Energy Efficiency Tune-Ups for Mid- to High-Rise Residential Buildings

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BCBEC Conference and AGM - September 21, 2011

Overview

→ Summary of a mid- to high-rise Multi-Unit Residential Building (MURB) energy study
→ Measured energy savings from full building enclosure rehabilitations
→ Strategies to retrofit and improve the energy efficiency of existing MURBs
Multi-Unit High-Rise Residential Building Energy Study

→ Energy consumption of over 60 mid- to high-rise Multi-Unit Residential Buildings (MURBs)  
  ↔ Constructed between 1974 and 2002
→ Half of study buildings underwent a full-scale building enclosure rehabilitation  
  ↔ Allows for the assessment of actual energy savings from enclosure performance
→ Pre- and post-rehabilitation R-values, air-tightness characteristics analyzed with a decade of daily/month gas & electricity data.
→ Other building performance characteristics as the result of the enclosure improvements and other HVAC changes were also assessed.

Summary: MURB Energy Consumption Intensity

Average 39 Buildings = 213 kWh/m²/yr
Total Energy Consumption vs Year of Construction

![Graph showing energy consumption vs year of construction.]

Typical Energy Consumption: 1980s-1990s MURB

Average of 11 typical study buildings - Total 206 kWh/m²/yr

- Total Energy
- Space Heat

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment and Amenity (Common)</td>
<td>14%</td>
<td>kWh/m²/yr</td>
</tr>
<tr>
<td>Elevators</td>
<td>2%</td>
<td>kWh/m²/yr</td>
</tr>
<tr>
<td>Electric Baseboard Heating</td>
<td>12%</td>
<td>kWh/m²/yr</td>
</tr>
<tr>
<td>Fireplaces</td>
<td>18%</td>
<td>kWh/m²/yr</td>
</tr>
<tr>
<td>Plug and Appliances (Suites)</td>
<td>9%</td>
<td>kWh/m²/yr</td>
</tr>
<tr>
<td>Lights - Suite</td>
<td>16%</td>
<td>kWh/m²/yr</td>
</tr>
<tr>
<td>Lights - Common</td>
<td>2%</td>
<td>kWh/m²/yr</td>
</tr>
<tr>
<td>Hot Water</td>
<td>16%</td>
<td>kWh/m²/yr</td>
</tr>
<tr>
<td>Ventilation Heating</td>
<td>15%</td>
<td>kWh/m²/yr</td>
</tr>
</tbody>
</table>

Units of kWh/m²/yr, % total
Typical Energy Consumption: Post 2000/Modern MURB

Average of several typical modern MURBs – Total >222 kWh/m²/yr

- Equipment and Amenity (Common), 20, 9%
- Elevators, 3, 1%
- Electric Baseboard Heating, 18, 8%
- Fireplaces, 34, 16%
- Plug and Appliances (Suites), 19, 9%
- Lights - Suite, 16, 7%
- Lights - Common, 4, 2%
- DHW, 21, 9%
- Ventilation Heating, 87, 39%

Units of kWh/m²/yr, % total

Greenhouse Gas Emissions: Average of Study MURBs

- Equipment and Amenity (Common) 6%
- Elevators 1%
- Electric Baseboard Heating 6%
- Fireplaces 24%
- Plug and Appliances (Suites) 4%
- Lights - Suite 3%
- Lights - Common 1%
- DHW 24%
- Ventilation Heating 28%

% Total GHG Emissions – BC GHG Factors
Addressing Energy Efficiency in MURBs

MURB energy consumption is predominantly influenced by space-heating

- Building enclosure thermal performance is typically poor (<R-3)
  - Walls have low effective R-values due to thermal bridging, steel framing, exposed concrete slabs etc.
  - Window R-values are very low, and are the largest source of heat loss
  - Air-Leakage through enclosure, and through operable windows is high
- Make-up air unit gas consumption is high due to pressurized corridor ventilation flow rate and high set-point temperatures – yet very little of this air makes it into the suites
- Fireplace gas consumption is high as heating efficiency is poor and little incentive to conserve as usage appears “free”

MURB Energy Simulations: The Potential

Energy Model Calibrated with Billing Data and Building Enclosure and HVAC Characteristics

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Simulation Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline:</td>
<td>Walls effective R-3.6</td>
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<tr>
<td>Pre-Rehab</td>
<td>Windows single glazed: U = 0.7, SC = 0.67</td>
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<tr>
<td></td>
<td>Air tightness “Tight – High Average”: 0.05 cfm/ft</td>
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<td></td>
<td>Make-up air temperature set-point: 68°F</td>
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<tr>
<td></td>
<td>No heat recovery</td>
</tr>
<tr>
<td>Good:</td>
<td>Walls effective R-10</td>
</tr>
<tr>
<td>Target Performance</td>
<td>Windows double glazed, argon fill, low-e, low conductive frame; U = 0.27, SC = 0.34</td>
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<tr>
<td></td>
<td>Air tightness “Tight – Low Average”: 0.05 cfm/ft</td>
</tr>
<tr>
<td></td>
<td>Make-up air temperature set-point: 64°F</td>
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<tr>
<td></td>
<td>No heat recovery</td>
</tr>
<tr>
<td></td>
<td>No Fireplaces</td>
</tr>
<tr>
<td>Best:</td>
<td>Walls effective R-18.2</td>
</tr>
<tr>
<td>Green Design</td>
<td>Windows triple glazed, argon fill, low-e, low conductive frame; U = 0.17, SC = 0.23</td>
</tr>
<tr>
<td>Performance</td>
<td>Air tightness “Very Tight”: 0.02 cfm/ft</td>
</tr>
<tr>
<td></td>
<td>Make-up air temperature set-point: 60°F</td>
</tr>
<tr>
<td></td>
<td>80% Heat Recovery</td>
</tr>
<tr>
<td></td>
<td>No Fireplaces</td>
</tr>
</tbody>
</table>
Potential for MURB Space Heat Consumption in Vancouver

![Bar chart showing space heat consumption savings]

- 63% Space Heat Savings
- 91% Space Heat Savings

Impact of Space Heat Energy on Total Energy Consumption

- Can reduce energy by almost half with ventilation and enclosure upgrades only
- Further improvements from DHW, Lighting, Appliances, Controls etc.

![Bar chart showing energy consumption savings]

Current Levels ~ 200 kWh/m²/yr
We can get to ~100 kWh/m²/yr
Energy Savings from Building Enclosure Rehabilitations

- Enclosure rehabilitations performed at study MURBs primarily to address moisture ingress damage
- Little incentive for owners to perform energy upgrades due to increased cost – a huge missed opportunity
- Full 100% re-cladding, insulating and new windows at all study MURBs
- Thermal improvements from: exterior insulation assemblies, improved detailing (i.e. cladding attachments), better windows (thermally broken, low-e etc.)
- Improved air-tightness characteristics during rehabilitation

Typical Rehabilitation Thermal Detailing

Pre-Rehabilitation

Post-Rehabilitation
Improvement in Overall Thermal Performance: R-value

Overall Effective R-value by Year of Construction
Energy Savings from Enclosure Rehabilitations

Average 14% Space-Heat Energy Savings & 8% Total Building Energy Savings

Calibrated Energy Model Predictions vs Actual Savings

Average Metered (Actual Savings) = 8% (-11% up to 19%)
Average Modeled Savings = 3% (0% to 7%)
In all cases* actual savings exceeded modeled
Findings from study identified several key components of MURBs which can be improved during enclosure rehabilitation work or as part of specific energy retrofits:

- Building enclosure upgrades
- Mechanical ventilation system upgrades and tune-ups
- Installation of better space-heating controls
- Elevator & mechanical system retro-commissioning and upgrades
- Lighting upgrades
Impact of Wall and Window R-values

Impact of Air-Leakage

In-Service Air Leakage Rate, cfm/ft²

Annual Space Heating Consumption, kWh/m²/yr

Window U-value (R-value) - IP Units

- U-0.45 (R-2.2)
- U-0.27 (R-3.7)
- U-0.17 (R-5.9)

40% Window to Wall Area

Baseline: R-2.2 Windows, 40% WWR, R-16 Walls

High Performance: R-6 Windows, 20% WWR, R-18 Walls
Incremental Cost of Rehabilitation Energy Upgrades

→ Energy savings from full enclosure rehabilitations will not pay for the rehab anytime soon, however...
→ Incremental cost and energy savings analysis of the several retrofit measures was performed
  → In most buildings the incremental cost in reducing thermal bridging (i.e. more effective use of provided insulation) or adding extra insulation (i.e. 1-2") to the walls would have paid back over the life of the upgrade in energy savings
  → In most buildings the incremental cost for some higher performing window components (frames, IGUs) would have paid back over the life of the windows in energy savings
→ Beneficial to model the potential for incremental energy efficiency improvements while performing building enclosure rehabilitation work

HVAC and Mechanical System Improvements

- Domestic Hot Water
- Ventilation Make-up Air
- Elevators
Ventilation Distribution and Air Flow within MURBs

Pressurized Corridor:
Design flow rate varies <30 cfm/suite in older buildings up to >130 cfm/suite post 2000s.
Actual flow rate making it into the suites less, often as low as 1/3 of supply.
Ventilation/IAQ problems were common in most study MURBs.

Ventilation Make-up Air

Gas used to temper ventilation by make-up air is single largest component of energy use in most MURBs
- Regular service of make-up air units, burners, controls, filters etc. necessary for optimal energy performance
- Dirty MAU filters found to reduce flow rate significantly affecting both energy consumption and IAQ
- Ventilation is for occupant health
  - Flow-rate should never be turned down, off, setback, or on a timer unless sufficient ventilation is actually being delivered to occupants within the suites (not corridors)
- Consider set-back of temperature & controls to do so
  - Typically temperature of 21C or higher set by strata or by maintenance contractors – large savings from lowering this.
Impact of Make-up Air Set point Temperature

Total Space Heat Energy Consumption (Gas & Suite Electric) - Vancouver

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Gas</th>
<th>Electricity</th>
<th>Net Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>74°F (23°C)</td>
<td>117</td>
<td>24</td>
<td>93</td>
</tr>
<tr>
<td>70°F (21°C)</td>
<td>97</td>
<td>27</td>
<td>70</td>
</tr>
<tr>
<td>66°F (19°C)</td>
<td>78</td>
<td>29</td>
<td>49</td>
</tr>
<tr>
<td>62°F (17°C)</td>
<td>60</td>
<td>31</td>
<td>29</td>
</tr>
<tr>
<td>55°F (13°C)</td>
<td>37</td>
<td>36</td>
<td>0</td>
</tr>
</tbody>
</table>

Modern MURB - $27,000 net savings

Domestic Hot Water Systems

- Average DHW Load in typical MURB, 12 GJ/suite/yr (~$140/suite)
- Significant energy savings in MURBs where DHW system upgrades were performed during study period
- Mid-1980s continuous re-circulating DHW systems replaced with on-demand w/electric heat tracing in 2 study MURBs
  - Building 32 (135 suites), 50% reduction in DHW gas, savings of 1,285 GJ/yr ($14,000/yr, $104/suite)
  - Building 33 (165 suites), 64% reduction in DHW gas, savings of 2,200 GJ/yr ($26,000/yr, $160/suite)
Elevators and Controls

- Elevators rely on controls to be energy efficient
- Several of the 1980s-1990s MURBs within the study had AC-DC convertors running continuously (timers were broken for several years, or not installed), resulting in significant energy waste
- Building 33 Elevator (2 cabs, mid-80s controls)
  - w/ Faulty Timer (122,000 kWh/yr, ~$8,500/yr)
  - w/ Fixed Timer (46,000 kWh/yr, ~$3,200/yr)
  - w/ new VVVF system (21,000 kWh/yr, ~$1,500/yr)

In-Suite Space Heating and Ventilation

- Individual Fireplace Metering
- Supply and exhaust of ventilation air
- Electronic programmable thermostats
Fireplace use simulated in model and calibrated with data from buildings with only gas fireplaces on meter.

Average 17.6 GJ/year/suite average fireplace use (13.3 to 24.1 GJ depending on manual pilot light shut-offs).

Impact of Fireplace Energy Consumption: Typical MURB

<table>
<thead>
<tr>
<th>Month</th>
<th>Natural Gas, GJ/suite</th>
<th>Billed</th>
<th>Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0.0</td>
<td>-37.5</td>
<td>+4</td>
</tr>
<tr>
<td>Feb</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep</td>
<td>2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>0.1</td>
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</table>

Gas for fireplaces on single utility meter paid for by strata as part of maintenance fees – not directly by users.

Sub-metering is recommended to encourage conservation:
- Thermal meters are available to monitor time of use
- Pilot project within a study MURB estimated that after first year of sub-metering and shutting off pilot lights during summer – fireplace gas consumption was reduced by approximately half.
  - Cost of meter installation will be paid for by savings in few years
  - Sub-metering also found that 60% of the 138 occupants in same MURB leave pilot lights on year round, and 12 occupants use their fireplace regularly (i.e. to heat) over the summer.

Building wide pilot-light shutdown/lighting programs suggested

Alternately replace on-off switches with thermostat and/or timer controls.
Common Areas and Amenity Spaces

Pool/Jacuzzi gas at one study MURB – 2,500 GJ/yr.
Total gas for all hot water/ventilation air for same MURB– 5,000 GJ/yr

Parking Garages

CO2 controlled ventilation

Lighting
Questions

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