Energy Consumption of Low-Rise Wood-Frame Multi-Unit Residential Buildings

CCBST CONFERENCE, VANCOUVER BC

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Agenda

- → Introduction
- → Part 1
  - → Energy consumption trends
  - → Low-Rise vs High-Rise MURBs
- → Part 2
  - → Energy modelling
  - → Opportunities for savings
- → Conclusion

Project Objectives

→ Benchmark and characterize energy consumption of low-rise wood-frame MURBs in southwest BC

→ Compare low-rise wood-frame MURBs to mid- to high-rise non-combustible MURBs (from previous RDH study)

→ Identify opportunities for energy efficiency improvements

Project Methodology

→ Literature review

→ Building selection and data collection

→ Analysis of building data (23 low-rise buildings)

  → Energy consumption data and trends

  → Compare to mid- and high-rise MURBs

Part 1

→ Opportunities for energy conservation

  → Develop and calibrate 2 whole-building energy models

  → Analysis of Energy Conservation Measures (ECMs)

Part 2

→ Summarize complete results in full report

Part 1 – Analysis of Building Data

- → Analysis of low-rise energy consumption
  - → End use breakdown and trends
- → Compare low-rise to mid- and high-rise MURBs
  - → Similarities and differences

Buildings in Study

→ 23 Buildings

- → 20 Low-rise (3-4 storeys)
- → 3 Townhouse
- → 5 Low-rise market rental buildings

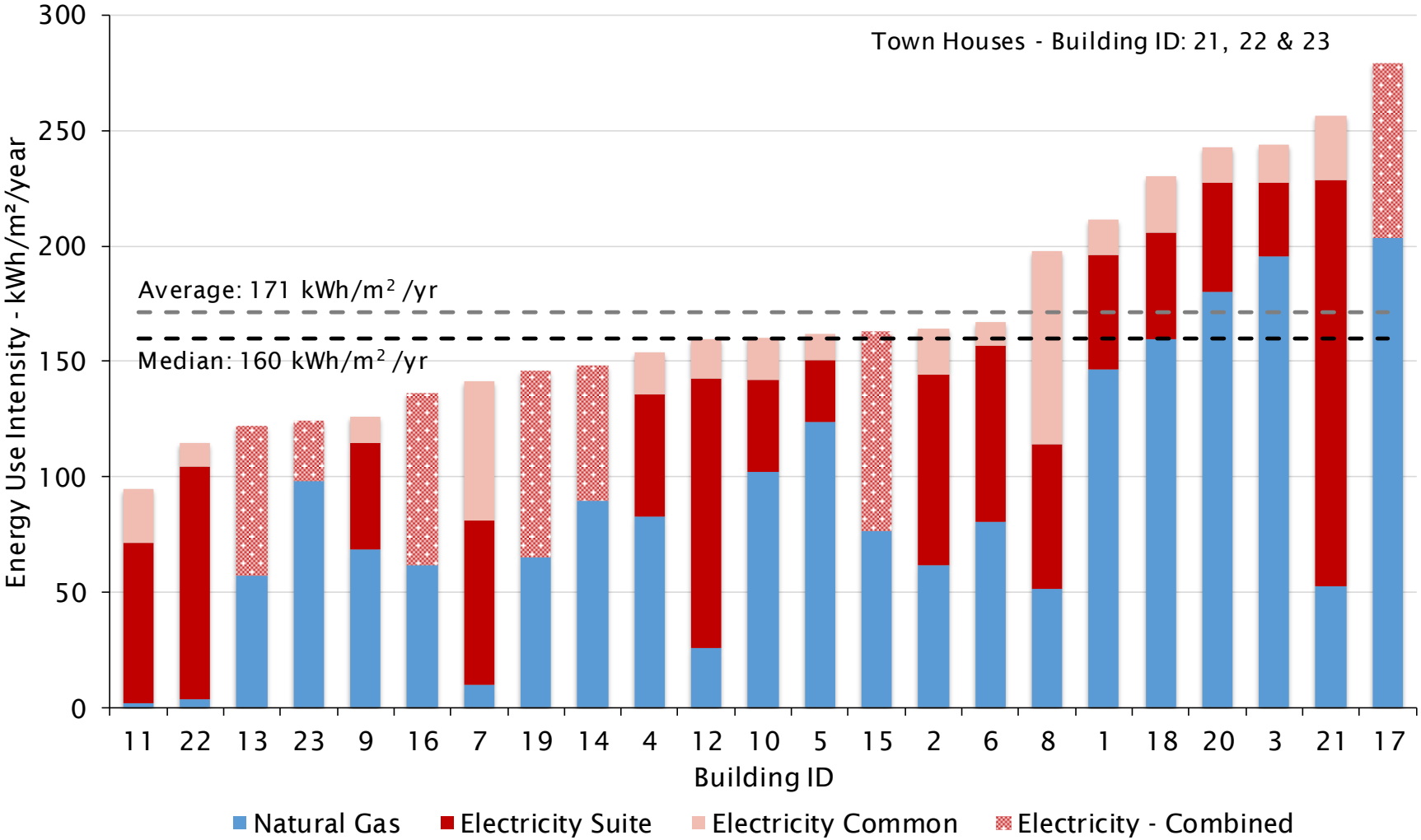
→ Range of construction years

- → 1974-2010

→ Typical heating systems

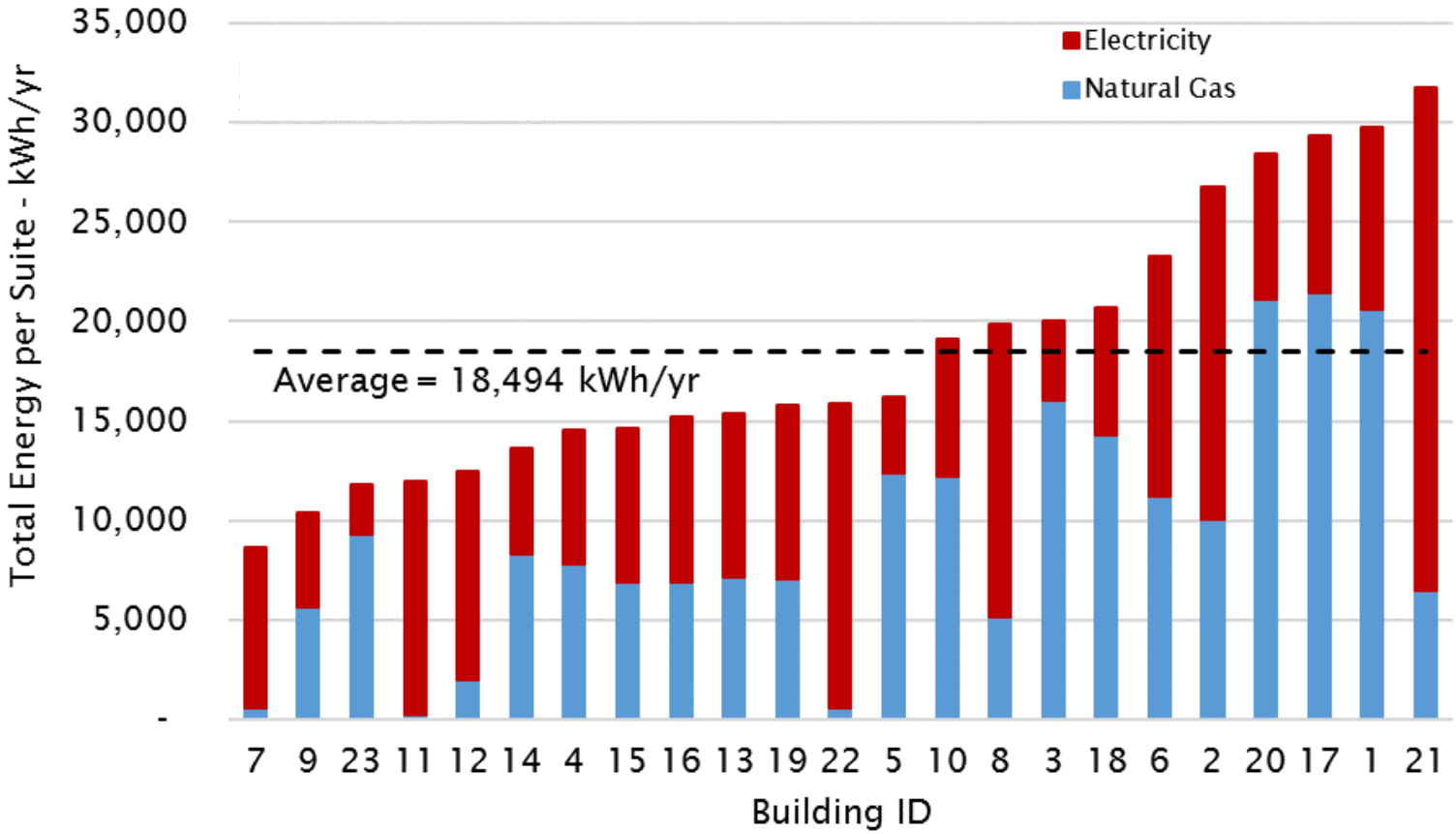
- → Electric Baseboards
- → Hydronic Baseboards

Energy Use Intensity – Low-Rise Buildings

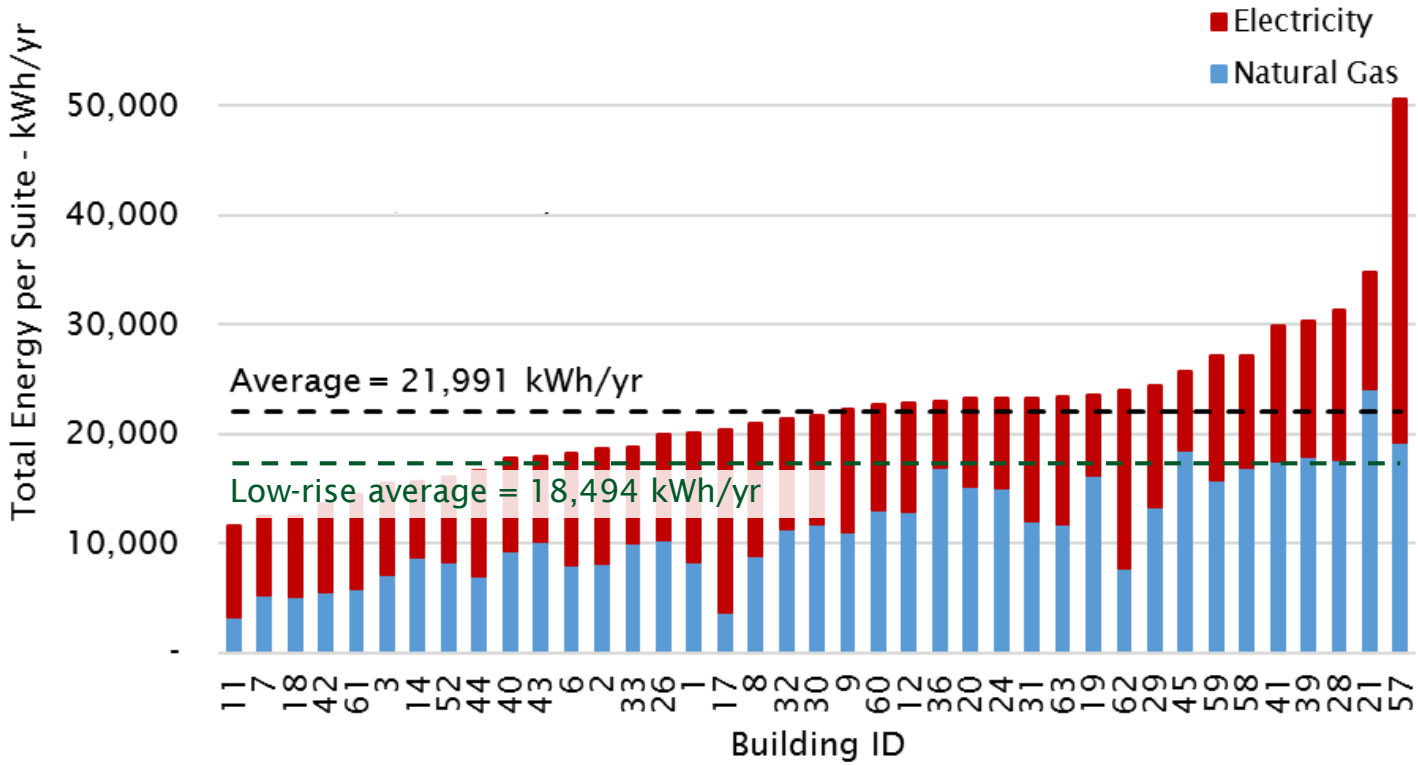


Energy Consumption by Suite – Low-Rise Buildings

→ In some cases, electric baseboards are intended as primary space heating, yet decorative gas fireplaces are used by occupants (Building 23)



Energy Consumption by Suite – High-Rise



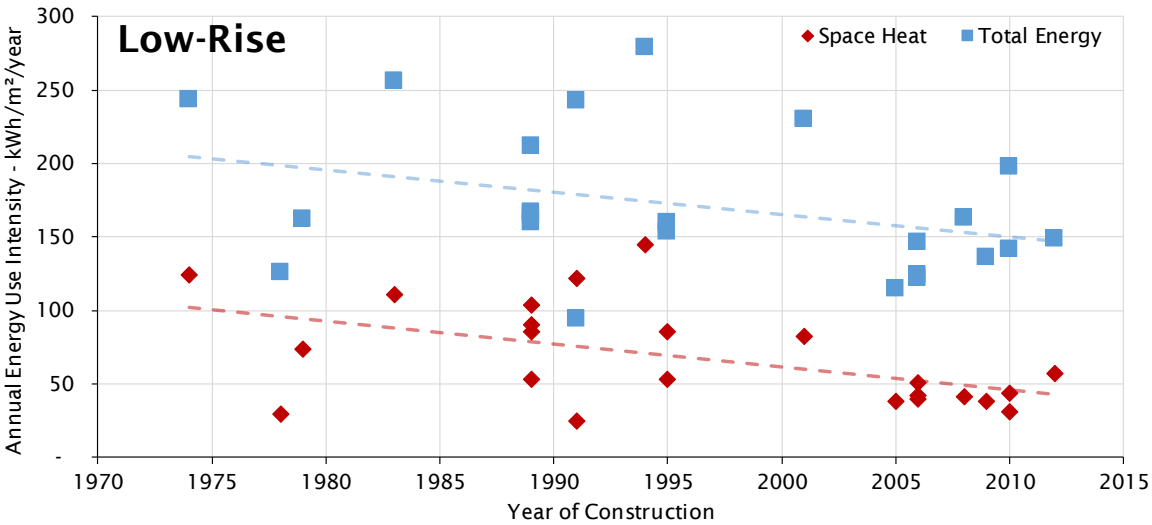
→ Average high-rise energy use per suite: ~22,000 kWh/yr

→ 19% increase over average low-rise suite consumption (~18,500 kWh/yr)

→ Highest suite consumption, Building 57

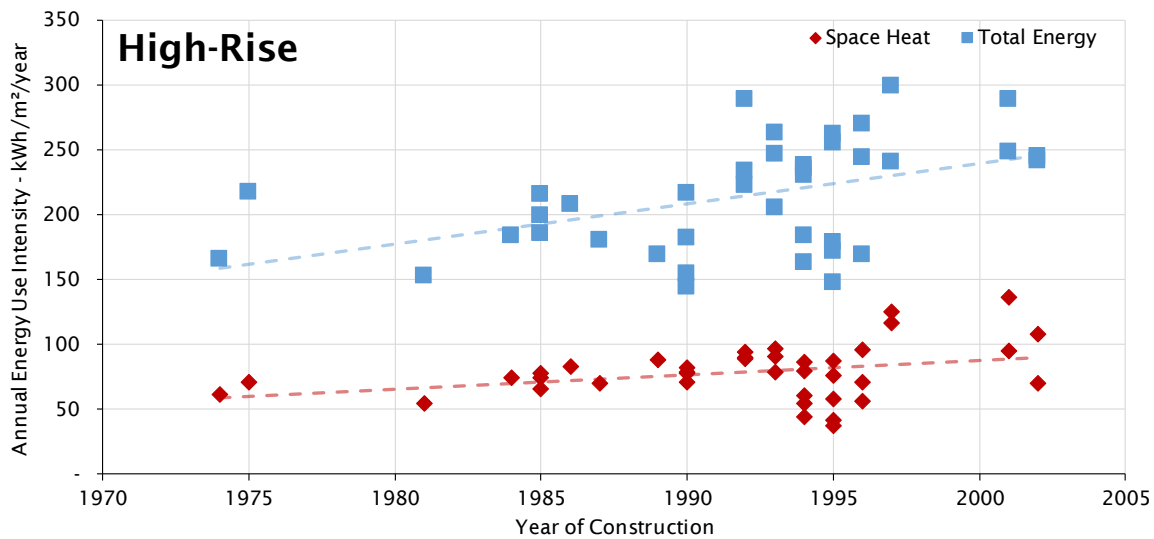
→ Luxury condominium with full amenities, i.e. air conditioning, in-suite fireplaces, common area pool, and recreation centre

Energy Consumption vs Year of Construction



→ Low-rise: Decrease in total energy (blue) & space heating (red)

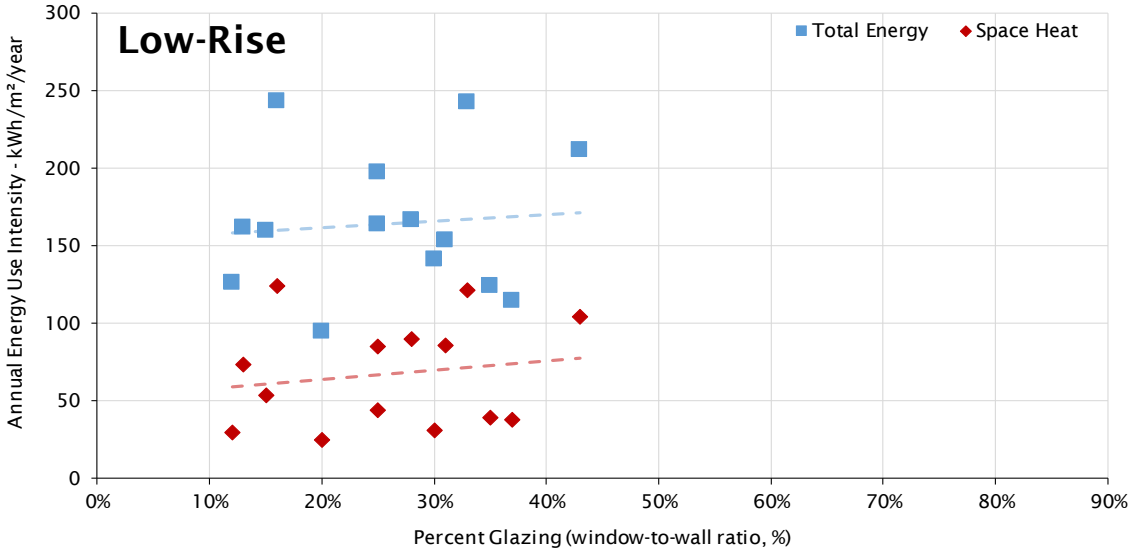
- → More efficient mechanical systems, lighting, and appliances
- → Improved performance of the building enclosures

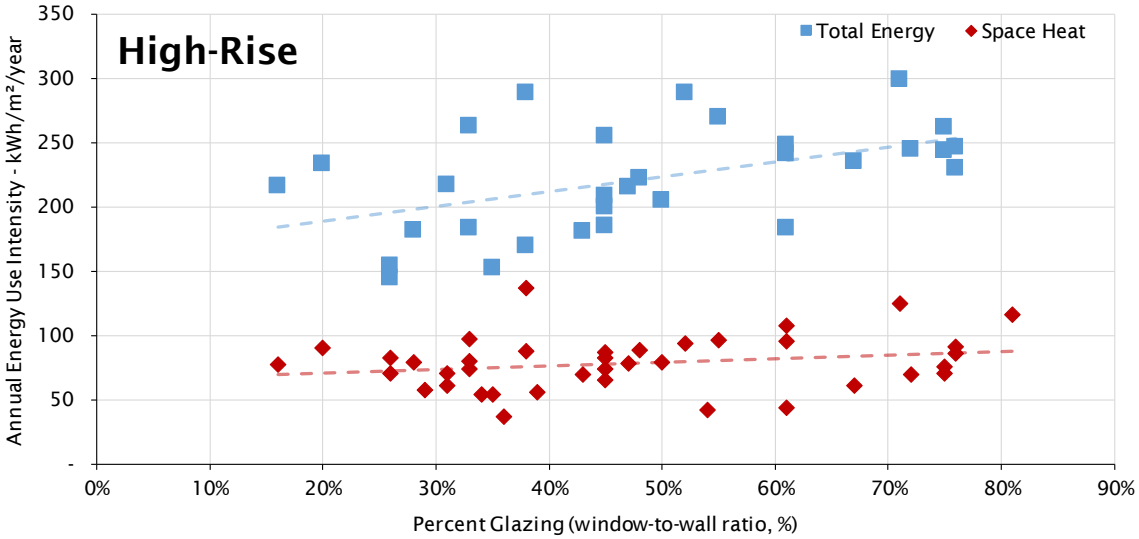


→ High-rise: Increase in total energy (blue)

- → Amenities in newer buildings (pools, hot tubs, gyms)
- → Higher ventilation rates
- → More complex building forms and glazing ratios

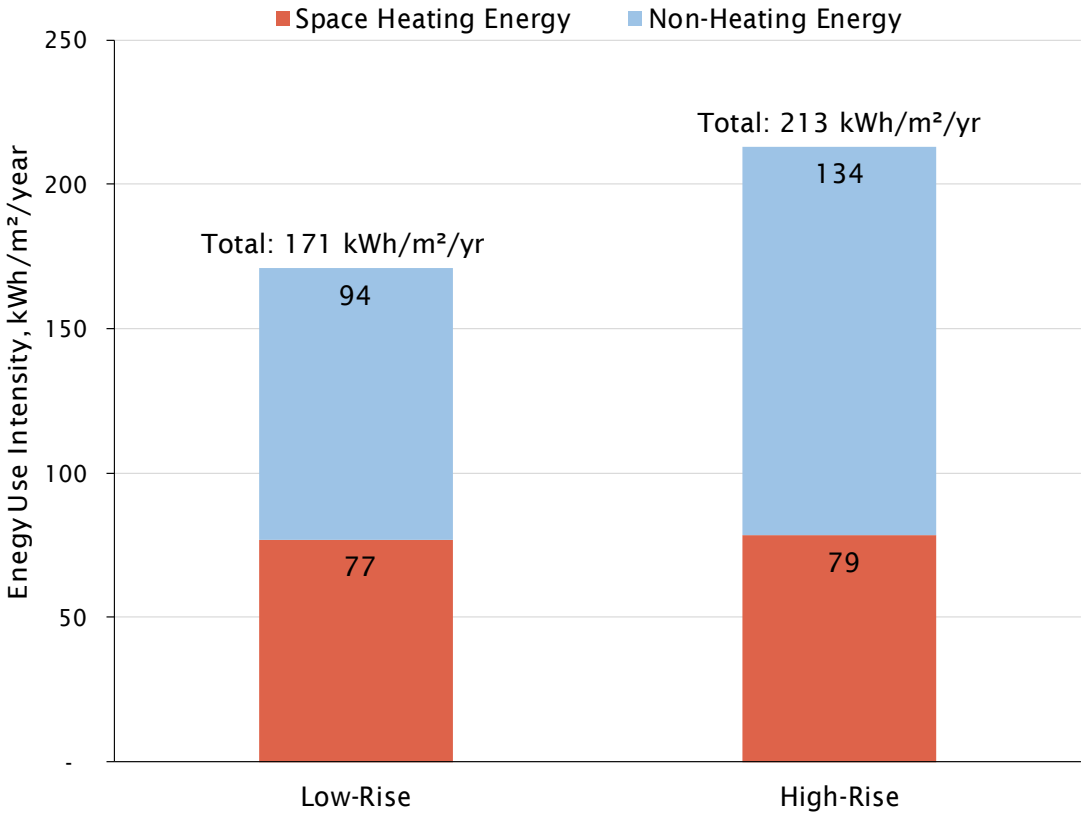
Energy Consumption vs Window-to-Wall Ratio





- → Low-rise: Inconclusive analysis
  - → Insufficient data
  - → Few buildings with available data
- → High-rise: Total energy (blue) increases with W/W%
  - → Building types with high W/W% generally have more amenities and are newer (recall trend with building construction year)

Space Heating Proportion of Total Energy



→ Low-rises only consume approximately ~2% less space heating energy than high-rises

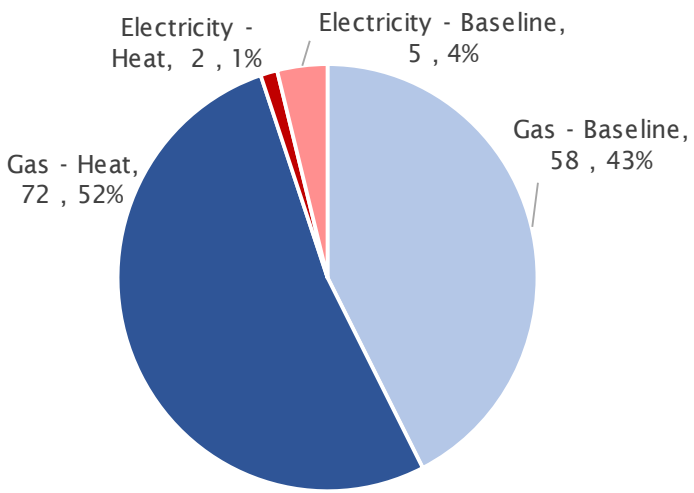
→ High-rises generally have higher non-heating energy consumption (more building amenities and higher ventilation rates)

→ Low-rise space heat makes up 45% of the total building energy

→ High-rise space heat makes up 37% of the total building energy

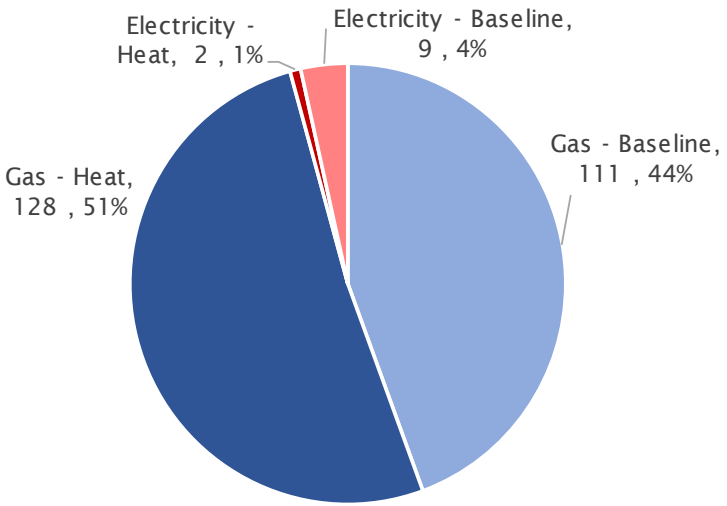
Greenhouse Gas Emissions

Low-rise



tCO_2e/yr and % of total

High-rise



tCO_2e/yr and % of total

→ Average GHGI: 17 kg-CO_2e/m^2

→ Average GHGI: 21 kg-CO_2e/m^2

→ The distribution and total amount of GHG emissions depend on building-specific systems and fuel source

Part 2 – Opportunities for Conservation

- Energy modelling
  - 4-storey low-rise
  - 3-storey townhouse
- Opportunities for energy conservation
- Older, pre-retrofit buildings

Calibrated Energy Modelling

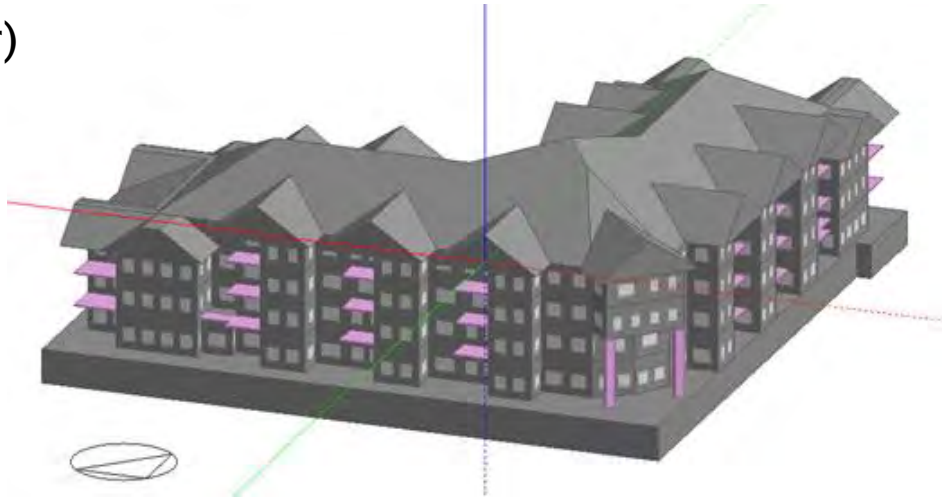
→ Two buildings were selected for energy modelling:

- → 4-storey MURB
- → 3-storey townhouse complex

→ Energy conservation measures (ECMs) were identified and modelled on both buildings

→ Bundles of ECMs were assessed as potential retrofit packages, using the following metrics:

- → Energy savings (kWh/m²/yr)
- → % heating savings
- → % GHG emission reduction



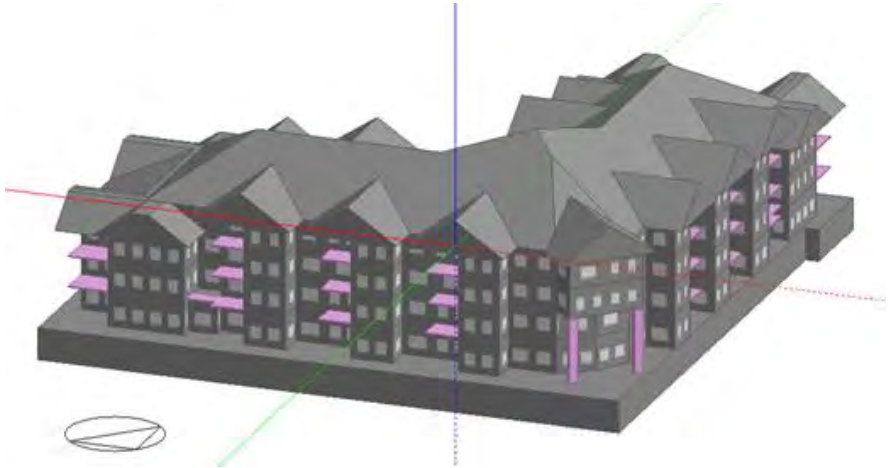
Low-Rise – Selected for Energy Modelling

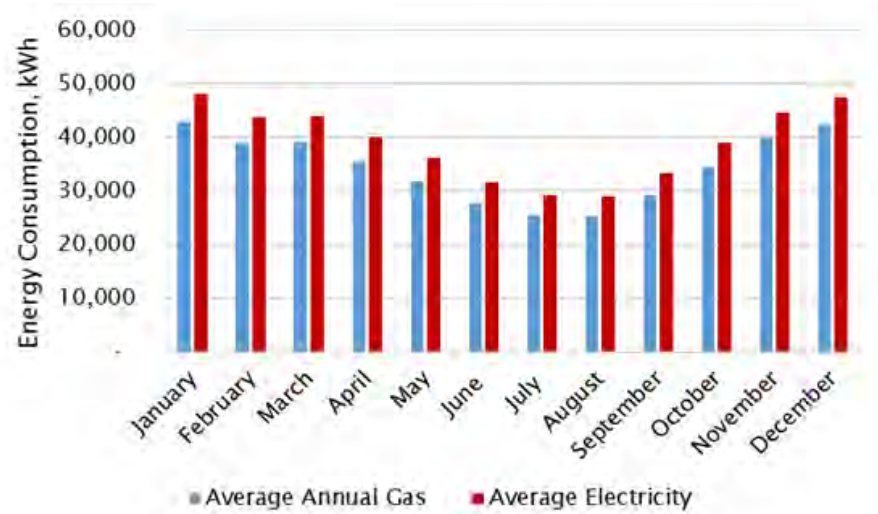
→ Characteristics

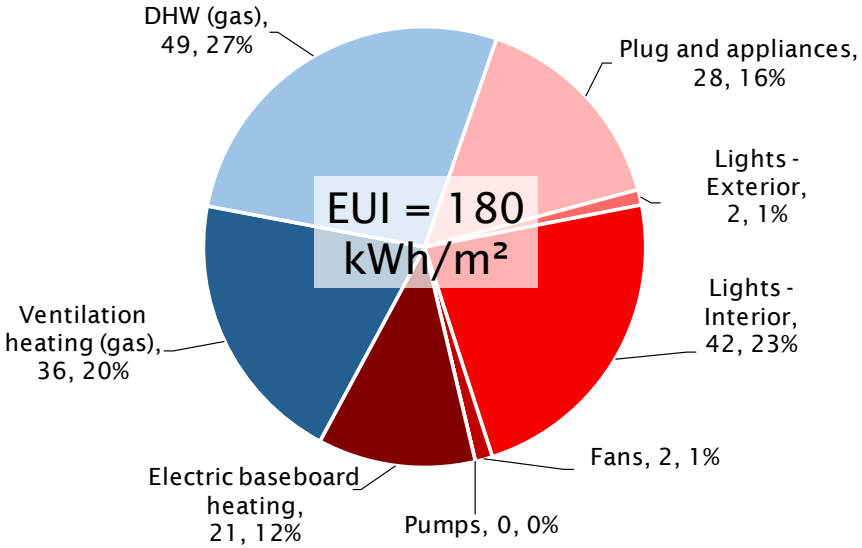
- → Constructed 2008
- → Gross Floor Area: 5,400 m²
- → 60 Suites, 4 storeys

→ Mechanical Systems:

- → Heating – Electric baseboards
- → DHW – Gas boiler, central
- → Ventilation – Gas tempered MUA







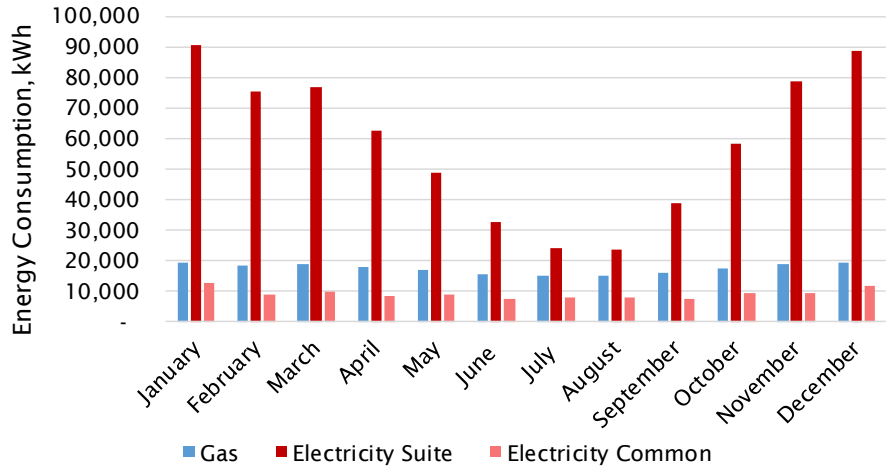
Townhouse – Selected for Energy Modelling

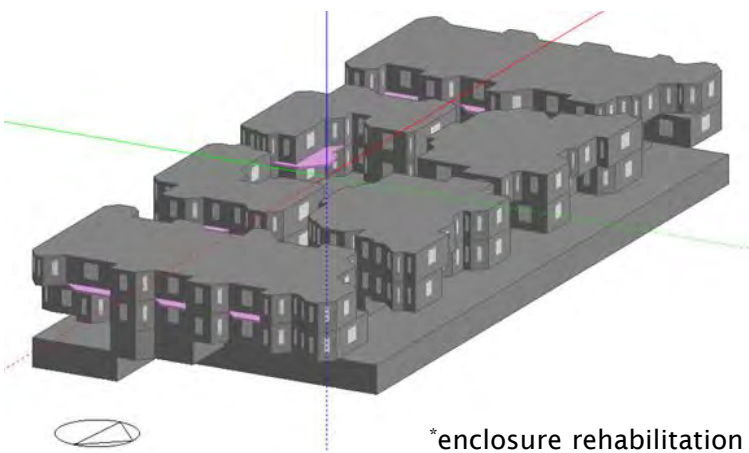
→ Characteristics

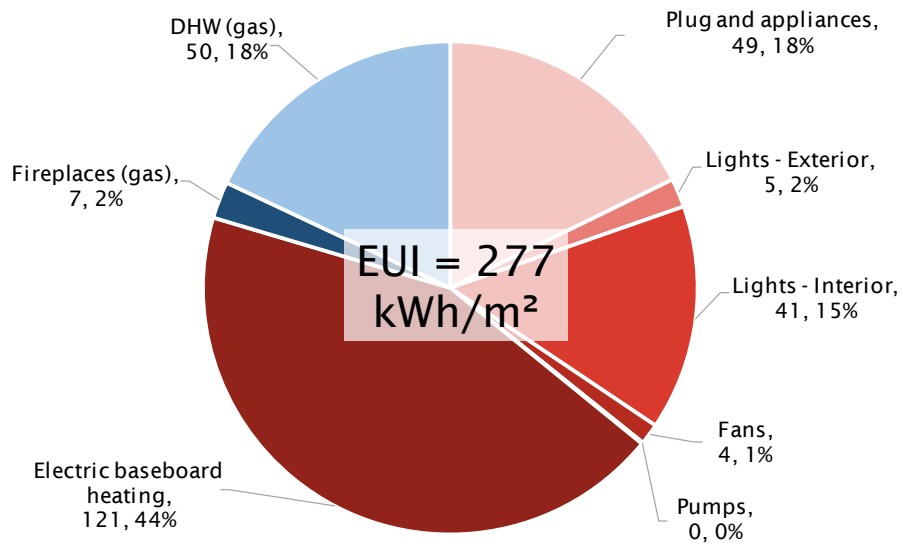
- → Constructed 1983*
- → Gross Floor Area: 4,000 m²
- → 32 Suites, 3 storeys

→ Mechanical Systems:

- → Heating – Electric baseboards (and gas fireplaces**)
- → DHW – Gas boiler, central
- → Ventilation – Suite exhaust only





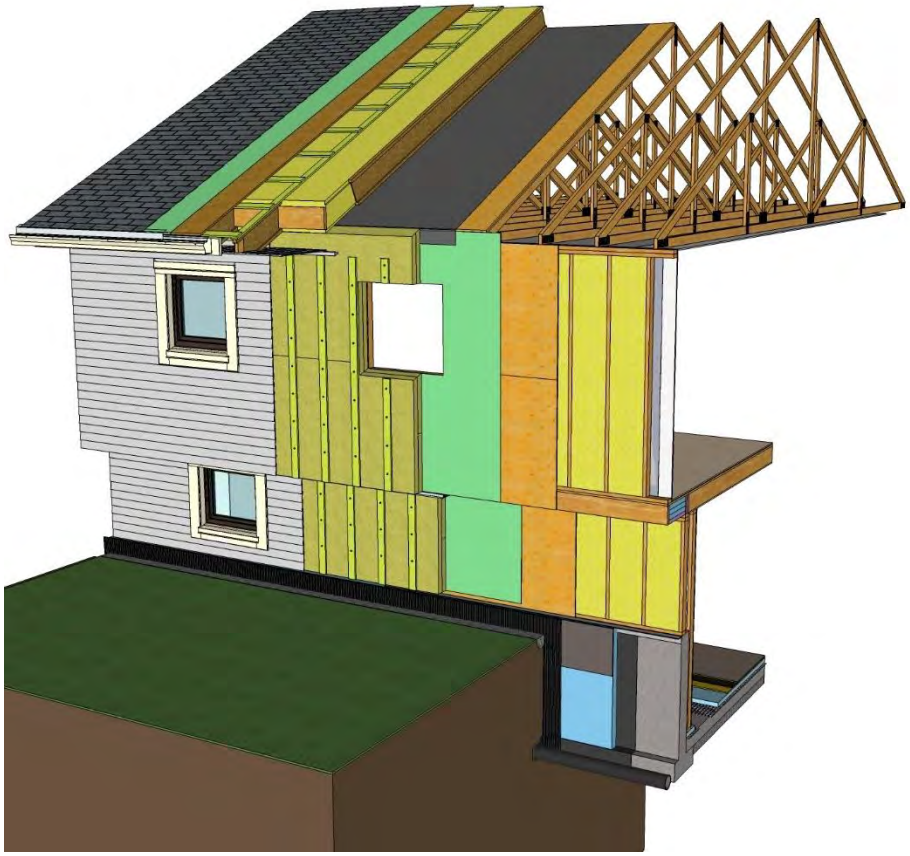


*enclosure rehabilitation in 2000
**some original wood fireplaces

Opportunities for Energy Conservation (1/3)

Enclosure ECMs

- → Add insulation to walls
  - → Exterior insulation
- → Add insulation to roof
  - → Attic and low-sloped
- → Upgrade windows
  - → High performance double
  - → Triple glazed
- → Improving airtightness
  - → Up to US Army Corp standard

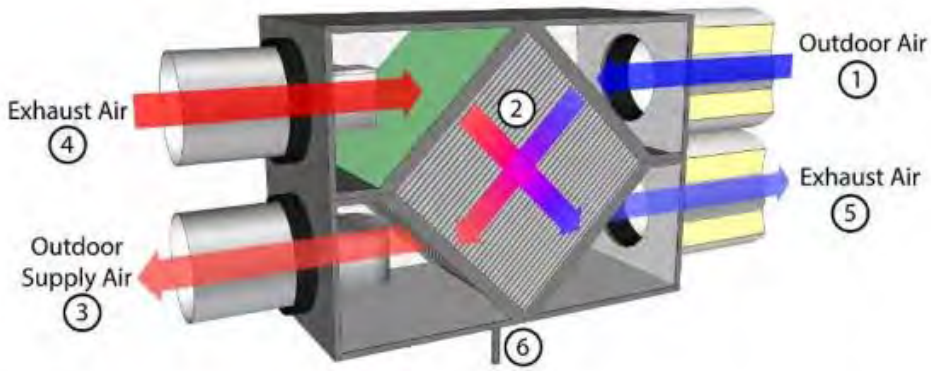


Opportunities for Energy Conservation (2/3)

Ventilation ECMs

→ Heat Recovery Ventilators (HRVs)

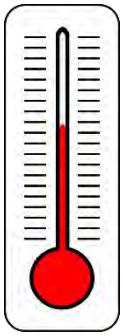
→ 60% and 85% efficient sensible heat recovery



→ Make-up air unit (MUA)

→ Efficiency improvements

→ Set point temperature reduction



Opportunities for Energy Conservation (3/3)

DHW ECMs

→ DHW

- → Upgrade to low-flow fixtures
- → Install drain water heat recovery
- → Boiler efficiency improvement

Lighting ECMs

→ Lighting

- → Occupancy sensors in common spaces
- → Upgrade to LEDs

Energy Analysis – Low-Rise ECM Bundles

LOW-RISE ECM BUNDLES

Bundle 01 – Better Enclosure

- Walls: add R-5 (R-21 total)
- Roof: add R-10 (R-48 total)
- Windows: H-P double-glazed (U-0.28)
- Airtightness: 0.10 cfm/ft^2 (@4 Pa), a 33% improvement

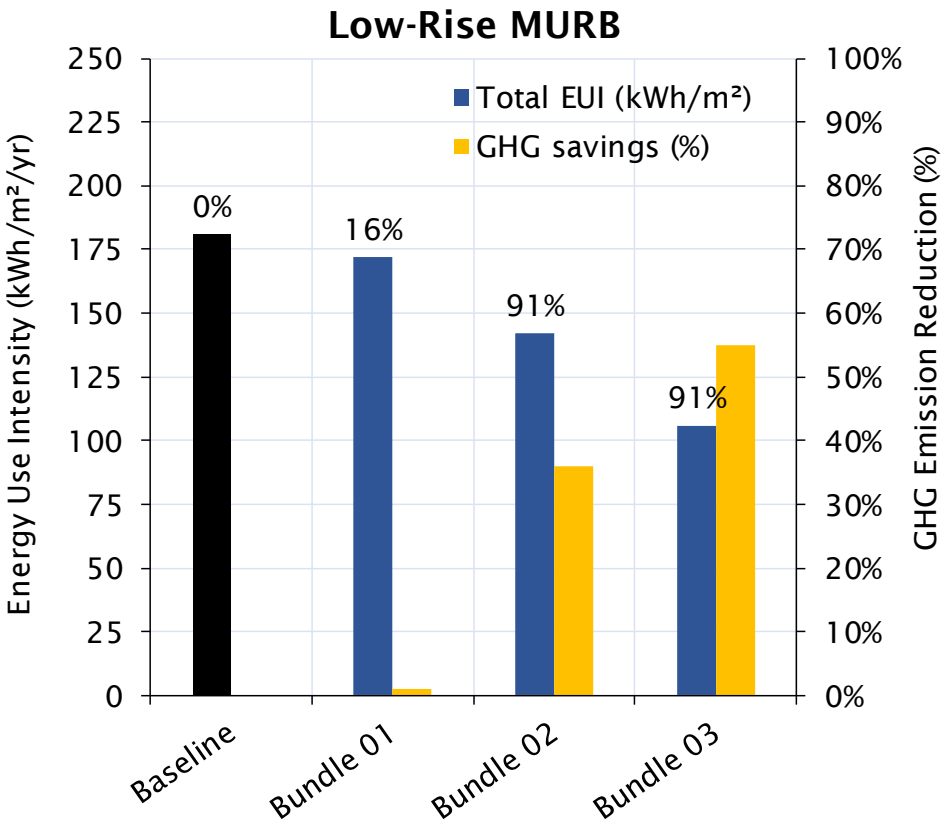
Bundle 02 – Best Enclosure

- Walls: add R-10 (R-26 total)
- Roof: add R-10 (R-48 total)
- Windows: triple-glazed (U-0.17)
- Airtightness: 0.04 cfm/ft^2 (@4 Pa), a 73% improvement
- HRVs: 85% efficient

Bundle 03 – plus Mechanical/Electrical

Bundle 02, plus:

- MUA: condensing (93% efficient)
- MUA: set point lowered to 17˚C
- DHW: low-flow fixtures
- DHW: condensing (93% efficient)
- Lighting: LEDs, occupancy sensors



Heating energy savings is shown as %'s

Energy Analysis – Low-Rise Summary

→ Individual ECMs with the largest heating energy impact:

ECM	Heating savings
Install 85% eff. HRVs	47%
Lower MUA set point to 17˚C	17%
Airtightness (0.04 cfm/ft²)	15%
Triple glazed windows	14%

→ Very high savings from HRVs are enabled by turning down the MUA flow rate

→ ECM Bundles achieve extremely low heating EUIs:

- → Near 5 kWh/m²/yr
- → Occupant behaviour needs to be considered

→ Up to 55% GHG emission reduction

Energy Analysis – Townhouse ECM Bundles

TOWNHOUSE ECM BUNDLES

Bundle 01 – Better Enclosure

- Walls: add R-5 (R-16 total)
- Roof: add R-10 (R-28 total)
- Windows: H-P double-glazed (U-0.28)
- Airtightness: 0.10 cfm/ft^2 (@4 Pa), a 50% improvement

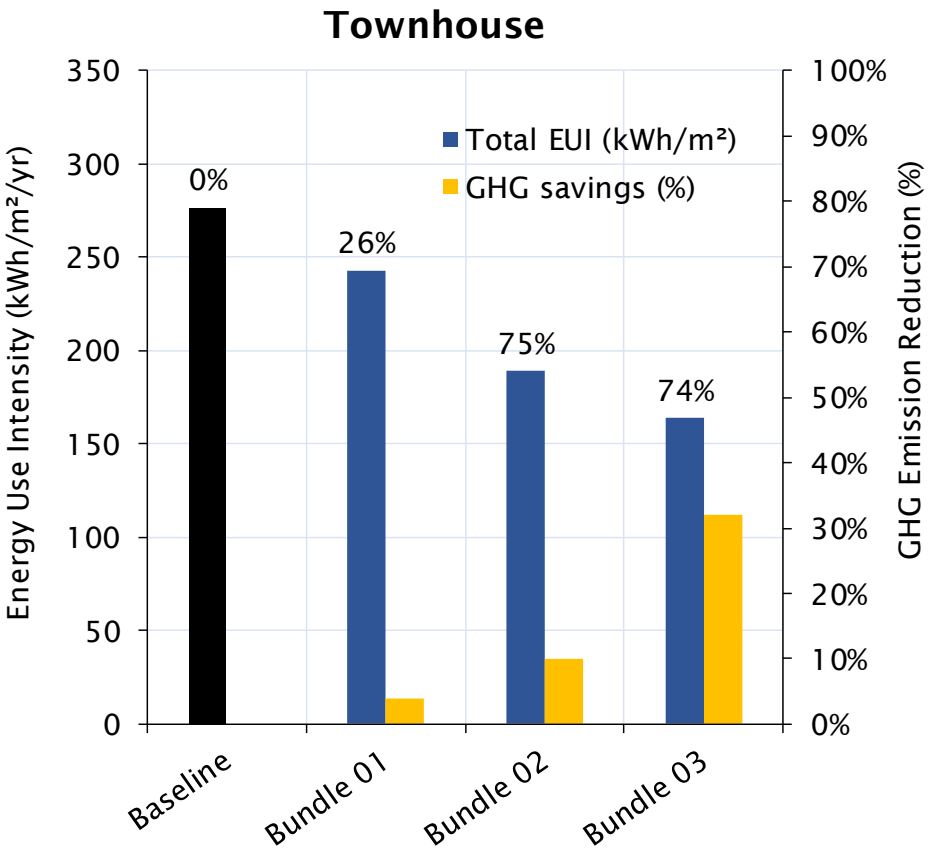
Bundle 02 – Best Enclosure

- Walls: add R-10 (R-21 total)
- Roof: add R-20 (R-38 total)
- Windows: triple-glazed (U-0.17)
- Airtightness: 0.04 cfm/ft^2 (@4 Pa), an 80% improvement
- HRVs: 85% efficient

Bundle 03 – plus Mechanical/Electrical

Bundle 02, plus:

- DHW: low-flow fixtures
- DHW: condensing (93% efficient)
- Lighting: LEDs, occupancy sensors



Heating energy savings is shown as %'s

Energy Analysis – Townhouse Summary

→ ECMs with the largest heating energy impact:

ECM	Heating savings
Airtightness (0.04 cfm/ft²)	24%
Install 85% eff. HRVs	19%
Triple glazed windows	10%
Adding R-10 to walls	8%

→ Airtightness plays a bigger role in leakier baseline building

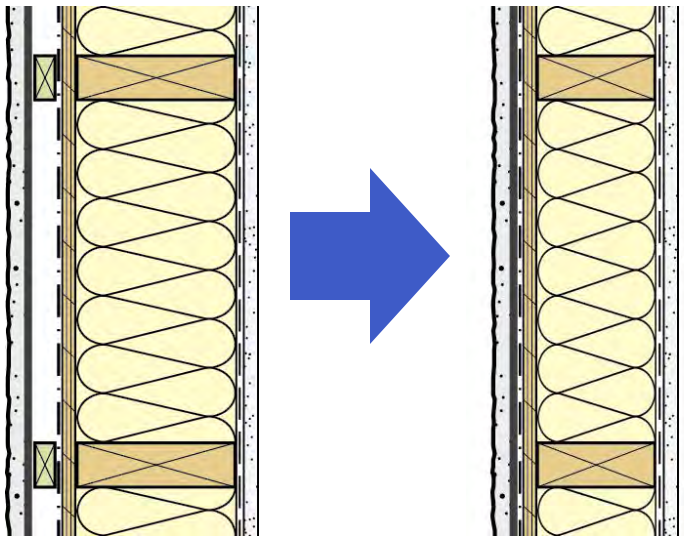
→ Up to 32% GHG emission reduction

- → Lower than Low-Rise due to gas fireplaces
- → No Make-Up Air, so MUA ECMs do not apply to this archetype

Potential Impact on Older, Pre-Retrofit MURBs

→ Archetypical pre-retrofit building models

→ Low-Rise and Townhouse models were adjusted to reflect typical materials/practices from the 1970's era:



Walls

› 2x4 framing with R-11 batt and uninsulated balconies (R-7.5 effective)

Windows

› U-1.0/R-1.0, single glazed with aluminum frames

Air leakage

› 0.20 cfm/ft² at operating pressure (leaky)

Potential Impact on Older, Pre-Retrofit MURBs

Higher baseline heating energy consumption = **More opportunities for energy savings**

→ ECM Bundles for existing, pre-retrofit low-rise buildings can result in:

- → Near 50% total energy savings
- → Near 90% heating energy savings
- → Up to 60% GHG emission reductions

→ Big opportunity in the existing, low-rise housing stock

- → Especially at time of enclosure renewals

Conclusions

→ Energy trends for low-rise multi-unit residential buildings:

- → EUIs are lower for buildings constructed more recently
- → Average low-rise EUI is 171 kWh/m^2/yr

→ High-rise energy consumption per suite is 19% higher than low-rise energy consumption per suite

→ Very high energy savings are possible for low-rise MURBs

→ Three biggest opportunities:

- → HRVs
- → Airtightness
- → Triple-glazed windows

→ Higher net energy savings are possible with older MURBs

→ GHG savings depend on the fuel breakdown

Full Report is Available with More Information

Questions

FOR FURTHER INFORMATION PLEASE VISIT

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Extra Slides

Baseline Model Assumptions

KEY BASELINE MODEL INPUTS*		
	Building 15 (Low-Rise)	**Building 21 (Townhouse)**
Walls	R-16 – 2x6 framing with R-20 batt and insulated balconies	R-11 – 2x4 framing with R-12 batt and insulated balconies
Roof	R-38 – Vented attic with R-40 batt insulation	R-18 – Low-slope with batt insulation
Windows	U-0.35 – Double glazed with vinyl frame and low-e coating, w/w 36%	U-0.40 – Double glazed with vinyl frame, w/w 23%
Air-leakage	0.15 cfm/sf at operating pressure	0.20 cfm/sf at operating pressure
Mech. vent.	2,400 cfm MUA (gas-tempered, 21˚C)	None (natural only)
1° Heating	Electric baseboards, 22 °C	Electric baseboards, 23 °C
2° Heating	None	Gas fireplaces, 7.5 W/m²
DHW flow	2.5 L/m²/day	2.2 L/m²/day
Lighting	5 W/m² in suites, 8 – 17 W/m² in common areas, 2200 W exterior	8 W/m² interior, 4400 W exterior

*Obtained from architectural/mechanical drawings, site visits, and calibration to real utility data