SIDEWALK LABS TORONTO MULTI-UNIT RESIDENTIAL BUILDING STUDY

DIAGNOSING THE PERFORMANCE GAP BETWEEN DESIGN AND OPERATIONAL ENERGY USE

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SIDEWALK LABS

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HOW CAN THE MULTI UNIT RESIDENTIAL MARKET USE THESE FINDINGS?

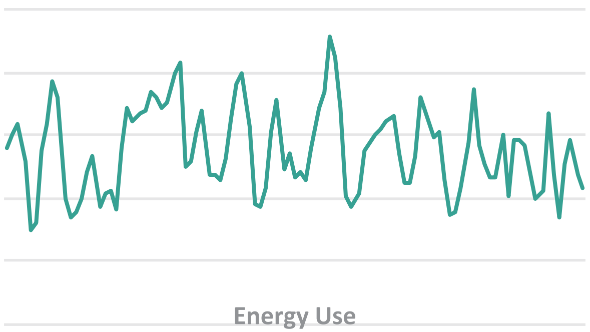
1. On average, multifamily buildings in Toronto use 13% more energy than predicted by modelling. Gas use is 24% higher, and electricity nets out at 11% higher, as a result of in-suite electricity use being lower than modelling assumptions.

2. The study identifies 4 key areas where different modelling assumptions can significantly improve energy use prediction.

3. Most new Toronto MURB projects in design and construction would not meet the newly released Version 3 of the Toronto Green Standard Tier 1 performance threshold.

APPROACH

BACKGROUND – ENERGY MODELS AND THE PERFORMANCE GAP.



Energy Models predict how much energy a building is intended to use, based on a number of different parameters, such as size, location, design, and mechanical systems. Building models are usually completed during the design phase of a building.

Once a building is constructed, the gas and electricity usage is tracked by meters. **Suite-level meters** measure the energy usage of residential tenants. **Utility-level meters** measure the *entire* building's energy usage, including residential and retail tenant usage.

The difference between a building's actual energy usage and the prediction from the energy model is referred to as a **performance gap**.

SO WHAT?

Developers use energy models to help design the building and choose investments to reduce energy usage. Energy models are also used to demonstrate compliance with building codes and performance targets like the Toronto Green Standard. Therefore, significant discrepancies between modeled and actual performance decreases the credibility of models for their important roles.

APPROACH – MULTI UNIT RESIDENITAL DATABASES USED.

Design Models Dataset
95 BUILDINGS

Pre-Construction, Site Plan or permit stage whole building energy models completed between 2015-2017 for Toronto Green Standard Code Compliance.

Suite Dataset
83 BUILDINGS

Suite-level electricity, heat and gas data for existing, occupied buildings constructed between 2000-2015.

Utility Dataset
43 BUILDINGS

Whole building monthly utility bill data for existing, occupied buildings constructed between 1995-2015.

Combined Modelled & Metered Dataset
19 BUILDINGS

Whole building monthly energy use and as-constructed energy models.
All buildings achieved LEED certification.

End Use Dataset
6 BUILDINGS

Extensive plant and system level submetering

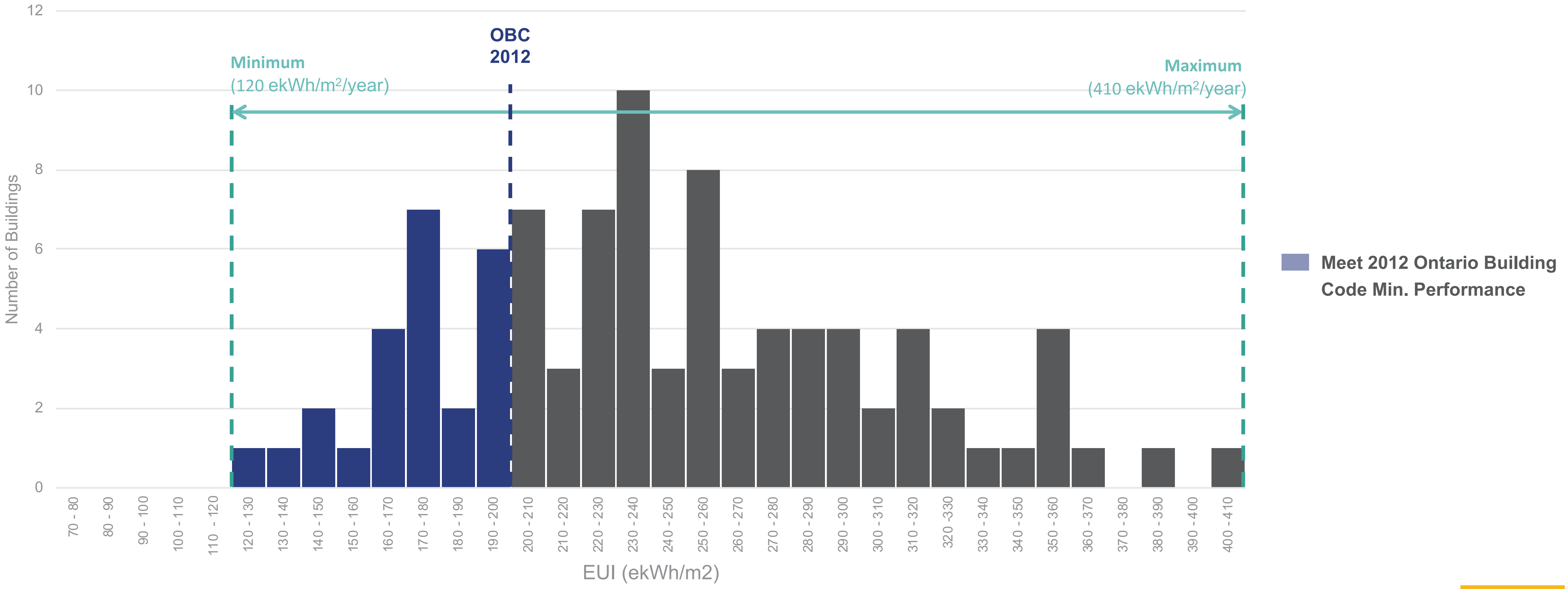
Published Datasets
 # OF BUILDINGS VARY

Mix of metered and measured performance targets

MODELLED   METERED   MODELLED + METERED

KEY FINDINGS
PERFORMANCE GAP

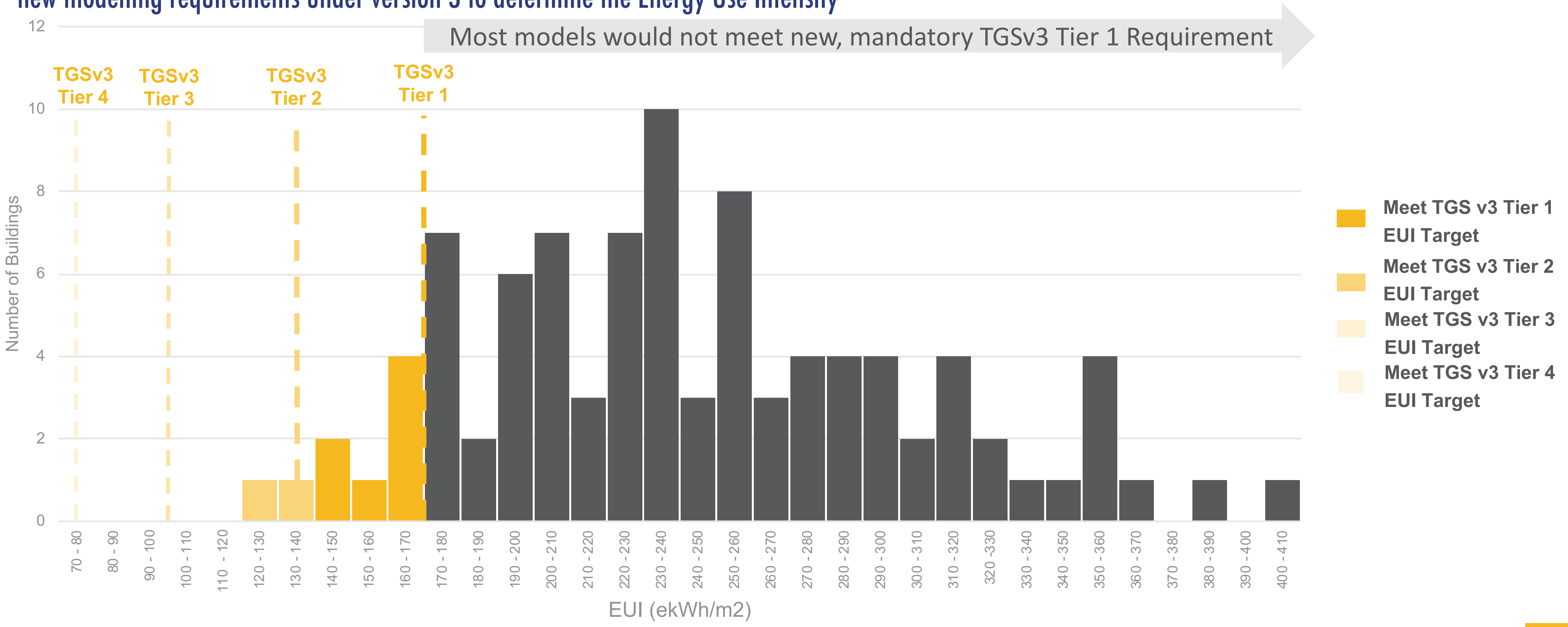
WHAT IS THE MODELLED PERFORMANCE OF DESIGN STAGE MURBS IN TORONTO IN THE LAST 5 YEARS?



MODELLED

WHAT IS THE MODELLED PERFORMANCE OF DESIGN STAGE MURBS IN TORONTO IN THE LAST 5 YEARS?

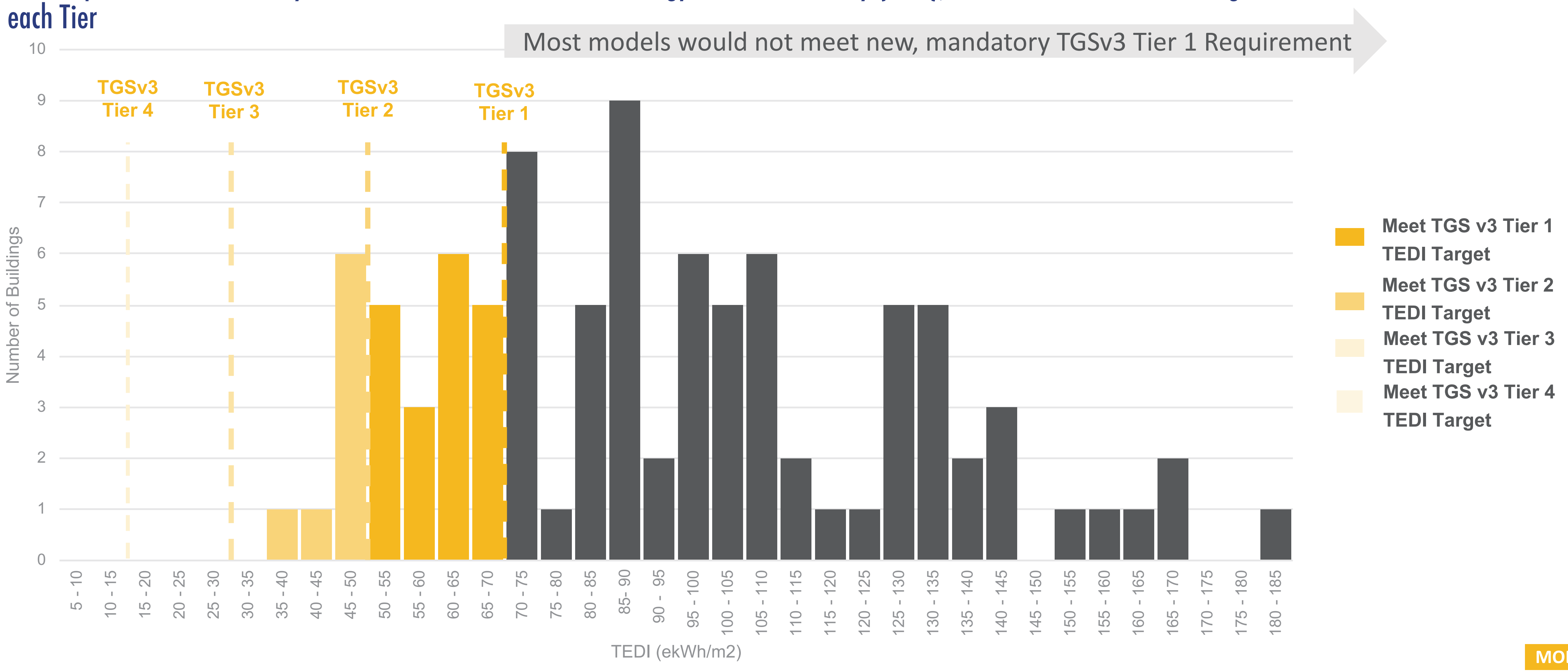
To compare these buildings against the targets in the new Toronto Green Standard (TGS) version 3, we updated the models to reflect the new modelling requirements under version 3 to determine the Energy Use Intensity



MODELLED

WHAT IS THE MODELLED PERFORMANCE OF DESIGN STAGE MURBS IN TORONTO IN THE LAST 5 YEARS?

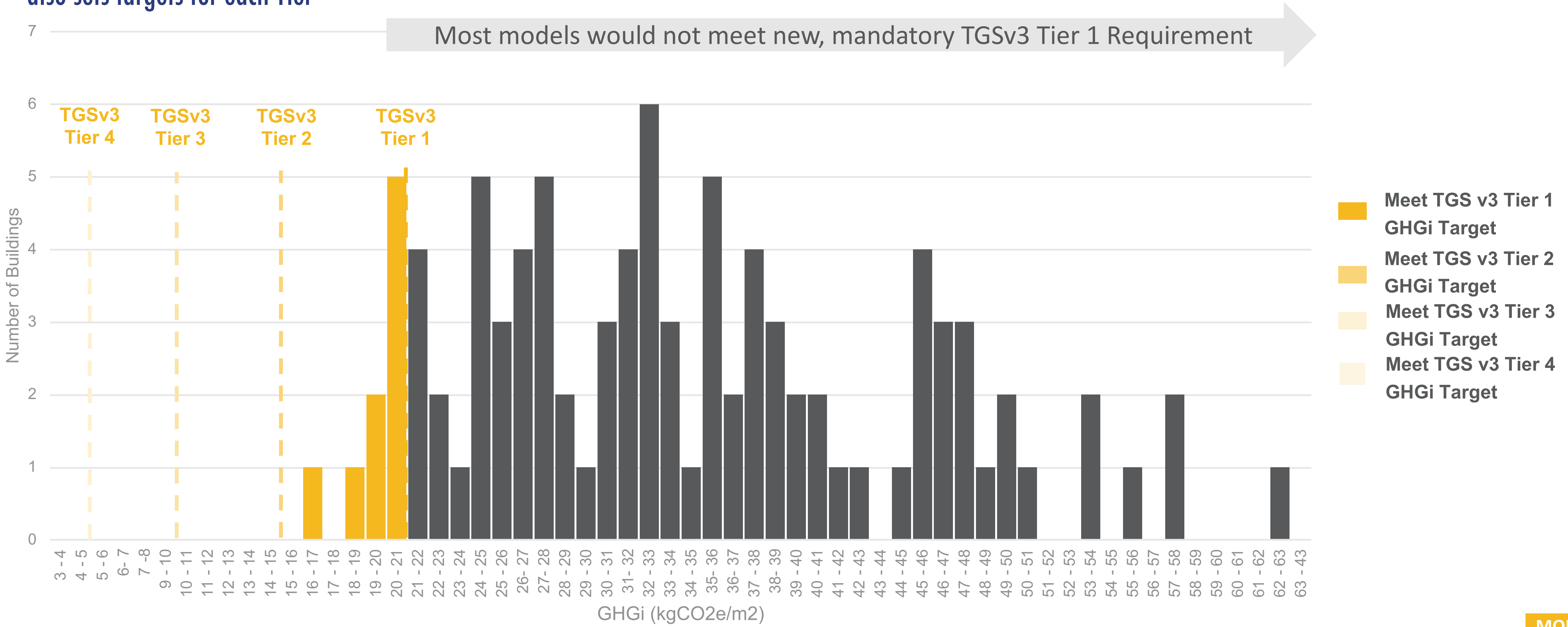
We completed the same analysis under the metric of Thermal Energy Demand Intensity (TEDI), of which TGSv3 also sets targets for each Tier



MODELLED

WHAT IS THE MODELLED PERFORMANCE OF DESIGN STAGE MURBS IN TORONTO IN THE LAST 5 YEARS?

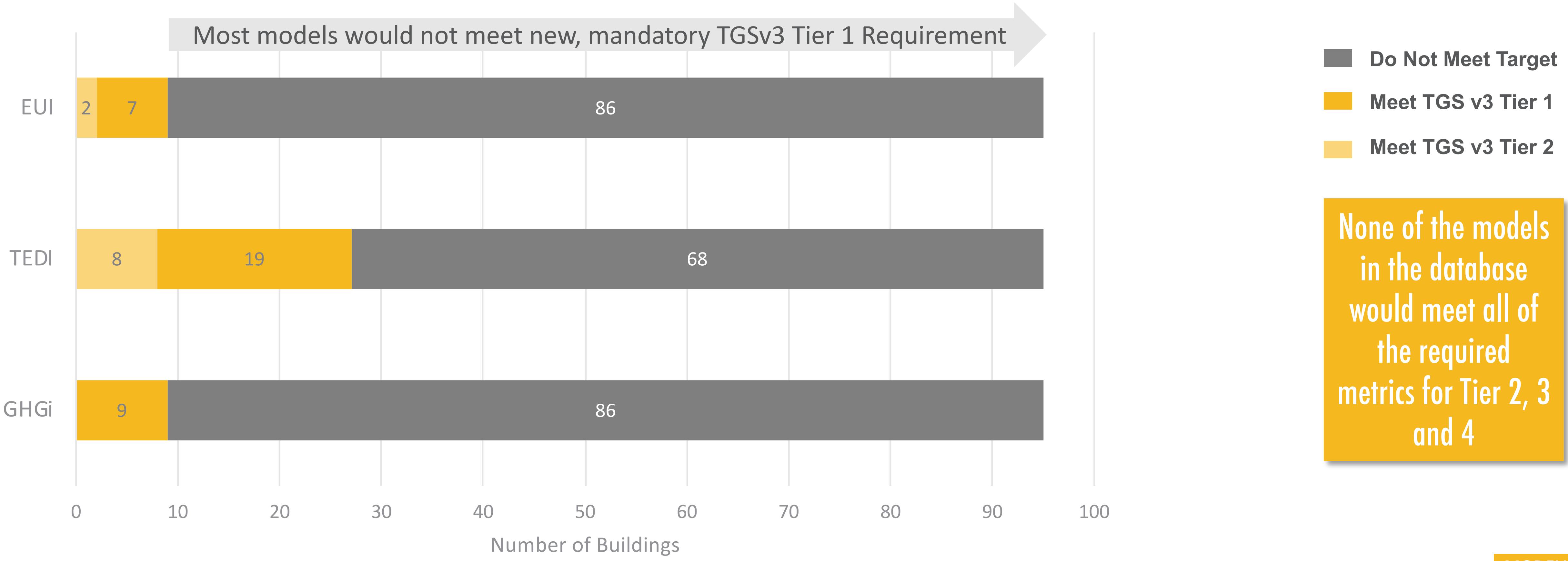
Finally, we completed the same analysis under the metric of Greenhouse Gas Intensity (GHGi), expressed in $kgCO_2e/m^2$, of which TGSv3 also sets targets for each Tier



MODELLED

WHAT IS THE MODELLED PERFORMANCE OF DESIGN STAGE MURBS IN TORONTO IN THE LAST 5 YEARS?

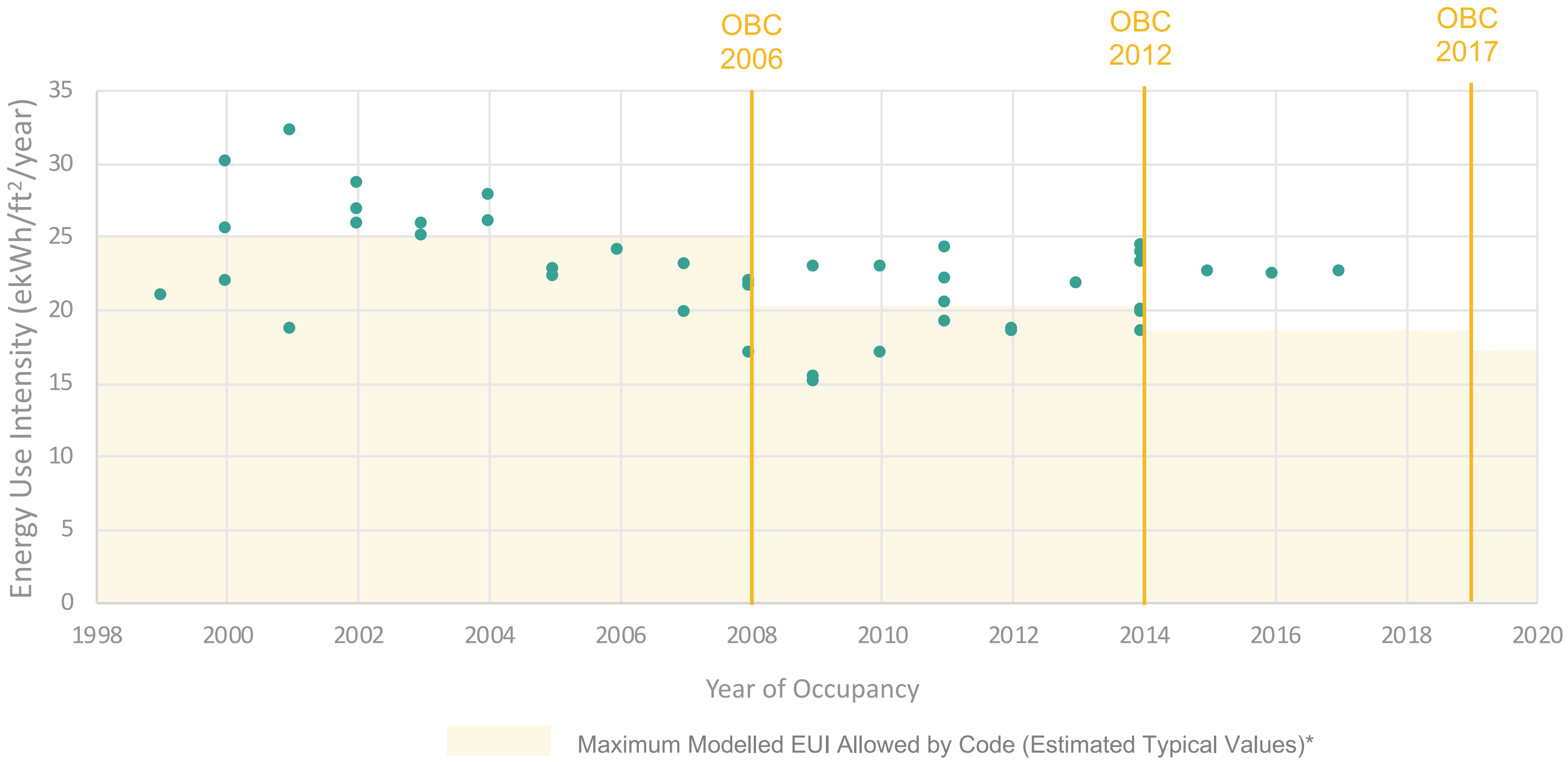
To compare these buildings against the targets in the new Toronto Green Standard (TGS) version 3, we updated the models to reflect the new modelling requirements under this version to determine the Energy Use Intensity (EUI), Thermal Energy Demand Intensity (TEDI), and Greenhouse Gas Intensity (GHGi)



None of the models in the database would meet all of the required metrics for Tier 2, 3 and 4

MODELLED

BUILDING PERFORMANCE HAS NOT SIGNIFICANTLY INCREASED OVER TIME, DESPITE UPDATES TO THE ONTARIO BUILDING CODE.

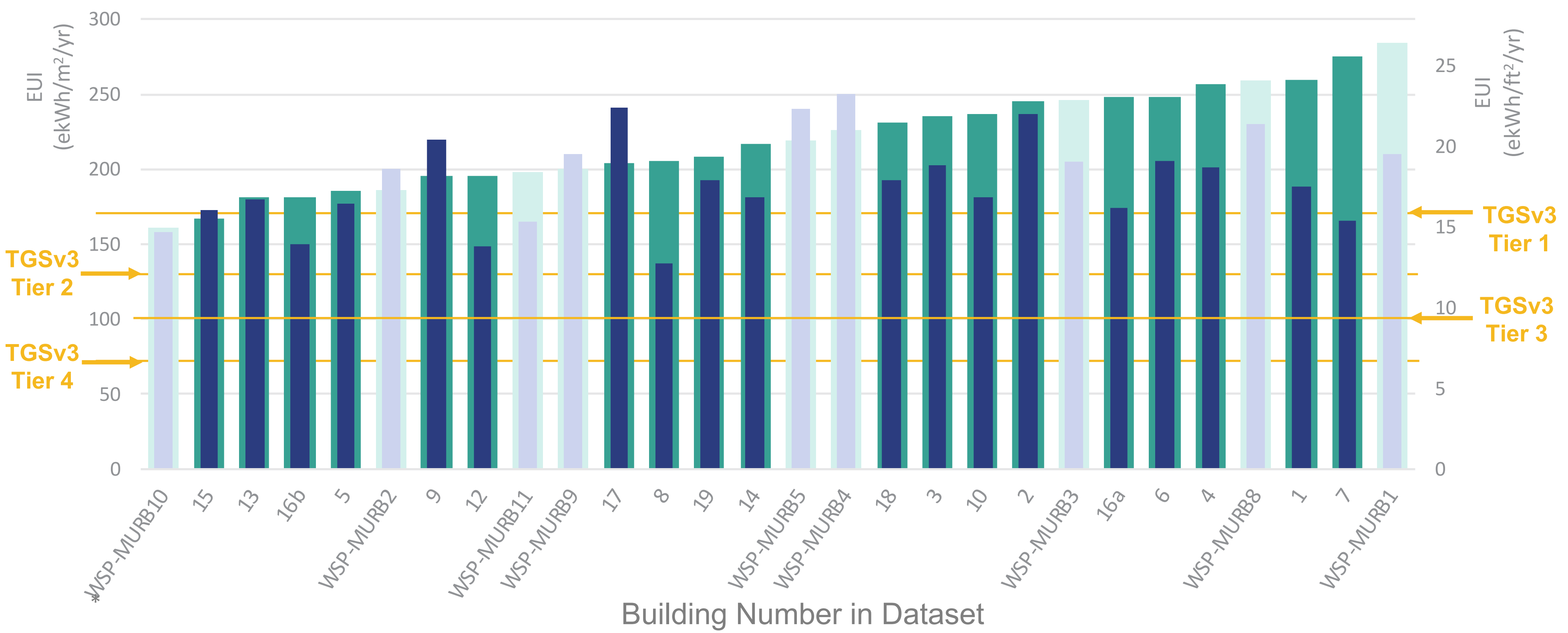


**Source: Development of Energy Efficiency Requirements for the Toronto Green Standard – Sustainable Buildings Canada*

Effects of the Ontario Building Code are lagged by two years on this graph to demonstrate the approximate time till expected realization of energy use savings for new builds.

METERED

COMPARING METERED ENERGY USE INTENSITY AGAINST THEIR CALIBRATED ENERGY MODELS FOR 19 BUILDINGS.



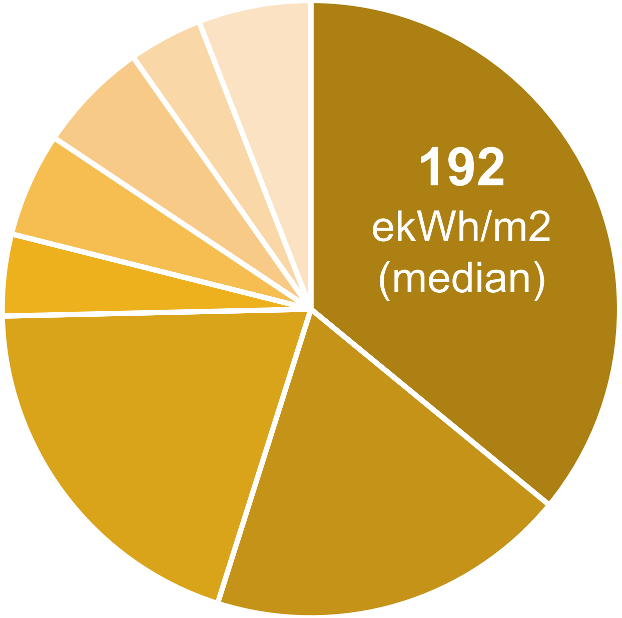
* Light coloured bars indicate buildings from published datasets by WSP

NORMALIZATION

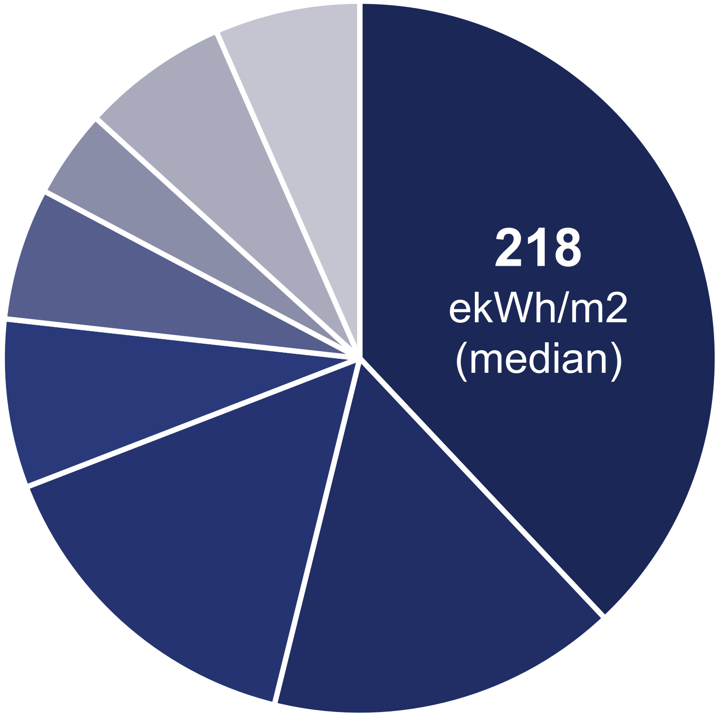
Building models have been calibrated to reflect actual weather conditions.

MODELLED + METERED

COMPARING METERED ENERGY USE INTENSITY AGAINST THEIR CALIBRATED ENERGY MODELS FOR 19 BUILDINGS SHOWED A 13% GAP.



MODELLED



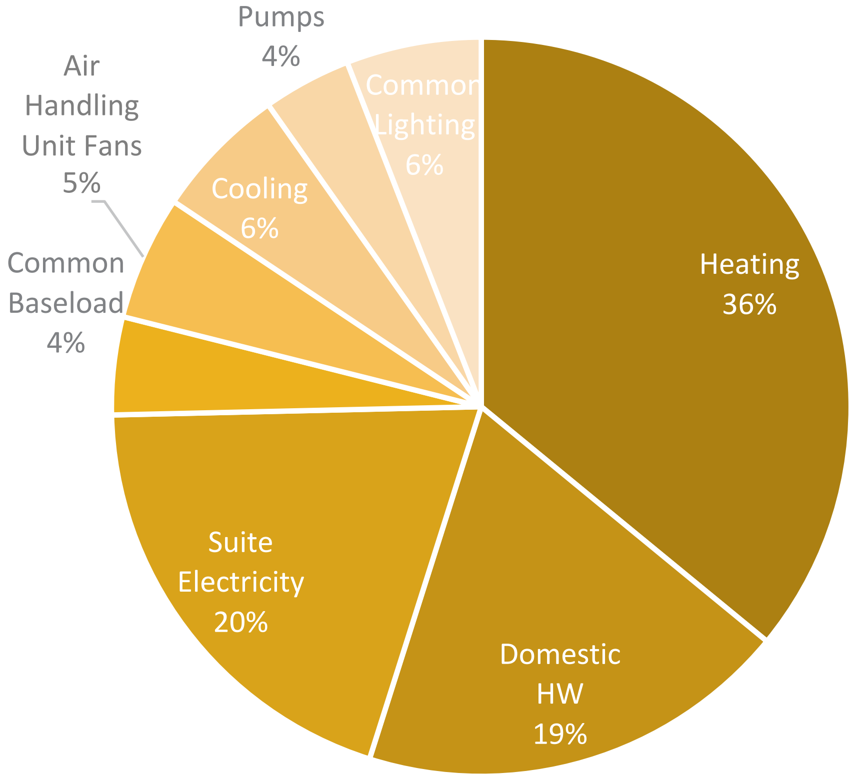
METERED

ENERGY USE INTENSITY

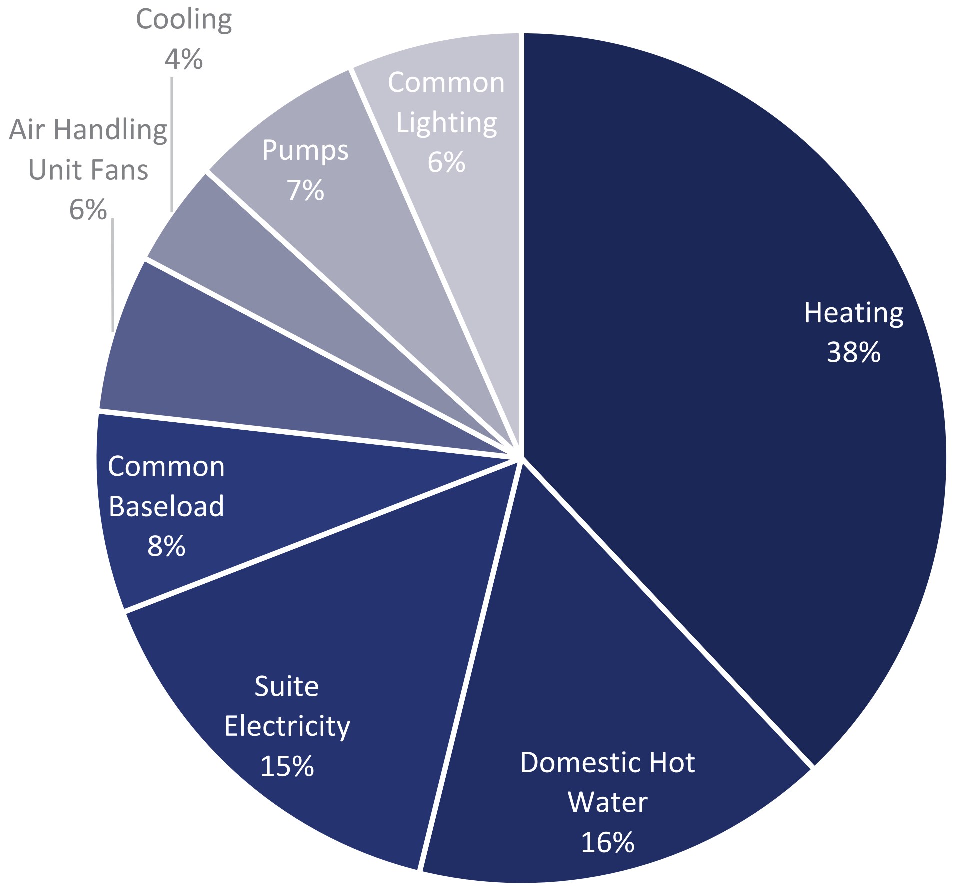
Energy Use Intensity (EUI) is a metric used to compare different annual building energy usage per unit of space.

MODELLED + METERED

VARIATIONS BETWEEN METERED ENERGY END USAGE AND THEIR CALIBRATED ENERGY MODELS FOR 19 BUILDINGS.



MODELLED



METERED

MODELLED + METERED

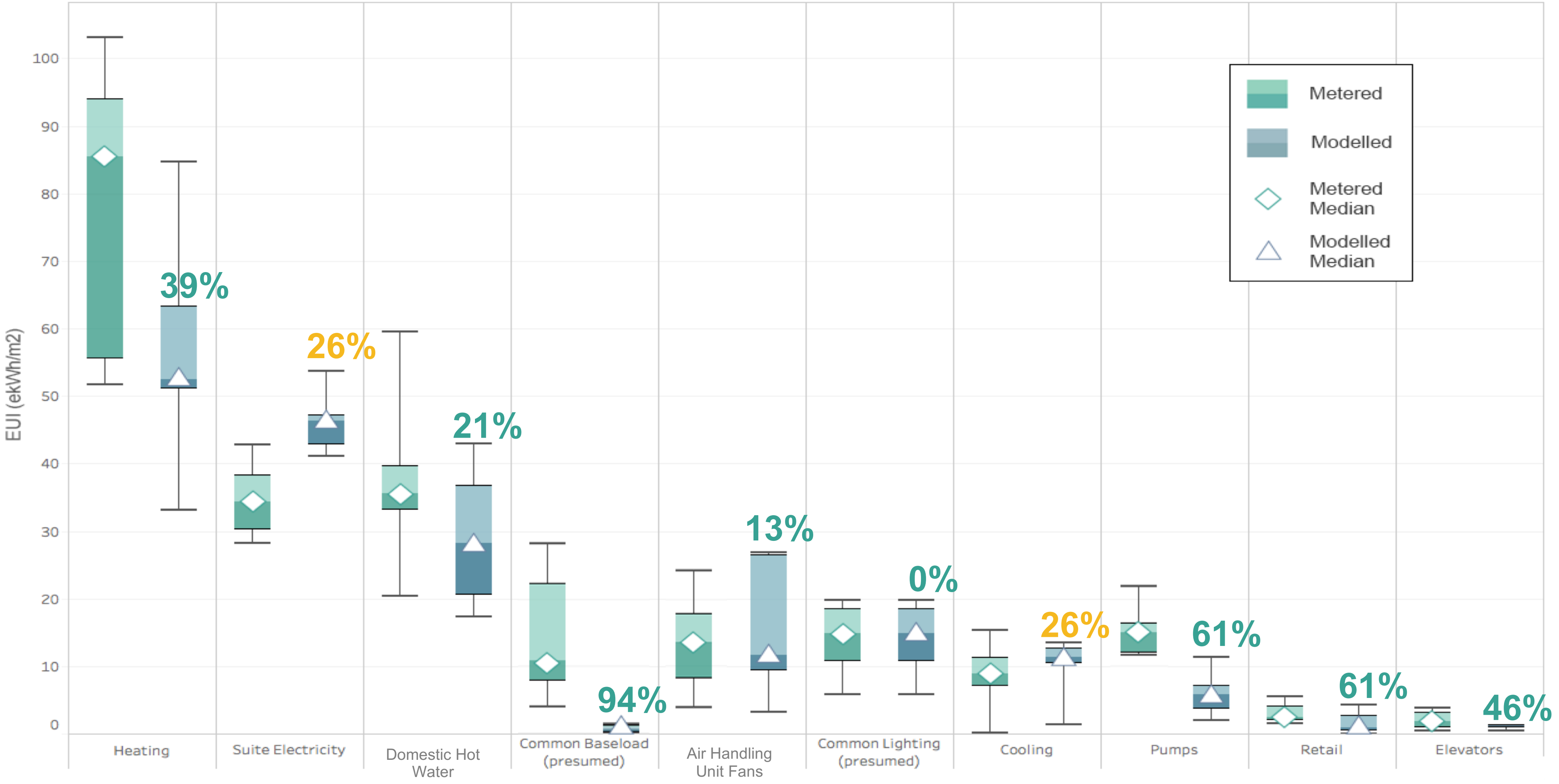
A SUBSET OF 6 REPRESENTATIVE BUILDINGS WAS USED TO FURTHER EVALUATE THE PERFORMANCE GAP.

These buildings cover a range of commonly used HVAC systems, large and small performance gaps between modelled and metered data, and a range of detailed metering installed

Building Number in Dataset	Approx. Year Complete	Gross Floor Area (m^2)	# of Units	HVAC System	Energy Recovery Type	Pool?	DHW Boiler Efficiency	Window to Wall Ratio	Modelled R Value
1	2011	63,292	871	2-Pipe Fan Coil	Central	No	85%	37%	7.16
4	2014	41,571	555	2-Pipe Fan Coil	In-suite	Indoor	87%	31%	4.79
15	2011	17,572	228	Water Source Heat Pump	Central	No	85%	36%	5.87
16a	2010	19,178	178	2-Pipe Fan Coil	In-suite	Indoor	87%	48%	4.20
16b	2010	31,912	282	2-Pipe Fan Coil	In-suite	Indoor	87%	48%	4.37
18	2013	56,483	683	2Pipe/4-Pipe Fan Coil	Central	Outdoor	85%	62%	3.39

PERFORMANCE GAP BY END USE – METERED VS. MODELLED ENERGY USAGE.

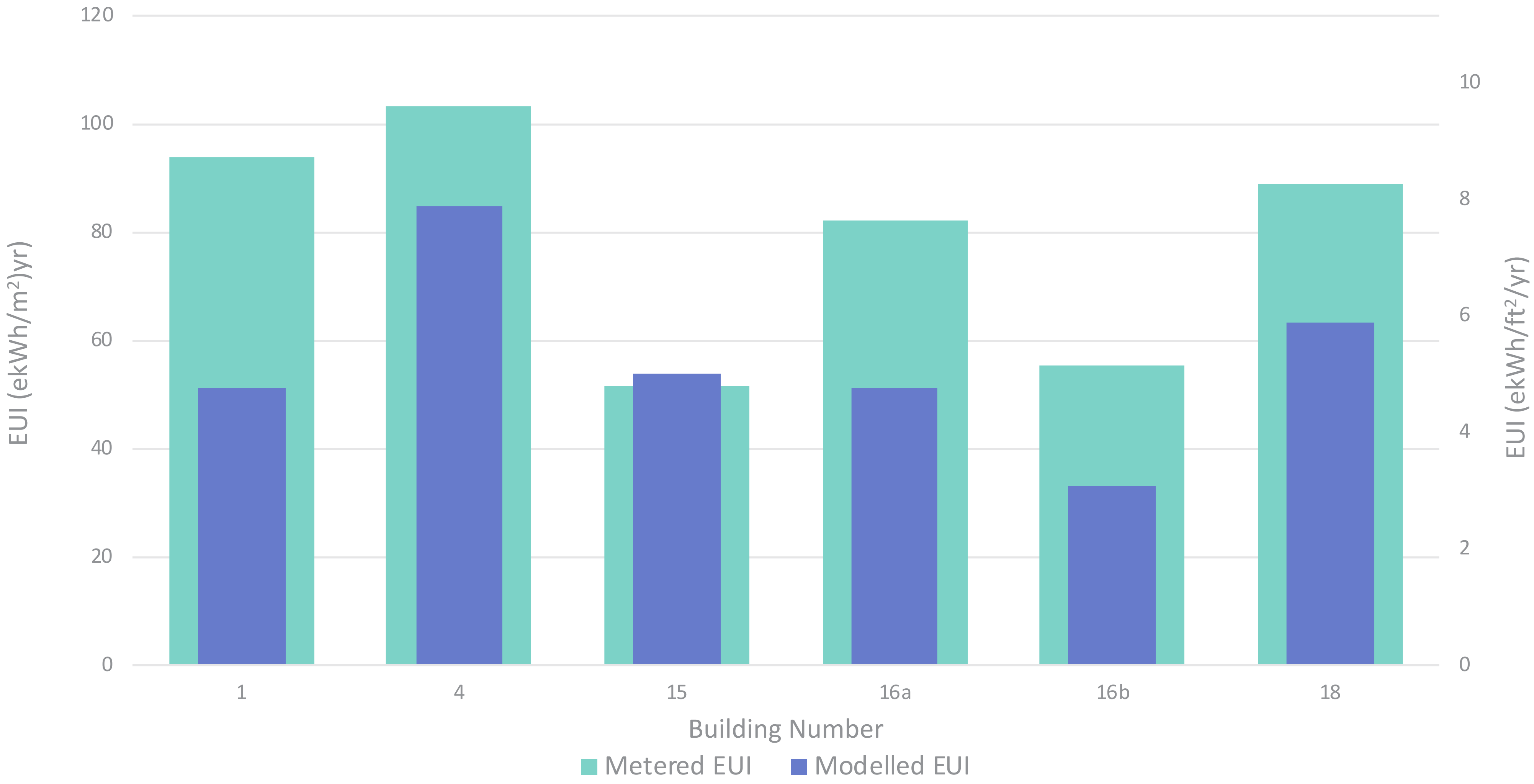
Closer look at 6 building subset reveals significant deviation for many energy uses.



MODELLED + METERED

PERFORMANCE GAP - SPACE HEATING.

Modelled gas usage for space heating is 39% lower than metered performance

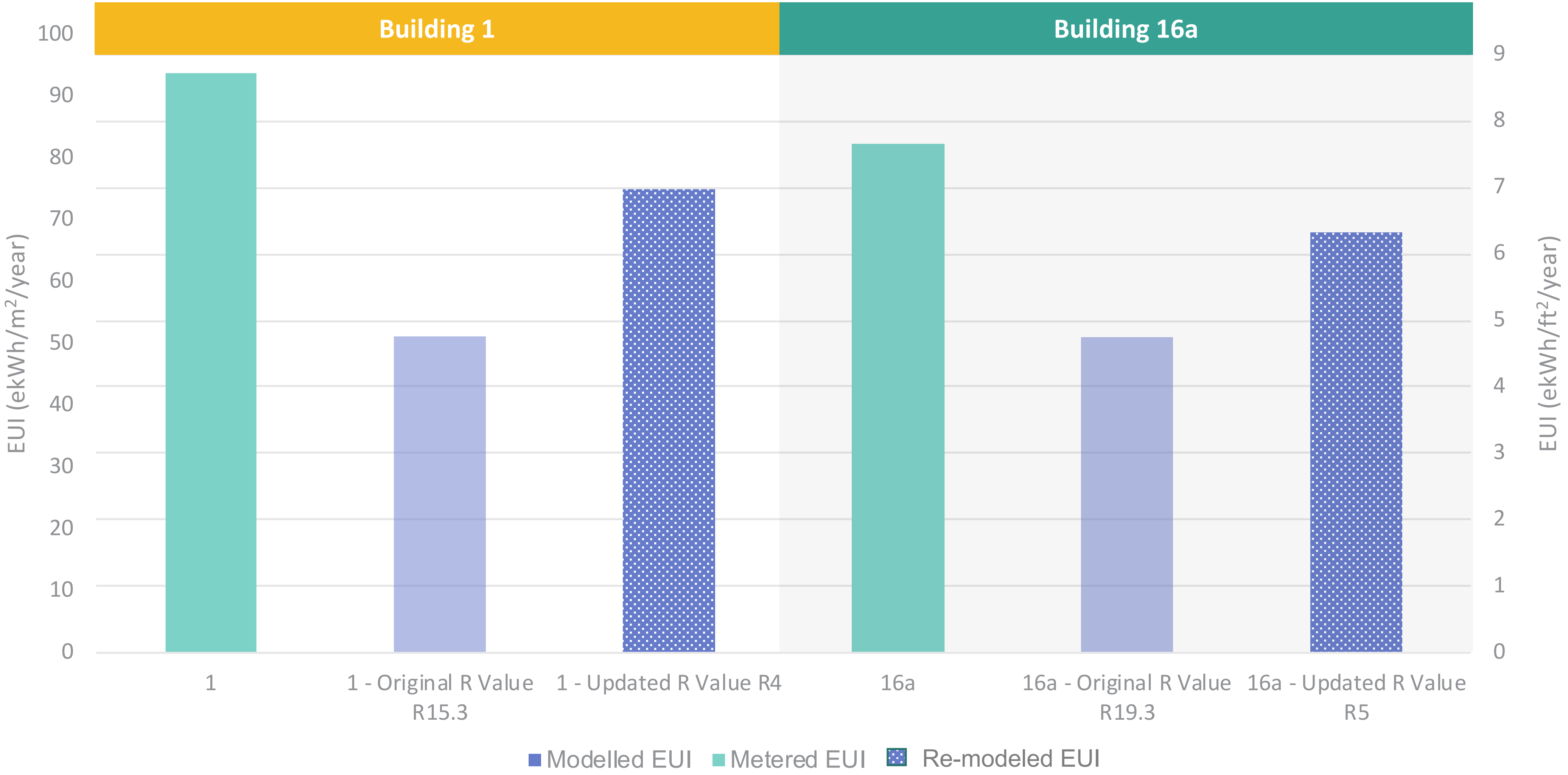


Building 15, uses a Water Source Heat Pump, all other building use Fan Coil Units. The WSHP uses gas heating for central building with electricity to heat the suites. The suite level electricity use is not reflected in this graph.

MODELLED + METERED

SPACE HEATING – EFFECTS OF THERMAL BRIDGING.

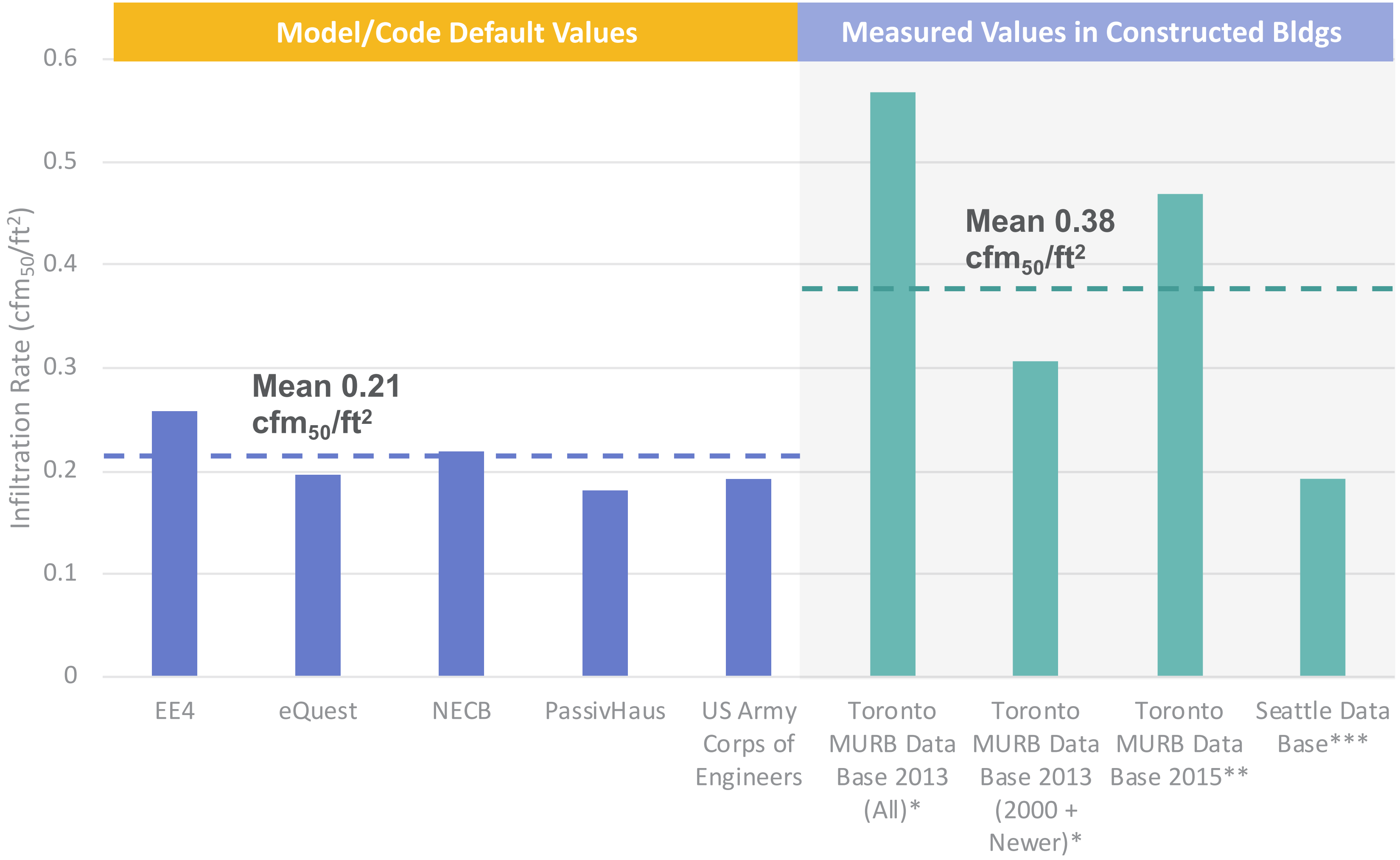
Updating original energy models with more detailed thermal bridging inputs reduced the space heating performance gap in the 2 buildings evaluated



MODELLED + METERED

SPACE HEATING – EFFECTS OF INFILTRATION RATES.

Energy modeling standards assume aggressive levels of air tightness relative to measured results.



NOTES

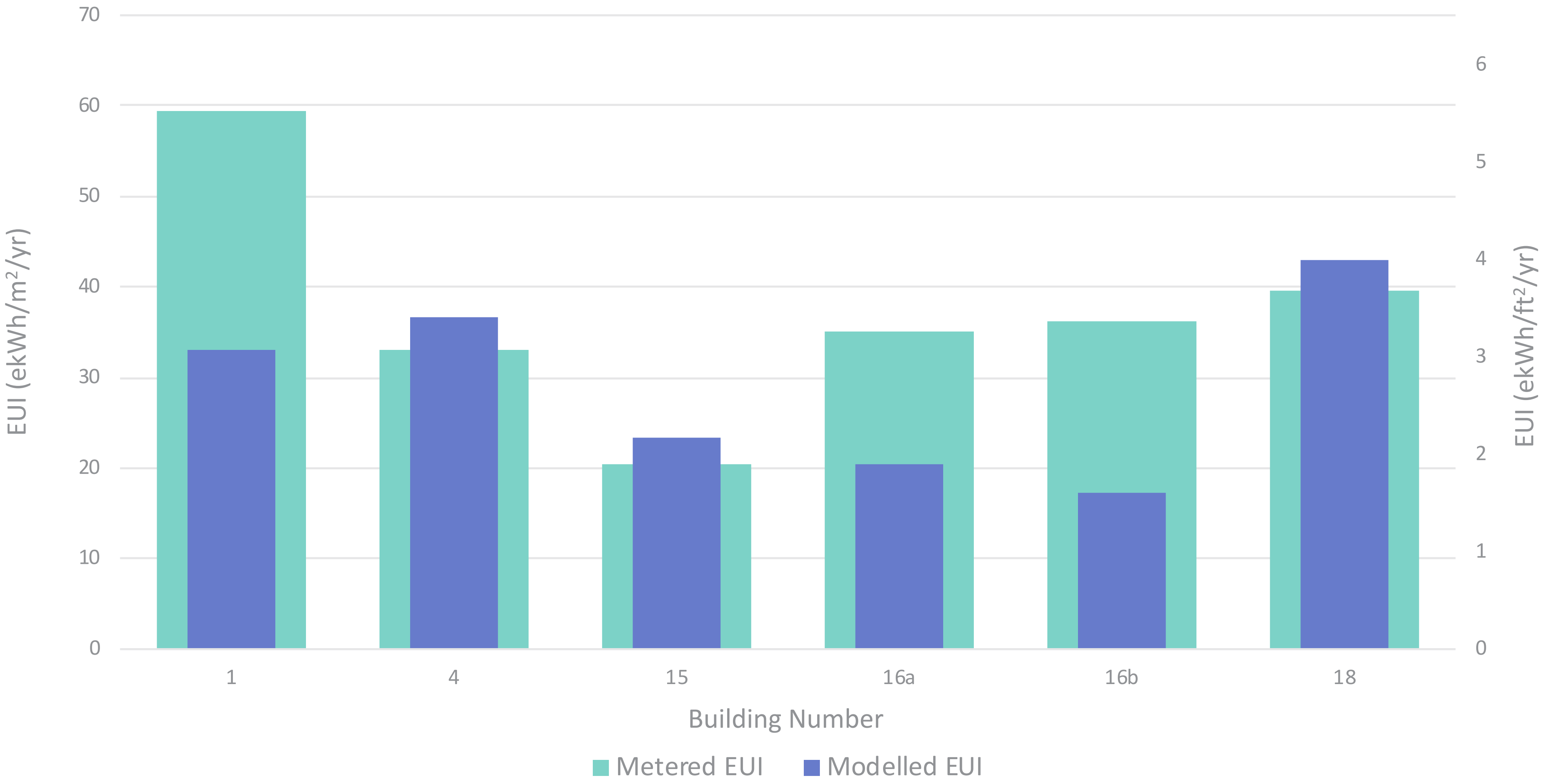
Air Tightness can be improved by requiring air tightness testing, as demonstrated in Seattle.

**Source: Air Leakage Control in Multi-Unit Residential Buildings – RDH Building Engineering Ltd.*
*** Source: Study of Part 3 Building Airtightness – RDH Building Science Inc.*
**** Source: Building Enclosure Airtightness Testing in Washington State – RDH Building Science Inc.*

MODELLED + METERED

PERFORMANCE GAP – DOMESTIC HOT WATER.

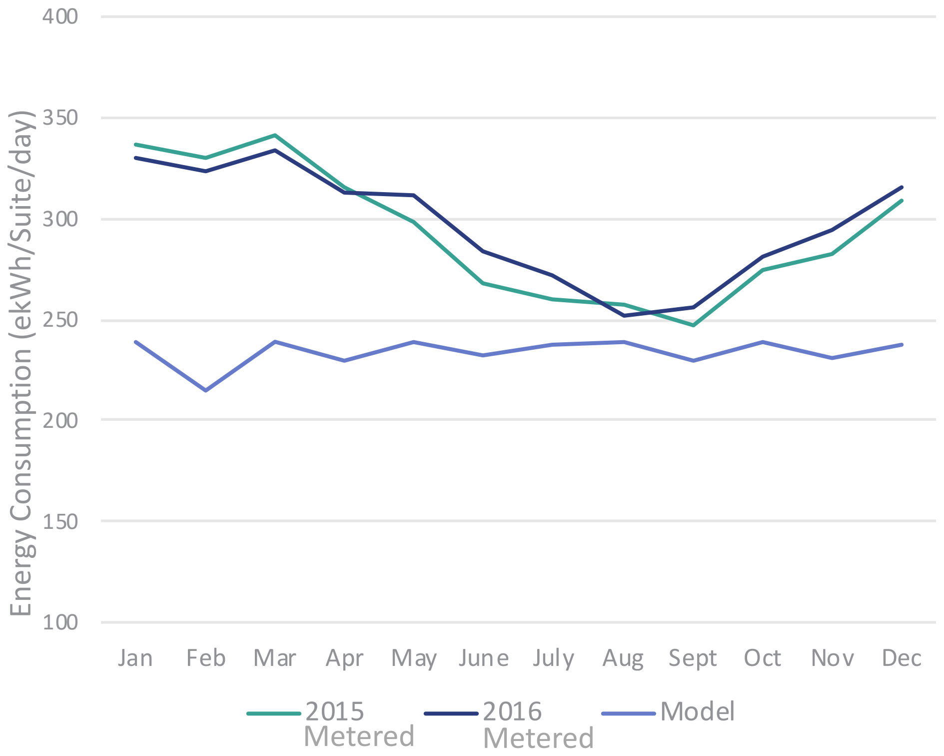
Modelled gas usage for domestic hot water production varied from 44% lower to 14% higher than metered performance, with a median of 21% lower

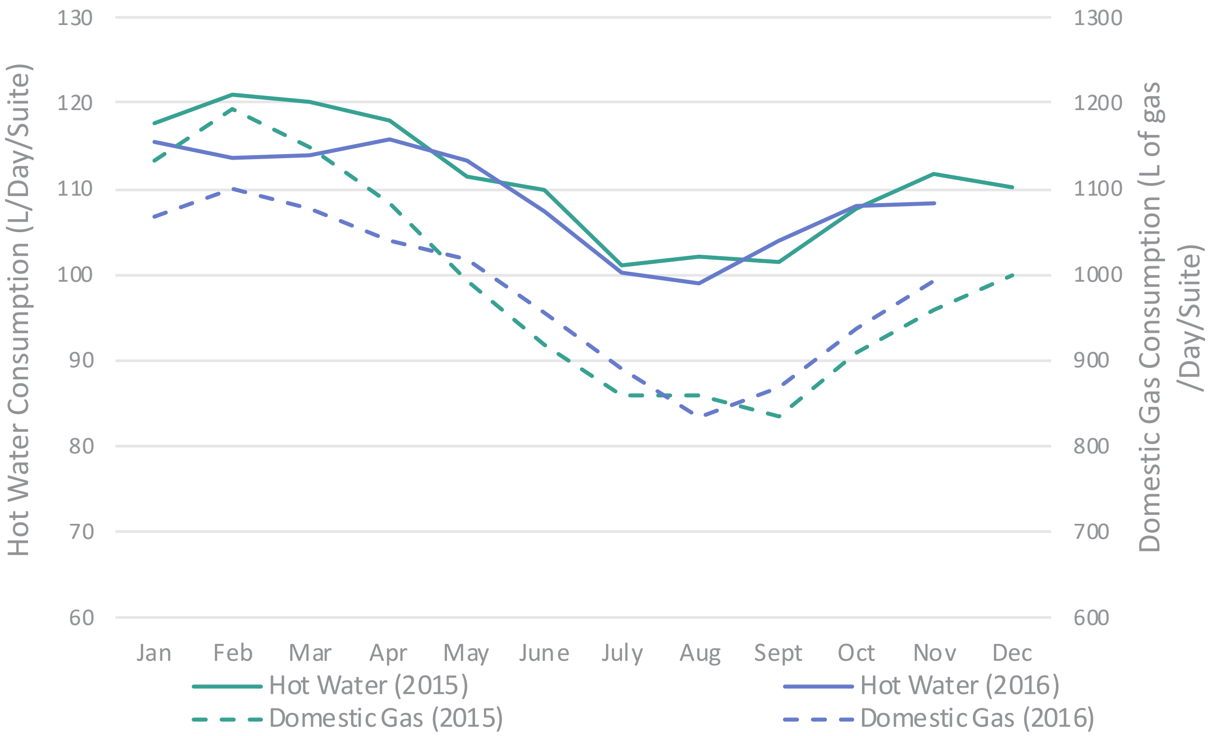


MODELLED + METERED

PERFORMANCE GAP – DOMESTIC HOT WATER.

Domestic hot water is a seasonal load - there is less energy consumption for domestic hot water in summer months

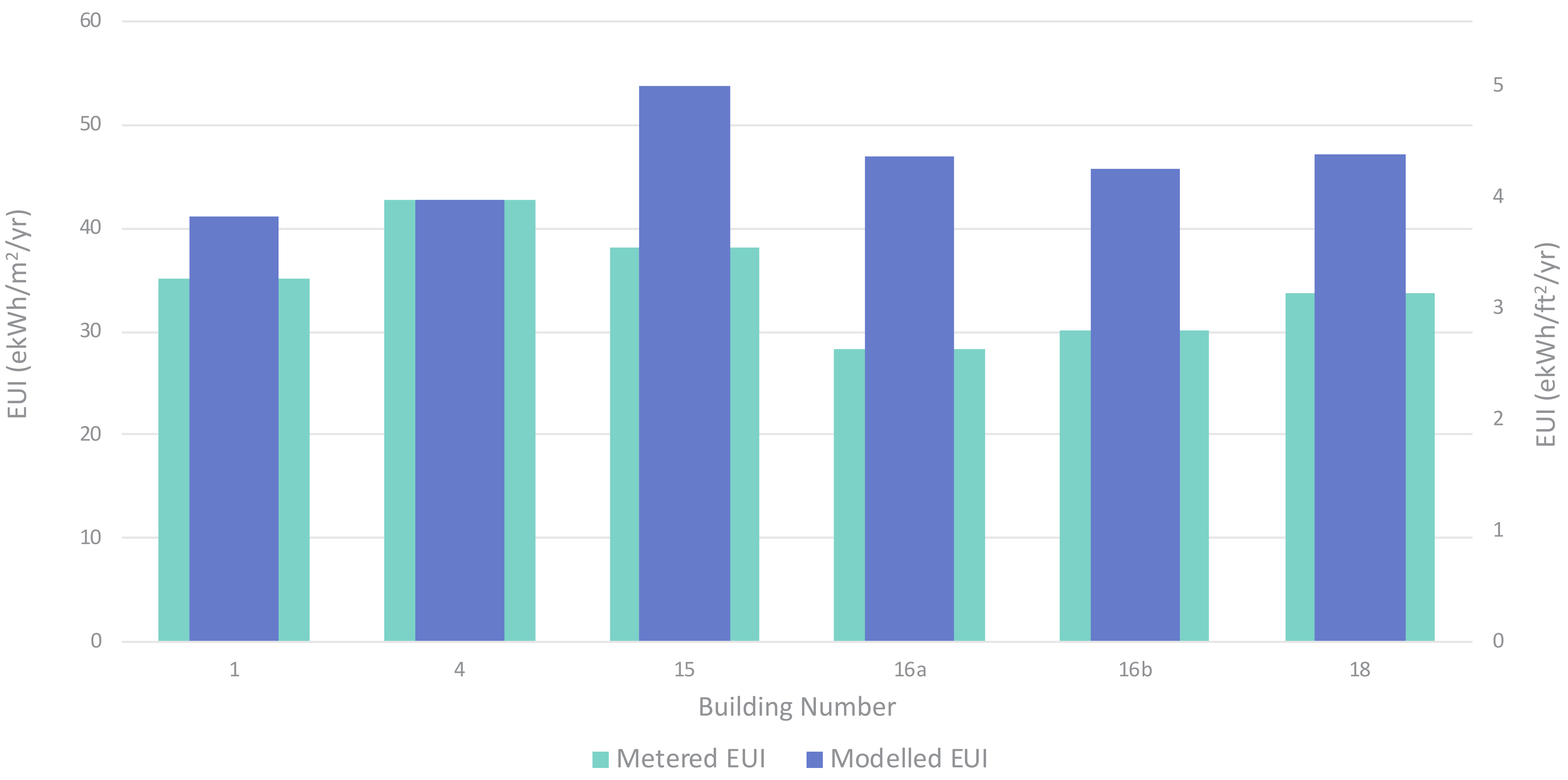




MODELLED + METERED

PERFORMANCE GAP – IN-SUITE ELECTRICITY.

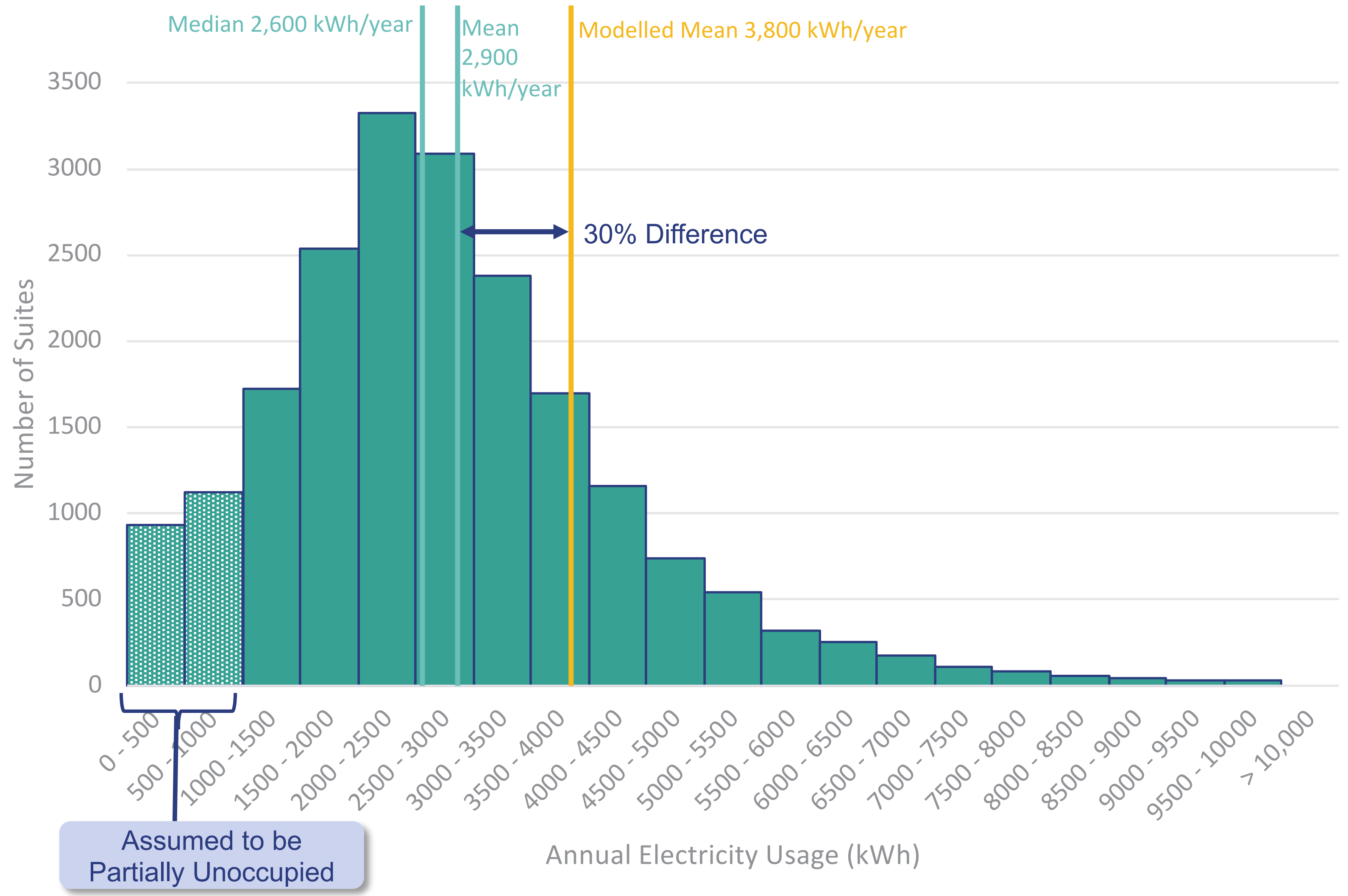
Modelled in-suite electricity usage is 26% higher than metered performance



MODELLED + METERED

IN-SUITE ELECTRICITY – AGGREGATE DATA.

Data pulled from 80 Toronto MURBs, constructed between 2000-2015, shows actual suite electricity is lower than modeled.



MODELLING PRACTICES

Models assume default power densities, expressed per area of floor space, and default usage schedules.

Current code requirements use default power densities from 1997.

MODELLED + METERED

PERFORMANCE GAP – COMMON AREA ELECTRICITY.

Modelled common area electricity usage is 94% lower than metered performance

COMMON AREA ELECTRICITY

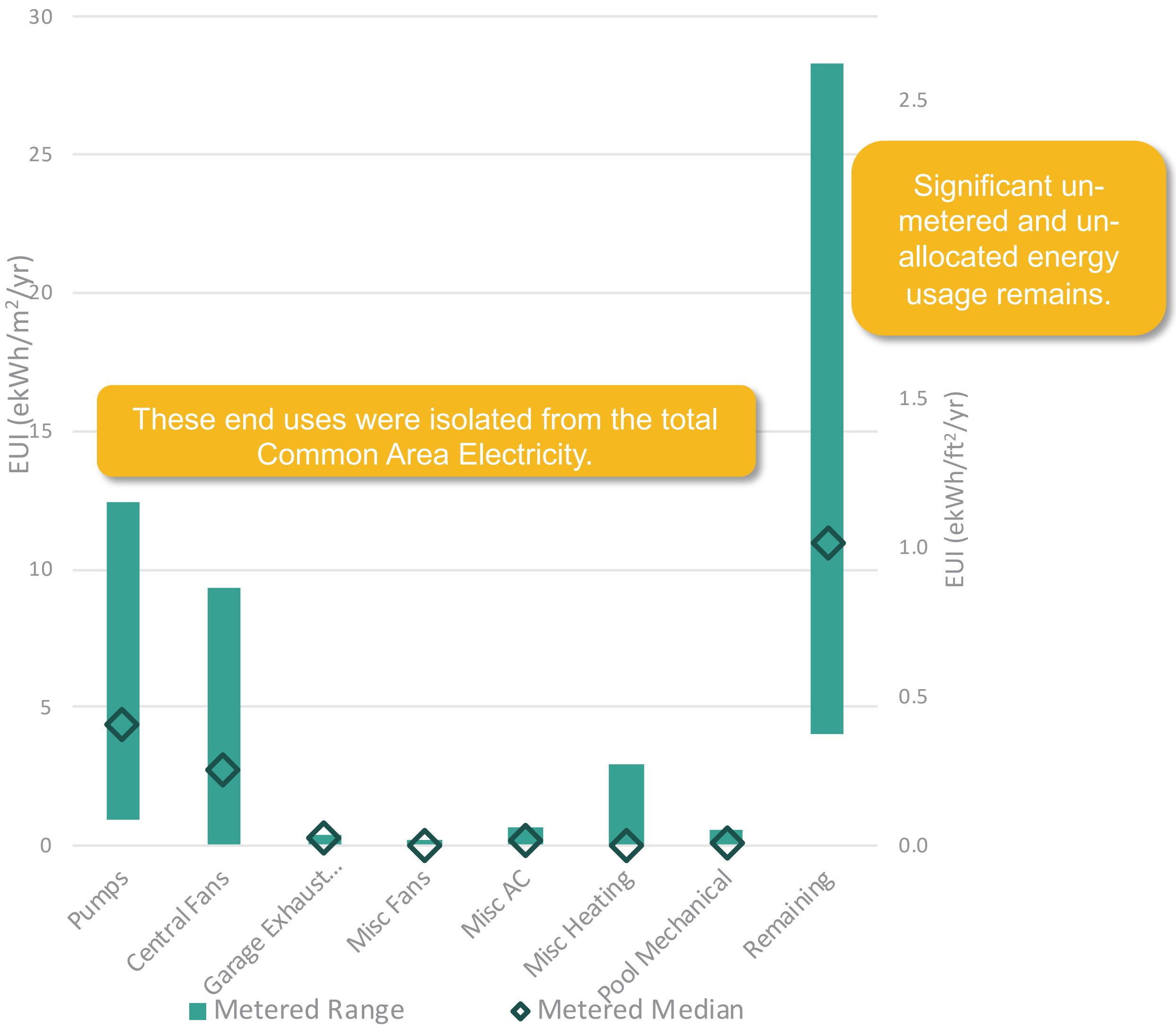
Common Area Electricity includes central plants, fans, lighting, and equipment loads.

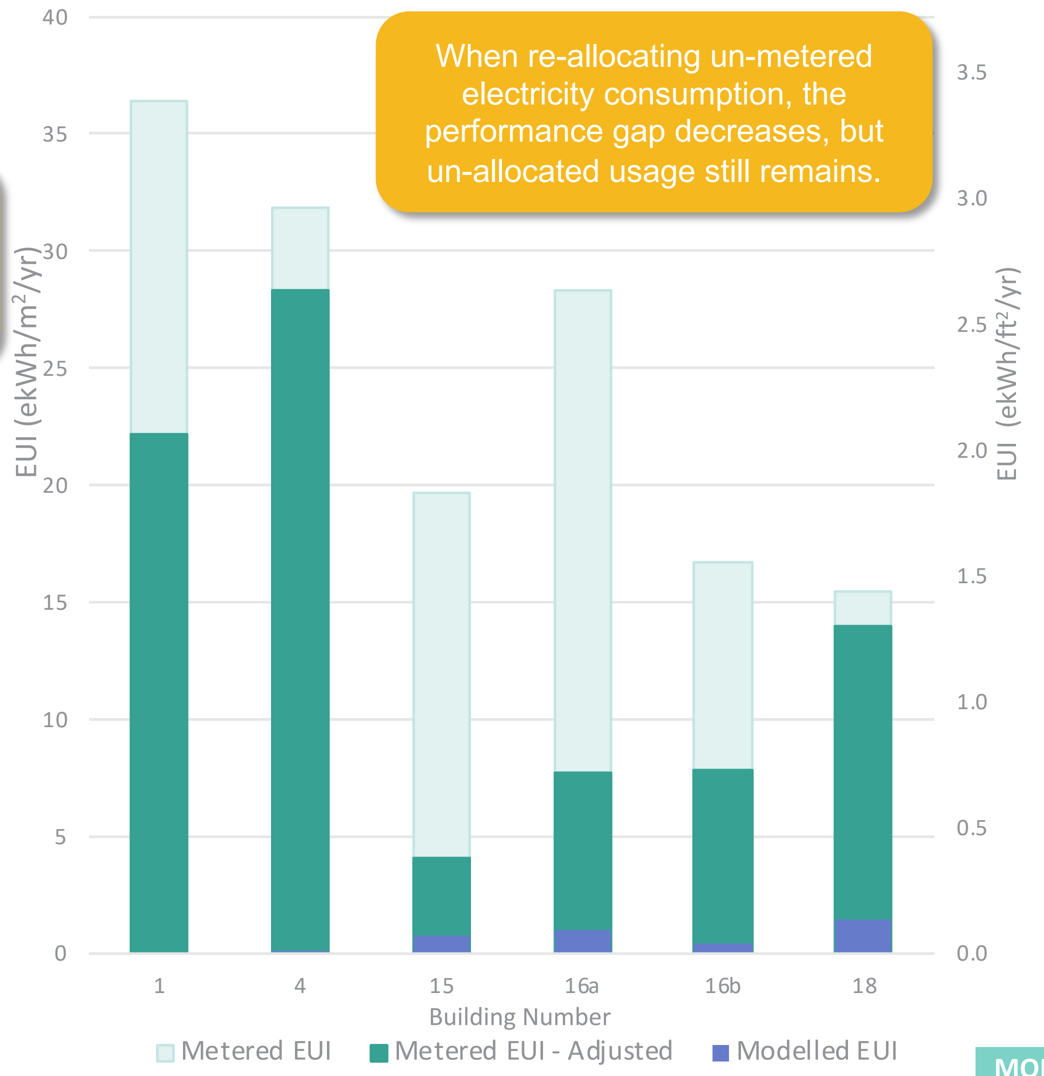
The buildings in this dataset were subject to either LEED v1.0 or the Toronto Green Standard v1.0, neither of which required accounting for common area electricity.

MODELLED + METERED

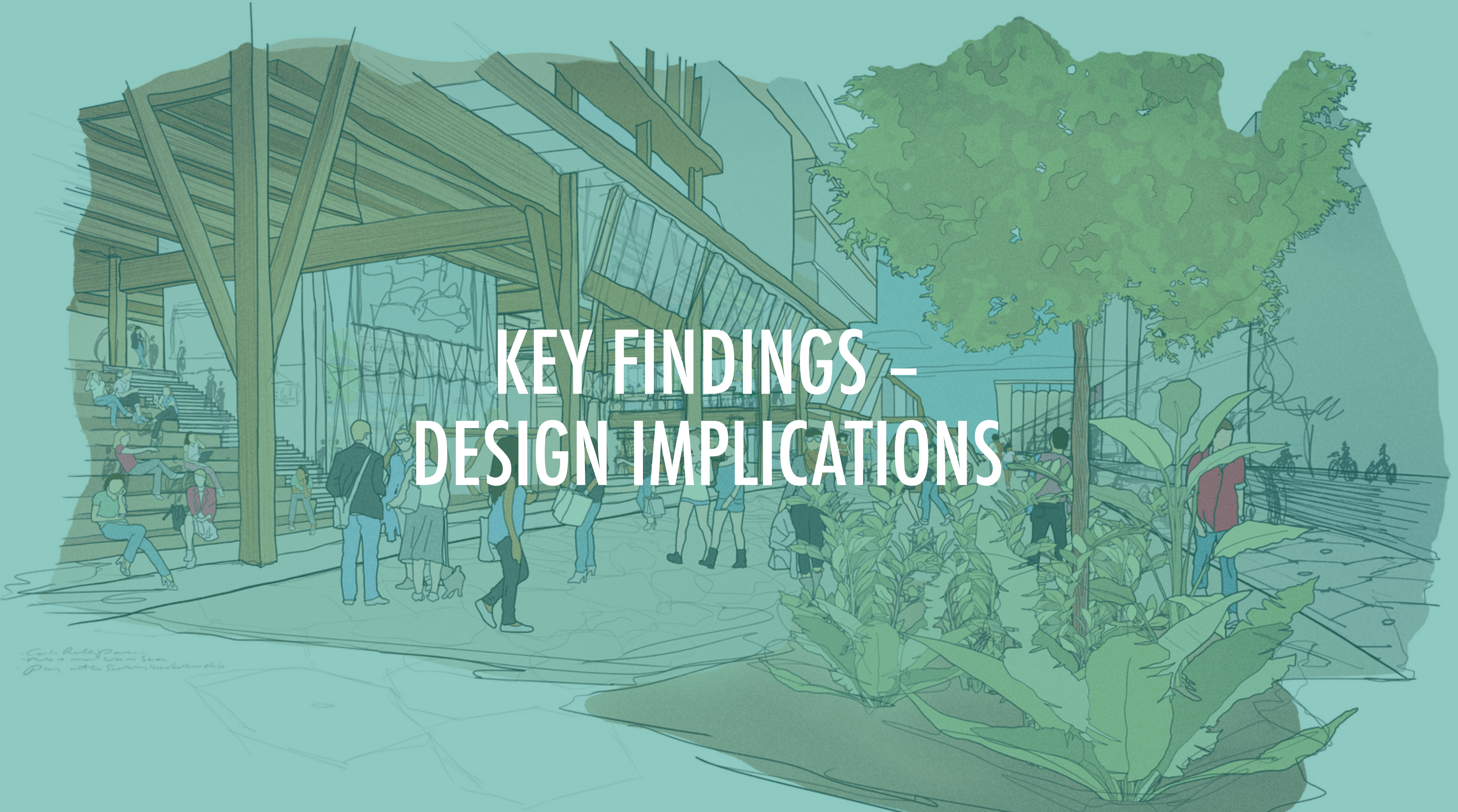
PERFORMANCE GAP – COMMON AREA ELECTRICITY.

Common area electricity re-allocation decreases the performance gap, but a gap still remains relative to model



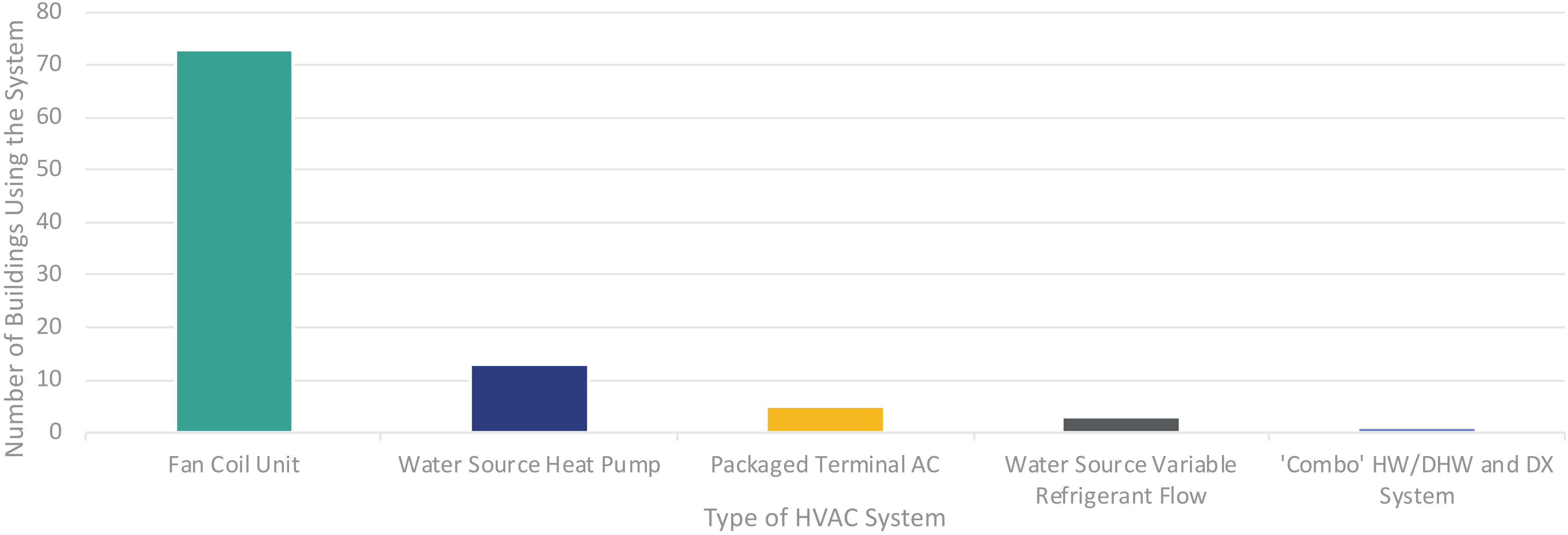


MODELLED + METERED



KEY FINDINGS – DESIGN IMPLICATIONS

COMMON HVAC SYSTEMS IDENTIFIED FROM 95 MURBS MODELLED IN TORONTO IN THE LAST TWO YEARS.



Heat Pump systems are assumed to be more efficient as they are ”electric” systems.

Fan Coil Unit Advantages

- In cooling mode, central chillers are able to achieve higher coefficients of performance than technologies like variable speed & magnetic bearing chillers
- In energy models, efficient Fan Coil Systems use less energy than water source heat pump systems

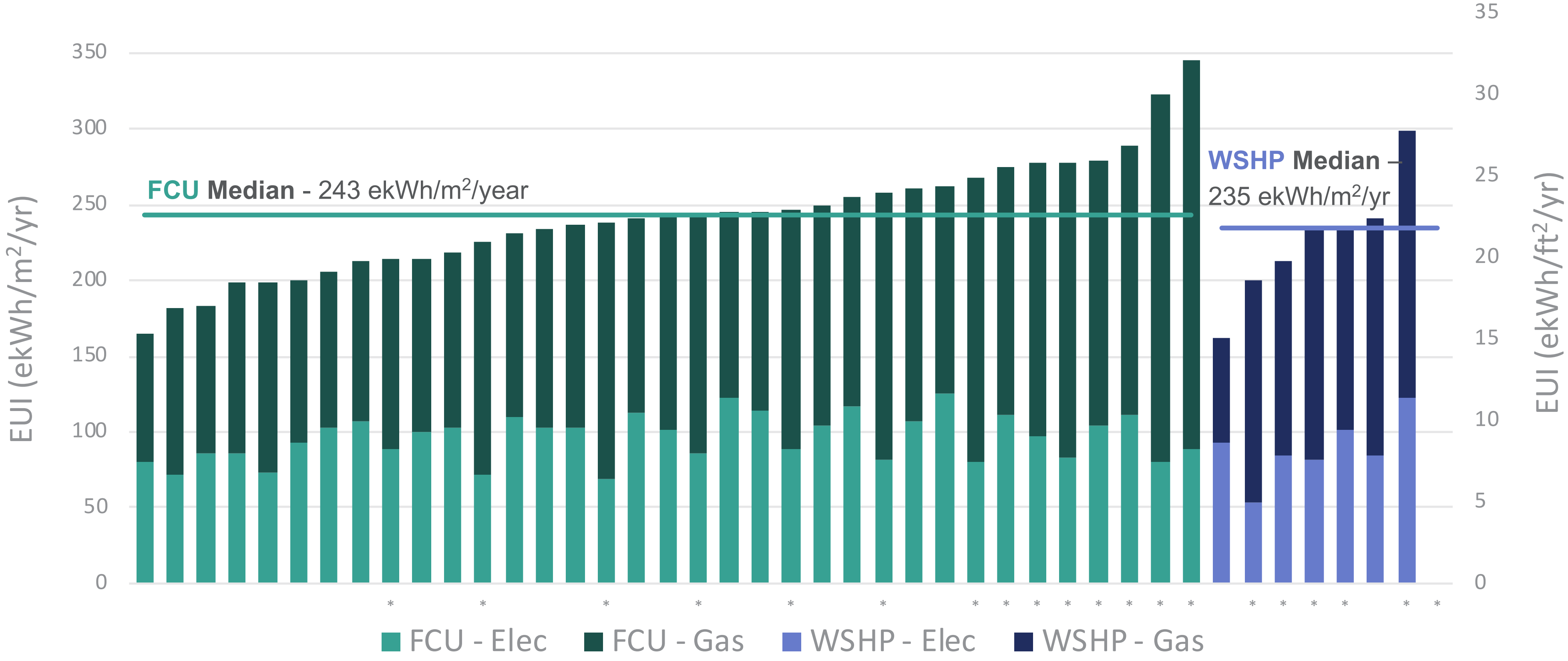
Heat Pump Advantages

- Allow for recovery of heat during periods of simultaneous heating and cooling
- Run a lower water loop temperature, allowing for lower return water temperatures, less piping losses, and higher efficiencies in condensing boilers
- Heating is commonly provided through electric compressors, which provides heat at higher efficiencies compared to hydronic heating systems
- In an energy model efficient heat pump systems use more energy than fan coil unit

MODELLED

METERED ENERGY USE INTENSITY OF BUILDINGS BUILT BETWEEN 1995 and 2015.

Metered energy use intensity performance of buildings with FCUs and WSHPs are relatively similar



FCU – Fan Coil Unit

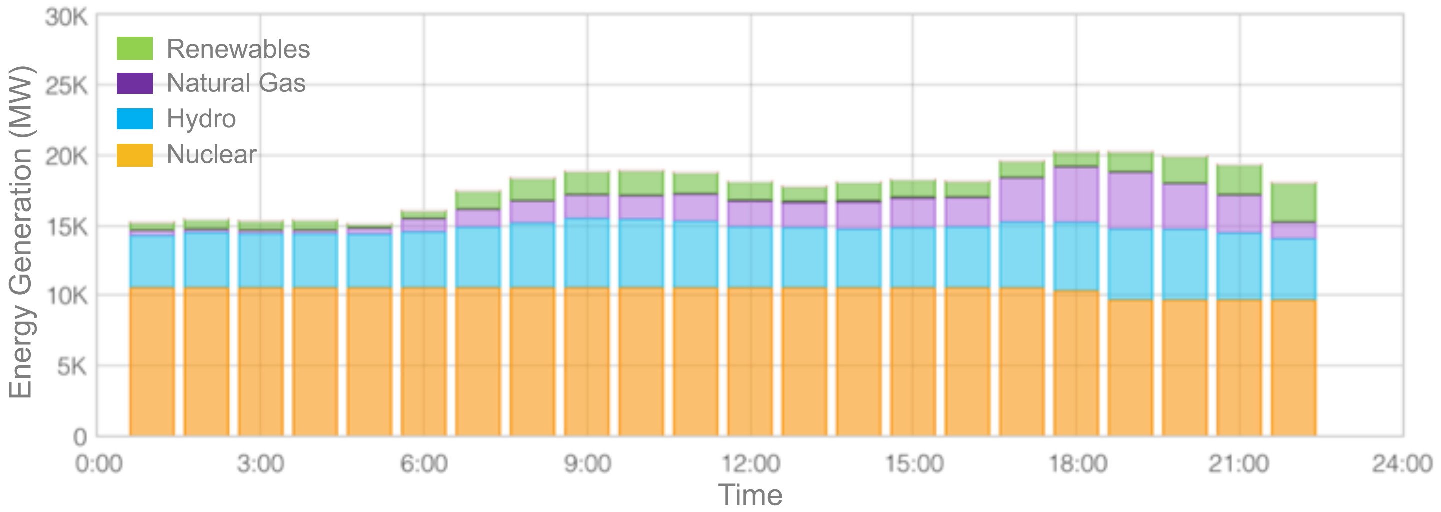
WSHP – Water Source Heat Pump

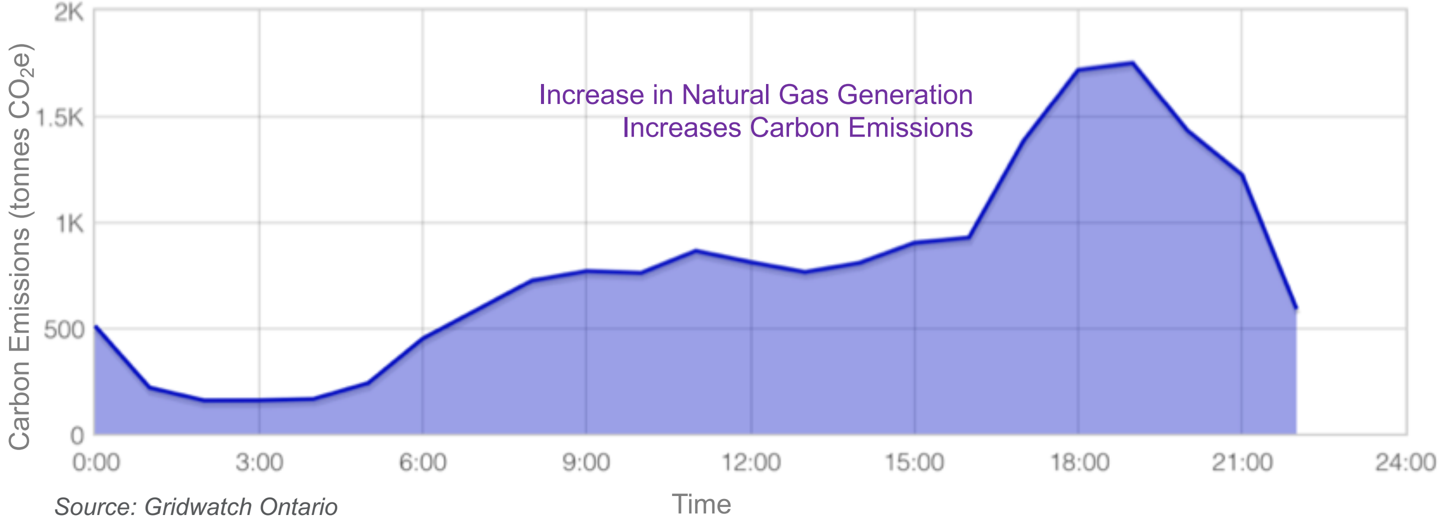
** Denotes a building where the Gross Floor Area was estimated*

METERED

CARBON EMISSIONS AND THE ONTARIO ELECTRICITY GRID.

Electricity grid greenhouse gas intensities vary over time due to marginal generation





Source: Gridwatch Ontario

Electricity in Ontario is generated by a mix of sources including **nuclear**, **hydro**, **renewables**, and **natural gas**. This mix is constantly varying, resulting in a unique carbon emission factor at every hour.

Fuel sources that are **on the margin** respond to peaks in electricity demand, engaged as needed. Because of their quick response time, **natural gas** plants are a common marginal fuel source in Ontario.

CARBON EMISSIONS AND THE ONTARIO ELECTRICITY GRID.

Electricity grid greenhouse gas intensities vary over time due to marginal generation

Electricity Grid Greenhouse Gas Intensity can be described in three ways:

1. Annual Average Ontario Grid Emissions:

- Most common method
- Current value**: 50 g CO2e/kWh**
- Per Ontario Building Code /Toronto Green Standard

***Unless otherwise stated, this report uses average grid emissions.**

2. Hourly Grid Emissions:

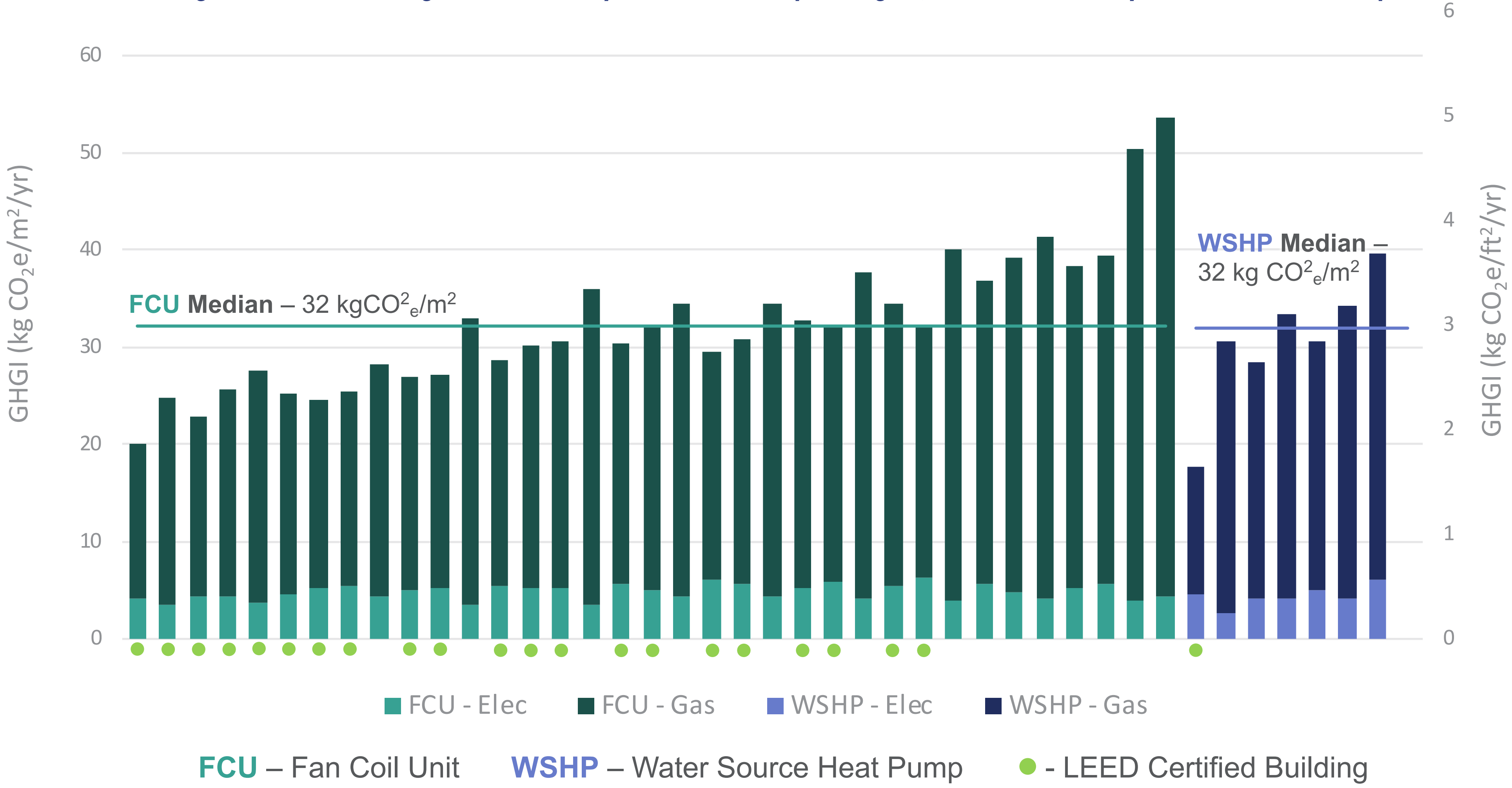
- Varies by hour
- May range from ~**2 to ~145 g CO_2e/kWh**

3. Hourly Grid Marginal Factor:

- Varies by hour
- May range from **68.7 to 247.1 g CO_2e/kWh**
- Reflecting avoidance of fuel that is '**on the margin**'

GREENHOUSE GAS INTENSITIES PER METERED DATA FROM BUILDINGS BUILT BETWEEN 1995 AND 2015.

While WSHPs are considered "electric" systems, the buildings in this dataset with WSHPs used as much gas as the buildings with FCUs. When evaluated using the annual average GHG-intensity values for the power grid, the GHG-intensity of the WSHP was equal to that of the FCU buildings

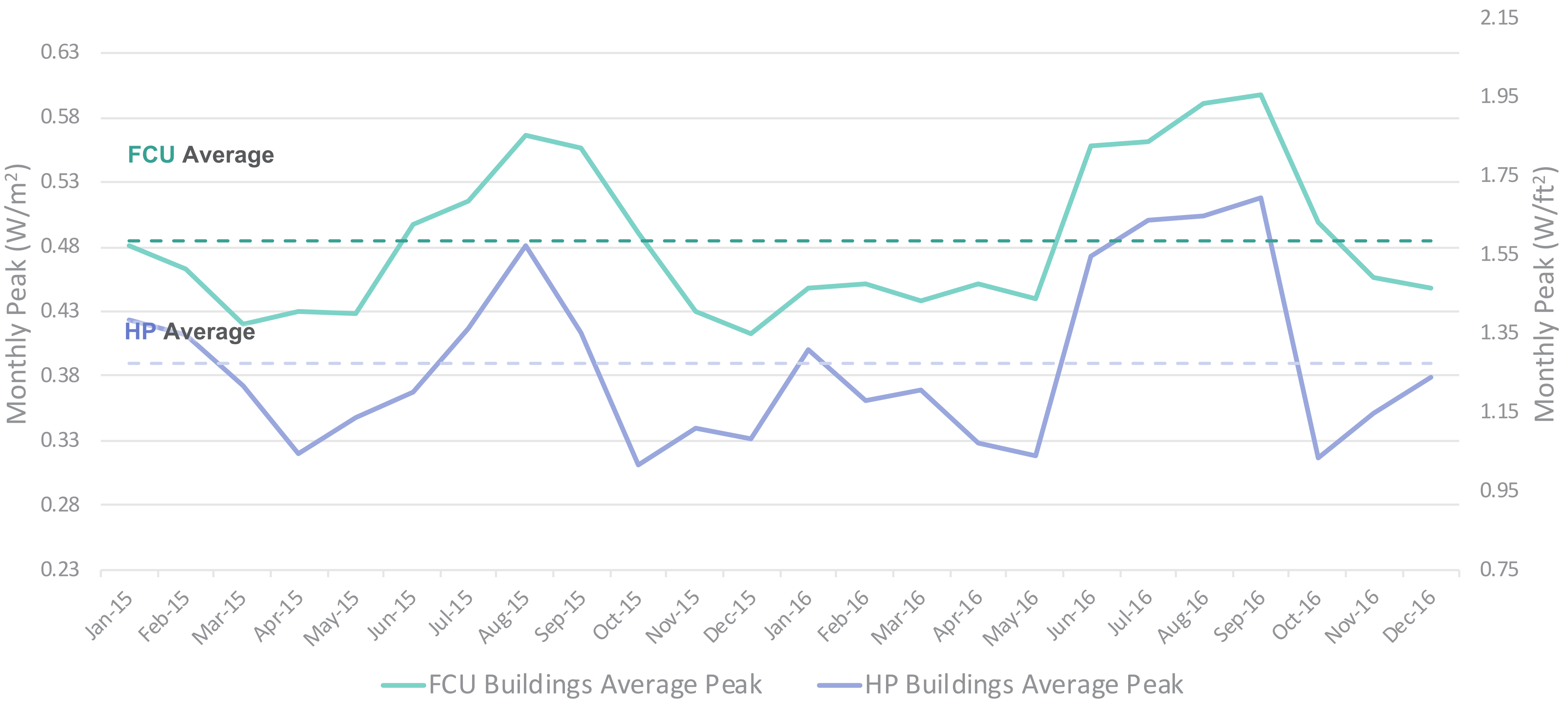


When further normalized for age, the WSHP buildings generated only 11% less GHG emissions.

METERED

WHOLE BUILDING PEAK ELECTRICITY USAGE.

Interestingly, WSHP buildings in the dataset showed a lower peak electricity usage than FCU buildings – For this reason, an FCU building would have higher GHG emissions if the marginal GHG factor was used for calculations

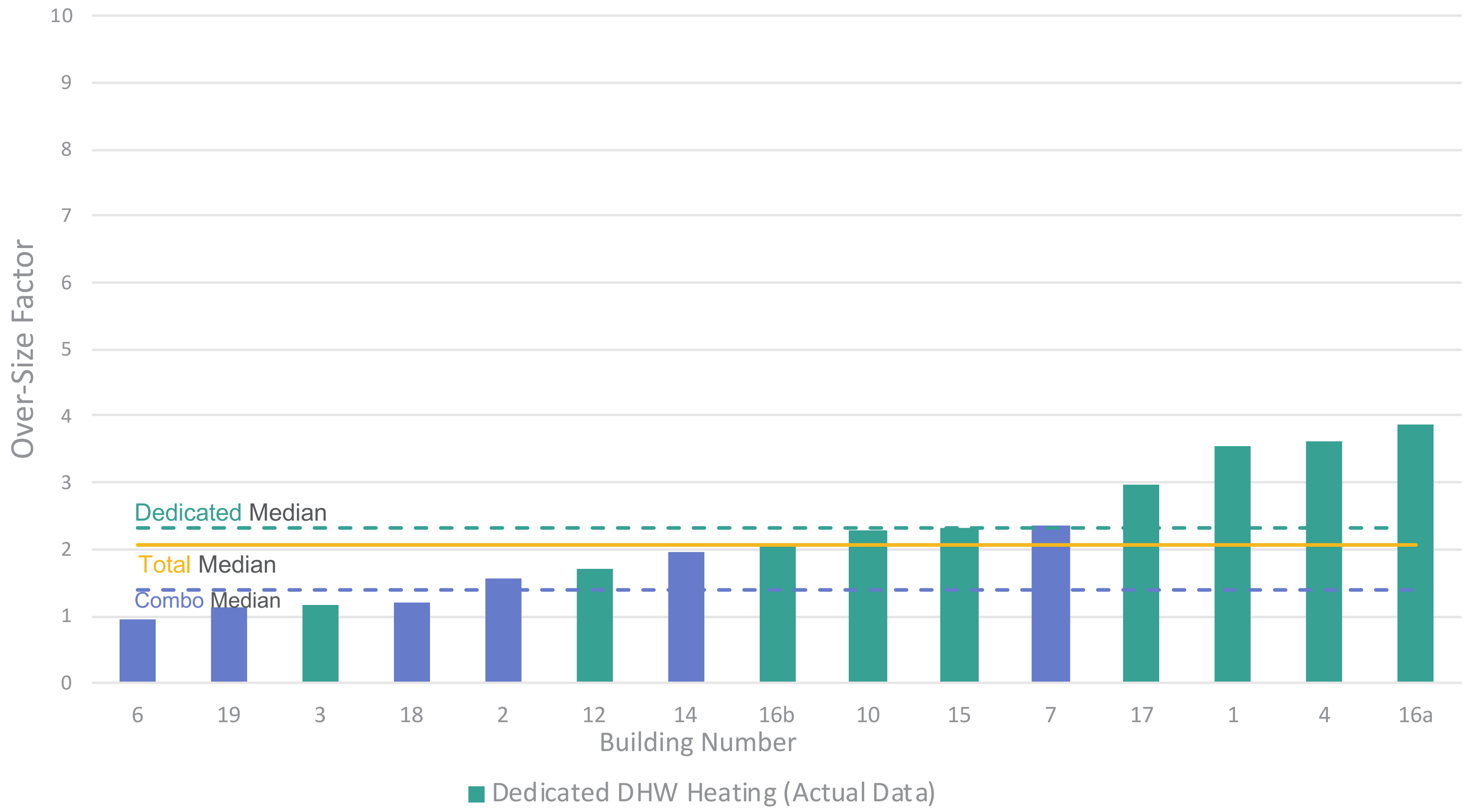


METERED

ADDITIONAL FINDINGS

IN 15 BUILDINGS WITH METERED DOMESTIC HOT WATER BOILERS, COMBINED HEATING SYSTEMS WERE MORE APPROPRIATELY SIZED THAN DEDICATED SYSTEMS.

No consistency was identified in how either system is sized by designers



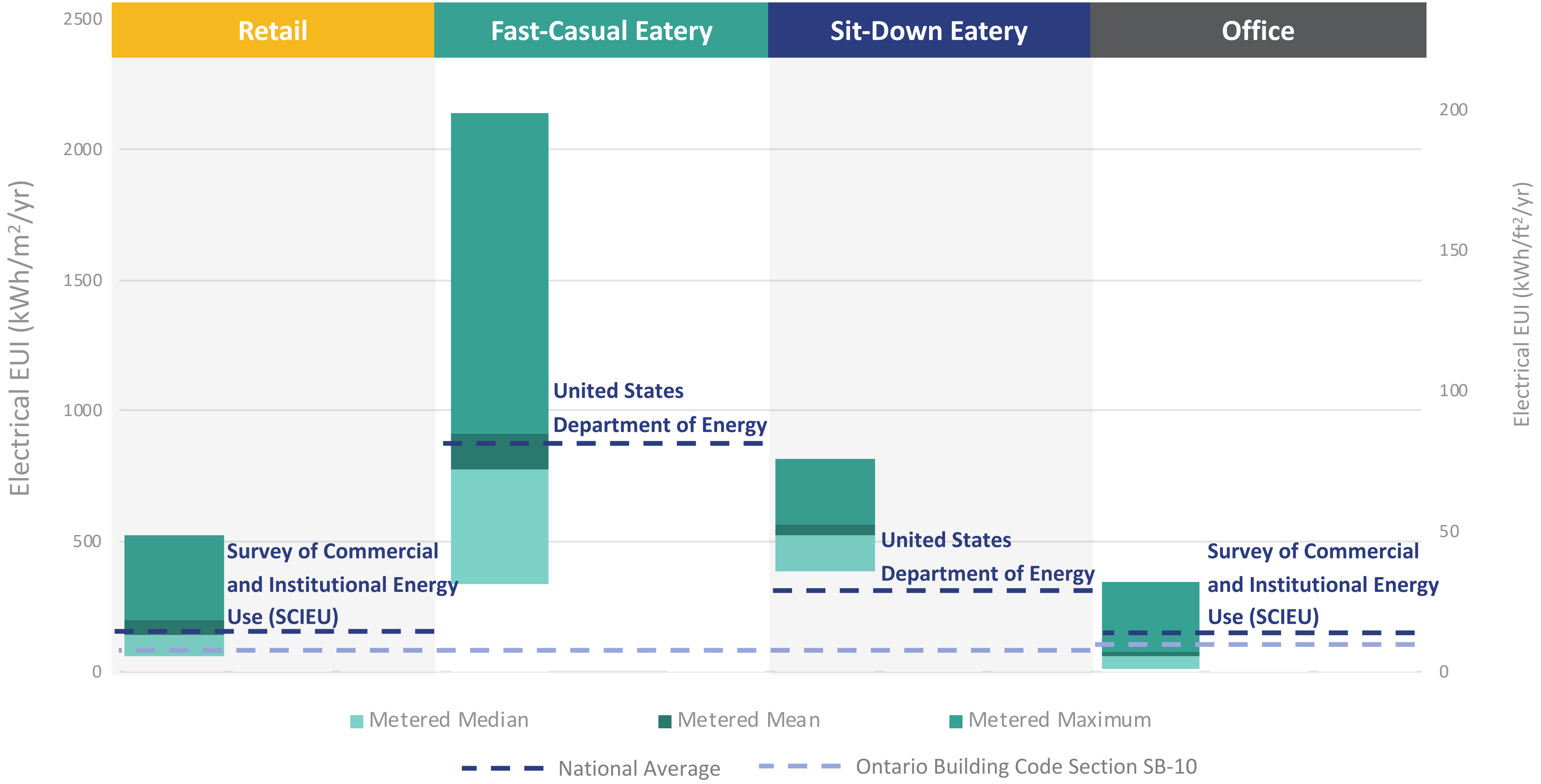
COMBINED HEATING

Combined heating systems are used for both space heating and domestic hot water.

METERED

NON-RESIDENTIAL TENANT ELECTRICITY USAGE.

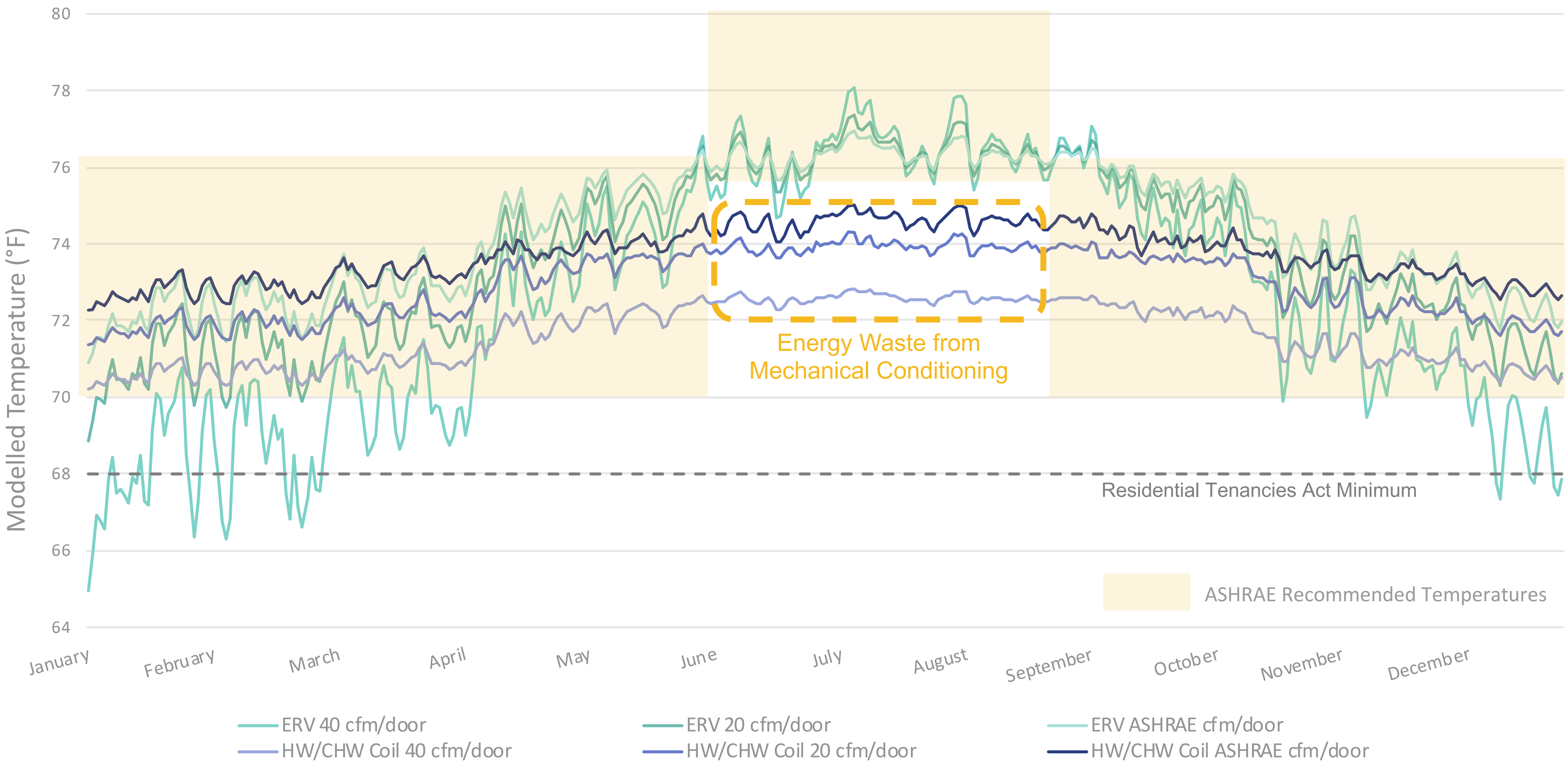
Actual metered energy consumption for retail and commercial tenants varied by as much as 500%, all greatly exceeding the assumptions provided by the Ontario Building Code SB-10 – The averages from national databases of metered data were more in line and thus better assumptions to use in energy modelling



METERED

CORRIDOR CONDITIONING.

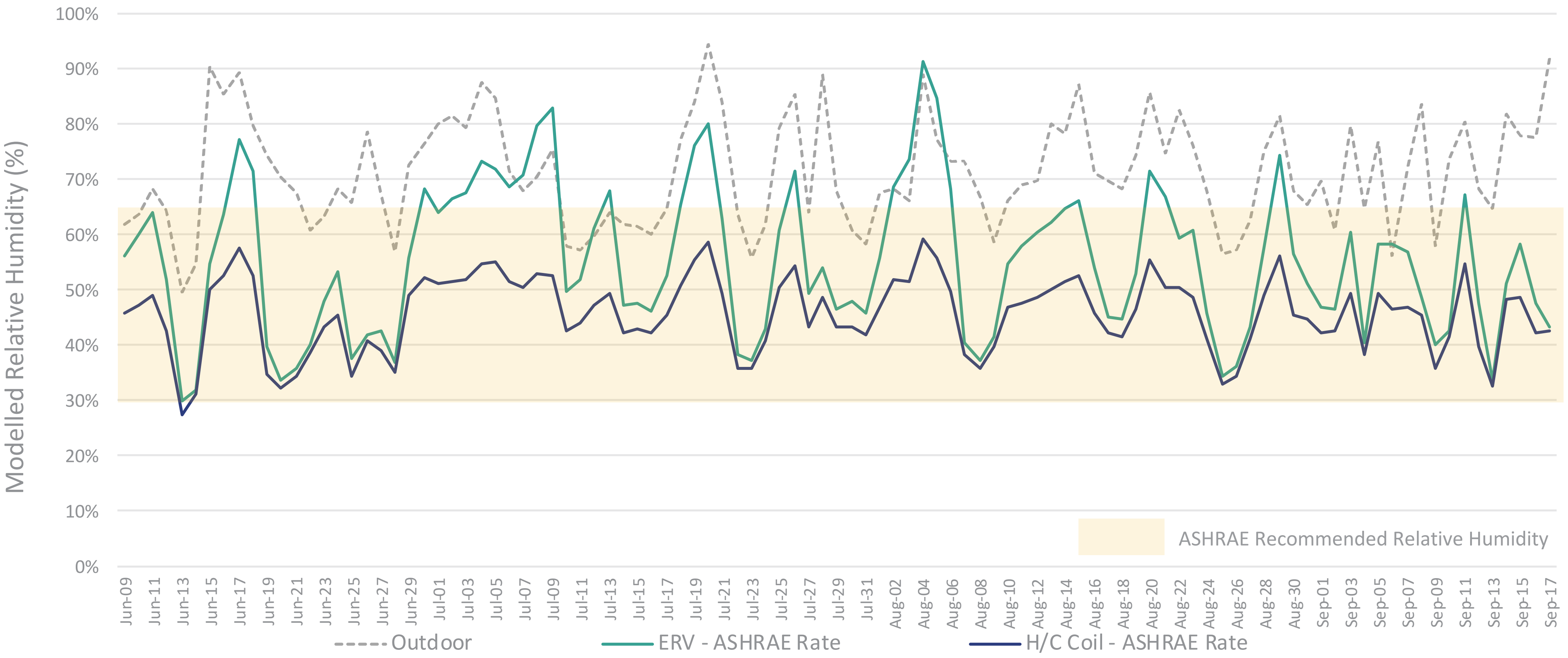
Depending on design conditions and humidity, a central Energy Recovery Ventilator (ERV) can be used in lieu of mechanical conditioning through hot and chilled water coils



MODELLED

CORRIDOR CONDITIONING – EFFECTS ON RELATIVE HUMIDITY.

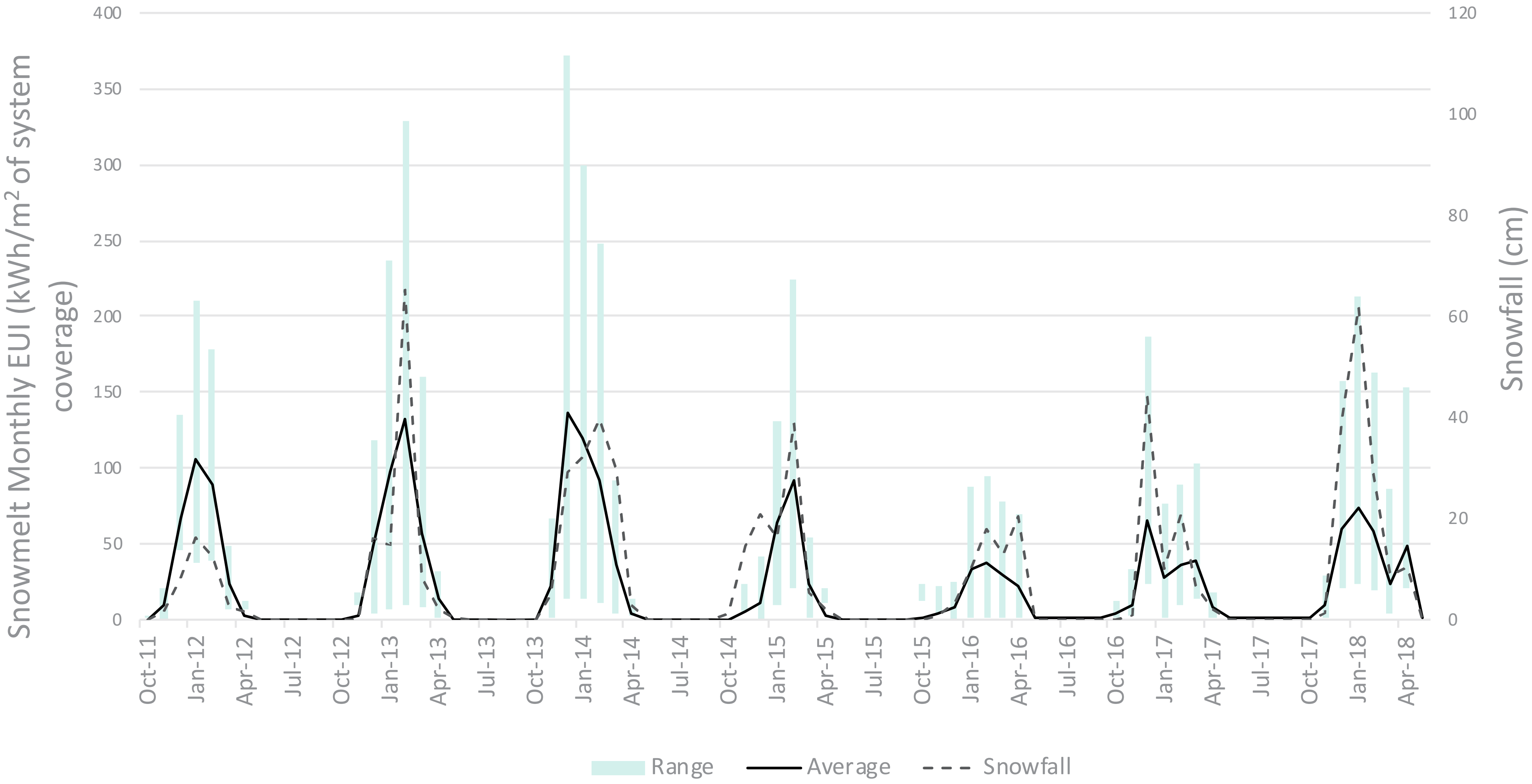
Additional strategies to remove relative humidity from the air stream may be needed to avoid condensation build up during peak periods



MODELLED

SNOW MELT SYSTEMS.

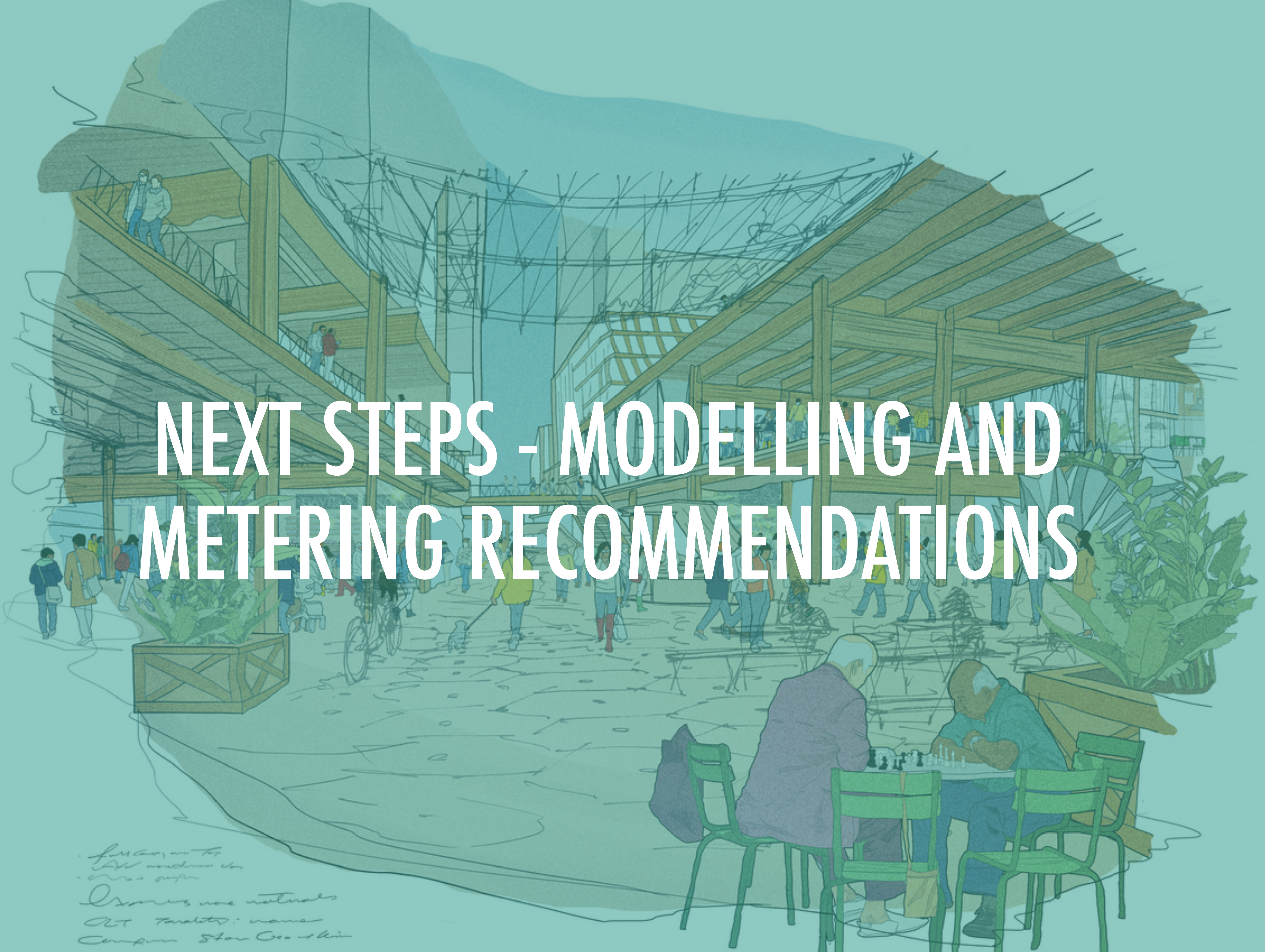
Sub-metered snow melting systems demonstrated a wide range of annual energy use – electric systems use sensors in order to activate heating, thus showing a correlation between energy use and snowfall



In General, most MURBs in the Greater Toronto Area have some sort of snow melt system, primarily at parking ramps.

METERED

NEXT STEPS - MODELLING AND METERING RECOMMENDATIONS



MODELLING RECOMMENDATIONS.

How to start closing the performance gap with updated modeling strategies

Seasonal Gas

- Model more accurate envelope performance using the BC Hydro Building Envelope Thermal Bridging Guide
- Require energy model submissions to document assumptions and calculations as part of the review process
- Require whole building air tightness testing for all developments (TGS version 3 requires Whole Building Air Tightness testing for Tier 2 - 4)
  - Update energy model submissions to reflect whole building air tightness testing results for post occupancy model calibration
  - Assume a higher default infiltration rate at the design stage until whole building air tightness testing results are available

Domestic Hot Water

- Account for seasonal changes in incoming cold water temperatures rather than assuming a constant, year-round value
- Model domestic hot water as a seasonal load, with usage schedules reflecting greater consumption in the winter, and a decrease in consumption in the summer

MODELLING RECOMMENDATIONS.

How to start closing the performance gap with updated modeling strategies

Suite Electricity

- Update in-suite lighting and plug load power densities to more closely reflect the findings of this study (Metered mean value of 2,900 kWh/suite per year)

Common Area Electricity

- Increase typical common area baseload power densities by at least 20%
- Identify likely retail tenant type as early in the design stage as possible
- Model typical power densities for retail tenants based upon national database values instead of the Ontario Building Code for more accurate predictions

METERING RECOMMENDATIONS.

How to start better aligning models and actual building data through increased energy metering

Domestic Hot Water

- In order to determine efficiency of the domestic plant, submeter domestic hot water gas consumption, either directly via a gas meter or indirectly via a thermal meter, and submeter both cold and hot water use in-suite in order to track total water consumption and relate to energy usage

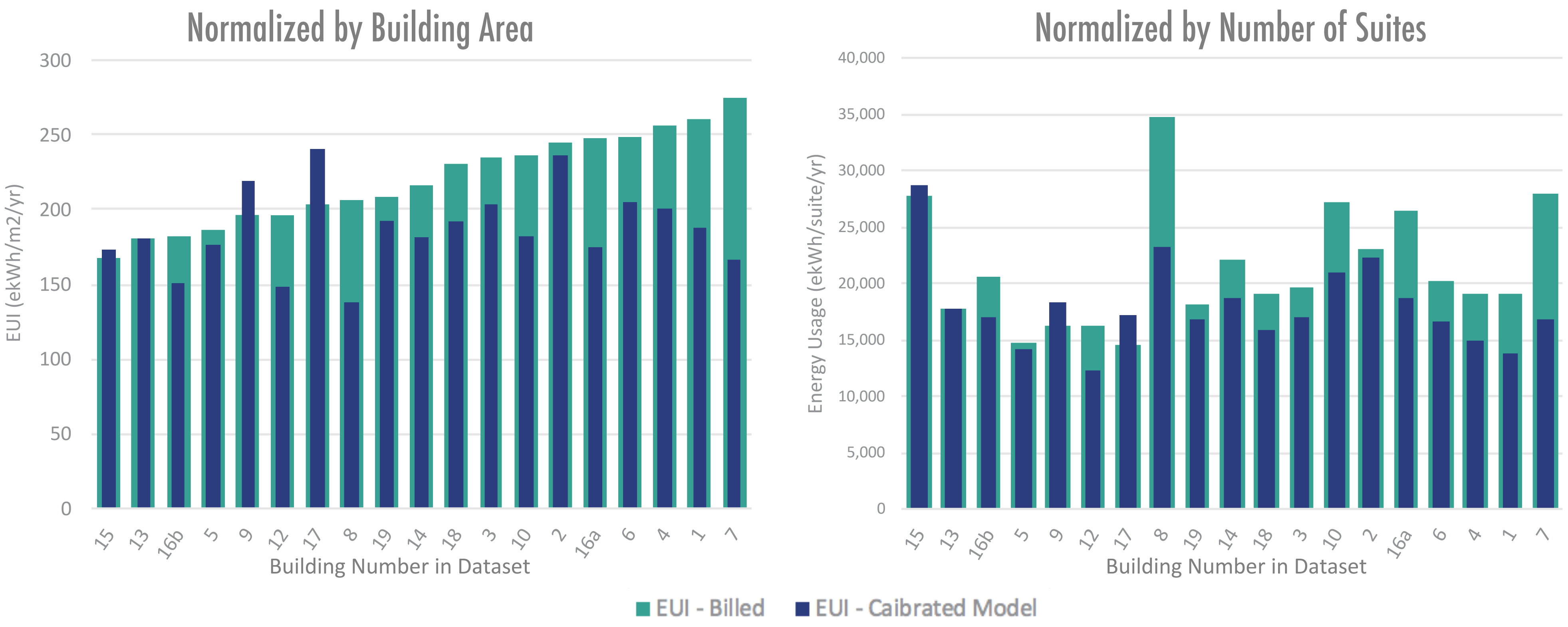
Common Area Electricity

- In order to calibrate meters to models, submeter all major common area end uses in such a way that all major pumps, fans, amenities, heating, and cooling equipment can be isolated

- To hold tenants accountable for energy use, submeter all non-residential tenants for electricity use to compare to national averages/estimates - consider submetering for water, natural gas, and thermal energy use as well, as appropriate for the space function

NEXT STEPS – CONSIDER REFINING NORMALIZATION AND BENCHMARKING FOR MURBS.

Energy use normalized by area, the metric used in this study, is the most commonly used metric for MURBs due to lack of data available (such normalizing by number of suites and occupancy) - Accounting for additional normalization data changes results



Building 15, the top performer when normalized by Building Area, became the second worst performer when normalized by number of suites.

Natural Resources Canada is currently conducting a national survey of energy usage for MURBs in order to develop Energy Star scores and proper benchmarking methods for this building type, which may include additional normalization methods.

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