



SIDEWALK LABS TORONTO MULTI- UNIT RESIDENTIAL BUILDINGS STUDY:

ENERGY USE AND THE PERFORMANCE GAP

January 16, 2019

Commissioned by:

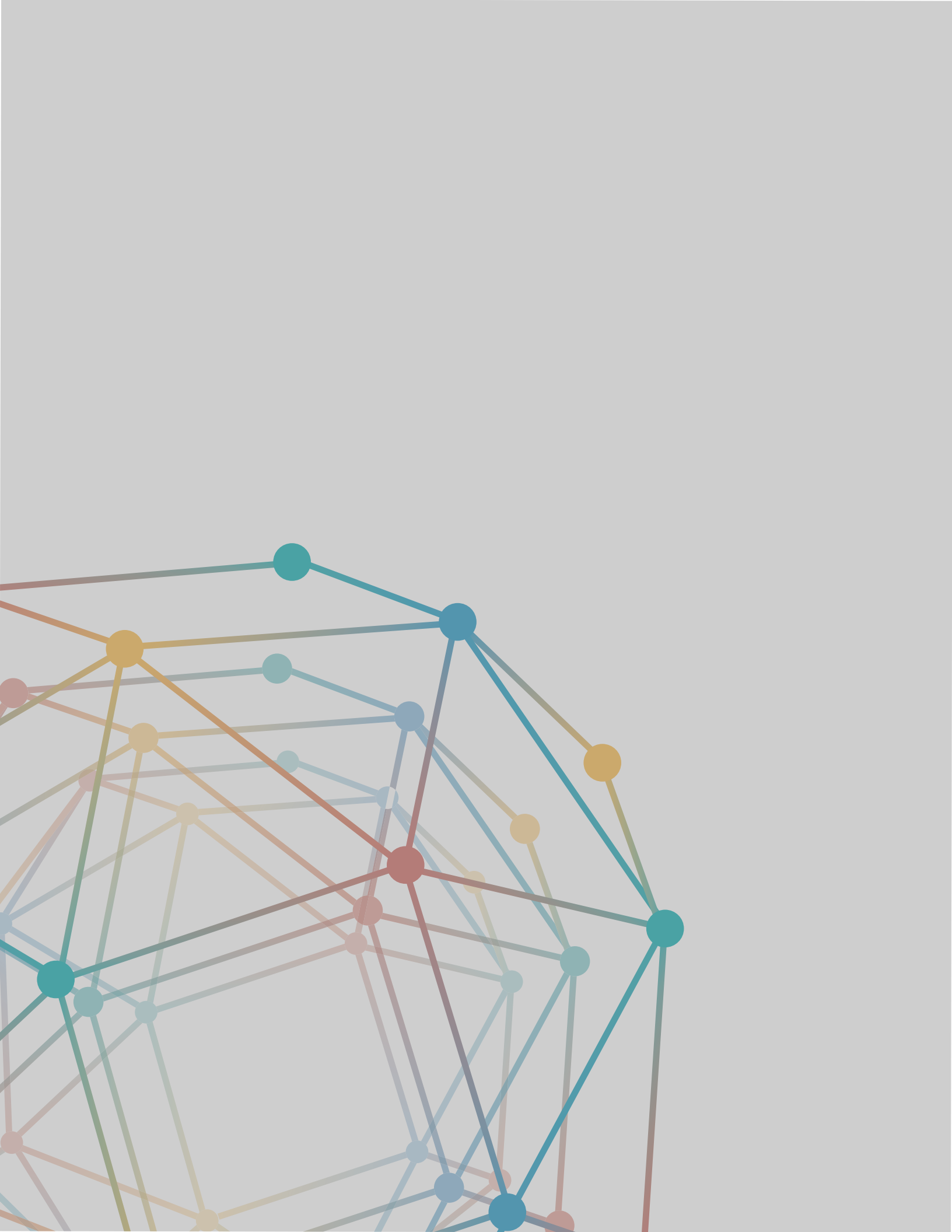
SIDE WALK LABS

Prepared by:



**BUILDING
PERFORMANCE**

**URBAN
EQUATION**



Executive Summary

Sidewalks Toronto: Looking for Energy Efficiency

In February 2018, Sidewalk Labs Toronto engaged EQ Building Performance and Urban Equation to investigate how multi-unit residential buildings (MURBs) in Toronto use energy.

In particular, Sidewalk Toronto wanted to understand how energy models differ from actual building energy performance, and how current energy modelling practices contribute to setting realistic building energy performance targets. Ultimately, Sidewalk Toronto is looking for ways to create people-centred neighbourhoods that achieve precedent-setting levels of sustainability, affordability, mobility, and economic opportunity.

For this study, EQ Building Performance and Urban Equation had unprecedented access to six major MURB datasets of modelled and metered energy readings as well industry standards and guidelines. By analyzing this data at various levels, the team was able to determine the performance gap – *the difference between a building's actual energy usage and the energy model prediction*.

This report is a special collaboration between EQ Building Performance, Urban Equation, and Sidewalk Labs, born by a shared understanding of the lack of available data and studies completed on the topic. Sidewalk Labs helped guide the topics of study and utilizes the report for widespread interest and applicability. The findings were individually studied and represented by the consulting firms.

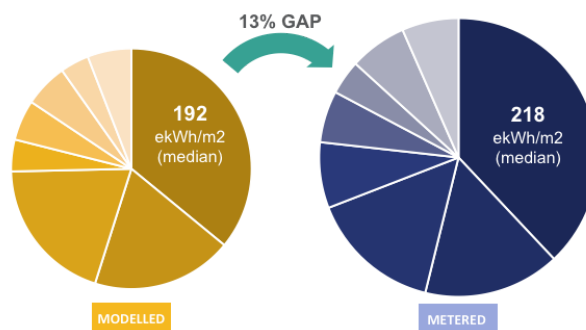
Unlocking the Data: Six Datasets

1. **Design Models** – Data from energy models for 95 Greater Toronto Area (GTA) MURBS completed between 2015-2017
2. **Suite** – Sub-metered electricity and gas readings for approximately 20,000 suites in 83 buildings constructed between 2000-2015
3. **Utility** – Metered readings for whole building monthly energy usage, both gas and electricity, for 43 buildings constructed between 1995-2015
4. **Combined Modelled & Metered** – Metered readings for whole building monthly energy usage, and as-constructed energy models for 19 buildings, all LEED-certified
5. **End Use** – Extensive plant and end use metered readings and detailed energy models for 6 buildings
6. **Public** – Mix of public metered and measured data, as well as performance targets

Detailed information on the datasets and the purpose of each can be found at Section 2 of the report.

Key Findings

- Only 5% of MURBs analyzed, that are in either design and construction, would meet the Toronto Green Standard version 3 Tier 1.
- There is no clearly identified improvement in the energy efficiency of the MURBs analysed, since 1998.
- The overall greenhouse gas emissions performance gap is 28% while the energy use performance gap is 13%. Both are based on comparing metered energy use and greenhouse gas emission intensities (EUI and GHGI) against the calibrated models for 19 MURBs with both modelled and metered data.
 - This is supported by larger datasets: the average EUI of 83 existing buildings (age 1998-2017) was 12.5% higher than average EUI of 95 models (2015-2017).
- This 13% energy use gap, which is less than many would expect, hid much larger performance gaps when looking at energy end uses:
 - Four end uses represent 75% of the total building energy usage: space heating, suite electricity, domestic hot water and common area electricity.
 - Space heating was 39% higher in metered data than models, also representing the single largest end use. This energy is entirely supplied by natural gas.
 - Domestic hot water was 21% higher in metered data than models, also entirely supplied by natural gas.
 - There was a staggering 94% gap for common area electricity. It was found that these loads were not required to be included in the energy modeling standards in effect during the time these buildings were modeled, despite being the fourth largest energy usage.
 - Metered data was higher than the modelled predictions in most cases except in-suite electricity usage, where models over-predicted energy usage by 26%.
 - This is largely due to code requiring modelers to use plug load assumptions that date back to 1997.
 - Cooling only contributed to 4% of the building's total energy usage, and metered data was 26% lower than modelled.
- The energy performance comparison of buildings changes significantly when buildings are normalized by number of suites rather than floor area.



Additional Findings: Implications for Design

1. Infiltration rates used in modeling are basically equivalent to Passive House and actual measured values are about twice as high. Requiring infiltration testing post construction shows significant improvement in infiltration rates.
2. Accounting for thermal bridging impacts reduced thermal effectiveness (R-values) by 73%, when modeled using the new BC Hydro Building Envelope Thermal Bridging Guide.
3. DHW usage is seasonal, with more consumption in winter months than summer. The efficiency of the system also declines in winter.
4. Despite being considered “electric” systems, Water Source Heat Pump buildings use about as much gas as Fan Coil Unit buildings.
5. Overall, WSHP buildings have a slightly lower EUI and peak load. This is a surprise considering the relative efficiency of a central chiller plant in an FCU system, compared to the multitude of compressors in a WSHP system.
6. The choice of HVAC system alone is not a significant factor in energy performance. It is necessary to consider a number of other, more nuanced factors, including suite-level electricity usage, whole building peak electricity usage, and the operation of the Ontario Electricity Grid, in order to properly assess emission levels of MURBs.
7. Ground floor retail in MURBs use significantly more energy than modeling assumptions, particularly eateries. National databases of retail energy usage are closer to metered average values.
8. Using enthalpy recovery in lieu of mechanical heating and cooling for corridor conditioning can reduce building energy use by as much as 21%. Energy savings drop to as low as 4% when ventilation levels are dropped from industry standard to Passive House.

Recommendations: Updates to Modelling and Metering Practices

1. Current modelling practices do not adequately account for all energy inputs. Our analysis of actual metered data provides insight into how modelling inputs could be updated to provide more accurate energy predictions. In Section 6 of this report, we provide recommendations for modelling practices for the four largest energy consuming end uses: seasonal gas, domestic hot water, suite electricity, and common area electricity.
2. Energy metering practices should also be updated. We provide recommendations for two of the top energy consuming end uses – domestic hot water and common area electricity.

We hope this study not only helps Sidewalk Toronto design a truly climate-positive neighborhood, but also provides the larger building industry with sound and timely data on which to base important decisions when designing and constructing new buildings.

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Section 1: What is this Report About: The Performance Gap and Why it Matters

Sidewalk Toronto: Looking for Energy Performance

Sidewalk Toronto is a joint effort by Waterfront Toronto and Alphabet's Sidewalk Labs to create a new kind of mixed-use, complete community on Toronto's Eastern Waterfront. Starting with the creation of Quayside, Sidewalk Toronto will combine forward-thinking urban design and new digital technology to create people-centred neighbourhoods that achieve precedent-setting levels of sustainability, affordability, mobility, and economic opportunity.

Sidewalk Toronto wants to address some of the biggest challenges facing cities, including building energy use. In a step to achieve its goals, Sidewalk Toronto engaged EQ Building Performance and Urban Equation to investigate how multi-unit residential buildings (MURBs) in Toronto use energy.

Understanding how buildings in Toronto use energy will support Sidewalk Toronto in moving beyond industry-standard energy use predictions towards real energy use reduction results.

Energy Models: Predicting how much energy a building will use

Energy models allow developers to predict how much energy a building will use. Developers use energy models during the building design phase to help inform their decisions about energy reduction investments. Energy predictions depend on several different variables, such as a building's size, location and design and its mechanical systems.

After construction, building operators use meters to track actual gas and electricity usage. 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 energy model prediction is known as a performance gap.

Using Data to Measure the Performance Gap

One of Sidewalk Toronto's key objectives is to have their buildings achieve the performance predicted from their associated energy models.

Energy models rely on certain assumptions about tenant loads and usage schedules, as well as building system operations. While the practice of metering to obtain actual building energy usage data has increased in recent years, analysis of this data is rare. The inputs and assumptions used in the energy models are rarely updated or validated based on actual usage data.

With rare access to anonymized energy models and metered data for over 100 MURBs, our study aimed to support or demystify rules of thumb and assumptions that are commonly drawn upon in the building industry. By comparing actual metered data to modelling predictions, our study will help Sidewalk Toronto close the performance gap between modeled and actual building performance. It also allows us to recommend more accurate energy model inputs for Sidewalk Toronto to use when designing their communities.

Our analysis also provides insight into several different elements of building energy use, including how current buildings are performing in relation to building codes and targets.

Finally, the analysis is helpful in maintaining the reliability of energy models. Energy models are used to demonstrate compliance with mandatory building codes and performance targets like the Toronto Green Standard. Therefore, any significant discrepancies between modeled and actual performance brings the credibility of those models into question. (The City of Toronto acknowledged this performance gap between building energy models and real building operation in its [Zero Emissions Building Framework](#), published in March 2017.)

In short, we hope this study not only helps Sidewalk Toronto design a truly climate-positive neighborhood, but also provides the larger building industry with sound and timely data on which to base important decisions when designing and constructing new buildings.

Section 2: Investigating the Gap: Six Datasets

Our study was based on an in-depth analysis of six (6) building datasets. We used the various datasets to make findings on the performance gap as well as additional findings on design considerations and building energy use patterns. These datasets are described in Table 1. The relationships between each dataset is shown in Figure 1a.

Table 1: Datasets - Descriptions and Purpose

Dataset Name	What the dataset contains	Purpose of the dataset
Design Models	- Data from energy models for 95 Greater Toronto Area (GTA) MURBS - Models were completed between 2015-2017 - Generated during pre-construction, site plan, or permit stages of the buildings	Represents the current mainstream MURB market – showing modelled performance according to modelling conventions and guidelines.
Suite	- Sub-metered electricity and gas readings for approximately 20,000 suites in 83 buildings - Buildings were constructed between 2000 - 2015	Informed the analysis of aggregate suite level data to show high level trends on usage and patterns.
Utility	- Metered energy usage, both gas and electricity, for 43 buildings - Buildings were constructed between 1995-2015	Represents actual whole building energy use of GTA MURBs. This allowed us to analyze the performance of two typical HVAC systems, and to compare actual energy usage against industry benchmark datasets and targets.
Combined Modelled & Metered	- Metered energy use, and as-constructed, calibrated energy models for 19 buildings - All buildings achieved LEED certification - Sub-set of the Utility Dataset	Allowed us to identify the overall performance gap between modelled and actual energy usage in specific buildings.
End Use	- Extensive plant and end use metered readings and detailed energy models for 6 buildings - Sub-set of the Combined Modelled & Metered Dataset	Allowed us to identify the performance gap by energy end use between modelled and actual energy usage in specific buildings.
Public	Mix of metered and measured data, as well as performance targets from: Atmospheric Fund (TAF) utility data, Toronto Green Standard (TGS) v3 modelled performance targets, Passive House modelled performance targets, and WSP (a design consulting firm) Dataset of modelled and metered data for 9 buildings	Allowed us to compare our data against industry benchmark datasets and targets.

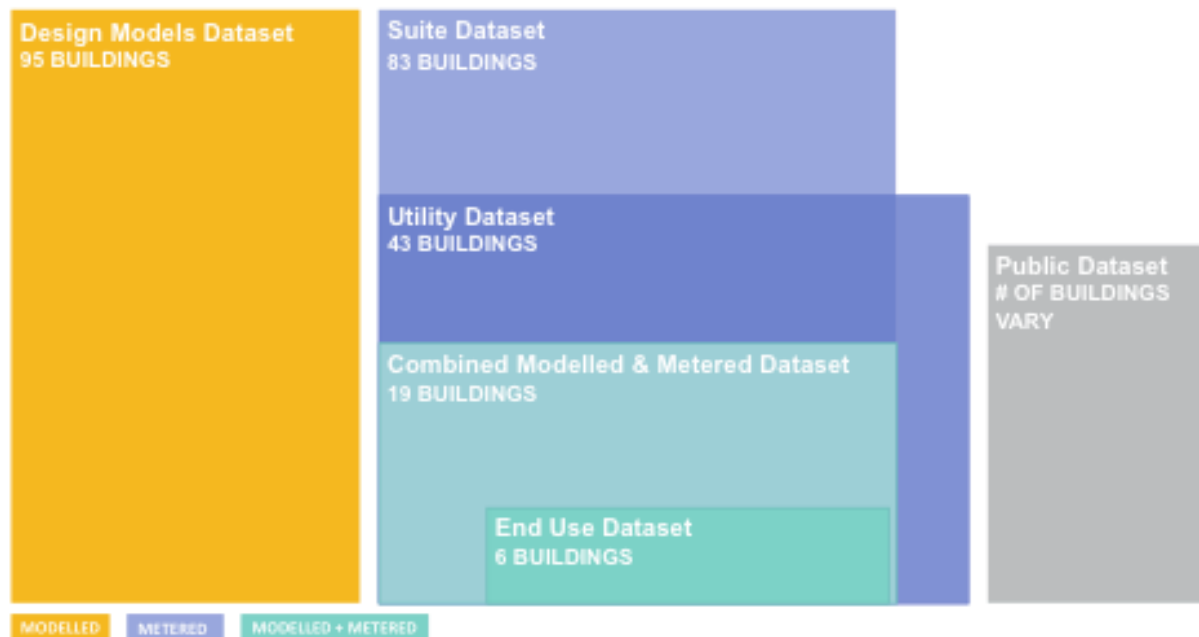


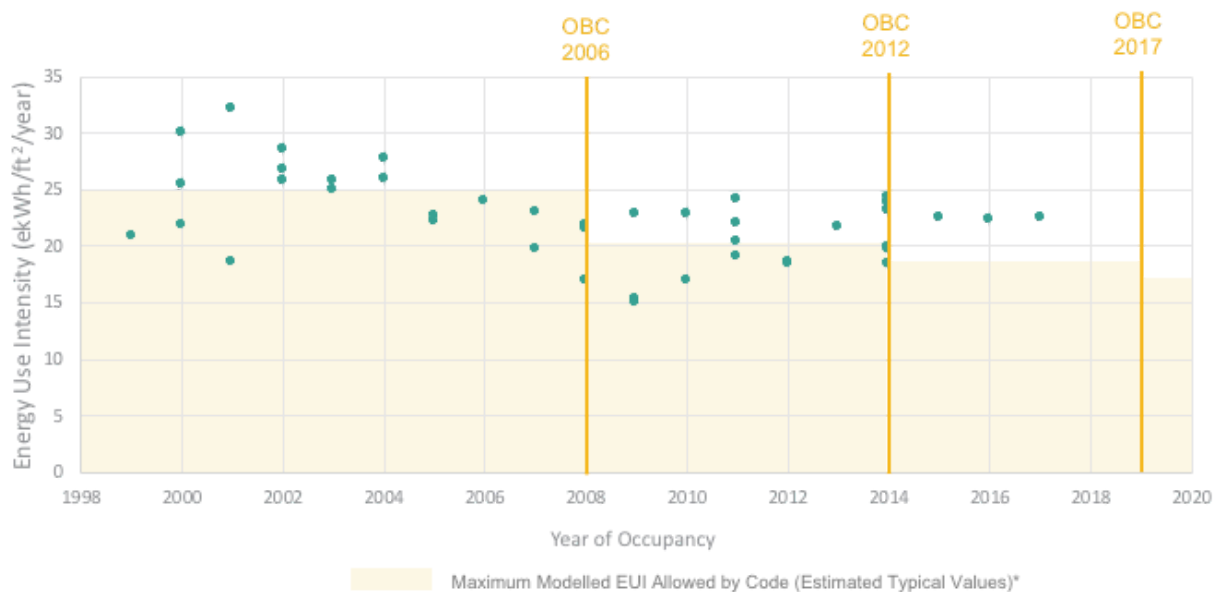
Figure 1a: Representation of Relationship between Sets

Relationship Between MURB Age and Energy Use

Designed from 2015 onward, the buildings in the **Design Models Dataset** are in most cases much newer than the buildings in any other dataset in this report. To explore the possible relationship between building age (year of occupancy) and energy use intensity (EUI), we examined the **Utility Dataset**. This dataset consisted of buildings with occupancy dates ranging between 1998-2017. They also represented many different energy codes over time.

As seen in Figure 1b, the correlation between EUI and time is not significant enough to draw any conclusions. The Toronto Green Standard introduced mandatory energy efficiency in 2010, that was eventually matched by the Ontario Building Code in 2012, requiring that all Part 3 (MURB) buildings be 25% more energy efficient better than pre-2006 code (MNECB).

The oldest building in the dataset has a lower EUI than the newest building, and the presence of outliers may be skewing the trend. In addition, there does not appear to be a significant trend between updated energy code requirements overtime and building performance. 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. For this reason, the comparison of datasets with different building ages is justifiable.



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

Figure 1b: Energy Use Intensity - Relationship to Building Age

Normalization and Benchmarking for MURBs

The metric chosen to compare buildings for benchmarking purposes is particularly significant for MURBs. In the absence of alternative data, the most commonly used metric for MURBs is total annual energy use normalized by area, EUI. That is the metric used in this study.

As energy can be provided from different sources, we use units of equivalent kWh (ekWh) to represent the sum total of energy usage, a standard unit of energy consumption which converts all energy sources into ekWh. In Ontario, the main two sources of energy are electricity and natural gas. To convert natural gas to ekWh, a conversion factor of 10.68 ekWh per m³ of natural gas is used¹. Electricity usage is reported in kWh and does not require conversion.

All energy usage values presented in this report are site energy, accounting only for energy used directly at the buildings and not accounting for delivery or production losses.

When setting energy performance targets for MURBs, both EUI as well as alternate metrics should be considered. At the time of this study, we understand that 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.

¹ Source: Energy Star Portfolio Manager Technical Reference: Thermal Energy Conversions, September 2014, Figures 2 & 3

Section 3: Key Findings: Modelled vs. Metered Energy Use

Using the six datasets, our analysis was able to unlock several key findings on the energy performance of buildings, as well as the gap between modelled and metered data at different levels of granularity. This section presents findings on:

- The modelled performance of buildings in the last 5 years in relation to building codes and mandatory requirements;
- The total performance gap between modelled and metered energy performance of buildings;
- The performance gap broken down by energy end uses;
- Detailed exploration into the performance gaps of space heating, domestic hot water, in-suite electricity, and common area electricity.

GTA MURBs: Modelled Performance in the Last 5 Years

At a glance: We analyzed the [Design Models Dataset](#), which includes energy models for 95 Greater Toronto Area (GTA) MURBs currently in various stages of design and construction. This analysis allows us to understand the performance of new buildings, and how they relate to building codes and standards.

The models in this dataset were completed between 2015 – 2017 to verify compliance with the mandatory Toronto Green Standard (TGS) Version 2, which was in effect at the time the models were created. The current version of TGS is Version 3, which came into effect in May 2018, requires further energy efficiency than TGS v2. In Version 3, TGS consists of four performance tiers, Tiers 1 - 4. Tier 1 is mandatory for all developments, while Tiers 2 - 4 are optional. The various Tiers were established to demonstrate to the building industry the step changes that will be required to drive toward zero emission buildings. The City of Toronto's [Zero Emissions Building Framework](#) describes the various tiers, where Tier 4 compliance is roughly aligned with a Net Zero Ready level of performance.

TGS Version 3 also includes updates to the energy modelling requirements. To compare the buildings in this dataset against the targets in the new TGS version 3, we updated the models to reflect these new modelling requirements. Whole building Energy Use Intensity (EUI) of the models ranged between 120 and 410 ekWh/m² (11.1 and 38.1 ekWh/ft²), as seen in Figure 2. The median for the entire [Design Models Dataset](#) was 237 ekWh/m² (22.0 ekWh/ft²).

The modelling practices used to create the TGS requirements suggests that an Ontario Building Code (OBC or Code) compliant building has an EUI of 190 ekWh/m² (17.6 ekWh/ft²), as defined in the [Zero Emissions Building Framework](#). Buildings with higher EUIs, however, can still meet the Code due to the reference building approach used to demonstrate compliance.

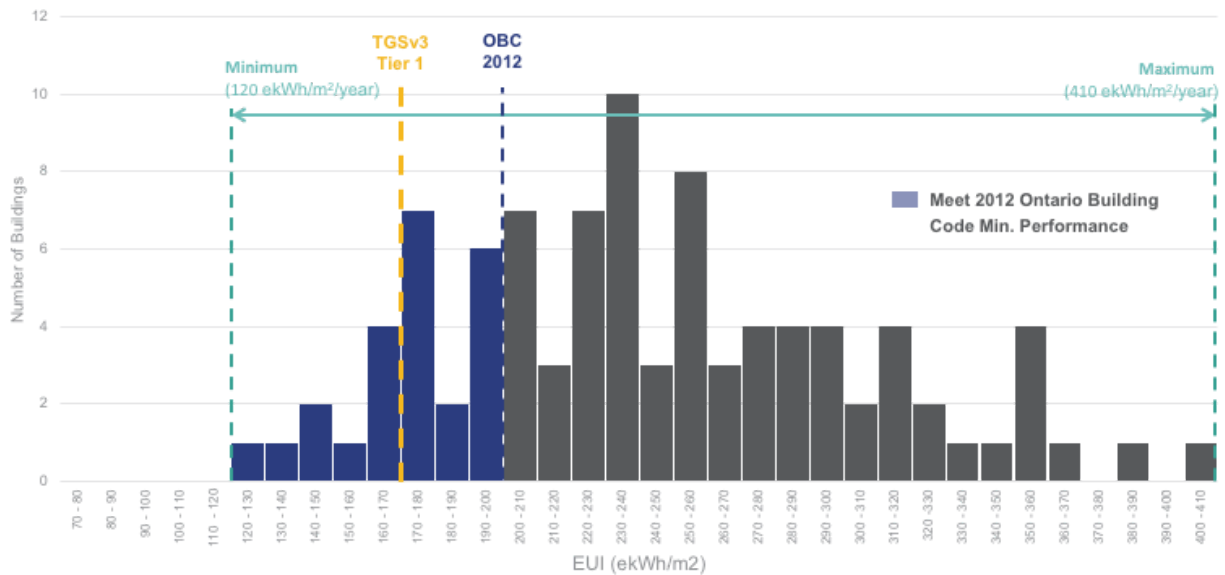


Figure 2: Modelled Building Dataset – Whole-Building EUI

If we look at the current version of the Toronto Green Standard, TGSv3, Tier 1 requires a minimum EUI performance of 170 ekWh/m², as well as a minimum Thermal Energy Demand Intensity (TEDI) of 70 ekWh/m² and a Greenhouse Gas intensity of 20 kgCO₂e/m². Figure 3 makes it clear that most of the buildings in the **Design Models Dataset** would not meet the new, mandatory TGSv3 requirement.

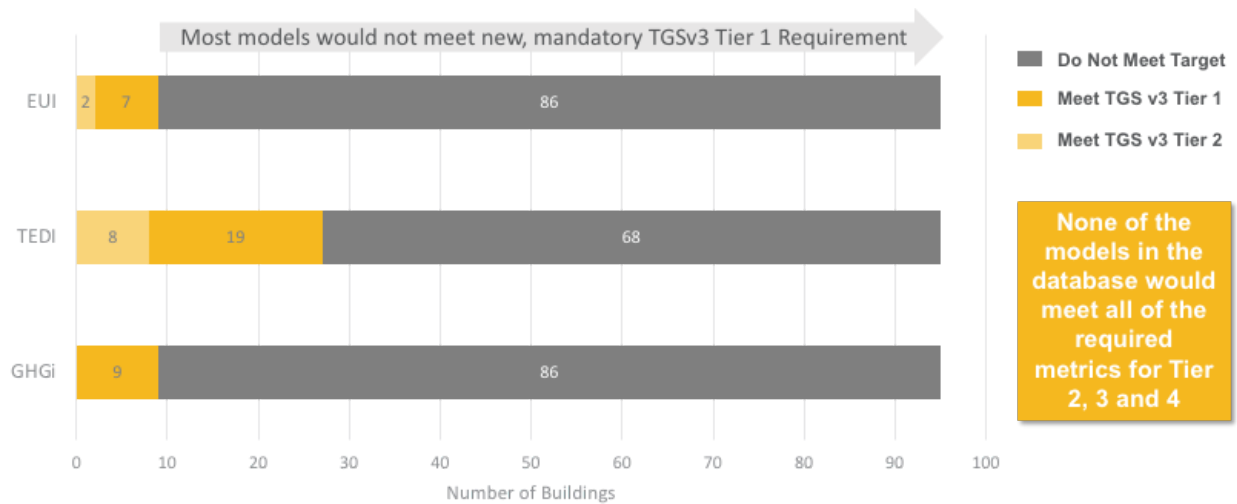


Figure 3: Modelled Building Dataset - Whole-Building EUI Compared to Toronto Green Standard v3

GTA MURBs: Design Trends in the Last 5 Years

Building design contributes to energy performance; however, our study showed that energy consumption is multivariate and complicated. As a result, the OBC sets design based requirements rather than actual energy use targets. This allows developers to demonstrate compliance with the OBC, even though the building has not achieved any actual reduction in energy usage. To achieve compliance, developers often use trade-offs, such as implementing a high-performing envelope combined with a poor performing HVAC system, or vice-versa.

The **Design Models Dataset** allows us to gain insight on current design trends for buildings in the GTA. Many of the buildings in the dataset represent preliminary models where many building details have not yet been defined. As such, modellers typically use building codes or reference guides to determine values for design parameters that are not yet defined. The high-level design trends identified throughout the buildings in the dataset are:

- About 40% of buildings were modelled with R-values of R-8 and R-11 for the building envelope as seen in Figure 4, which represent commonly used spandrel wall assemblies.
- The majority of buildings in the dataset modelled the U-value of the building's glazing at U-0.33 as seen in Figure 5. This aligns with the recommended reference value from National Energy Code of Canada for Buildings (NECB), modified by the OBC section SB-10, for all glazing.
- Window to Wall ratios of buildings are most commonly at 35% - 60%, as seen in Figure 6. There is a peak at 35-40%, which could be a result of reference standards penalizing buildings with ratios above 40%.

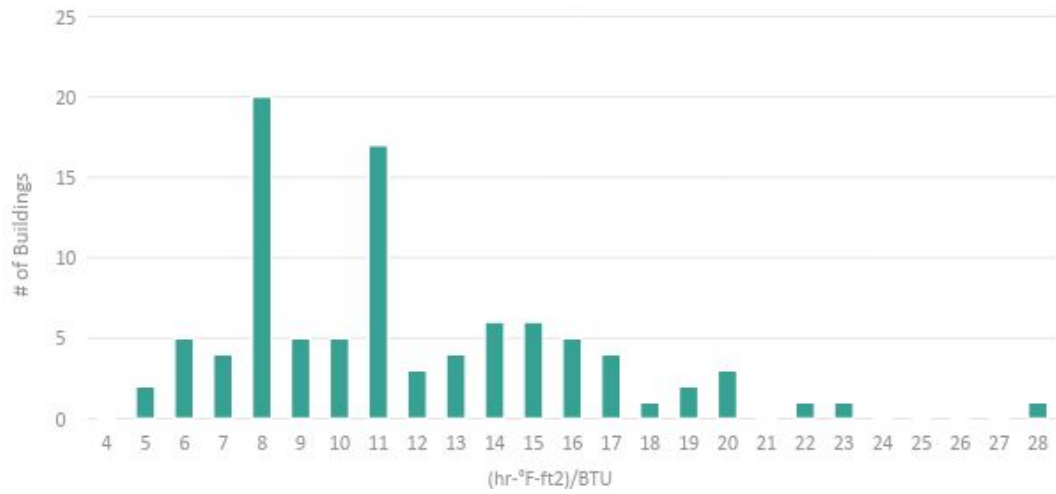


Figure 4: Design Trends in MURBs - R-Values

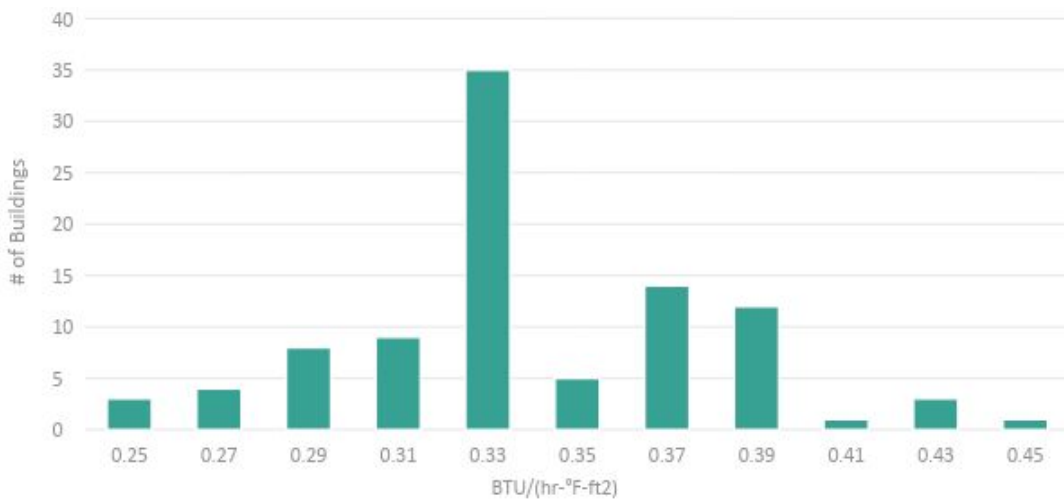


Figure 5: Design Trends in MURBs - U-Value

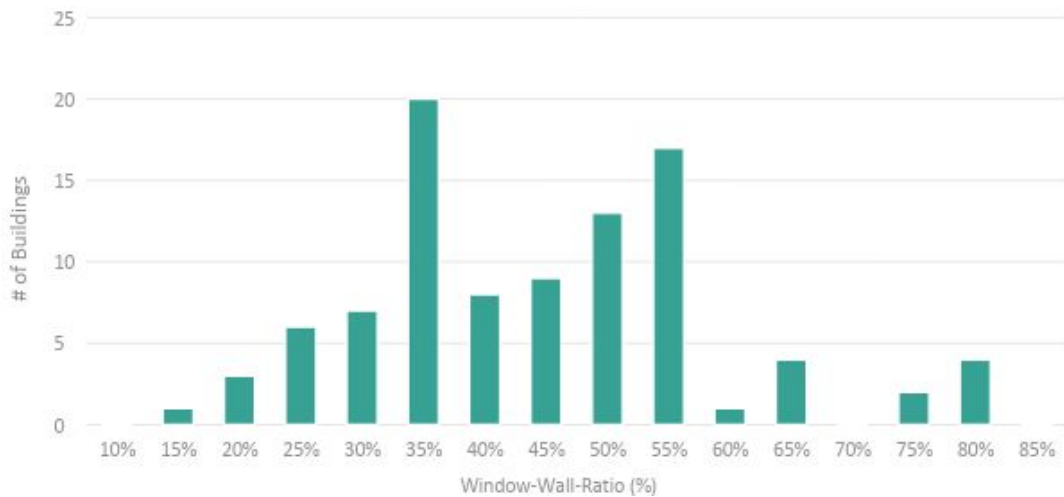


Figure 6: Design Trends in MURBs - Window to Wall Ratios

Performance Gap: Meter Readings vs. Calibrated Energy Models for 19 Buildings

At a glance: Using the **Combined Modelled & Metered Dataset** which contained both metered energy usage data and building energy models for a set of 19 buildings, we analyzed the differences between a building's actual energy usage and what was predicted by its design-stage model. This allowed us to identify high-level trends related to the performance gap.

Findings: Overall metered, median energy usage is higher by 13%

Overall, the metered energy use intensity is a median **13% higher** than what was predicted by the calibrated models. We identified this performance gap by comparing building energy usage at the utility level, specifically natural gas and electricity, with their associated models in the **Combined Modelled & Metered Dataset**. When looking at the greenhouse gas emissions gap between models and metered data, we found a 28% gap.

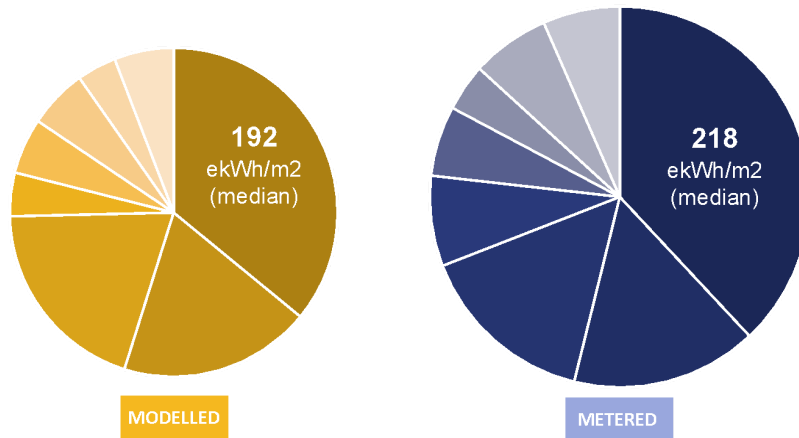


Figure 7: Modelled vs. Metered Energy Usage - 192 ekWh/m² vs. 218 ekWh/m²

Results for the 19 individual buildings are shown in Figure 8. These are organized from best to worst performers in terms of metered Energy Use Intensity (EUI). EUI measures a building's annual energy usage per unit of space. It is used to compare energy use among differently designed buildings.

With few exceptions, the modelled predictions under-represent actual utility bills. Within this dataset, only two buildings meet the current Toronto Green Standard Tier 1, none meet Tier 4.

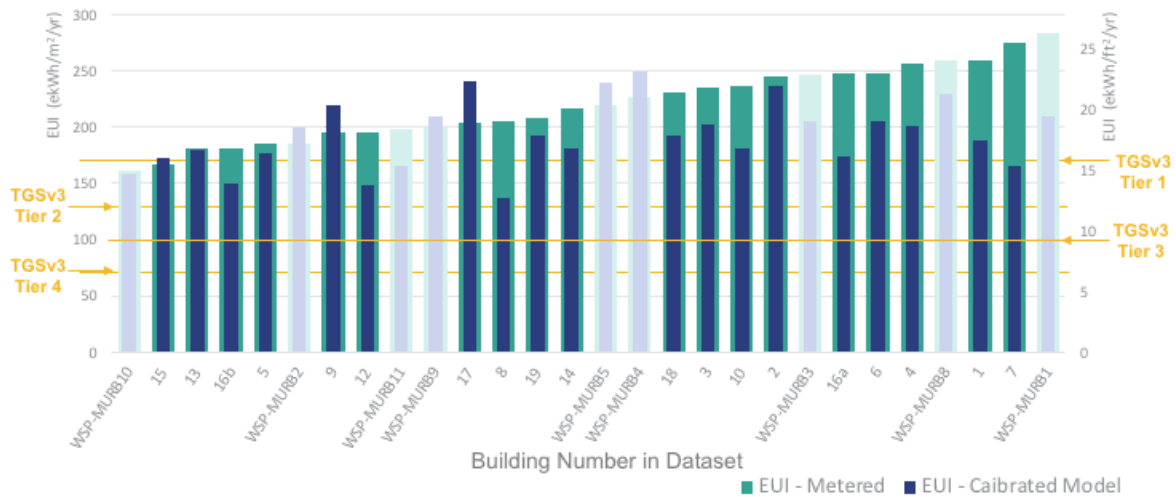


Figure 8: Comparison of Modeled and Metered EUI for Individual Buildings

Note: Figure 8 also includes nine buildings with models and actual energy use data from a study completed by WSP, a design engineering firm.

This finding is supported by the larger datasets. The median EUI of the **Utility Dataset** (containing actual energy usage data from 43 existing buildings) is 12.5% higher than the median EUI of the **Design Models Dataset** (containing models for 95 buildings). Although the two larger datasets do not contain identical groups of buildings, the comparison is valid as we found there to be little correlation between a building's age and energy use intensity, discussed further in Section 2.

All of the modeled energy use results in the datasets were normalized for the impacts of weather. We used the normalization process to categorize the bulk metered energy use into seasonal and non-seasonal loads for both electricity and natural gas. Seasonal Loads reflect energy used for heating or cooling, including any associated HVAC loads that fluctuate due to outdoor weather conditions. Non-seasonal/base loads are loads such as plug loads, lighting, domestic hot water, and remaining HVAC loads, which are assumed to be constant year-round.

When we look at seasonal and non-seasonal energy use, energy modeling is shown to slightly over-represent seasonal electricity while under-representing seasonal natural gas, baseload natural gas, and baseload electricity. The largest performance gaps are seen in seasonal natural gas and baseload electricity. These two energy uses also represent 82% of the buildings' total EUI, Figure 9.

The seasonal and baseload energy use results, including the range of values for each end use, as well as the gap in median values, are shown in Figure 10.

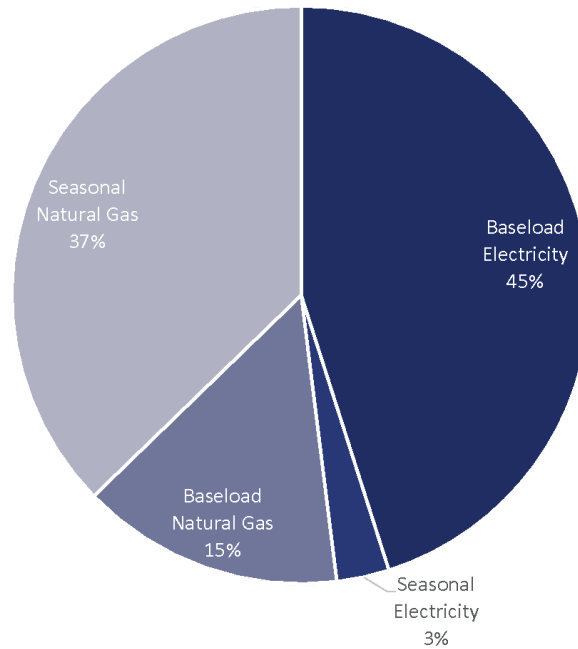


Figure 9: Seasonal and Base Loads - Percentage of Total Metered EUI

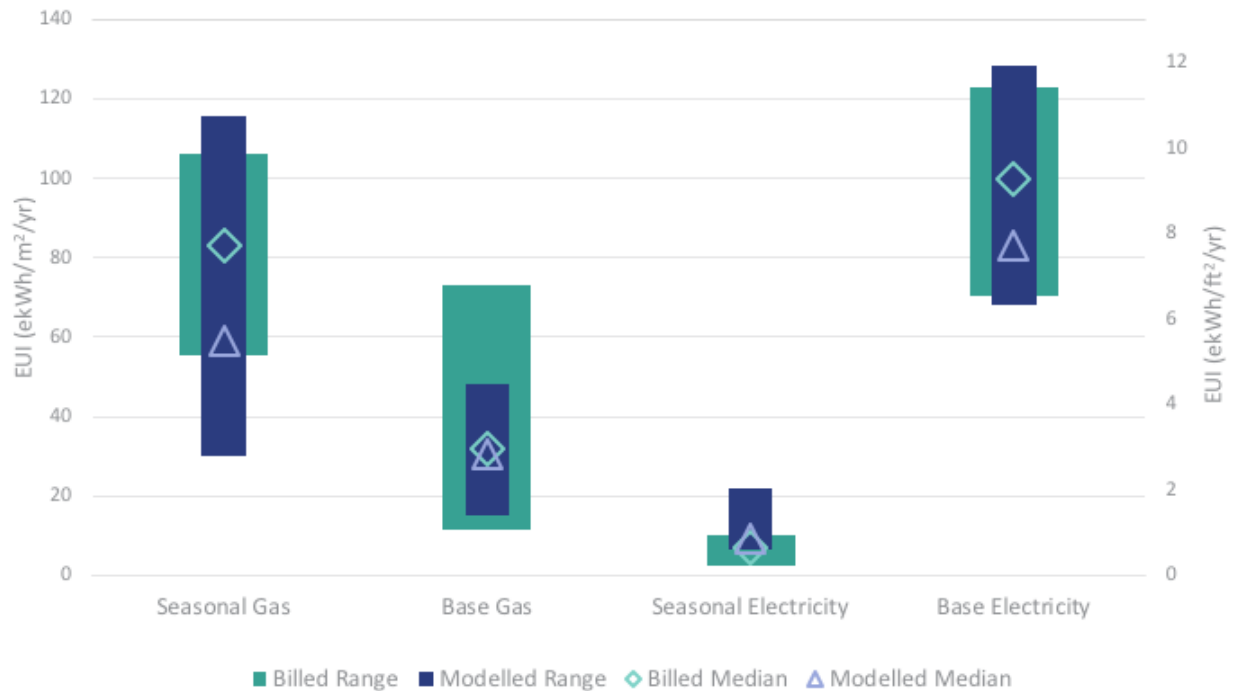


Figure 10: Performance Gap by Seasonal and Base Energy Usage

MURB energy use is dependent, in many ways, on occupant use and occupancy density. As such, energy use per suite may also be important performance indicators. The EUI of the

Combined Modelled & Metered Dataset was recalculated based on an ekWh/suite/year metric, Figure 11. The ascending order from best to worst performers based on billed ekWh/m² is maintained to demonstrate the impact that an alternate normalization method can have on the perceived performance of the building. It is clear that the best performer in terms of ekWh/m² is not the best performer in terms of ekWh/suite.

Many industry standards use energy use intensity (EUI) per floor area for benchmarking, to which we have aligned the findings in this report. EUI alone does not necessarily tell the full energy story. Suite size, among other parameters, can impact benchmarking and should be considered when comparing and justifying MURB performance. Multiple metrics to determine a building's success are valuable and should be considered where data is available.

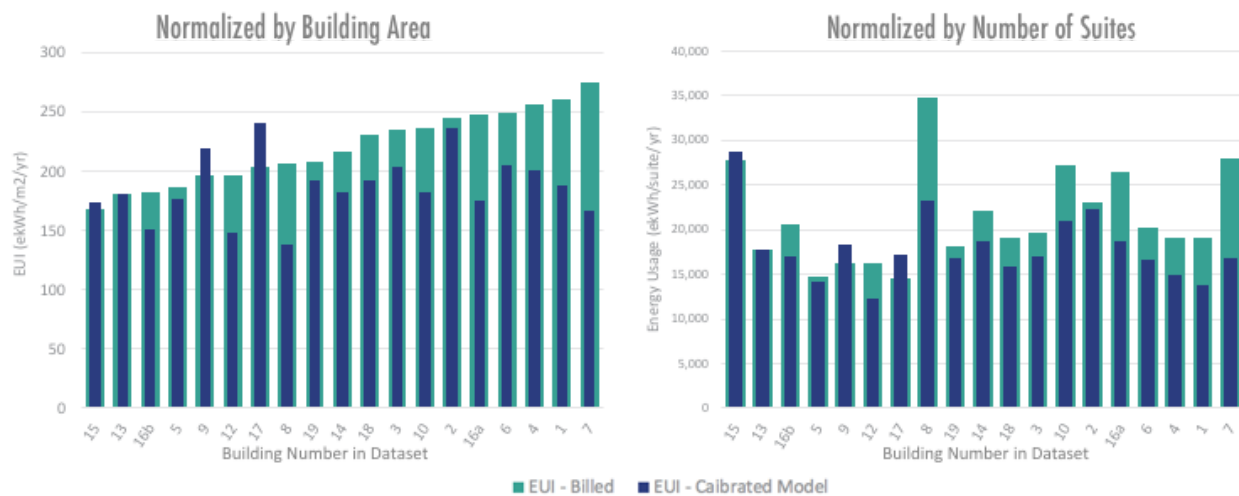


Figure 11: MURB Energy Use - Alternative Benchmarking

Energy End Use Breakdowns: Variations between Modeled and Metered Data

At a glance: To further analyze energy by end use, we examined a subset of six (6) buildings from the [Utility Dataset](#). We call this subset the [End Use Dataset](#). This included extensive sub-metering data.

Finding: Four end uses represent over 75% of total building energy usage

In Toronto MURBs, the four end uses which represent the majority of total building energy use in both metered and modeled data are: space heating, domestic hot water, in-suite electricity, and common area electricity. Together, these end uses represent over 75% of total building energy usage.

Using median values from the subset of six buildings (the [End Use Dataset](#)), we created a metered end use breakdown². We then compared it to the end use breakdown from the median of the [Design Model Dataset](#). The models were shown to closely predict the distribution of energy end uses. Despite the 13% performance gap in total energy usage, the distribution of end uses in the two datasets aligns relatively well. This is shown in Figure 12.

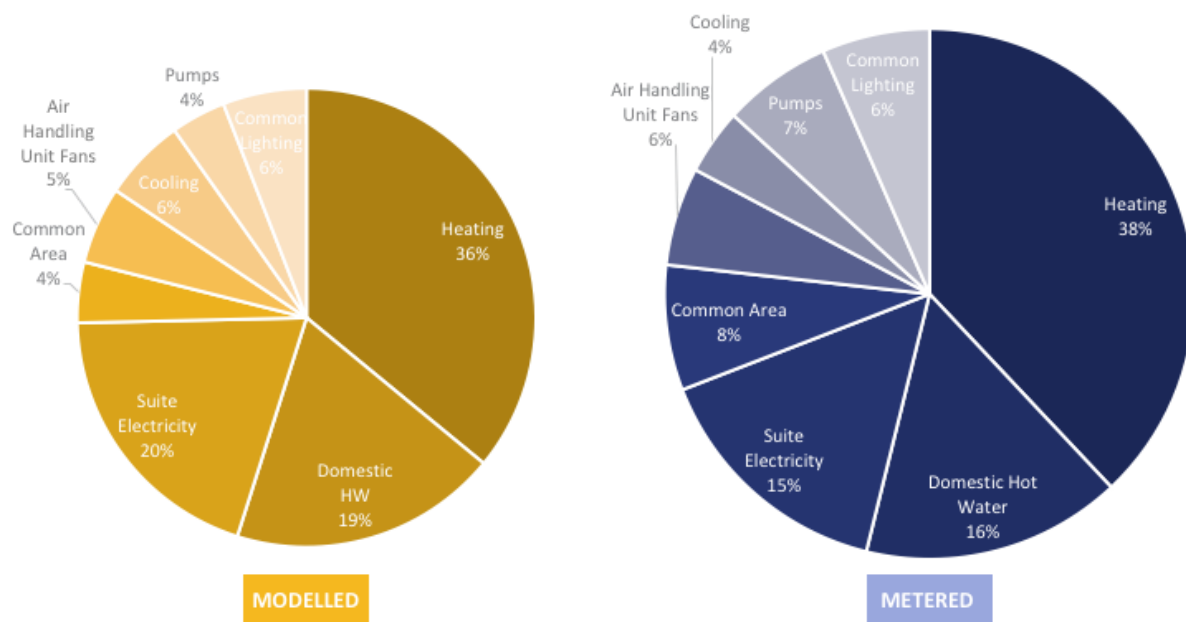


Figure 12: Energy End Use for Metered and Modeled Buildings

² Note that the metered common area baseload electricity has been further divided by end use to match those of the modelled data, including air handling fans, cooling, pumps, and common lighting, as these end uses are not commonly metered. This is explored further on page 34.

Finding: Energy end uses contribute differently to total building energy use

Access to extensive sub-metered energy usage data at these buildings allowed us to analyze the performance gap at a level that is more granular than seasonal/non-seasonal loads.

Space heating, domestic hot water, in-suite electricity, and common area electricity are the four major energy end use contributors to total building energy use. They also represent significant performance gaps.

While performance gaps were observed in other end uses – pumps, central cooling and elevators – these end uses do not contribute significantly to building energy consumption. Therefore, closing the performance gap in those areas will have less impact on the modelling gap as a whole.

Findings shown in Figure 13 represent the percentage gap between median values for each end use. The two toned colours in each bar represent the second and third quartiles of energy data, surrounding the median value. Tall box plots represent greater ranges in values, and vice versa. For example, metered heating energy use varied greatly among the buildings, whereas metered suite electricity use has a relatively small range.

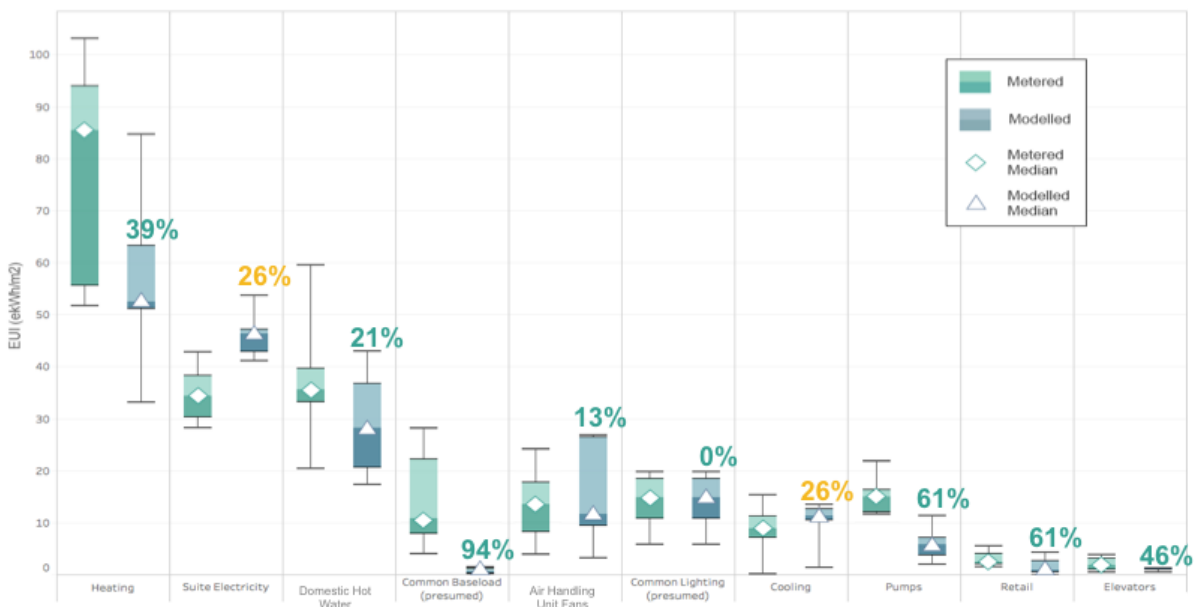


Figure 13: Performance Gap by Energy End Use

To provide the necessary context on the energy usage patterns of the **End Use Dataset**, we have outlined in Table 2 the key characteristics of the six buildings in the dataset. These buildings were chosen because they represent commonly used HVAC systems and building design strategies in the market, and the buildings had extensive metering equipment installed, which provided detailed data on their energy usage.

Table 2: End Use Dataset Building Characteristics

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

Space Heating: Measuring the Performance Gap

At a glance: Space heating represents the largest energy end use for MURBs in Toronto. It also presents a large performance gap between modelled predictions and actual metered data. For space heating, we investigated two modeling inputs for the building enclosure that inform energy use predictions: thermal bridging and infiltration rates.

Finding: Metered gas usage for space heating is 39% higher than modeled predictions



Figure 14: Space Heating Energy Use - Metered vs. Modeled

Space heating represents the highest energy end usage for MURBs in Toronto. Not only does space heating use the most energy, but it also represents one of the largest performance gap between modelled and metered data. Overall, metered gas usage for space heating is 39% higher than modeled predictions.

Space heating energy use is related to a building's Heating Ventilation and Air Conditioning (HVAC) system:

- In the energy models of all five buildings in the **End Use Dataset** that have fan coil unit (FCU) HVAC systems, space heating energy is under-represented.
- In the one building that uses water-source heat pumps (WSHP), Building #15, natural gas-fired space heating was represented relatively accurately in the model. This WSHP building uses natural gas for heating the central building and common areas through a

hot water boiler system, while electricity supplements heating of the suites. The suite-level electricity used for heating is not reflected in these findings.

MURBs which use FCU systems show a large range of EUI. One possible reason is inefficiencies within the piping configuration of the fan coil systems. Because the FCU system requires high hot water temperatures, thermal losses through piping occur throughout the building and within the fan coils themselves. These losses would not be reflected in a typical energy model.

By comparison, WSHP systems are less likely to suffer from thermal losses as condenser water flows through the building at a more moderate temperature.

Further discussion on FCUs and WSHPs can be found in Section 4 of this report.

Space Heating: Effects of Building Enclosure – Thermal Bridging

Thermal bridging through building enclosure elements contributes significantly to space heating energy loads. Examples of such elements include: balcony slabs, parapets, detailing around windows, and mechanical penetrations. Thermal bridges act as direct routes for heat transfer to the exterior of a building, which then increases the amount of energy needed to keep the interior heated.

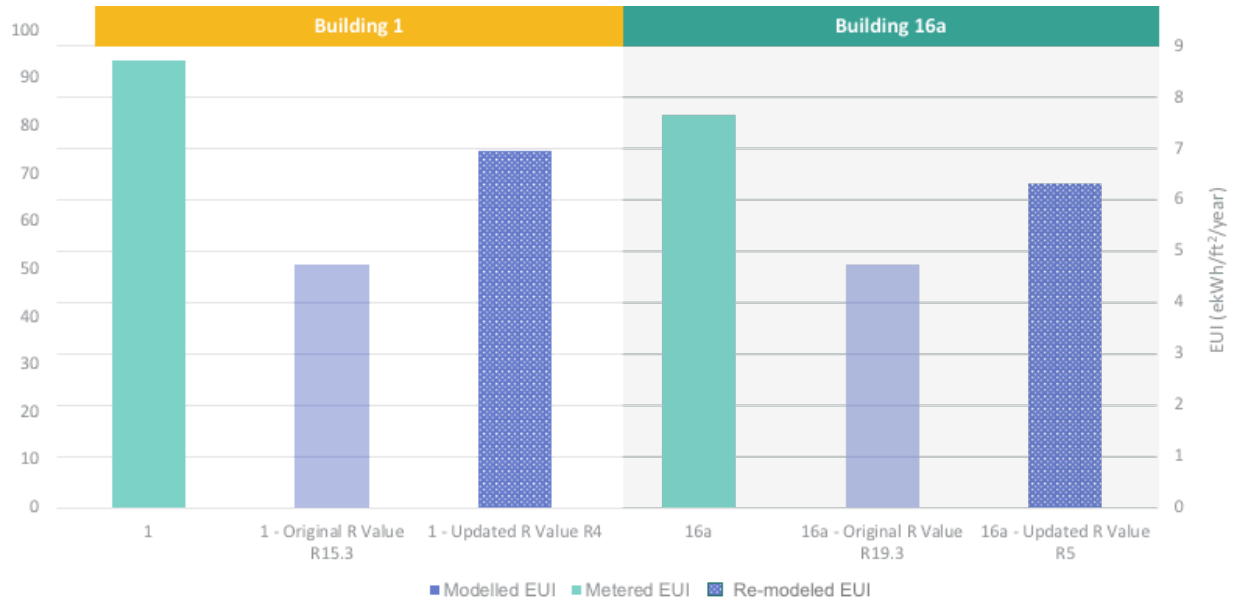
Improper accounting of thermal bridges can impact modeled heating energy use. Building enclosure performance in the existing energy models was found to be overstated in all cases. On average, the effective R-value was 73.4% worse than initially modelled.

Recent trends in building design and updates to the Ontario Building Code put a higher emphasis on reducing thermal bridging. Modelling guidance in TGS v3, referencing the BC Hydro Building Envelope Thermal Bridging Guide, requires energy models to account for all major thermal bridges.

Prior to TGS v3, modelling guidance allowed up to 2% of the building envelope area to be ignored. This often resulted in significant thermal bridging considerations being omitted from the energy model. Building models did not require accounting for heat loss through most atypical thermal bridges unless the heat loss was very significant. Building models focused only on typical framing members and provided allowances for additional penetrations. This was the case for all original energy models we reviewed for this report. It still applies for energy models submitted to demonstrate compliance with the Ontario Building Code.

When we updated the R-values in two of the original energy models with more detailed thermal bridging inputs, the space heating performance gap was reduced.

Figure 15 shows the effects of the updated thermal bridging inputs on the performance gap. While the performance gap is reduced, it is not closed entirely in Buildings 1 and 16a. We conjecture the remaining gap may be caused by air infiltration.



Bldg. #	Modelled R-Value	Updated R-Value	Previous Space Heating Performance Gap	Updated Space Heating Performance Gap
1	15.3	4	45%	20%
16a	19.3	5	38%	17%

Figure 15: Effects of Updated Thermal Bridging on Performance Gap

Space Heating: Effects of Building Enclosure – Air Infiltration

Whole-building air infiltration can significantly impact a building's energy consumption, thermal comfort, and moisture control. As seen in Figure 16, energy modeling standards assume aggressive levels of air tightness relative to measured results. The default infiltration rate from eQuest, a common modeling software, of $0.196 \text{ cfm}_{50}/\text{ft}^2$ nearly meets the *PassivHaus* infiltration requirement of $0.181 \text{ cfm}_{50}/\text{ft}^2$, a top-performing standard in terms of airtightness.

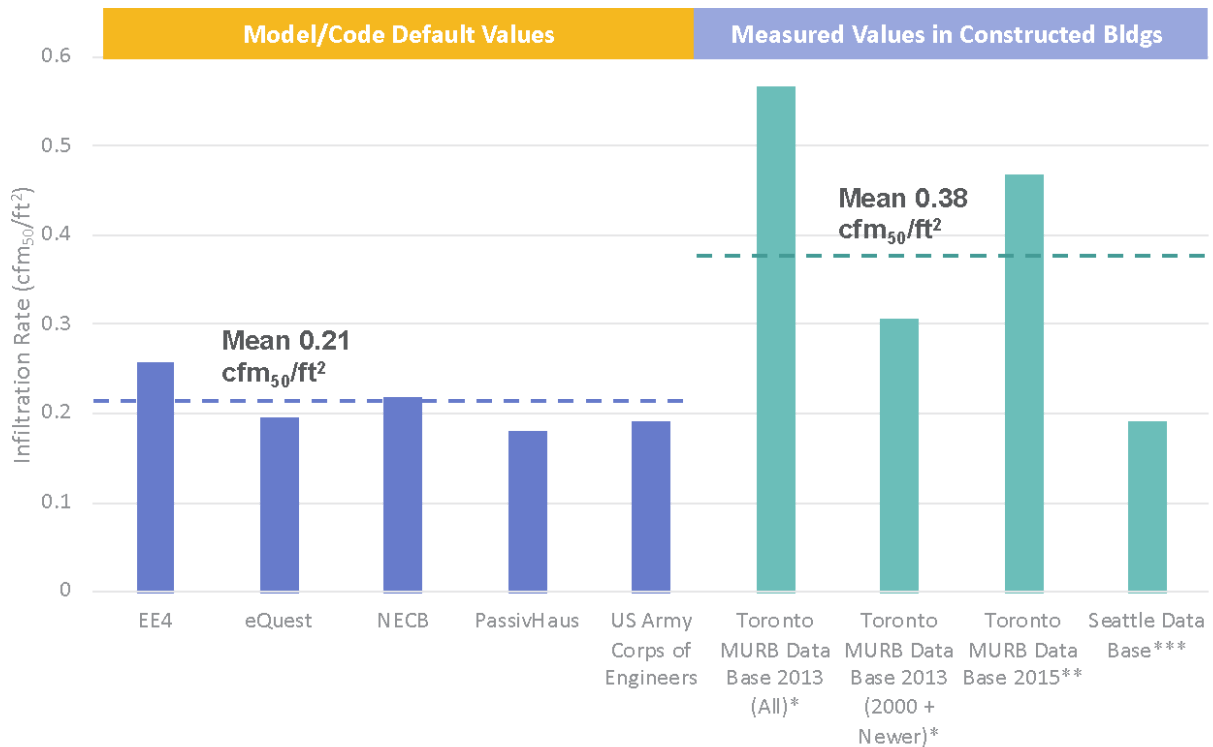


Figure 16: Infiltration Rates in Models vs. Measured Buildings

*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.

Typically, modelers simplify the inputs for infiltration by using a default value and maintaining the same values for the proposed building model and the code reference energy model. This is a common practice because infiltration rates are difficult to predict without air-tightness test results. As well, most standards require infiltration to be neutral between 'proposed' and 'reference' buildings.

Actual building air tightness can be improved by requiring air tightness testing, as demonstrated in the Seattle Database in Figure 16. This database consists primarily of newer Seattle buildings for which air-tightness testing was required. Even without set targets, airtightness improved as builders became more conscious of the deleterious effects on infiltration of improper installation techniques or poor material selection. Additionally, as the buildings are newer, the enclosures

have had less time to deteriorate. It is also important to note that the Seattle Database contains a number of different building types, such as commercial buildings, which typically contain far fewer operable windows and are less prone to air leakage.

Infiltration is measured by conducting blower-door tests, either on the whole building or suite-by-suite. There are many ways to conduct these tests, but all methods involve using fans to pressurize (and depressurize) a space to a reference pressure. While whole-building testing for large buildings has been used in limited applications in North America, like Seattle, it is not currently required by the Ontario Building Code, nor is it a mandatory requirement of TGS.

Domestic Hot Water Usage: Measuring the Performance Gap and Investigating Modeling Practices

At a glance: Domestic hot water (DHW) usage is the second largest contributor to MURB energy consumption. As illustrated from our analysis, DHW also presents a large performance gap between modelled predictions and actual metered readings. In our study, we looked at actual occupant hot water usage patterns and compared these to modeling inputs, which assume hot water usage to be constant throughout the year.

Findings: No clear trends in hot water usage

We did not detect any clear trends that explain the performance gap among the six buildings in the **End Use Dataset**. As shown in Figure 17, modelled gas usage for domestic hot water (DHW) production varied from 44% lower to 14% higher than metered performance, with a median of 21% lower.

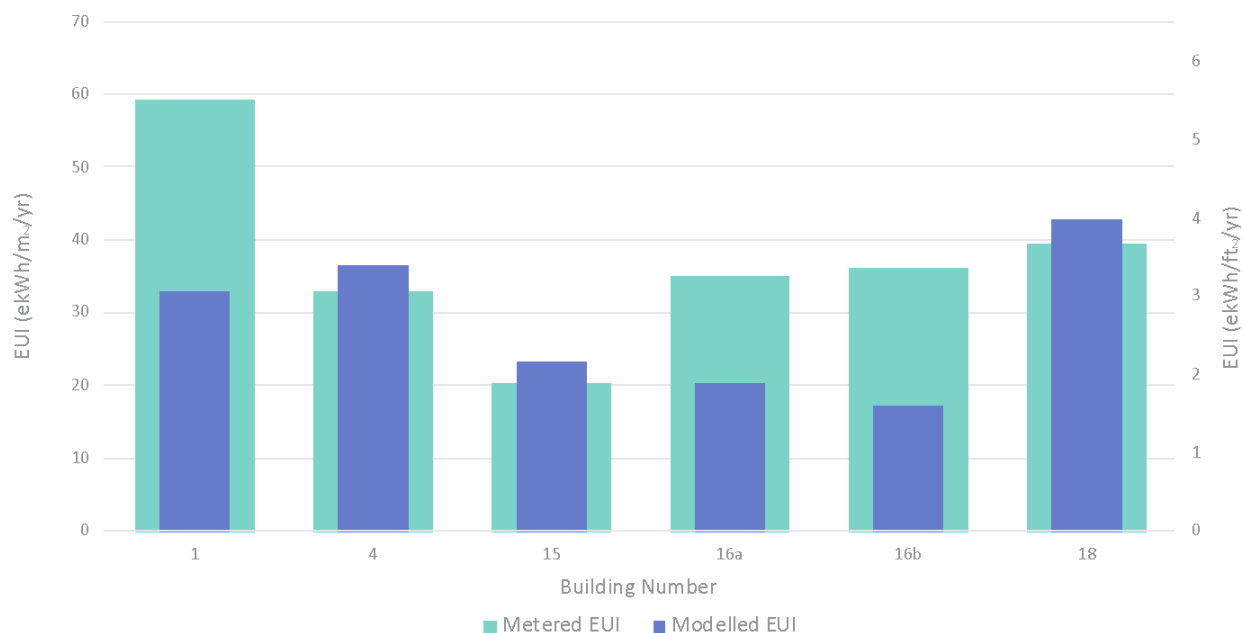


Figure 17: Domestic Hot Water Heating Energy Usage – Metered vs. Modelled

Currently, energy modelling software and reference code schedules assume that domestic hot water consumption within a residential building is consistent throughout the year. Therefore, the energy used to heat this load should also maintain a relatively flat annual profile.

Analyzing metered data, however, we found that domestic hot water is a seasonal load – less energy is consumed for domestic hot water in summer months and more in the winter months. As seen in Table 3, hot water consumption itself varied - on average – up to 12% between

seasons³. Occupancy of buildings would have an affect on the consumption of DHW. Unfortunately, occupancy data is not commonly available, so we were not able to analyze the effect of occupancy on DHW usage as part of this report.

This seasonality in DHW energy is not currently reflected in energy models. The models most closely align with the lower end of the annual domestic heating usage which occurs in the summer months. Figure 18 shows the discrepancy between the modelled and metered results throughout the year.

Table 3: Variation in Metered Hot Water Consumption between Seasons

Building #	Mean Daily Hot Water Consumption (m ³ /day)	Summer		Winter	
		Summer Mean (m ³ /day)	Difference (%)	Winter Mean (m ³ /day)	Difference (%)
1	112.7	104.9	-7%	124.9	11%
15	11.8	11.3	-4%	11.8	0%
16a	19.0	17.5	-8%	19.8	4%
16b	34.0	31.2	-8%	35.5	5%
18	54.7	54.0	-1%	55.2	1%
		Weighted Average	-6%		6%

³ In this analysis, it is important to note:

- Building 18 uses combined heating and domestic natural gas boilers; the remaining buildings have dedicated DHW heating.
- Building 4 was excluded from all in-suite hot water consumption studies, due to inconsistency in data integrity.

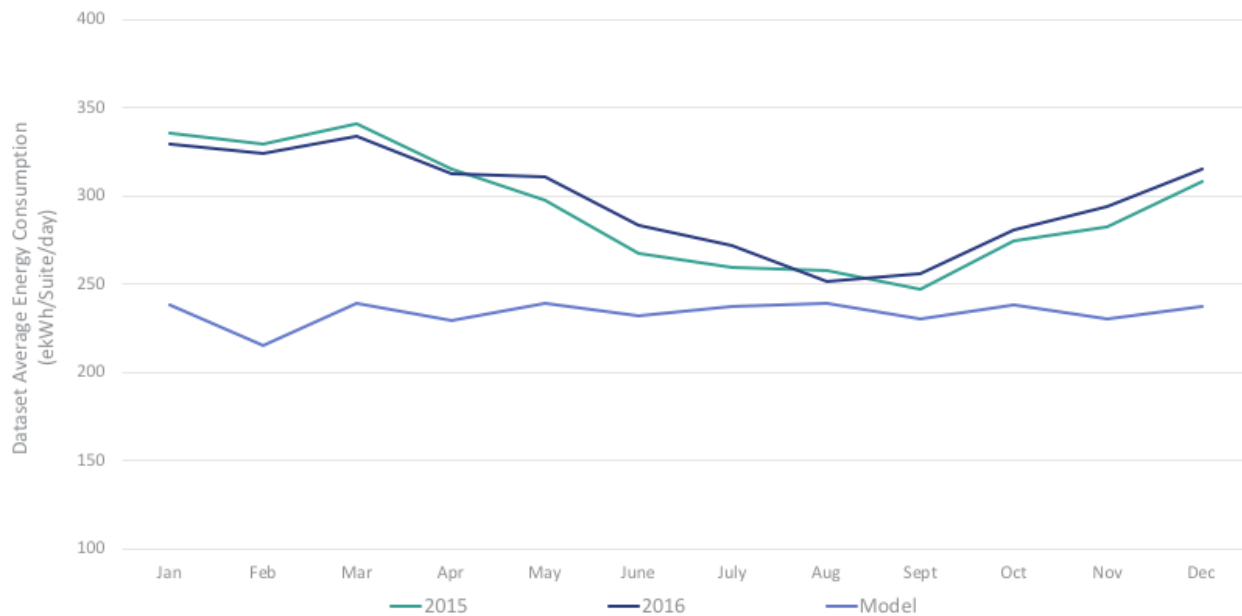


Figure 18: Domestic Hot Water Energy Use - Metered vs. Modeled

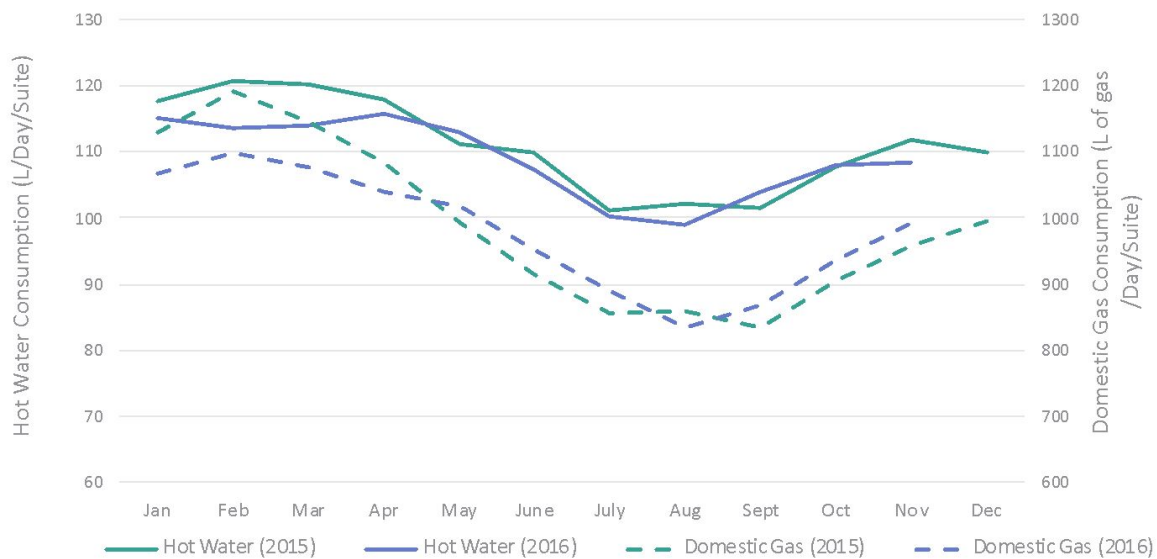


Figure 19: Seasonal Variations in Both Hot Water and Domestic Gas Consumption

Both hot water consumption and domestic gas energy consumption vary seasonally. However, as shown in Figure 19, domestic gas use varies disproportionately more than the hot water use during the winter and summer months. This suggests two things: the seasonal variation in hot water consumption affects DHW energy use, and the efficiency of the DHW system also varies seasonally.

Systems become slightly less efficient in the winter months as less hot water is produced per unit of natural gas consumed. We calculated this by dividing the volume of hot water (m^3) by the

volume of domestic gas used to heat the water (m^3) for all buildings. We also checked individual buildings in the dataset to confirm the trend shown here is representative. Figure 20 shows the average efficiency of the DHW systems across the buildings.

There are two potential causes for the reduced efficiency: variations in boiler efficiencies due to fluctuating loads and [seasonal changes of incoming domestic cold water temperature](#) from the municipal distribution system due to soil temperature. Unfortunately, detailed monitoring data regarding inlet and outlet hot and cold water temperatures were not available; therefore, at this stage, we have not been able to identify the exact cause for this trend. Designing DHW boiler systems to allow for more flexibility and efficiency at widely varying loads could mitigate the reduced efficiencies observed in the data set.



Figure 20: Domestic Hot Water Systems Monthly Efficiency

In-Suite Electricity: Performance Gap Quantification and Investigation

At a glance: In-suite electricity usage contributes 15% of overall building energy usage. This energy end use is one of the few end uses that is overestimated by models.

Findings: Modelled in-suite electricity usage is generally higher

Figure 21 shows that the median modelled in-suite electricity usage is 26% higher than metered performance. Metered in-suite electricity is consistently lower in all buildings except Building #4, where the model accurately predicted energy use in this category.

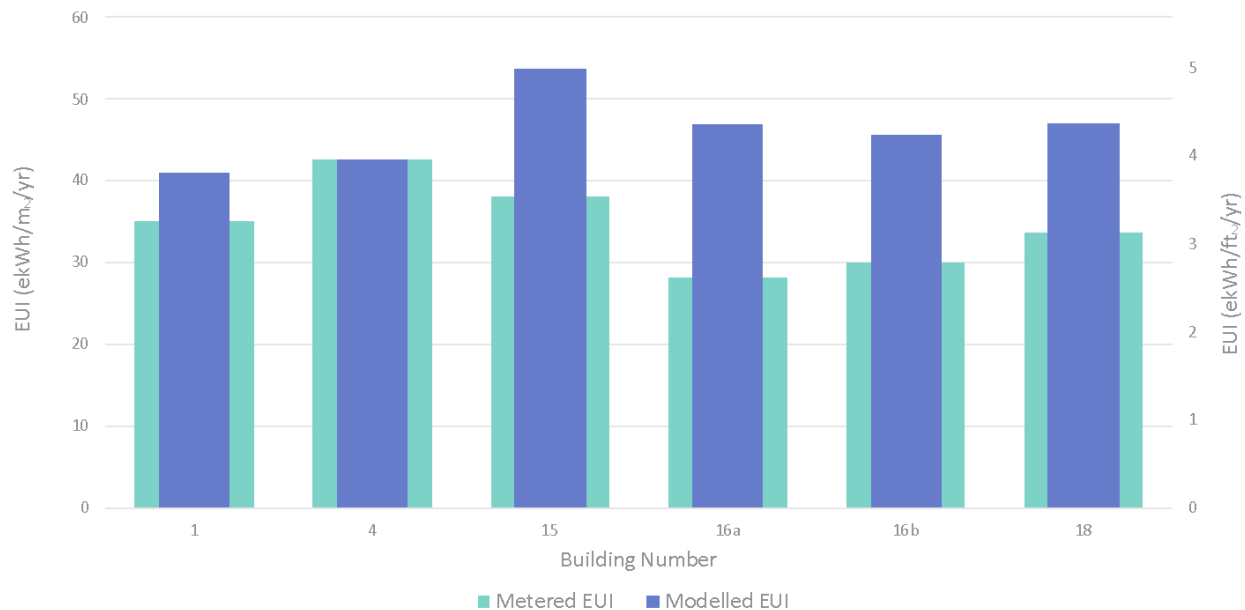


Figure 21: In-suite Electricity Usage – Metered vs. Modeled

To arrive at this finding, we compared current modeling practices to large sets of actual suite-level usage data.

To find energy use trends at the suite level, we analyzed the [Suite Dataset](#). This includes metered annual electricity usage for approximately 20,000 residential suites across approximately 100 Toronto MURBs. This dataset includes a wide range of bedroom counts and suite sizes. Metered data was taken from May 2017 to April 2018.

The majority of the metered suite electricity usage data is within the range of 2,000 – 3,000 kWh/year. The mean annual electricity usage of the metered suites is approximately 2,900 kWh/year, and the median is 2,600 kWh/year. This is shown in Figure 22.

This finding supports the performance gap identified in the six buildings. In the [Suite Dataset](#), modelled usage is 30% higher than the average metered usage. Models assume default power densities, expressed per area of floor space, and default usage schedules that are generally identical between buildings and across all suites. Current code requirements use default power

densities that haven't been updated since 1997. Our research shows these plug load assumptions are much higher than observed - reasons could be due to buildings being partially unoccupied (AirBnB culture, high portion of rentals), higher efficiency and smaller appliances, and floor lamps that use LEDs or CFLs more than incandescents. This is all despite presumably higher phantom loads from increased use of consumer electronics.

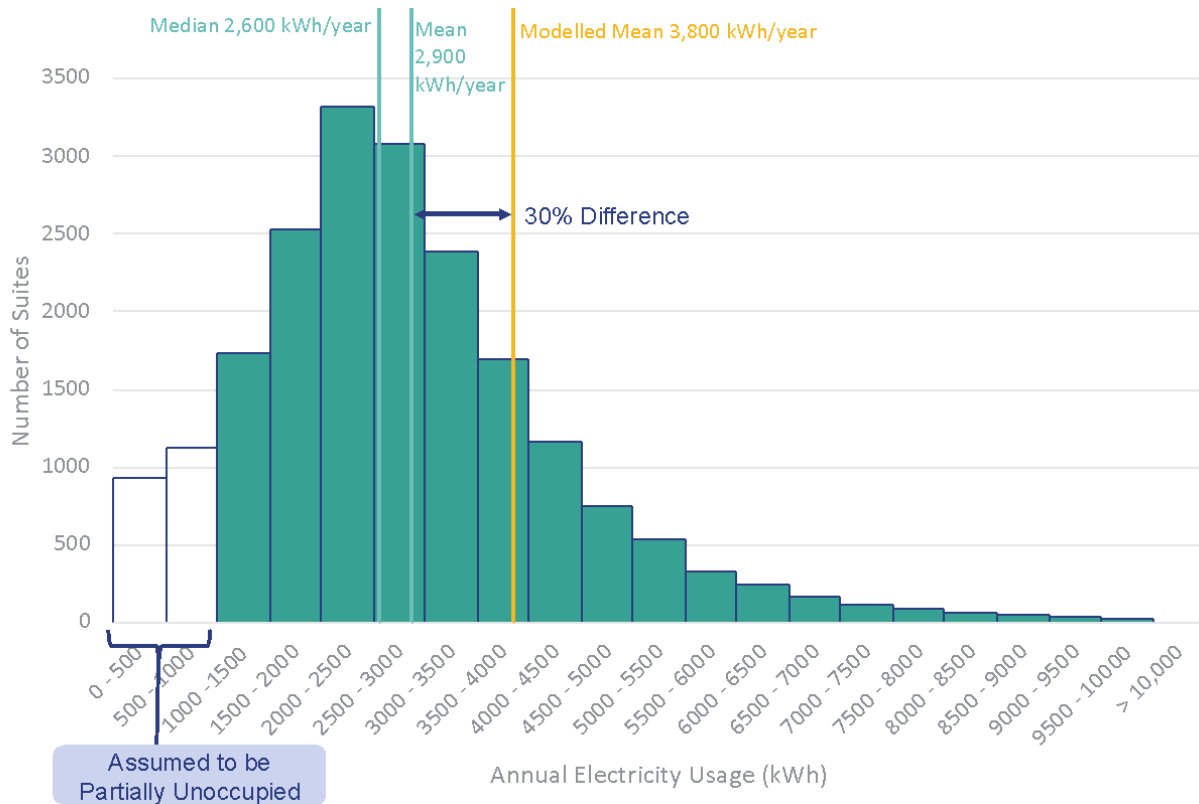


Figure 22: Annual Suite Electricity Usage - Metered Data

Common Area Electricity: Measuring the Performance Gap

At a glance: Common area electricity usage represents the largest performance gap between metered data and modelled predictions. This is largely due to modeling practices that do not require accounting for this end use. We further investigated the common area electricity use to isolate uses that could be identified. However, significant amounts of un-allocated electricity usage still remained.

Findings: Modelled common area electricity usage⁴ is 94% lower than metered performance

As shown in Figure 23, we found that modelled common area electricity usage is 94% lower than metered performance⁵. The buildings in the [End Use Dataset](#) were subject to either LEED v1.0 or the Toronto Green Standard v1.0. Modelling protocols in these standards did not require accounting for most process loads. Loads such as pools, exterior lighting, garage systems and other process loads have therefore not necessarily been modelled, which resulted in understated base electricity loads.

Metering of these end uses is not common, so we analyzed the design documents of the buildings to identify significant, unmetered electrical loads and removed this energy use from common area electricity usage. Energy uses that were isolated included pumps, central fans, garage exhausts, miscellaneous AC and heating, and pool mechanical loads.

We would expect to see some amount of uncharacterized common area electricity use after reallocation, representing small fans and pumps, electric space heaters, small split air conditioning systems or office equipment. However, the presence of larger amounts of unaccounted energy suggests something further is impeding performance, see Figure 24. Examples of situations that could potentially increase electricity include constantly running equipment rather than having it on a control system or adding equipment to the building without the knowledge of the system operator.

⁴ Metered common area electricity is electricity that cannot be attributed to in-suite usage, submetered central pumps, fans, and cooling equipment, and other ancillary uses.

⁵ Note: Common area lighting is not commonly sub-metered. We easily estimated this energy usage by reviewing modelled results and removed it from the common area electricity usage early in analysis.

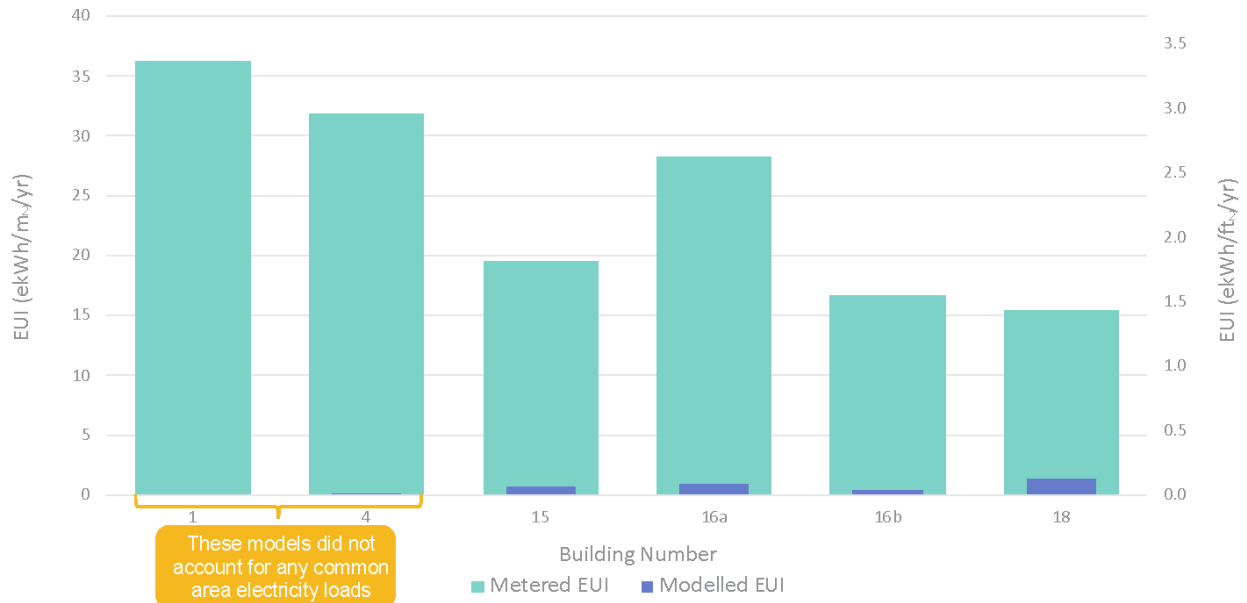


Figure 23: Common Area Electricity Usage - Metered vs. Modeled - Before Re-allocation

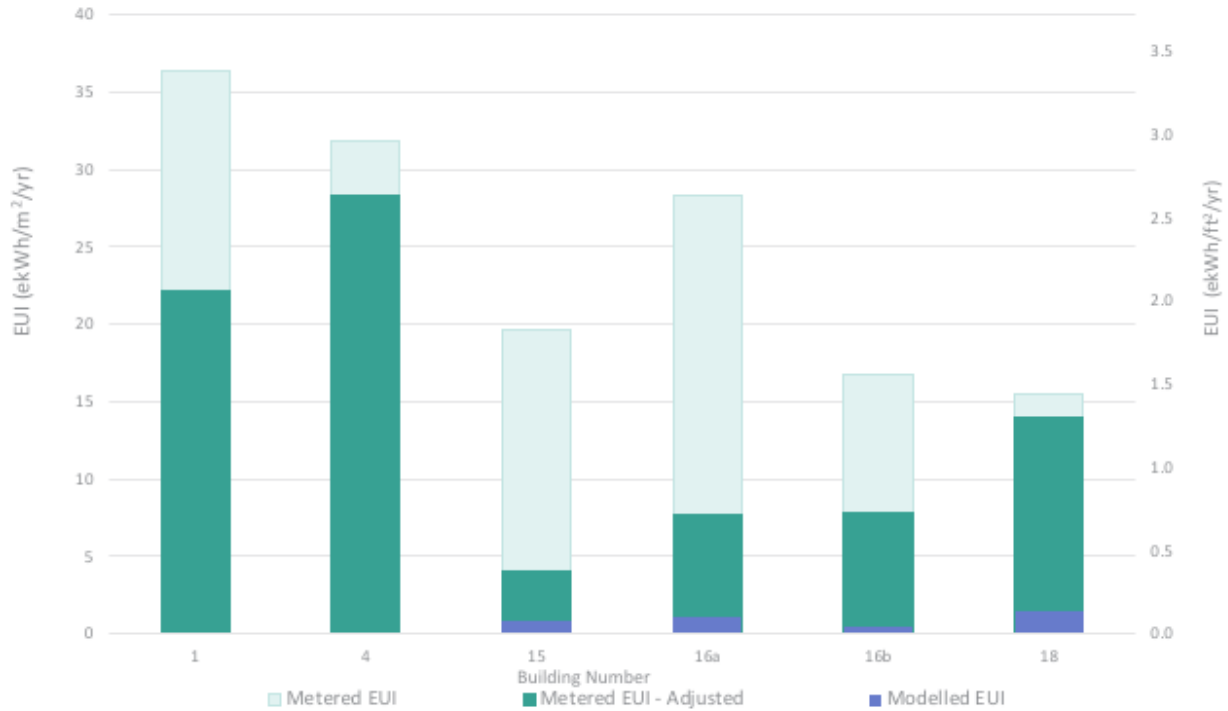


Figure 24: Common Area Electricity Usage - Metered vs. Modeled - After Reallocation

Section 4: Implications for Design: Performance of Common HVAC Systems

Toronto MURBs: Common HVAC System Choices in the Last 5 Years

Having access to the **Design Models Dataset** of 95 modelled buildings allowed us to identify design trends for HVAC systems. As space heating is the largest contributor to total building energy usage, the HVAC system can be an important design choice.

Finding: Fan Coil Unit HVAC systems dominate market

As seen in Figure 25, Fan Coil Unit (FCU) HVAC systems have been the dominant choice for typical MURBS designed in the last five years, with 2-pipe FCU systems being twice as popular as 4-pipe FCU systems. The next most popular choice, Water Source Heat Pumps (WSHP) systems, are a distant second.

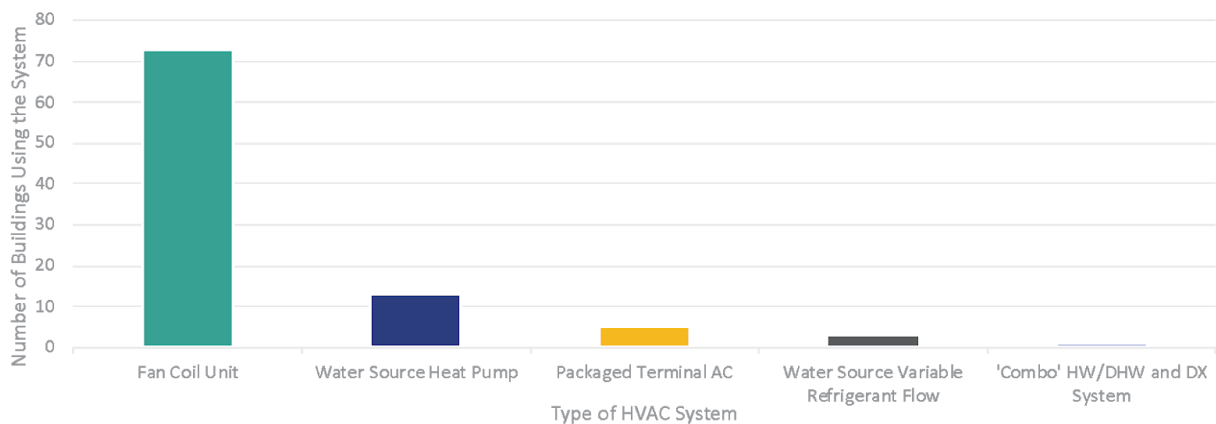


Figure 25: Common HVAC System Design Choices in Toronto in the Last 5 Years

In terms of the ventilation heat recovery system, the buildings were split almost equally. Approximately half of the modelled buildings used some kind of air-side heat recovery ventilation, and the remainder did not use heat recovery at all.

The most common method of producing domestic hot water in GTA MURBs is with natural gas-fired equipment. Equipment may be in the form of centralized hot water tanks or boilers, or smaller hot water tanks located in each suite. Central systems may be dedicated systems for hot water, or combined systems with both space heating and hot water boilers. Non-gas systems, such as electric and heat pump water heaters, are much less common.

Fan Coil Units: System Description and Advantages

In 2-Pipe FCUs, space heating or cooling is created when a fan blows air over a coil filled with either hot or chilled water. Two water pipes are attached to the coil – one supply and one return.

This system requires a spring and fall changeover at the building's central heating and cooling plant. At those times building operators switch the pipes from hot water, typically between 60°C and 82°C (140-180°F), to chilled water, typically 13°C (55°F). Heating and cooling is supplied by gas fired boilers and electric chillers respectively. In this system, only heating or cooling, but not both, is available to the building at the designated seasons.

4-pipe systems work in the same way as a 2-pipe fan coil, however they have two coils with two pipes attached to each – a hot water supply and return and a chilled water supply and return. No system changeover is required, and both heating or cooling is available to end users year-round. This requires central heating and cooling equipment to operate year-round as well, which leads to higher energy use.

The advantages of Fan Coil Unit systems are:

- In cooling mode, central electric chillers are able to achieve higher COP values than distributed heat pumps, through use of technologies such as variable speed / magnetic bearing chillers
- Heat pump buildings are more often specified with packaged HVAC units for corridor make-up air units, where fan coil buildings will typically be specified with higher-efficiency plant-connected hydronic systems
- Heat pump buildings generally have larger water distribution pumps that are designed to be constant speed, while fan coil buildings are more often fitted with variable-speed pumping systems

Water Source Heat Pumps: System Description and Advantages

This system provides either space heating or cooling via a compressor running a refrigerant cycle. With a Water Source Heat Pump (WSHP), the equipment is attached to a water loop which is 'tempered' to stay within a specific temperature band, typically 21-32°C (70-90°F). To condition the space, the WSHP will either reject heat into or extract heat from the water loop. Depending on how many heat pumps require heating or cooling at any given time, the water loop itself is warmed or cooled to reduce the work by the heat pump. Typically, this is done by an electrically powered cooling tower or a gas-fired boiler.

This water loop can also be configured to connect to a ground loop heat exchanger. This is referred to as a Ground Source Heat Pump (GSHP) system.

In other scenarios, the heat pumps do not connect to a water loop at all, but instead reject or extract heat directly from the outdoor air. These systems are called Air Source Heat Pumps (ASHP). ASHP typically have a backup heat source (often electric) because only a limited amount of heat can be extracted from the outdoor air at low temperatures. Though less common in the GTA, both geothermal and ASHP can be all electric systems.

In all heat pump configurations, heating and cooling are both available year-round.

The advantages of Water Source Heat Pump systems are:

- WSHP systems allow for recovery of heat during periods of simultaneous heating and cooling
- WSHP systems run at a lower water loop temperature than FCUs, allowing for lower return water temperatures, lower thermal losses through piping, and an opportunity to achieve higher efficiencies in condensing boilers
- A large proportion of heating is performed using electric compressors, which provides heat at higher efficiencies compared to conventional hydronic heating systems

Metered Energy Performance of Existing Buildings

Using the [Utility Dataset](#), we were able to determine how buildings with different HVAC systems perform in reality.

Finding: HVAC system alone is not a significant factor in energy performance

We found that HVAC system type alone is not a significant factor in a buildings energy performance. We found that metered EUI performance of buildings with FCU and WSHP systems are relatively similar, with only a 3.5% difference in median EUI.

Buildings with a WSHP system show only a slightly lower median total energy use (both gas and electricity) than those with FCUs. However, we would have expected a greater difference, as heat pump systems are assumed to be higher efficiency systems. The whole building EUI of the [Utility Dataset](#) buildings range between 161 and 346 ekWh/m² (15 and 31 ekWh/ft²), with buildings commonly achieving an EUI between 210 and 250 ekWh/m² (19.5 and 23.2 ekWh/ft²), as seen in Figure 26.

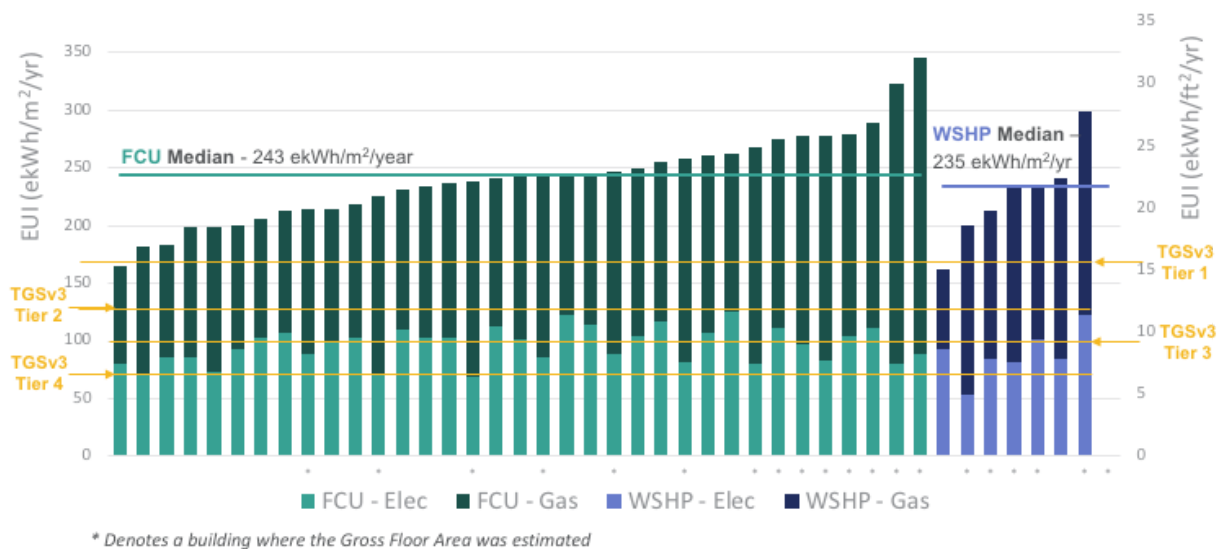


Figure 26: Common HVAC Systems - Metered Energy Use Intensities

Modelled Energy Performance of Designed Buildings

This finding is supported by the energy models from the [Design Models Dataset](#). As seen in Figure 27, we found that energy models showed FCU buildings having a 5.7% lower EUI than WSHP buildings. While the difference between FCU and WSHP is flipped, it remains small enough to be considered relatively insignificant.

We used the [Design Models Dataset](#) to create an end use breakdown for each of the common HVAC systems, Figure 28. As one can expect, the EUI of non-HVAC components, such as lighting, equipment and domestic hot water, remains relatively consistent between HVAC

system types, as these aspects are not heavily influenced by the building's heating/cooling systems. Cooling is more intensive in WSHP buildings, as heat pump cooling coefficient of performance (COP) typically averages around 3.7, versus a water-cooled chiller with a much higher COP of around 5-6.

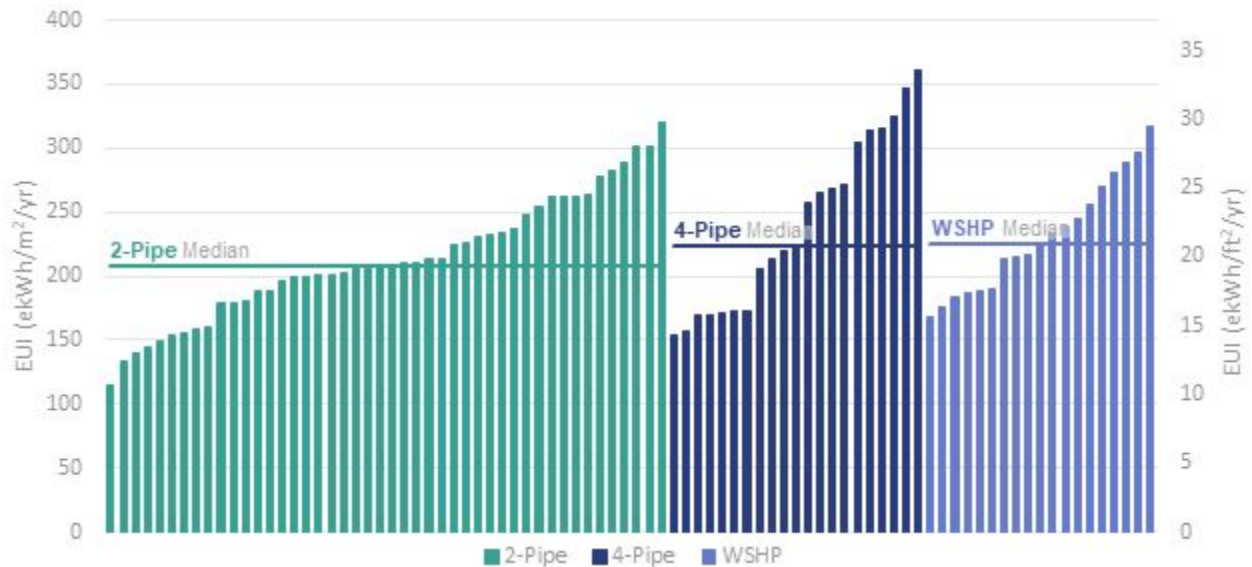


Figure 27: Common HVAC Systems - Modelled Energy Use Intensity

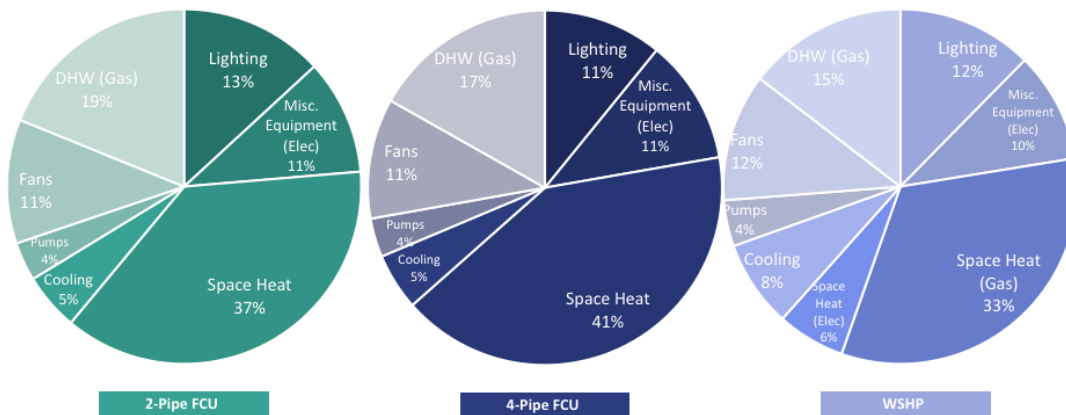


Figure 28: Common HVAC Systems - End Use Breakdown

Non-LEED Buildings

The [Utility Dataset](#) confirms that LEED-certified MURBs in Toronto, and the Toronto market in general, are primarily FCU buildings. To better compare the two systems, a deeper analysis was warranted. We compared the non-LEED buildings in the [Utility Dataset](#) in isolation.

As shown in Table 4, this revealed that non-LEED WSHP buildings performed 8.0% better on average than non-LEED FCU buildings. While this difference is slightly larger than the 3.5% difference when looking at the full dataset, the comparison still suggests that HVAC system type alone is not a significant factor to total building energy performance.

Table 4: Common HVAC Systems - Non-LEED Building Energy Consumption

System	Count	EUI Electricity ekWh/m2 (ekWh/ft2)	EUI Gas ekWh/m2 (ekWh/ft2)	EUI Total ekWh/m2 (ekWh/ft2)
WSHP	7	90.2 (8.38)	156.8 (14.57)	247.0 (22.95)
FCU	14	88.7 (8.24)	179.9 (16.72)	268.6 (24.96)
% Better (than FCU)		-1.7%	12.8%	8.0%

Suite Electricity Usage

To further compare energy usage within buildings with these two common HVAC systems, we used the [Suite Dataset](#) to isolate and analyze suite-level electricity usage.

We found that suites in WSHP buildings use more electricity than suites in FCU buildings. The WSHP mean suite electricity usage is approximately 1,100 kWh/year higher than the FCU mean suite electricity usage. This is expected, as buildings with WSHP systems use electricity in suites for conditioning the space, see Figure 29.

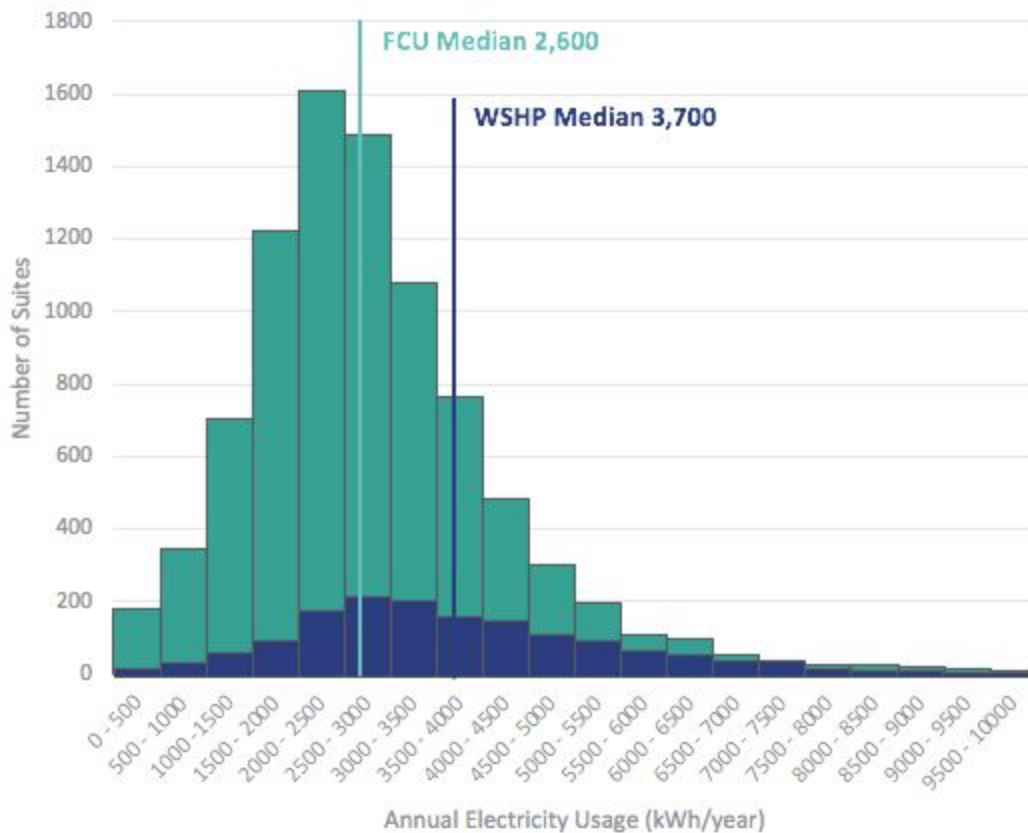


Figure 29: Common HVAC Systems - Metered Suite Electricity Usage

Cost Implications of Existing Buildings

To estimate the buildings' energy costs, we used the energy usage data for 43 existing buildings in the [Utility Dataset](#), along with blended rates for both electricity and gas usage. The blended rates for energy in Ontario are \$0.14/kWh for electricity and \$0.30/m³ for natural gas.

As seen in Figure 30, we found that the median whole building energy cost for buildings with a WSHP system is slightly less than for those buildings with an FCU system. This indicates a lower peak demand as well as lower overall energy costs.

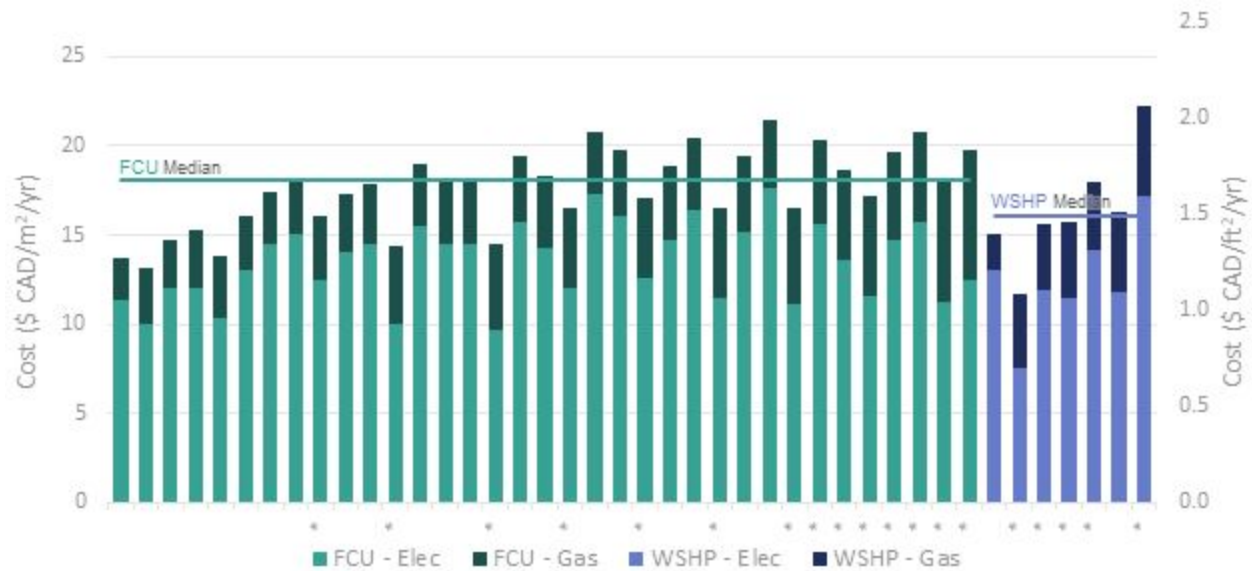


Figure 30: Common HVAC Systems – Energy Cost Intensities

Ontario's Electricity Grid: Greenhouse Gas Emissions

To analyze the greenhouse gas emissions of the buildings, we considered the Ontario electricity grid and its associated energy sources. In Ontario, electricity 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, as shown in Figure 31. These graphs were generated at 3pm on a typical weekday, showing that marginal energy sources were engaged starting around 8am, and increasing throughout the day as demand increases.

Fuel sources that are “on the margin” (i.e. fuel sources that are engaged as needed) respond to peaks in electricity demand. Because of their quick response time, natural gas plants are a common marginal fuel source in Ontario. On off peak times, Ontario's electricity grid has a relatively low emissions factor. For this reason, when designers are looking for ways to reduce a buildings greenhouse gas emissions, they typically consider electric systems.

Greenhouse Gas Intensity (GHGi) of the electricity grid can be calculated in three ways, depending on when the emissions are averaged:

- Annual Average Ontario Grid Emissions:** This is the most common method for describing the emissions factor of the Ontario grid. This method is used in both the Ontario Building Code and the Toronto Green Standard. We use this method for calculations in the report, unless otherwise stated. Using this method, the current value is 50 g CO₂e/kWh as defined by the Ontario Building Code.

- **Hourly Grid Emissions:** This value varies from hour to hour and may range from ~ 2 to ~145 g CO₂e/kWh. This large range reflects the changing mix of energy sources, from low emission sources such as renewables and nuclear, to high emission sources such as natural gas.
- **Hourly Grid Marginal Factor:** This value varies from hour to hour, and ranges from ~ 69 to 247 g CO₂e/kWh. This value reflects the carbon emissions of fuel sources that are “on the margin” for that hour. These fuels need to be engaged during that hour to keep up with increased demand. This factor is calculated as the emissions from the additional electricity needed in that hour (if any) compared to the hour before, divided by the additional amount of electricity.

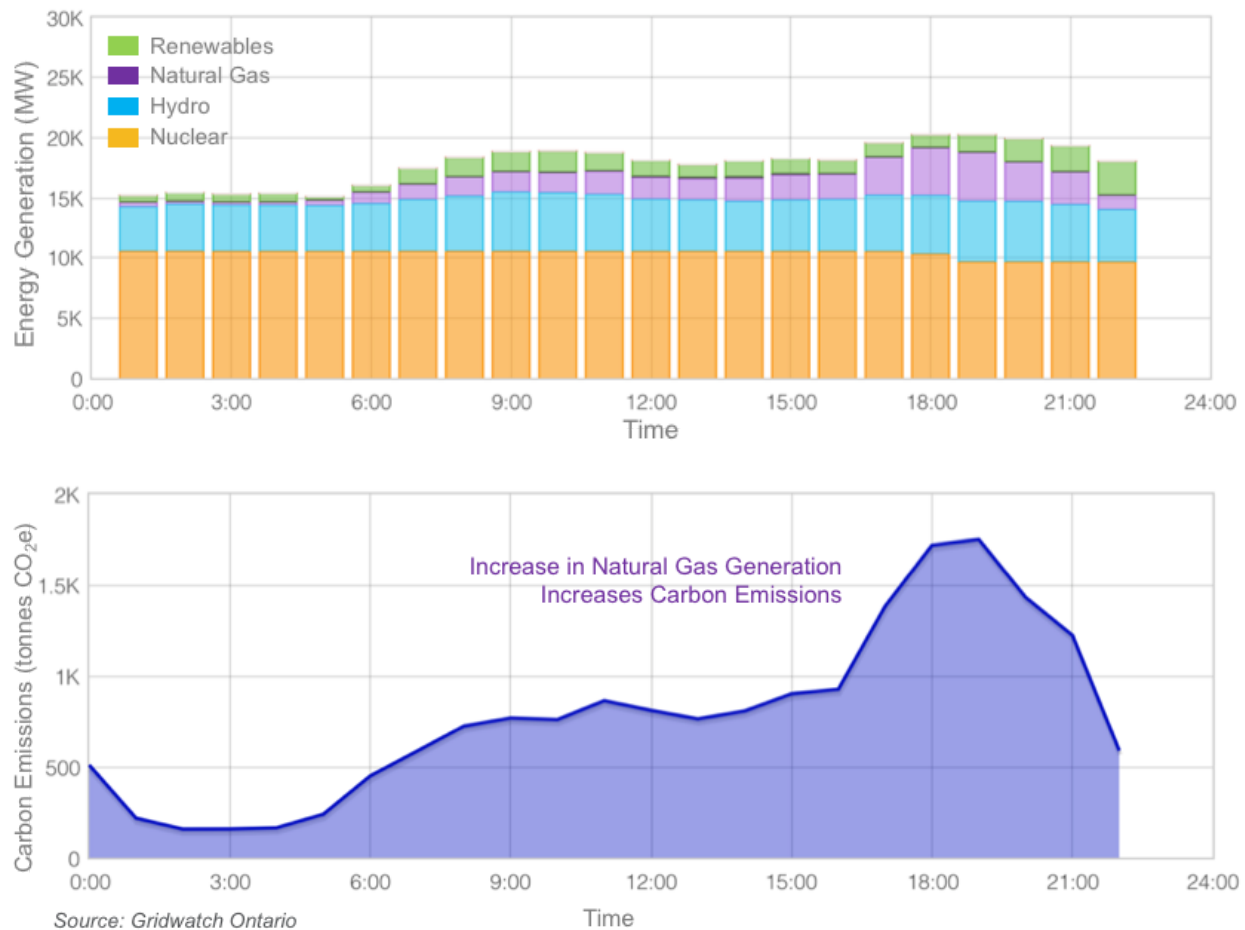


Figure 31: Ontario Electricity Grid Source and Emissions - Typical Work Day

Greenhouse Gas Emission Intensities of MURBs

To determine the different levels of GHG emissions from MURBs with common HVAC systems in the [Utility Dataset](#), we used the annual average GHG-intensity (GHGi) of the Ontario electricity grid.

While WSHPs are considered “electric” systems, we found that the existing buildings in this dataset with WSHPs used as much gas as the buildings with FCUs. When evaluated using the annual average GHGi values for the power grid, the GHGi of the WSHP was equal to that of the FCU buildings. The median GHGi for both building types is 32 kg CO₂e/m², as shown in Figure 32.

It should be noted that all of the WSHP buildings in this dataset use natural gas boilers to heat the central water loop. Because of this, the expected emissions savings from using a heat pump system aren’t realized in this dataset. This could also be attributed to natural gas usage for DHW in the WSHP buildings, but could not be confirmed at this time.

Despite this finding, heat pump systems have greater potential to reduce greenhouse gas emissions when the thermal energy source is renewable, commonly ground or air source heat pumps.

We found similar trends in the [Design Models Dataset](#), where the median GHGi’s of the building types were relatively equal, Figure 33.

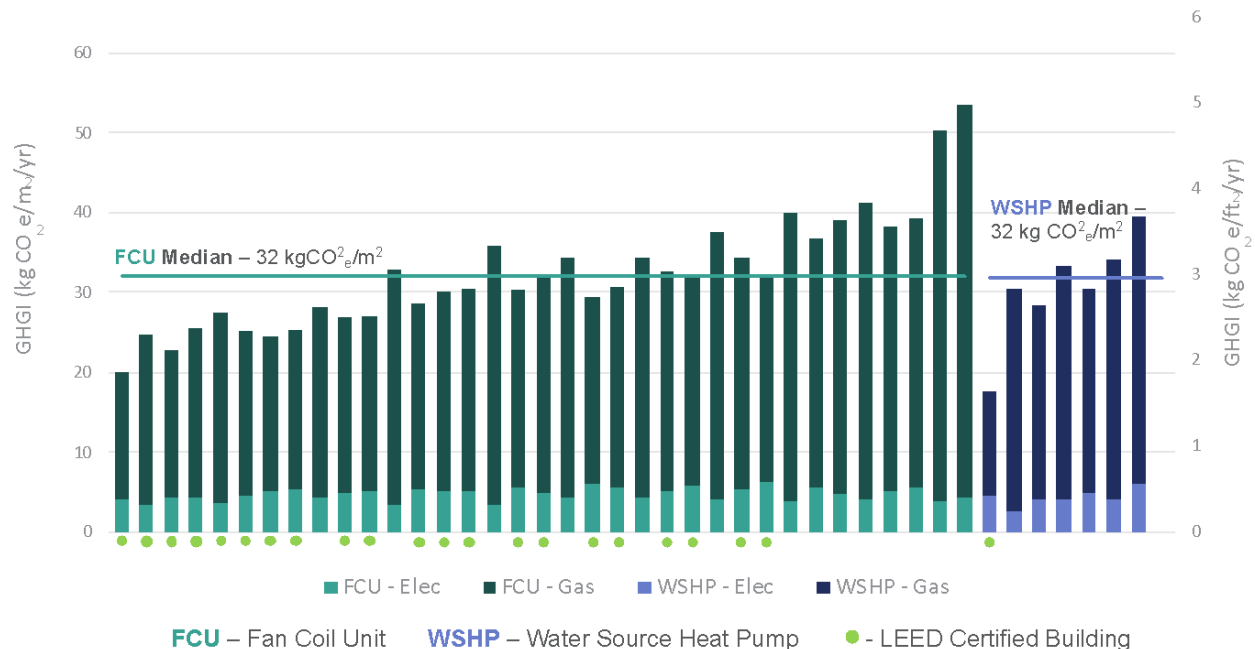


Figure 32: Annual Average Greenhouse Gas Intensity - Metered Buildings

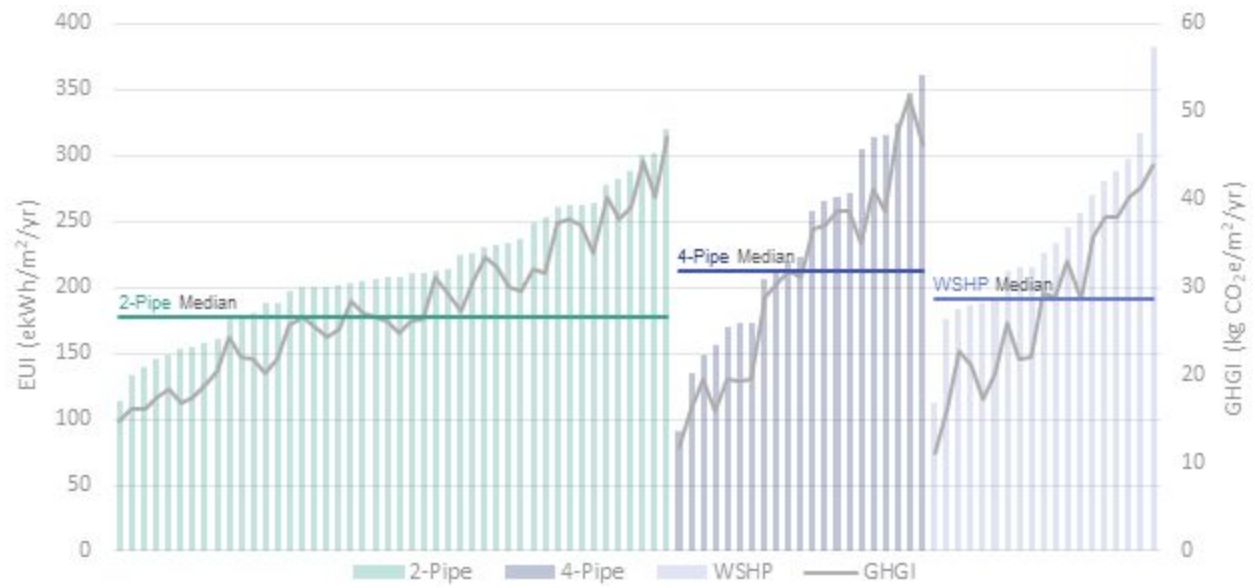


Figure 33: Annual Average Greenhouse Gas Intensity - Modelled Buildings

Whole Building Peak Electricity Usage Effect on Greenhouse Gas Emissions

Our findings suggest that the GHGi of MURBs with the two most common HVAC systems are relatively similar. Because these emissions were calculated using annual average emission factors, we wanted to take the analysis a step further to determine the effect of marginal electricity generation. To do this we analyzed the peak electricity usage of the buildings by tracking annual building peak electricity demand over a two-year period.

Findings: WSHP buildings showed a lower peak electricity usage than FCU buildings

As seen in Figure 34, buildings in the dataset with a WSHP system showed a lower peak electricity usage than those with a FCU system. On average, the WSHP buildings in this dataset had a 12.6% lower peak than FCU buildings.

This suggests that the assumed higher efficiency of a central chiller plant in an FCU system, compared to the compressors in a WSHP system, does not result in peak demand reduction. One explanation is that the distributed nature of the WSHP compressors results in some diversity of peak load. In winter, the difference in peak load is less pronounced, however, it is somewhat surprising that the peak value for WSHP heat pumps is still less than fan coil buildings, as there is no electric heat in FCU buildings. The implication is that if a marginal GHGi factor is used for calculating building emissions, the FCU buildings in the data set would have higher GHG emissions due to greater electricity usage during peak times.



Figure 34: Monthly Building Peak - Average for Common HVAC System Buildings

Figure 34 also shows the observed range in monthly peak values, normalized by building gross floor area (GFA). The trends over time between the systems are fairly similar, with highest peak values in the summer months, and lowest in the spring and fall.

When using energy peak usage by suite as an alternative benchmark, we are able to breakdown total peak between residential and common areas of the building. These peaks vary from season to season, as seen in Figure 35. On average, WSHP buildings have a 26% lower peak than FCU buildings in the common areas of the building. Within suites, however, FCU buildings have a 30% lower peak. With this alternate normalization, the difference between the average peaks of WSHP and FCU buildings narrows considerably as shown in Figures 36-37. Annually, the WSHP buildings had only an average 2% lower peak than the FCU buildings, when normalized by number of suites.



Figure 35: Building Level Peak - Breakdown of Common Area vs Suites

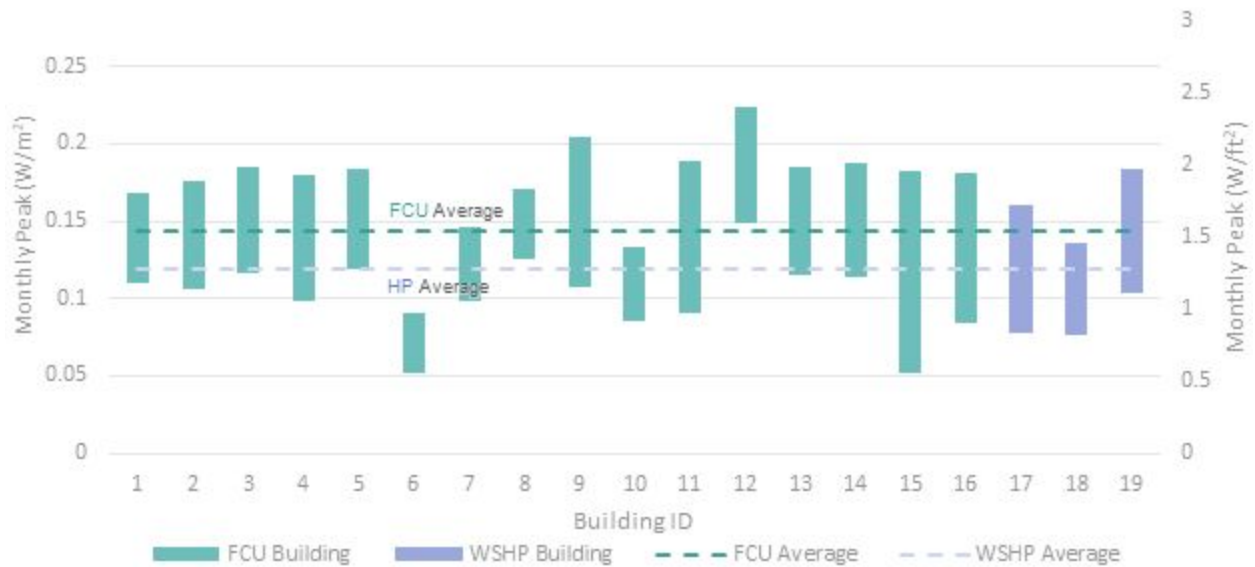


Figure 36: Building Peak Usage Normalized by GFA - Monthly Ranges



Figure 37: Building Peak Usage Normalized by Suite Count - Monthly Ranges

Finally, as shown in Figure 38, the findings from the **Design Models Dataset** do not reflect the same trends as the metered buildings. In this dataset, WSHP buildings show a slightly higher median peak value, normalized by suite count.

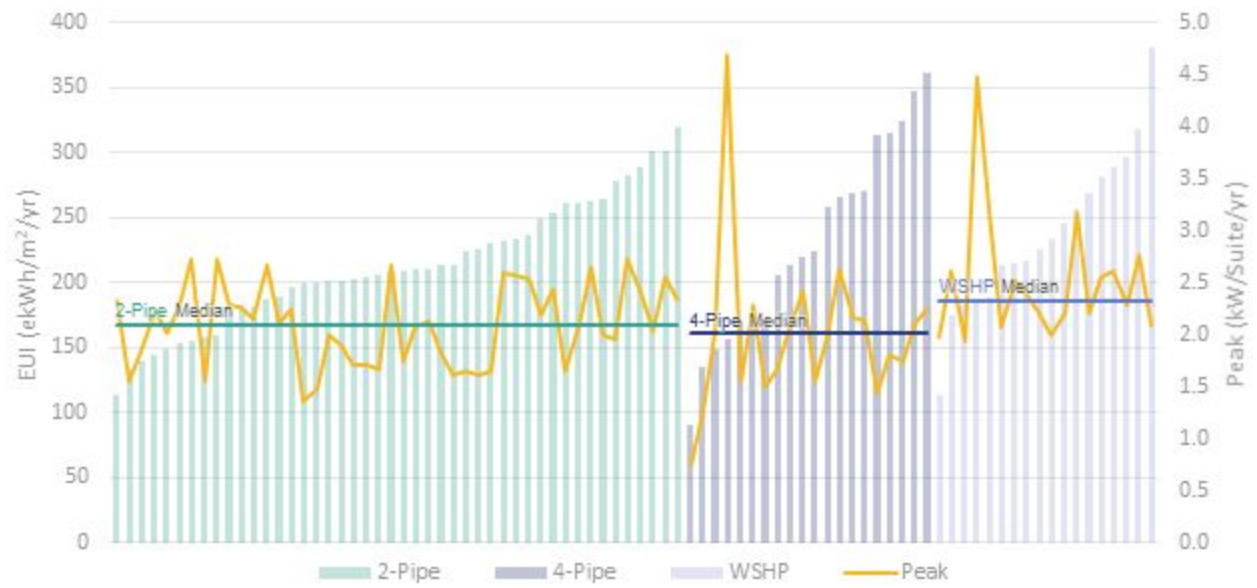


Figure 38: Building Level Peaks - Modelled Data

Building Level Peak Electricity Usage: Trends

To discover high-level trends in whole building peak electricity usage, we examined building level peak electricity in relation to a number of other building parameters. Designers can use these trends as a baseline for the typical conditions in Toronto, and to extrapolate for future designs.

- As may be expected, Figure 39 shows there is a near linear relationship between monthly peak and monthly consumption.
- There appears to be a strong linear relationship between building GFA and peak, with building #7 (with large suites) as an outlier in Figure 40.
- There is also a strong linear correlation between annual building peak and suite count, shown in Figure 41.

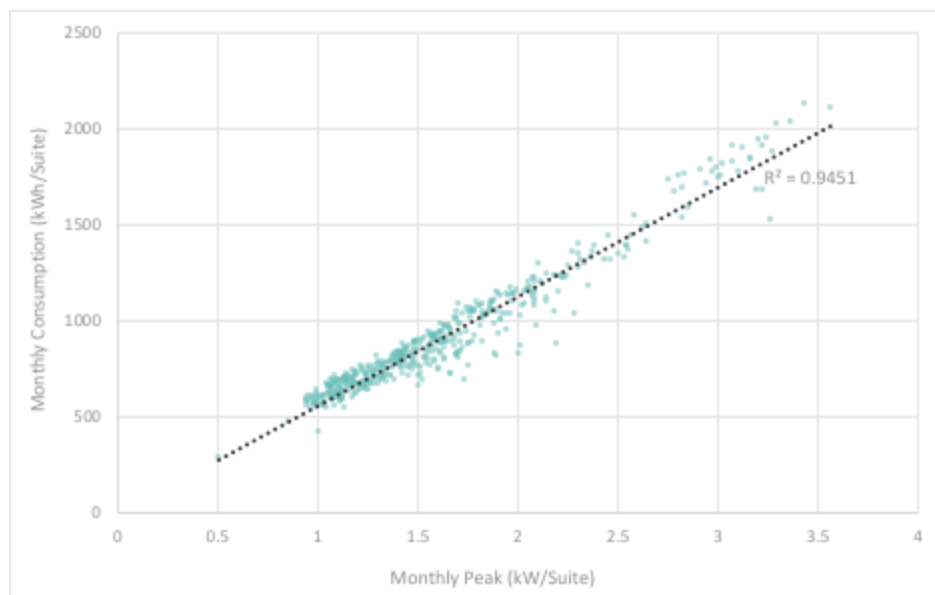


Figure 39: Building Level Peak - Monthly Peak vs. Monthly Energy Consumption

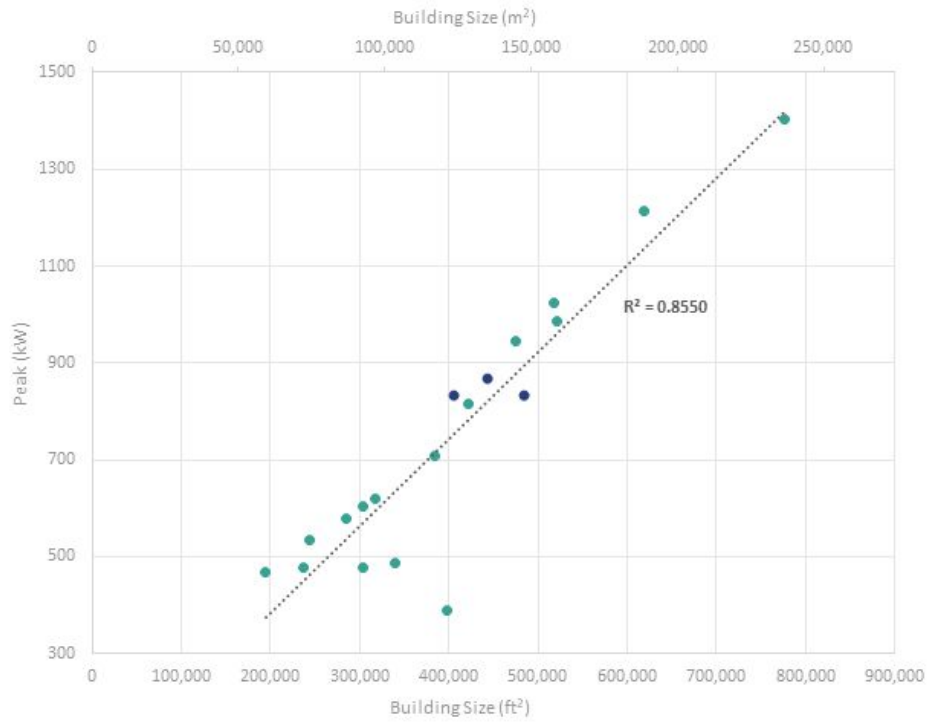


Figure 40: Building Level Peak - Annual Peak vs. Building Size

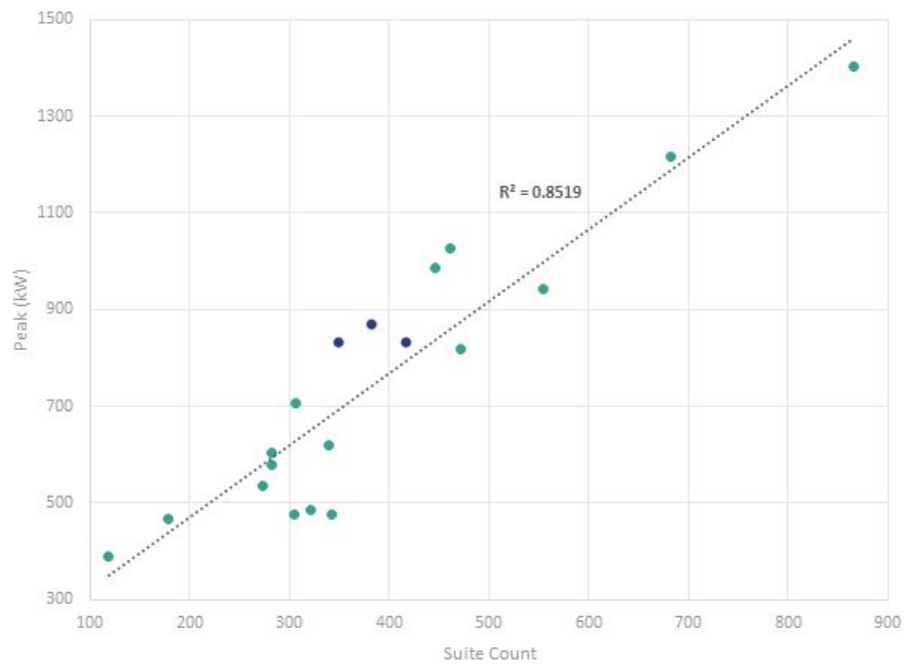


Figure 41: Building Level Peak - Annual Building Peak vs. Suite Count

Section 5: Additional Findings on Energy Consuming Systems

At a glance: Beyond the performance gap, our analysis of the datasets revealed important findings related to other energy consuming systems in MURBs: domestic hot water boilers, non-residential tenant energy use, corridor conditioning, snow melt systems, chillers, and suite energy use patterns.

Hot Water Boiler Systems: Sizing and Efficiency

To determine how accurate designers are in specifying appropriately-sized domestic boilers, we compared the metered annual peak of domestic hot water demand against the domestic boiler capacity for the buildings in the [Combined Modelled & Metered Dataset](#). The buildings in this dataset have two different types of domestic boiler systems: a dedicated system and a combined heating system. A dedicated system is used for domestic hot water only, whereas combined heating systems are used for both space heating and domestic hot water.

Finding: Combined heating systems are more appropriately sized than dedicated systems

When performing sizing calculations for HVAC systems, mechanical engineers will add safety sizing factors, and they will typically choose equipment based on the closest, higher capacity unit available in the market. We found no consistency in the way designers size either system; the over-size factors range from 1.0 to 3.5. Larger over-sizing factors indicate inefficient systems, which use more energy to deliver domestic hot water to the building. As shown in Figure 42, the median over-size factor for combined systems is approximately 1.5⁶, whereas the over-size factor for dedicated systems is approximately 2.5.

We also analyzed the modelled annual domestic hot water peak demand of the buildings in the [Combined Modelled & Metered Dataset](#). As shown in Figure 43, we found that in most cases, the models underestimated the metered peak demand, as the over-sizing factors were higher when compared to modelled peaks.

⁶ In cases where a building contained combined heating and domestic hot water boilers, the capacity reserved for DHW was determined as the ratio of the domestic thermal to heating thermal meter readings during the coincident boiler thermal peak.

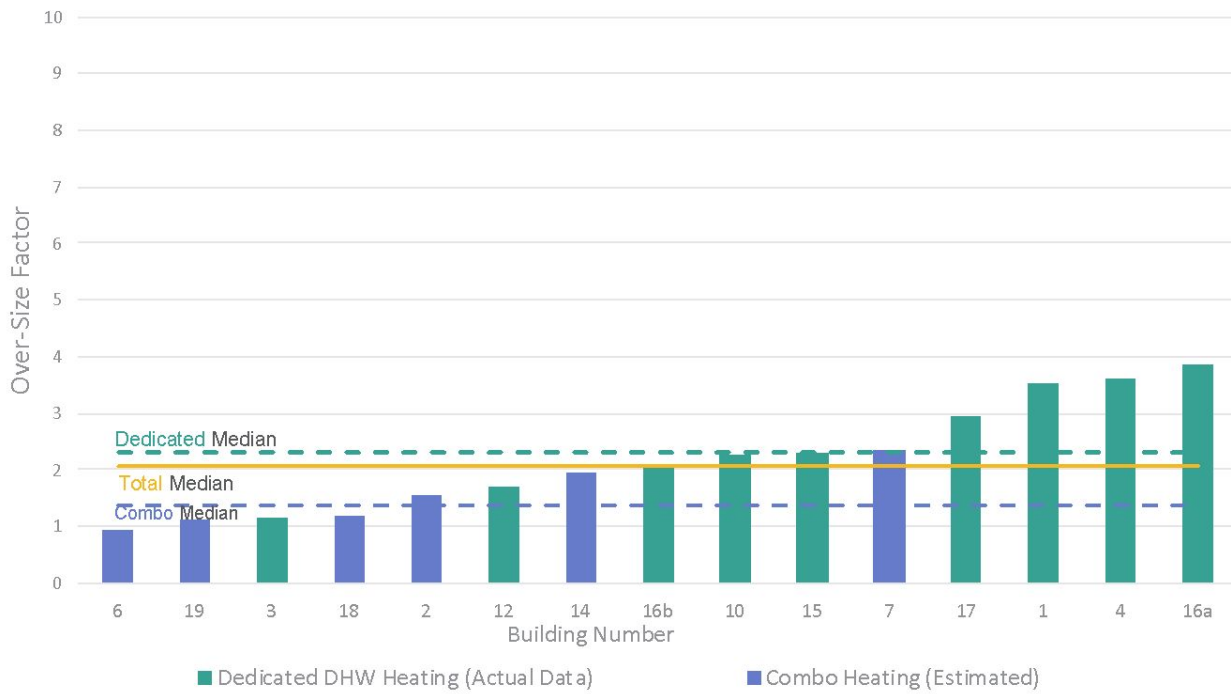


Figure 42: Domestic Hot Water Systems – Metered Over-Size Factors

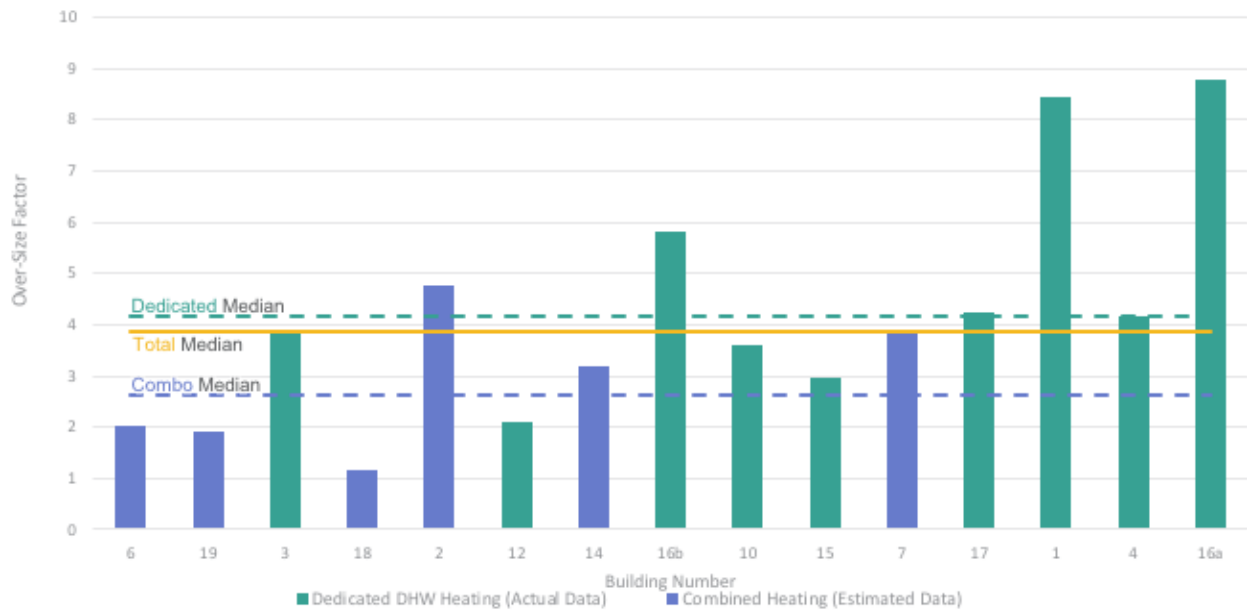


Figure 43: Domestic Hot Water Systems – Modelled Over-Size Factors

Non-Residential Tenants in MURBs: Electricity Usage

At a glance: To gain a better understanding of the consumption patterns and averages of non-residential tenant spaces in MURBs, we analyzed readings from various buildings' retail electric meters for 2016 and 2017.

Finding: Non-residential tenant energy usage is underestimated by energy models

Early in design, the type of tenants are not typically known. Designers and energy modelers typically default to 'retail' to cover all unknown ground floor spaces. Without knowing the use type, it is difficult to accurately predict energy usage, especially considering the range of energy use for different types of retail tenants.

We found that actual metered energy consumption for retail and office tenants varied by as much as 500% (Figure 44). This greatly exceeds the default assumptions required by code for energy modelling and compliance. The Ontario Building Code generally requires that modellers use standard plug load intensities and schedules that have not changed since the 1990's.

The average electricity usage for retail and office tenants in national databases of metered data were more in line with actual usage. Thus, for greater accuracy, we recommend energy modelers use the assumptions in the national databases.

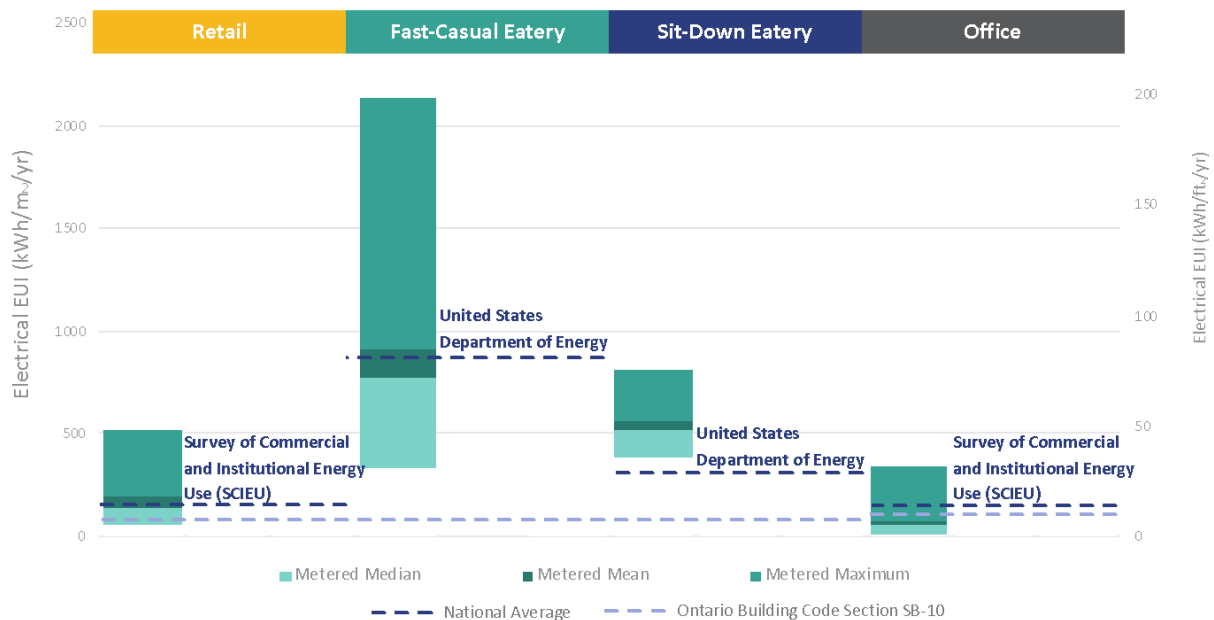


Figure 44: Retail and Office Tenant Electricity Usage - Comparison to Baselines

Non-Residential Tenants in MURBs: Retail Tenant Types

When we analyzed retail electricity use in more detail, we found that supermarkets use significantly more electricity per unit area than the other retail spaces (Figure 45). This is likely due to considerable refrigeration. Also note that retail unit 12 is a dry-cleaning facility, which consumes more electricity than other retail.

When comparing actual retail energy consumption to modelling defaults, we found that the metered data is greater than modelling defaults from the OBC and TGS, but is relatively close to the SCIEU and NECB/ASHRAE+LEED assumed values. All defaults, however, underestimated dry-cleaning, banking, pharmacy, and supermarket spaces.

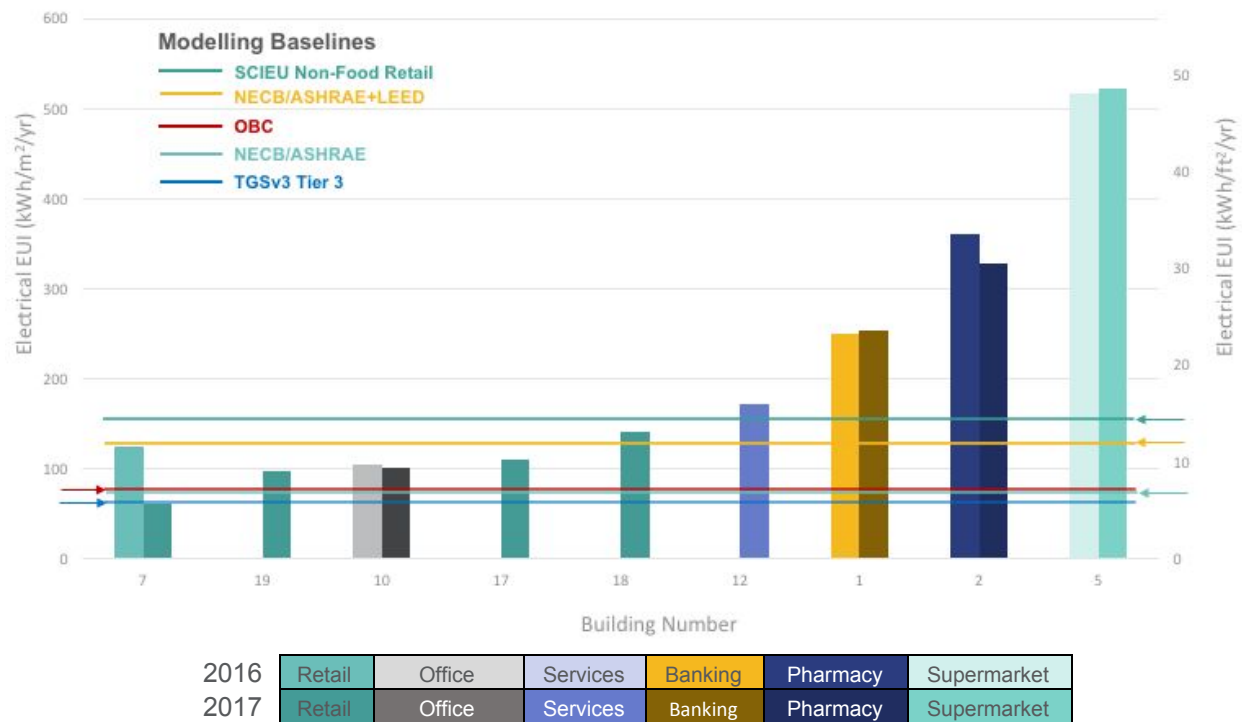


Figure 45: Non-residential Tenant Consumption - Retail

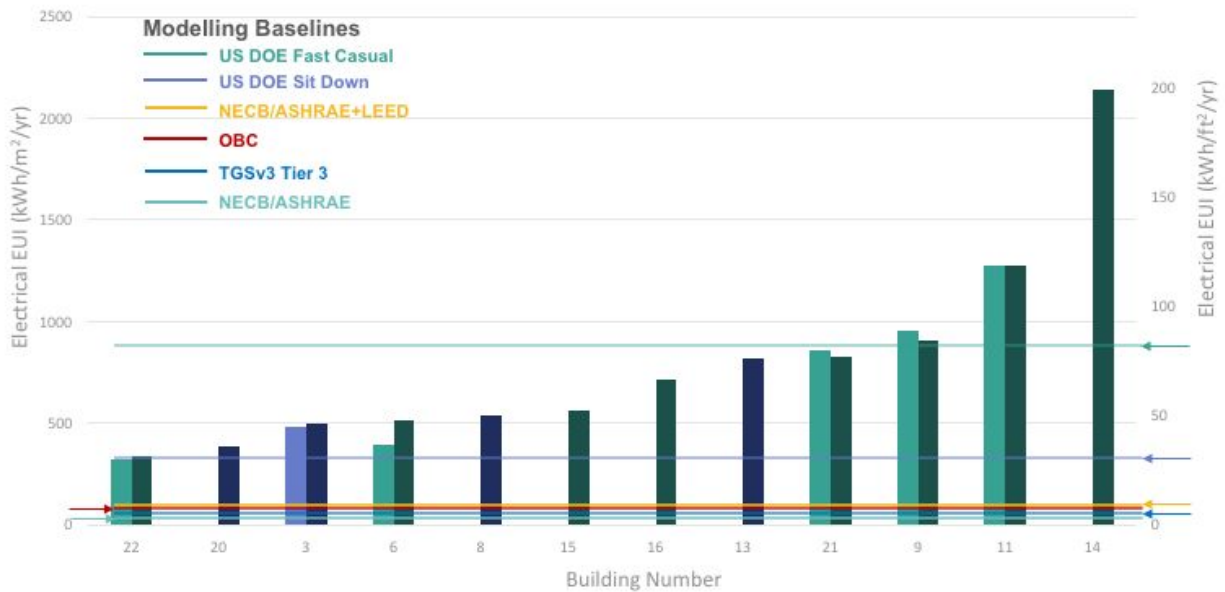
Non-Residential Tenants in MURBs: Closer Look at Eateries

To further analyze energy use in eateries, we split the eatery tenants dataset into sit-down and fast-casual operations.

We found metered usage for a sit-down eatery tended to show a lower electrical EUI than the fast-casual spaces (Figure 46). One contributing factor to this result is that the relatively low power-density of dining spaces found in sit-down eateries dilute the high energy intensity of commercial kitchens. Both the sit-down restaurants and fast-casual eateries consume

significantly more energy than what is expected by OBC default assumptions. They are, however, well aligned with values from the US Department of Energy.

In Building 14, the retail tenant consumes 13% of the building's total electricity and 6% of the building's total energy. If designers can distinguish early on between eatery spaces and generic retail spaces, they can use more appropriate default assumptions, thereby significantly reducing the performance gap in buildings with large retail spaces.



2016	Sit-Down	Fast-Casual
2017	Sit-Down	Fast-Casual

Figure 46: Non-residential Tenant Consumption - Eateries

Non-Residential Tenants in MURBs: Closer Look at Office Space

Metered office electricity consumption tends to fall in the range of current modelling estimates, based on NECB and LEED baselines. It can be easier to estimate energy usage in offices because work schedules are typically more definite.

We found that electricity consumption in offices varies significantly (Figure 47). This may be due to partial occupancy or the presence of data servers in some office spaces. The average and median values appear generally well-aligned with the baselines, and the NECB/ASHRAE+LEED estimate is very closely aligned with the observed average.

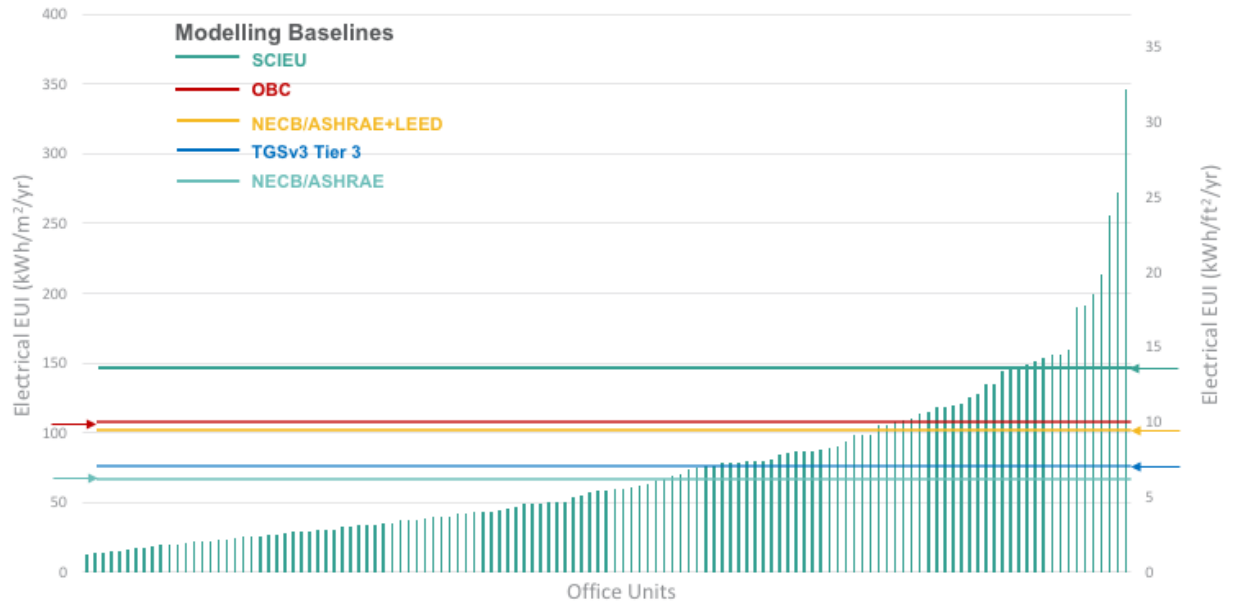


Figure 47: Non-residential Tenant Consumption - Offices

MURB Corridors: Potential to Reduce Mechanical Conditioning

At a glance: We analyzed an existing typical MURB with a central corridor which is currently conditioned by a hot water/chilled water (HW/CHW) coil providing 46 cfm/door of fresh air⁷. We analyzed the indoor temperature of the corridor at three different flow rates for both a conditioned scenario, and an unconditioned scenario with an ERV.

Depending on design conditions and humidity levels, a MURB corridor could use a central Energy Recovery Ventilator (ERV) in lieu of mechanical conditioning through hot and chilled water coils. If the corridor is not conditioned, a building may require additional strategies to remove relative humidity from the air stream to avoid condensation during peak humidity in summer. Removing mechanical conditioning from the central corridor air handler can significantly reduce building energy use.

As expected, there is greater variation in the average daily temperature of the unconditioned corridor space, compared to the actively conditioned corridor, however for the majority of the time even the unconditioned scenario meets minimum habitable temperature requirements. See Figure 48.

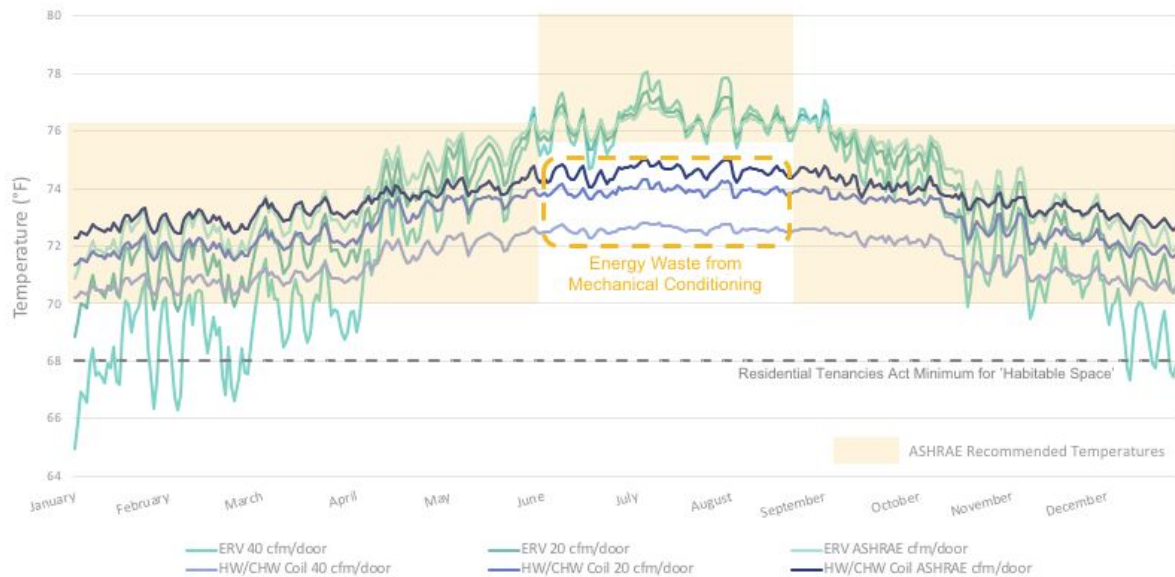


Figure 48: MURB Corridors - Effects of Conditioning on Indoor Temperature

There is less fluctuation in temperature in unconditioned corridors with lower flow rates as outdoor air flow and temperature have a smaller effect on indoor temperature in these cases. Particularly in the winter months, flow rates of 20 cfm/door or less do not cause the unconditioned corridor to go below 68°F.

⁷ For this study, the theoretical central enthalpy wheel is set at 75% effective, which is a typical for this type of heat recovery device - it should be noted that this effectiveness fairly heavily influences the results of the analysis.

In a Passive House inspired building, the flow rate would be similar to the Minimum ASHRAE 62 rate - approximately 7 cfm/door in this case. At this minimum flow rate, the effect of an unconditioned corridor on the daily temperature is minimal. The temperature falls within recommended ranges, theoretically negating the need for supplemental heating. Whether or not this kind of temperature range is acceptable to residents in a corridor space would need to be explored further. Current industry practices condition corridors to 70°F all year round, despite the fact that corridors are considered transient spaces.

According to ASHRAE Standard 55-2013: *Thermal Environmental Conditions for Human Occupancy*, indoor temperatures should range from 68.5°F to 75°F (20°C to 24°C) in the winter and 75°F to 80.5°F (24°C to 27°C) in the summer. While the [Residential Tenancies Act](#) stipulates minimum temperature (at least 68°F (20°C) or above) for “habitable space”, there is no specific requirements for corridor conditioning. Per O. Reg. 517/06, s.1. habitable space means a room or area used or intended to be used for living, sleeping, cooking or eating purposes and includes a washroom (“local habitable”).

Based on the study building, eliminating corridor conditioning can result in a 4 - 18% overall building energy use reduction based on the design flow rate, Figure 49. Percentage savings are greater with higher flow rates, as the overall building energy consumption is greater. This is a potentially great source of building energy use reduction with a relatively small impact on comfort. Most people are already dressed for the outdoors when they leave their suite. In order to maximize the enthalpy recovery potential, centralized exhaust should be used in the building, or Energy Recovery Ventilators (ERVs) in each suite.

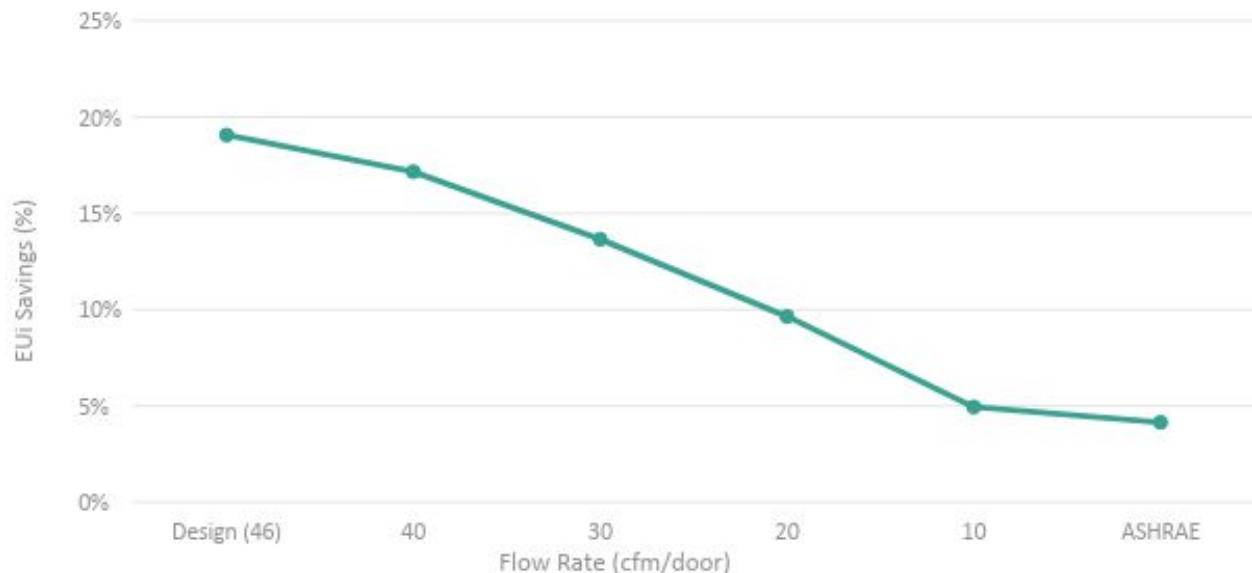


Figure 49: MURB Corridors - Unconditioned Corridor Effects on Energy Usage

In addition to calculated energy savings, the study showed that at high corridor flow rate, supplemental dehumidification may be required, see Figure 50. Ultimately, this could mean installing a cooling coil or a desiccant-based dehumidification system at the corridor air handler.

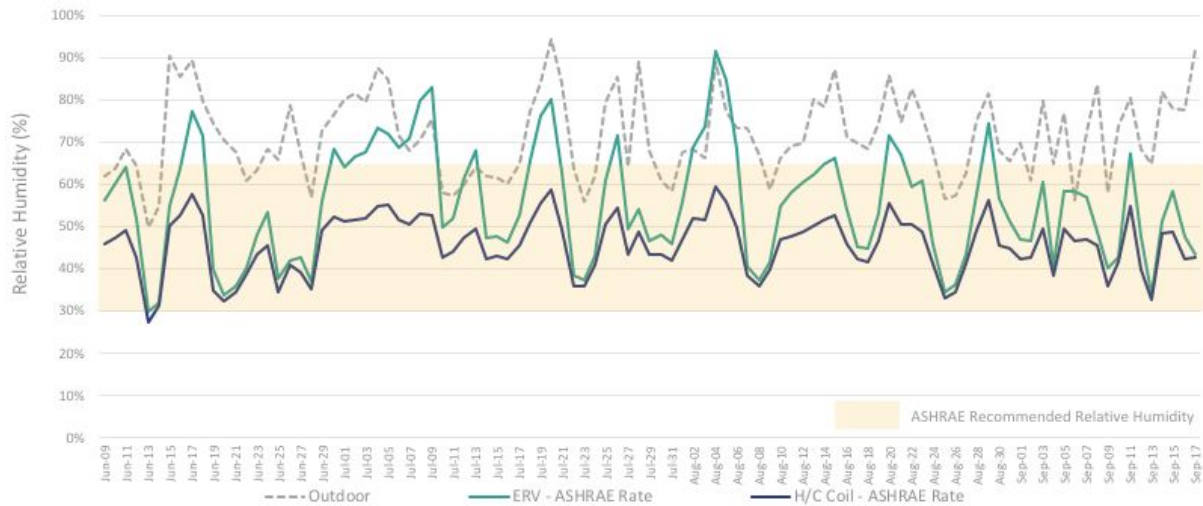


Figure 50: MURB Corridors - Average Relative Humidity in Summer for Conditioned vs. Unconditioned

Snow-Melt Systems: Range of Electricity Use

At a glance: We analyzed ten buildings from the [End Use Dataset](#) that have dedicated energy use meters for the snowmelt systems.

The data revealed a wide range of annual energy use (Figure 51). Electric snowmelt systems use sensors that measure air temperature and moisture content to activate heating. The correlation between energy use and amount of snowfall varies from year to year, but shows that in general, increased snowfall results in increased energy usage, with some outliers. EUI for the snowmelt systems shows the largest range in the years 2012 to 2014. From 2015 onwards, the range is smaller.

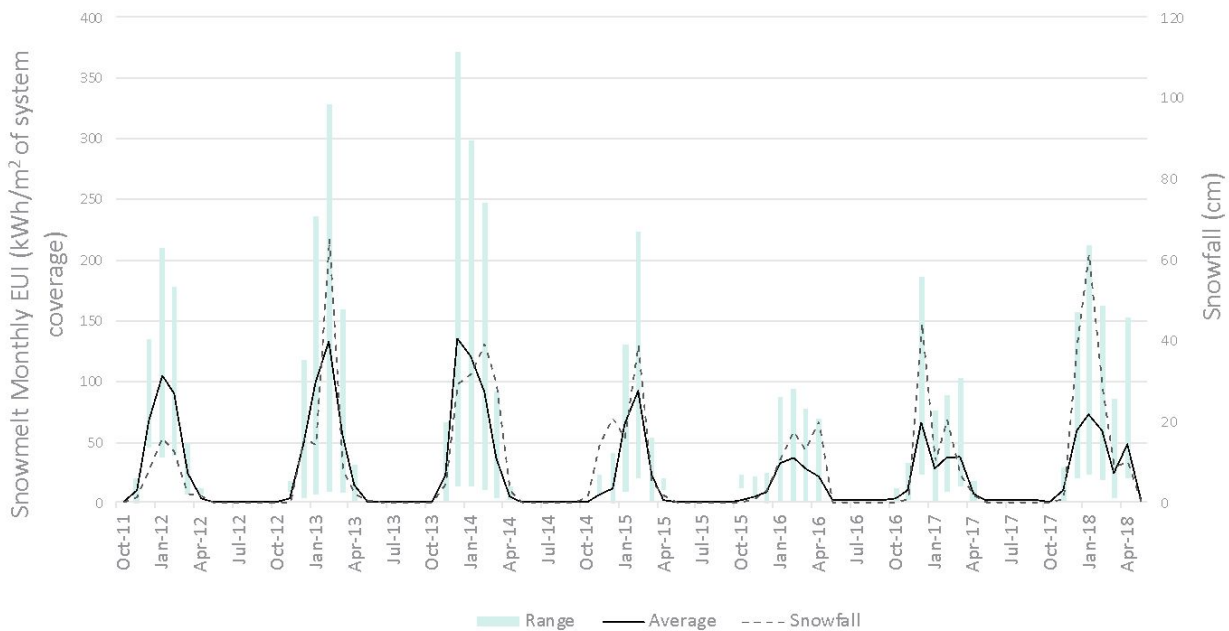


Figure 51: Snow-melt Systems - Range of Metered Energy Usage vs. Snowfall

For four of the systems, we were able to get information of the installed capacity of the systems, (Table 6). For these systems, we found that outdoor snowmelt systems operated for 400 to 800 hours per year. The systems were typically sized at about 0.4 kW per square meter of heated area (0.04 kW/ft²).

The EUIs varied considerably across the four systems, with a weak correlation between EUI and system area (m²/ft²), and system capacity (kW). There are likely micro-climatic conditions such as more direct sunlight impacting reduced energy to melt snow at Building A, however further analysis would be required to confirm actual site conditions.

We also recognized energy waste in the data. For example, the snow melt system for Building B is continually using energy in months where there is no snowfall, in contrast to Buildings A and C, which appear to shut off completely (Figure 52).

Table 6: Snow Melt Systems Descriptions and Energy Usage

Building Number	Snow Melt Area (m ²)	System Size (kW)	System Size (kW/m ²)	Energy Use kWh/m ²	Total System Hours On
A	35.1	12	0.342	73.3	452
B	23.4	11	0.470	199.5	826
C	71.92	30	0.417	212.2	643
D	128.3	55	0.429	219.5	632



Figure 52: Snow-melt Systems - Closer Look at Four Buildings

Chiller Design: Refrigerant Leakage of VRFs and Conventional Chillers

At a glance: In this part of the study, we compare the potential impacts of refrigerant leakage from a variable refrigerant flow (VRF) system to a conventional chiller system. To do this, we analyzed the five (5) LEED certified buildings from the datasets that pursued LEED credit EAc4 – Enhanced Refrigerant Management. We determined the leakage impacts of these building had they used VRF systems instead of a conventional chiller.

In Canada, VRF systems are growing in popularity as they are believed to be a highly efficient HVAC system. However, there are concerns in the industry about the amount of refrigerant required to run these systems, and the increased likelihood or rate of refrigerant leakage.

Most conventional refrigerants are potent greenhouse gases, so leakage can negate the benefit of reduced carbon emissions from an energy efficient system. While refrigerant loops are closed systems, there are still atmospheric impacts – either from refrigerants leaking over time as seals slowly fail, or due to catastrophic equipment failure causing the full refrigerant charge to be released into the atmosphere.

These concerns must be balanced against the potential benefits of VRF systems. Because VRF systems are compartmentalized, it is less likely for a leak to affect an entire building the way it might with a conventional chiller design. However, since VRF systems have so many compartments, there is a greater risk of small leaks.

To compare boilers and VRF systems, we analyzed five (5) LEED certified buildings with conventional chillers that pursued LEED credit EAc4 – Enhanced Refrigerant Management. To meet the requirements of this credit, the building must achieve a combined Lifecycle Direct Global Warming Potential (LCDGWP - lb CO₂/Ton-Year) and Life Cycle Ozone Depletion Potential (LCODP lb CFC 11/Ton-Year) value under 100. These metrics evaluate the background leakage potential of a refrigerant system, rather than catastrophic failures. As shown in Table 7, lifetime background refrigerant leakage can have a small impact on greenhouse gas emissions, but all are within the industry standard LEED allowances.

Table 7: Leakage Potential - Conventional Chillers

Buildin g	Refrigeran t Type	Chiller Capacity (Tons)	Refrigerant Charge (lbs/ton)	Full Charge Leak (Tons CO ₂)	Days of Carbon Savings Lost in a Full Leak	LCDGWP (lb CO ₂ /Ton-Year) <100 = Compliant
A	R134A	515	3.05	22.5	23.2	96.5
B	R134A	700	3.67	20.6	4.7	64.8
C*	R134A+ R410A	350+90	2.88	11.8	15.9	58.9
D	R134A	240	2.90	10.0	14.6	92.0
E	R410A	125	1.25	6.7	6.0	59.1

**Building C has two chillers with differing refrigerant types*

We analyzed the same buildings, assuming the use of a VRF rather than a chiller. Refrigerant charges for VRF systems are not typically published online, and as VRFs are only now emerging in the Toronto residential market, we did not have access to a completed design to apply to these buildings. VRF system design includes at least one VRF indoor unit in each suite, a branch selector serving multiple indoor units, and an outdoor unit serving multiple branch selectors. To estimate the refrigerant charge of VRF systems, we assumed that a maximum of eight (8) indoor units can be served by each outdoor unit. We also ignored refrigerant lines, reflecting a conservative estimate of refrigerant leakage. As refrigerant charges were unavailable for the VRF units, we used an online VRF refrigerant tool to suggest that the average indoor unit will have 2.2 lbs of refrigeration, and the average outdoor unit will have 6.6 lbs of refrigeration. R-410A has been assumed for the VRF units, which is commonly used in Daikin VRF systems.

The estimated results show that VRF indoor units can have between 140-500% of the refrigerant charge compared to a traditional chiller system – see Table 8. While this shows discouraging results for VRF systems, it represents the most catastrophic out of many potential leak scenarios. Note that this result does not account for the refrigerant associated with breaker boxes or refrigerant lines; these would represent additional carbon impact and additional opportunities for leakage. Based on the leakage rate for the systems, most of the sample buildings would not meet the LCDGWP limits set by LEED.

Table 8: Leakage Potential - VRF Indoor Units

Building	Refrigerant Type	Suite Count	Full Charge Leak (Tons CO ₂)	Days of Carbon Savings Lost in a Full Leak	LCDGWP (lb CO ₂ /Ton-Year) <100 = Compliant
A	R410A	760	45.1	46.5	192.9
B	R410A	479	28.4	6.5	89.5
C	R410A	335	19.9	26.9	99.6
D	R410A	241	14.4	20.9	132.3
E	R410A	282	33.6	30.1	296.6

Suite Energy Usage Patterns: Electricity

At a glance: Using data from the [Suite Dataset](#), we created typical in-suite electrical use profiles from three buildings to demonstrate tenant usage trends. To identify typical usage patterns, we analyzed three years' worth of hourly electricity usage data from all units for two buildings with an FCU HVAC system and one building with a WSHP system.

We created usage profiles for four suites per building for four days of the year, one each in winter, spring, summer and fall (Figure 53 - Figure 56). These suites represent moderate ranges of usage data from the buildings, and avoid the inclusion of outliers due to unoccupied suites.

There are no clear trends to this data. Suite-specific electricity profiles demonstrate occupant usage trends and how they shift from season to season. Knowing how in-suite electrical usage varies can potentially inform the design of mechanical and electrical systems.

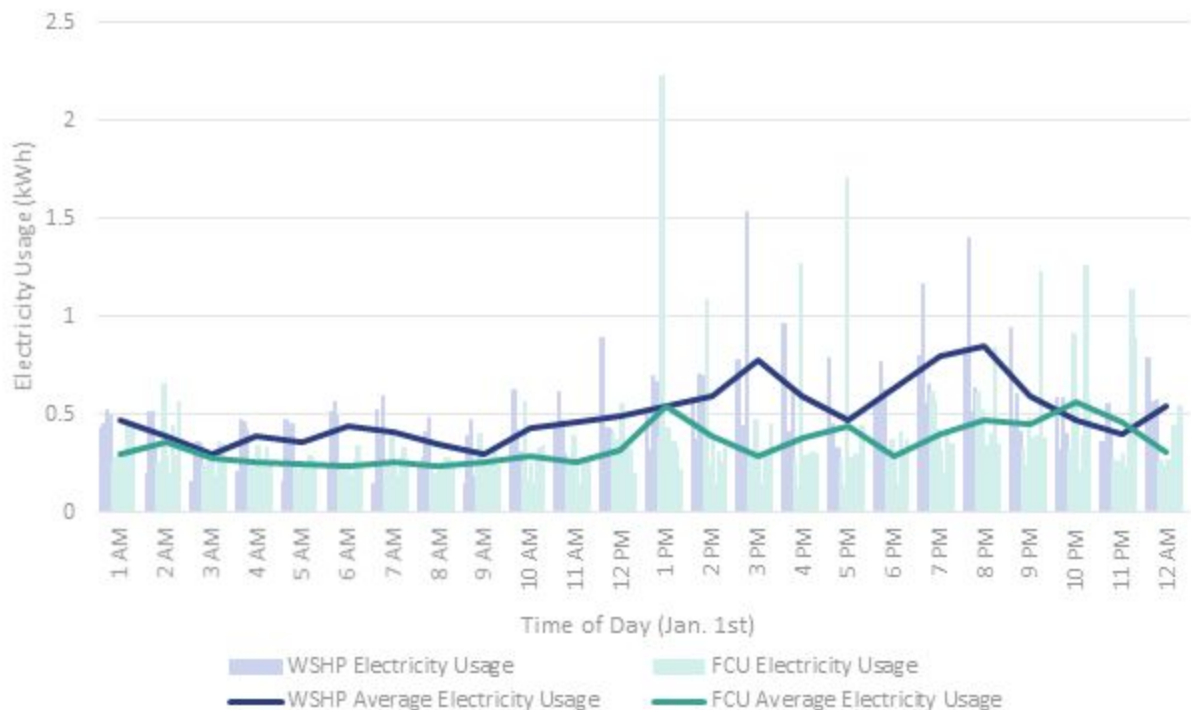


Figure 53: Suite Electricity Use - Winter

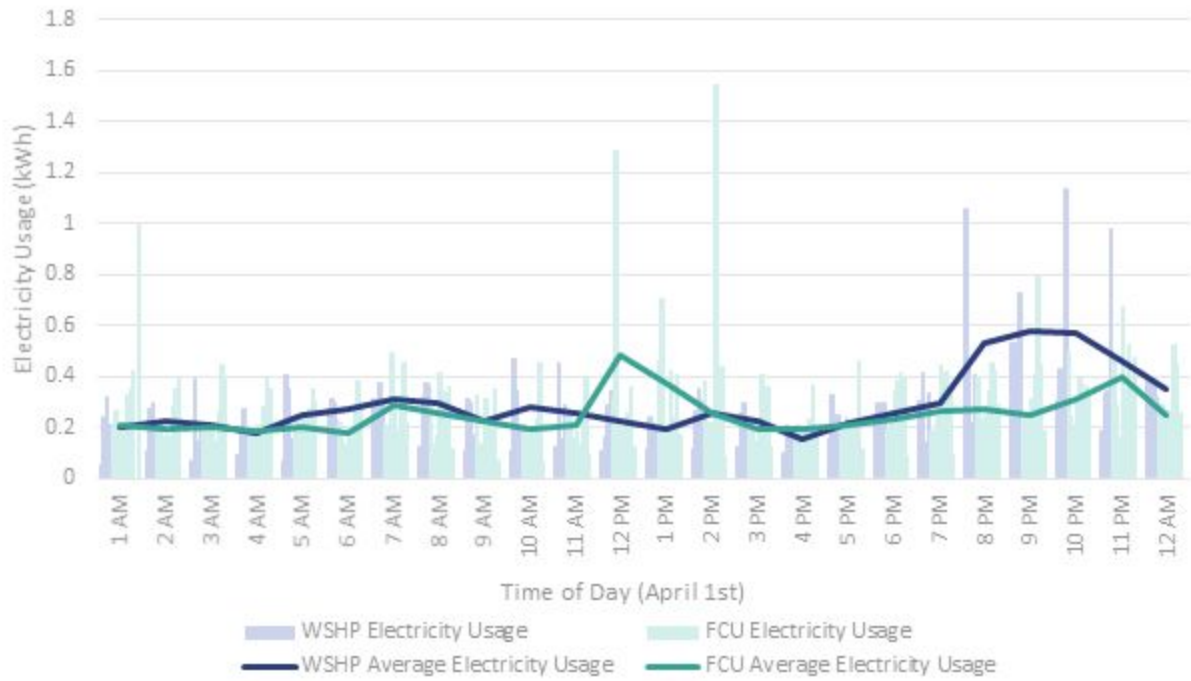


Figure 54: Suite Electricity Use - Spring

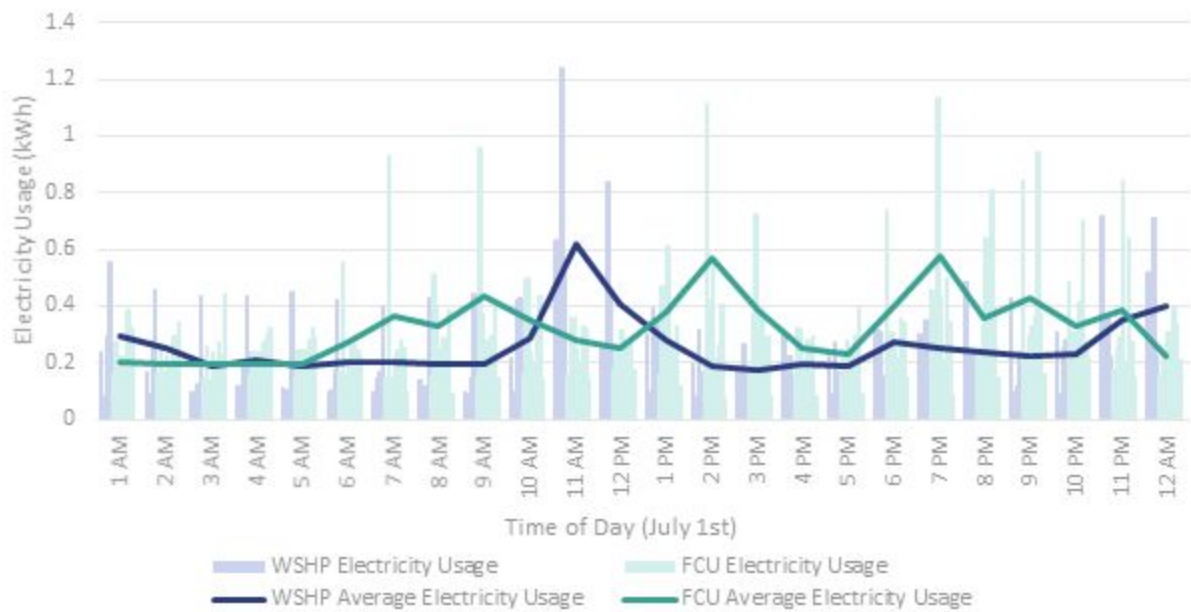


Figure 55: Suite Electricity Use - Summer

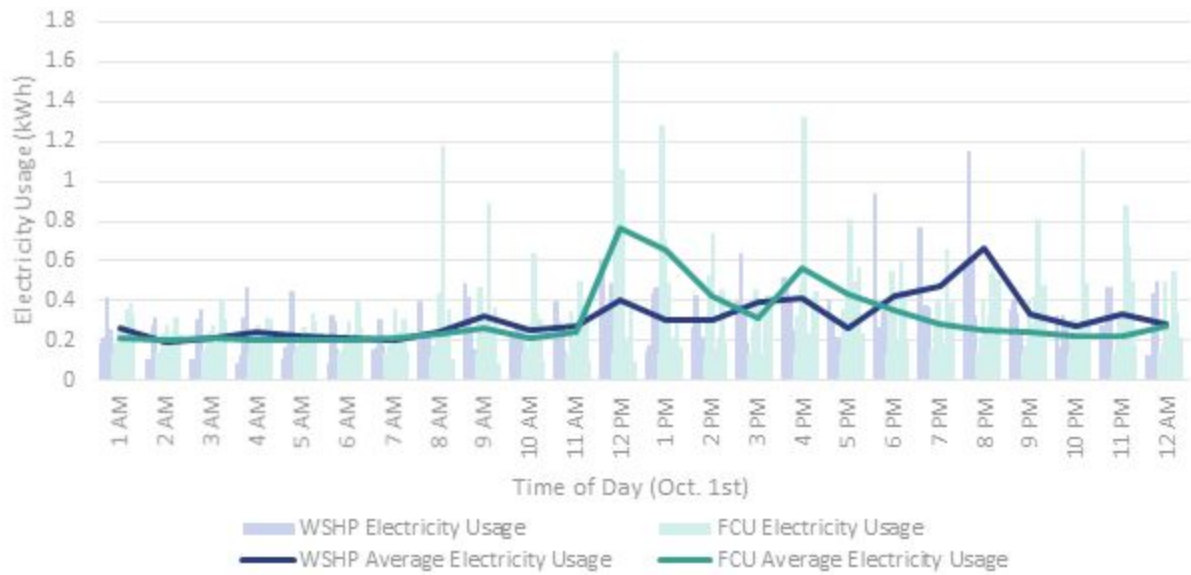


Figure 56: Suite Electricity Use - Fall

Suite Energy Usage Patterns: Thermal

At a glance: Using data from in-suite thermal submeters for two buildings that use an FCU HVAC system, we created suite-level heating and cooling profiles.

There are no clear trends to this data. Thermal profiles could be used to better inform the design of HVAC smart-system scheduling, as well as district energy systems.

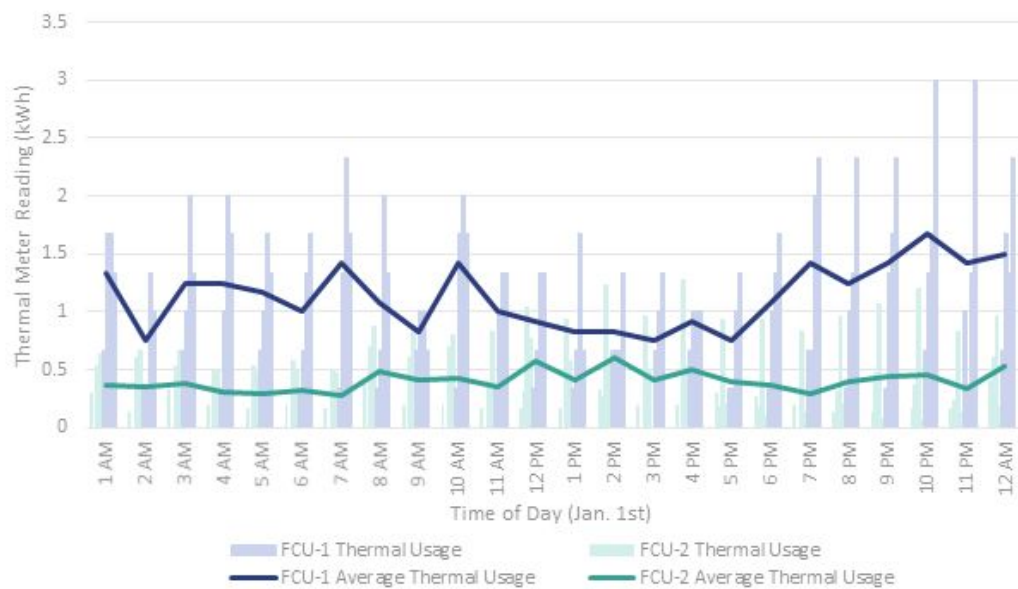


Figure 57: Suite Thermal Energy Use - Winter

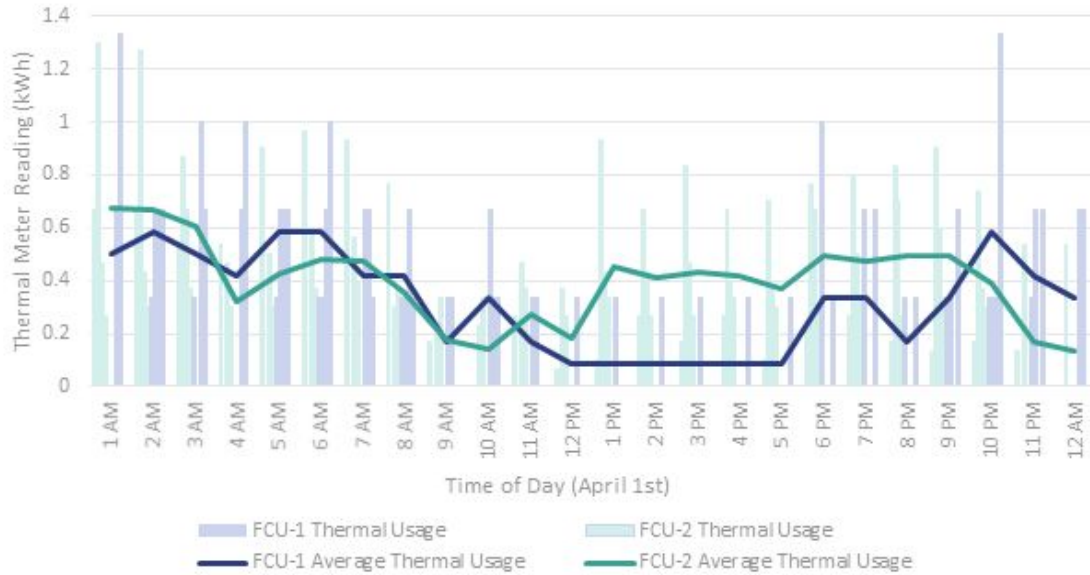


Figure 58: Suite Thermal Energy Use - Spring

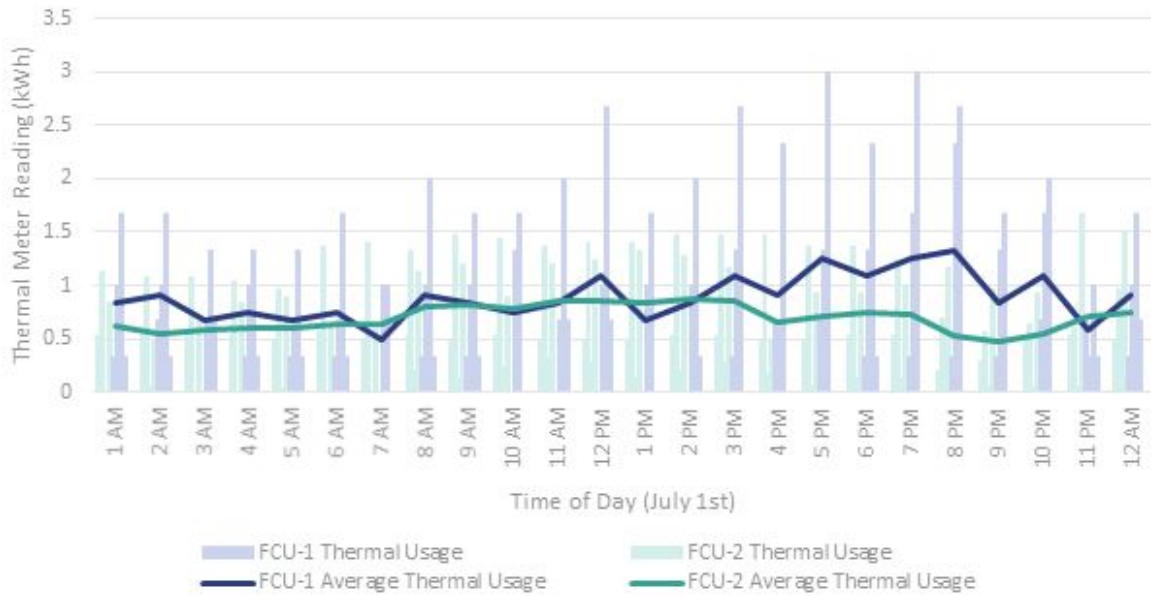


Figure 59: Suite Thermal Energy Use - Summer

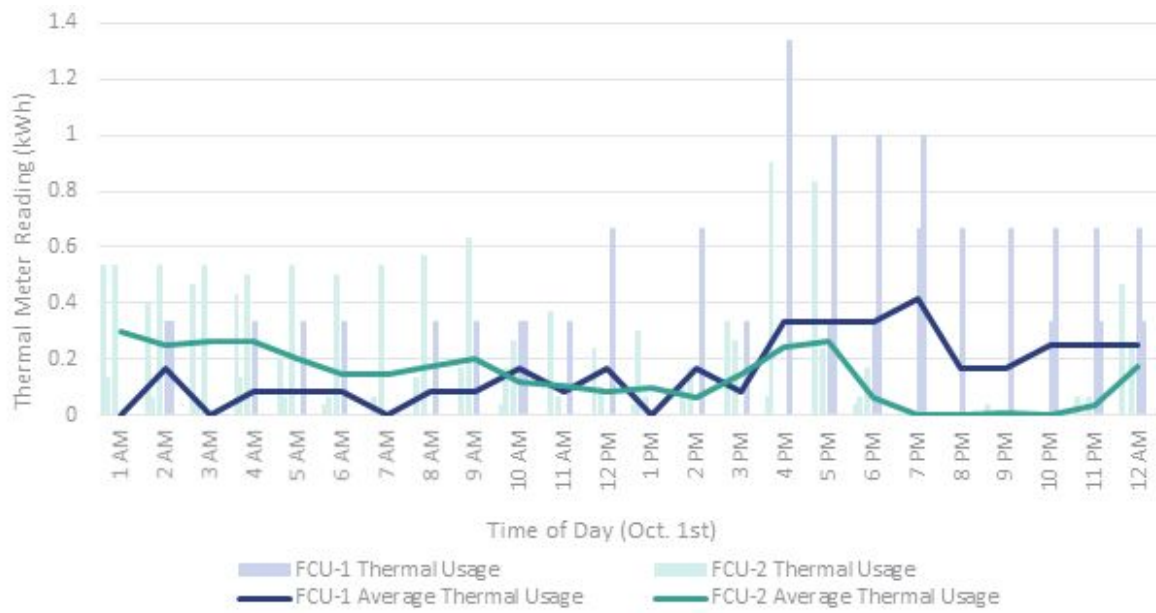


Figure 60: Suite Thermal Energy Use - Fall

Suite Energy Usage Patterns: Peaks

At a glance: We analyzed suite-level peak electricity demand for two buildings, one with an FCU system and one with a WSHP system. The buildings were anticipated to be representative of typical fully-occupied buildings in Toronto. In-suite electrical peak data is useful for properly sizing mechanical equipment, electrical infrastructure, and accurately anticipating the peak loads that a building will experience. Aggregate suite electrical peaks can be used to validate tenant demands in energy models.

Suite submeter data was used to create a histogram of how many suites in the building experienced their daily peak within 1-hour time frames. An analysis was performed for a typical weekday in the winter (January 2015) and summer (July 2015). These histograms are presented in the top graphs of Figures 61 and 62.

Similarly, histograms were created to analyze how many suites experienced their *monthly* peak on certain days of the month. Monthly peaks were compared to weather conditions (heating degree days (HDD) and cooling degree days (CDD) for winter and summer respectively) to investigate any influence of heating/cooling demand on suite peak. These histograms and weather graphs are presented in the bottom graphs of Figure 61 and 62.

In the building with the FCU HVAC system, peak distribution occurred at similar times throughout the day in the summer and winter, with most suites experiencing their peak electricity use later in the evening, Figure 61.

The time of day distribution in the building with the WSHP system is similar to the FCU building, most suites peak around the late evening.

In the FCU building, there did not appear to be a strong correlation between weather and the time of the month when most suites peaked. This was expected, as suite-level heating and cooling units in a FCU building do not use significant amounts of electricity for heating and cooling function.

The time of month distribution for the WSHP building displayed a moderate relationship between summer temperatures and number of suite peaks. This was expected, as in-suite heat pumps running to maintain temperature would contribute to suites peaking during hotter temperatures.

In the winter, there was no correlation between time of month peak and heating degree days in the WSHP building. This suggests that electricity to operate the in-suite heat pump in the heating season does not have an impact on monthly peak. A potential explanation is that coldest temperatures are experienced overnight, when other suite loads (such as plugs, lights, and appliances) are minimal. Time of month peak is driven by these other loads more so than the heat pump.

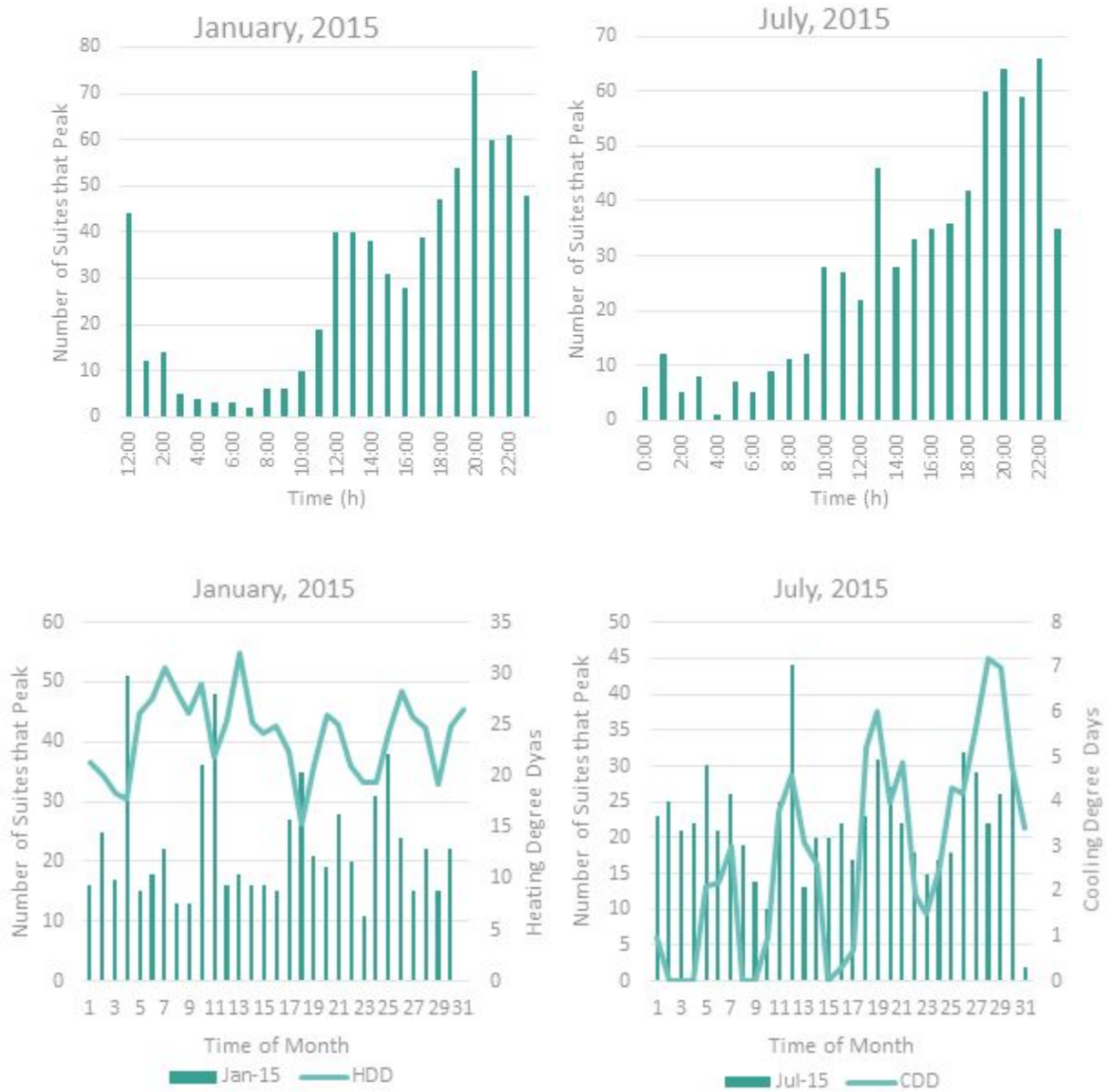


Figure 61: Suite-level Peak Usage Trends - FCU Building

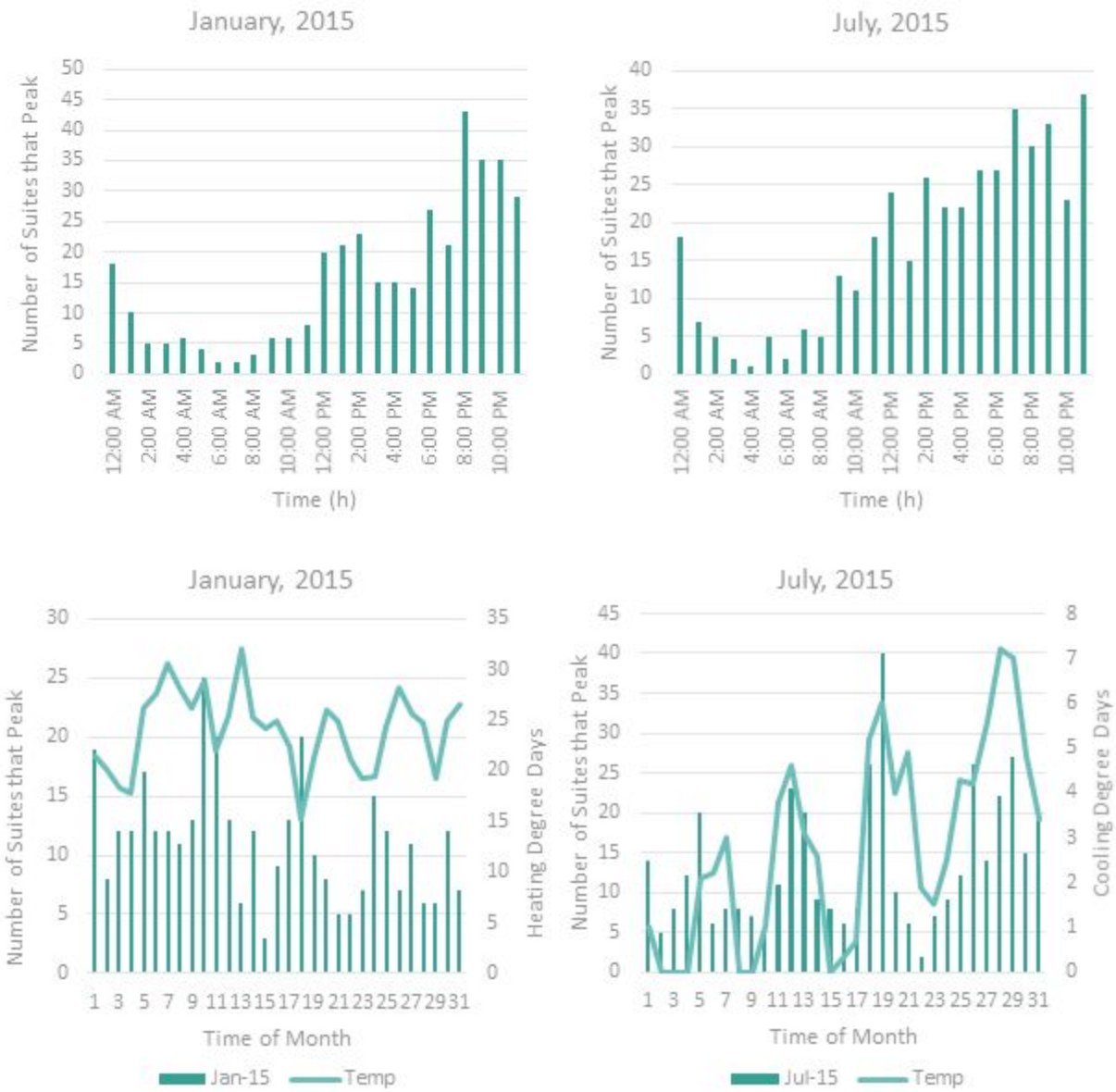


Figure 62: Suite-level Peak Usage Demand - WSHP Building

Section 6: Next Steps: Modelling and Metering Considerations

Modeling Recommendations: Closing the Performance Gap with Updated Modelling Strategies

At a glance: For models to more accurately predict a building's actual energy consumption, we recommend that Sidewalk Toronto diverge from current modelling practices in Toronto, as outlined in the tables below.

The following modelling recommendations were developed from the further investigation of the four largest energy consuming end uses: seasonal gas, domestic hot water, suite electricity, and common area electricity.

Seasonal Gas

- Model envelope performance using the BC Hydro Building Envelope Thermal Bridging Guide, which includes more rigorous accounting for heat loss through building envelopes than the Ontario Building Code.
 - Document the assumptions and calculations that were used to determine building envelope performance to aid the extended review process. This is not currently required by the Ontario Building Code.
- Require whole building air tightness testing for all new construction. This is in line with the voluntary criteria in TGS version 3, which requires Whole Building Air Tightness testing for Tiers 2 - 4.
 - Assume a higher default infiltration rate at the design stage until whole building air tightness testing results are available. We found that on average, measured infiltration values were 45% higher than modeling defaults.
 - After testing, update energy model submissions to reflect whole building air tightness testing results for post occupancy model calibration

Domestic Hot Water

- Model domestic hot water as a seasonal load, with usage schedules reflecting 6% greater consumption in the winter, and a 6% decrease in consumption in the summer.

Suite Electricity

- Assume in-suite lighting and plug load power densities of 2,900 kWh/suite per year in lieu of recommended values from the OBC.
 - This value is based on the findings in this study that provide greater data than what was previously available. If trends or usage profiles can be better identified based on information for a specific building, these should be used instead.

Common Area Electricity

- Increase typical common area base building power densities by at least 20% for each electricity load, including equipment power densities, pools, etc.
- Identify likely non-residential tenant type as early in the design stage as possible, and use national databases, such as SCIEU or US Department of Energy, instead of the Ontario Building Code, for default non-residential tenant plug loads

Metering Recommendations: Better Aligning Models and Actual Building Data through Energy Metering

At a glance: The practice of using meters to measure building energy use continues to grow in the MURB market. Better aligning modelled predictions and actual building energy usage data allows building owners and managers to assess the building's performance relative to how it was designed. Based on our findings for two of the top energy consuming end uses – domestic hot water and common area electricity – we recommend additional energy metering as described below.

Domestic Hot Water

- Submeter both gas consumption to generate domestic hot water and hot water output to calculate actual plant efficiency. This will inform whether or not energy efficiency for DHW is occupant usage driven or based solely on the system efficiency.
 - Submeter both hot and cold in-suite water use to track total water consumption and to relate that consumption to energy usage. This will also inform on whether or not efficiency is occupant usage driven or based solely on the system.
- Meter seasonal changes in incoming cold water temperatures rather than assuming a constant, year-round value. Monitoring cold water temperature is an effective method to validate the performance of the DHW system, as well as to align trends seen in actual system efficiency with modelled predictions.

Common Area Electricity

- To calibrate metered data to modelled predictions, all major common area end uses should be sub metered so that all major pumps, fans, amenities, heating, and cooling equipment can be isolated.
- To hold tenants accountable for energy use, all retail tenants should be sub metered for electricity use. This will allow a comparison to national averages/estimates. Submetering for water, natural gas, and thermal energy use, as appropriate for the space function, should also be considered.

Conclusion

Unprecedented access to both energy models and metered energy use data allowed us to better understand energy use by MURBs.

While the overall performance gap discovered was less than what might be assumed by industry, the individual discrepancies between each end use were significant. Namely, the four end uses that contribute to over 75% of a buildings energy consumption show performance gaps between 21 - 94%. Of equal importance is the gap in greenhouse gas emissions performance, where models underpredicted actual emissions by 28%.

In addition, energy data allowed us to understand trends on HVAC systems selection, as well as other energy consuming systems typical in MURBs. We identified several surprises from conventional wisdom, specifically:

- Infiltration rates used in modeling are basically equivalent to Passive House and actual measured values are about twice as high.
- DHW usage is seasonal, with more consumption in winter months than summer. The efficiency of the system also declines in winter.
- Despite being considered “electric” systems, Water Source Heat Pump buildings use about as much gas as Fan Coil Unit buildings.
- Overall WSHP buildings have a slightly lower EUI and peak load. This is a surprise considering the relative efficiency of a central chiller plant in an FCU system, compared to the multitude of compressors in a WSHP system.
- Using enthalpy recovery in lieu of mechanical heating and cooling for corridor conditioning can reduce building energy use by as much as 21%.

We hope this study not only helps Sidewalk Toronto design a truly climate-positive neighborhood, but also provides policy makers, developers, and consultants with real performance data and analysis to inform important decisions concerning the design and construction of new buildings.

Glossary

ACH₅₀ – Air changes per hour (measured at 50 Pascals) - Unit of measurement for building envelope infiltration rates.

Combination System – Refers to a system in which the domestic hot water and heating loads for a building are supplied by the same boiler system, rather than two dedicated boilers systems. Combination systems can refer to a central plant or in-suite systems in smaller applications.

Common Areas – Refers to spaces outside of the residential suites in a MURB, including corridors, amenity areas, parking garages, stairways.

Energy Modelling– The process of evaluating the energy performance of a building through use of computer simulation programs. Energy Modelling accounts for building specific details such as orientation, shading, occupancy type, envelope performance, lighting power, HVAC system type, and other aspects of the building design and operation that may impact energy use.

ekWh - A standard unit of energy consumption used to compare energy sources. Converts all energy, including natural gas, into kWh.

ERV – Energy Recovery Ventilator – Energy conserving mechanical device that recovers sensible and latent heat from exhaust air to pre-heat/dehumidify/condition incoming outdoor air. Also called enthalpy recovery.

EUI – Energy Use Intensity – Annual energy use of the building (measured in ekWh) divided by the gross floor area (m² or ft²).

FCU – Fan Coil Unit – A popular HVAC system in GTA MURBs, detailed description available in Section 4 of this report. System diagram available in Appendix A.

HVAC – Heating, Ventilation, and Air Conditioning – Refers to the mechanical systems or loads within the building.

Infiltration - The unintentional introduction of outside air into a building, typically through gaps or cracks in the building enclosure, that increases energy use for conditioning indoor air.

LEED – Leadership in Energy and Environmental Design - An international green building certification system.

MURB – Multi-Unit Residential Building - more simply known as an apartment or condominium building.

OBC – Ontario Building Code – Minimum building requirements in the Province of Ontario. In the context of this report, Supplementary Standard SB-10 of the OBC defines the minimum energy requirements for new buildings.

Passive House – *Also called PassivHaus* - An international certification system of high performance, low energy buildings.

PTAC – Packaged Terminal Air Conditioning - HVAC system consisting of a furnace for heating and direct expansion (DX) cooling rather than a central plant. The heating source can be gas-fired, hot water, electric, heat pump, among other sources.

Site Energy - The energy that is used directly at a building site, and does not include delivery and production losses.

Source Energy - Source energy accounts for all of the site energy used by the building plus the losses incurred during production, storage, transmission, and delivery of energy.

TGS – Toronto Green Standard. The current version of TGS is [Version 3](#), which came into effect in May 2018 and requires further energy efficiency than TGS version 2. In Version 3, TGS consists of four performance tiers, Tiers 1 - 4. Tier 1 is mandatory for all developments, while Tiers 2 - 4 are optional. The various Tiers were established to demonstrate to the building industry the step changes that will be required to drive toward zero emission buildings. The City of Toronto's [Zero Emissions Building Framework](#) describes the various tiers, where Tier 4 compliance is roughly aligned with a Net Zero Ready level of performance.

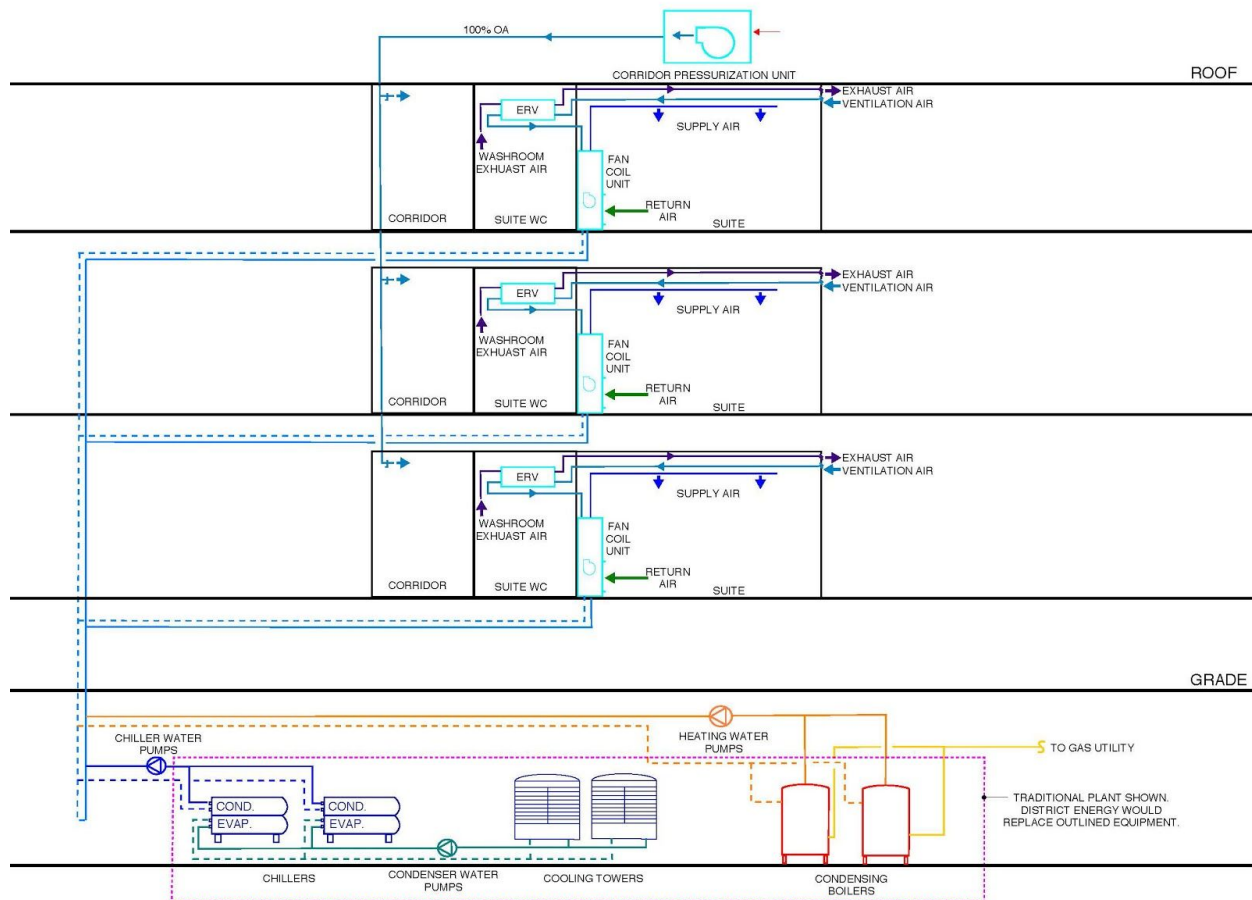
WSHP – Water Source Heat Pump – a popular HVAC system in MURBs, detailed description available in Section 4 of this report. System diagram available in Appendix A.

VRF – Variable Refrigerant Flow – An HVAC system that uses refrigerants as the cooling and heating medium. These systems typically achieve high efficiencies, and can have hot water (Water Source VRF) or electric (Air Source VRF) back-up systems.

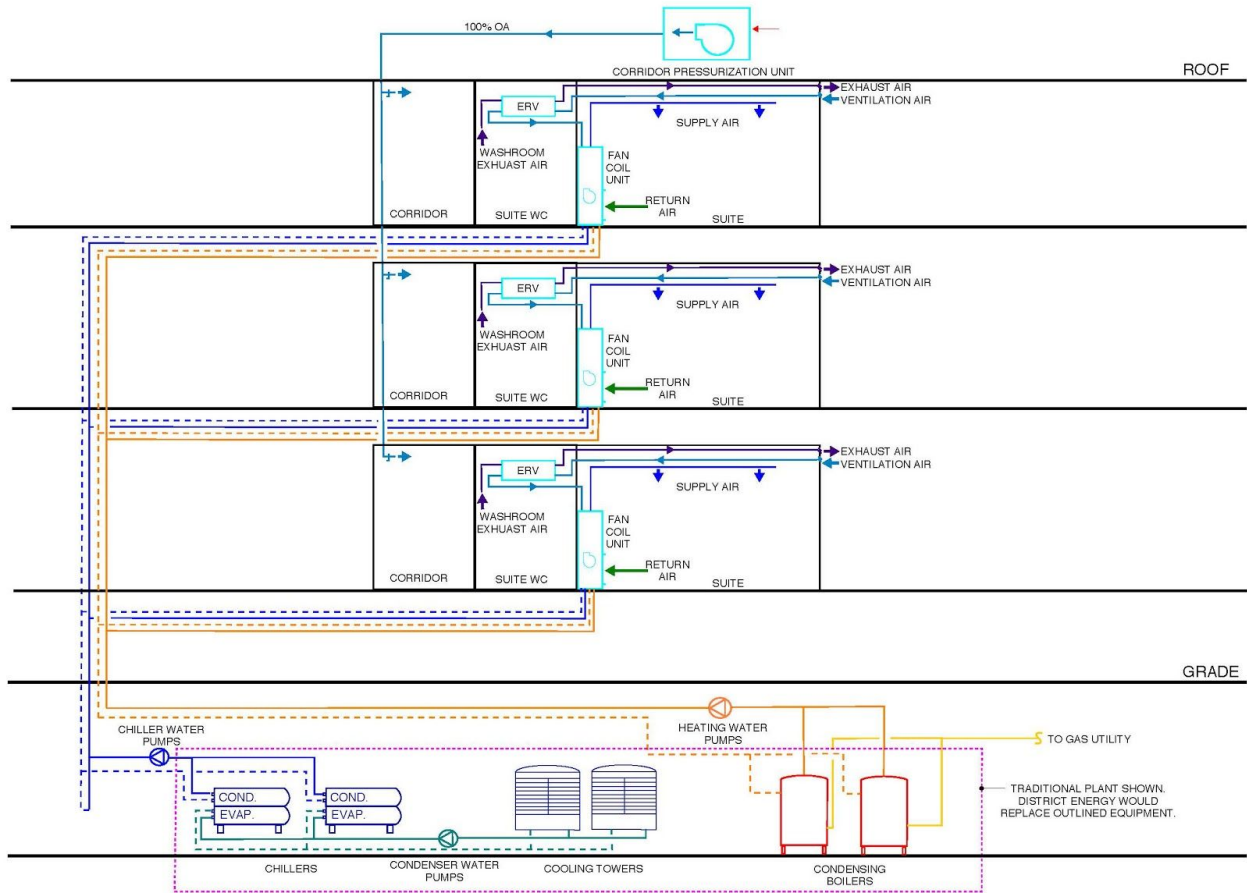
APPENDICES

Appendix A – Common HVAC System Diagrams

2-Pipe Fan Coil Unit System



4-Pipe Fan Coil Unit System



Heat Pump System

