<th>TMS2 Hrs &gt; 25°C</th>
<th>Peak Cooling Load* (kW) (thermostat &lt; 25°C)</th>
<th>Annual Cooling* (kWh/yr) (thermostat &lt; 25°C)</th>
<th>Annual Cooling with No Nat Vent** (kWh/yr) (thermostat &lt; 25°C)</th>
<th>Peak Cooling Load* (kW) (thermostat &lt; 22°C)</th>
<th>Annual Cooling* (kWh/yr) (thermostat &lt; 22°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular openings [24-7] - 16.0m² Pop-up Windows - 16.0m²</td>
<td>X</td>
<td>32.9</td>
<td>310</td>
<td>38.8</td>
<td>4950 (6.3 kWh/m².yr)</td>
<td>15400 (19.4 kWh/m².yr) + fan energy</td>
<td>15400 (19.4 kWh/m².yr) + fan energy</td>
<td>15400 (19.4 kWh/m².yr) + fan energy</td>
</tr>
</tbody>
</table>
Window Actuators
Window Actuators
Radiant Ceiling Heating and Cooling
Thank You!