Master Innovation & Development Plan

Technical Appendix

TITLE: Sidewalk Labs Canadian Commercial Office Buildings Study: Analysis of Energy Use and Performance

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ABSTRACT

This report provides the results of a study of the performance of Canadian commercial office buildings to help lay a foundation for setting building energy performance targets, developing energy modeling guidelines, and ultimately designing buildings in Sidewalk Toronto project developments.

Most relevant sections: Vol 2 (Sustainability)

SIDEWALK LABS CANADIAN COMMERCIAL OFFICE BUILDINGS STUDY:

ANALYSIS OF ENERGY USE AND PERFORMANCE

January 16, 2019

Commissioned by:

SIDE WALK LABS

Energy Profiles Limited

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Executive Summary

Energy Profiles Limited (EPL), along with Urban Equation and EQ Building Performance, was engaged by Sidewalk Labs to undertake a study of the performance of Canadian commercial office buildings in EPL's database to help lay a foundation for setting building energy performance targets, developing energy modeling guidelines, and ultimately designing buildings in Sidewalk Toronto-led developments.

Key Findings

- **Normalization:** Normalizing for operational factors like weather, vacancy, occupant density and exceptional loads (e.g. data centres and retail) is important for comparing performance across this asset class. Raw, non-normalized energy consumption is of little value in tracking the performance of buildings over time or comparing it to that of its peers. Similarly, non-normalized performance cannot usefully be compared to output from design-stage energy models, since those are typically based on default assumptions of weather and occupancy. And non-normalized energy use is not a useful basis for setting performance targets for new buildings nor for holding development teams accountable for hitting those targets. The normalized energy-use intensity (NEUI) is the key metric used for comparisons in this study.
- **In-Suite Tenant Loads:** There is a very wide range of tenant in-suite loads in office space, and especially in retail space. This wide range applies to both lighting and plug loads. There is also a large range of loads within most office tenant types (banking, law, accounting, etc).
- **Energy Performance of Top Office Buildings:** The 20 best performing office buildings in EPL's database of over 450 buildings have an average normalized energy use intensity (NEUI) of 139 ekWh/m2-year (12.9 ekWh/ft2-year), 41% lower than the average of the Canadian dataset and in line with the Toronto Green Standard Tier 2 target. Their average ENERGY STAR score is 94; 24 points better than the Canadian average in EPL's database and 44 points higher than the Canadian average. These best buildings are representative of current best practice in the Canadian commercial office market.
- **HVAC Systems & Energy Sources of Highest-Performing Buildings:** The 20 best -performing office buildings in EPL's dataset feature a variety of HVAC system types and energy sources that are not unique to these buildings. Commonalities among the best performers include:
    - Most have ventilation systems separate from heating and cooling, allowing each system to be better controlled to its demand, saving energy.
    - All have HVAC systems broken into smaller, more easily controllable zones (on a floor-by-floor basis, at minimum) allowing fans and other equipment to be shut off and controlled to suit occupant needs and schedules – “compartmentalized”, as opposed to large, central systems.
    - Each is managed by a top-class organization that values and manages building energy performance. (We have access to data from these buildings precisely because these organizations have engaged EPL to manage these buildings’ utility performance.)
    - Most are participants in some form of data-driven automation system analytics (i.e. “monitoring-based commissioning”) program – software, supported by offsite energy experts (in the case of these buildings, delivered by EPL).

- Most have extensive submetering in place, used for cost allocations and data/performance analytics.
- Whether a building had a distributed heat-pump heating and cooling system or a fan-coil unit system was not an indicator of performance. There are buildings with each of these systems among the best- and worst-performing buildings.

- **Energy Performance of "Bleeding Edge" Office Buildings Performance:** We have access to data for two exceptional, "bleeding edge" office buildings: Manitoba Hydro Place and A Grander View. These buildings both have a metered (actual) energy use intensity of about 75 ekWh/m^2-year (7.0 ekWh/ft^2-year). They are considered bleeding edge because they have energy-saving features that are not considered economically viable by the commercial, market-based leasing environment, such as:

  - Double-facades, and/or building envelopes with higher insulating values and much less vision areas (i.e. lower window-to-wall ratio)
  - Floor plates (areas/dimensions) focused on optimizing daylight harvesting and envelope to floorplate ratios, not on optimizing land-use in locations where land values are high (i.e. downtown)
  - Earth-tubes and/or thermal chimneys
  - Ground-source heat-pumps

- **Comparison of Modeled vs Metered (Actual) Office Building Energy Use ("Performance Gap").** The gap between modelled and metered building energy use is commonly called the "Performance Gap." We were able to compare 2017 metered energy usage and normalized energy usage of five buildings in EPL's database with their design-phase modeled energy consumption to quantify the Performance Gap. The models were <u>not</u> calibrated to actual 2017 weather.
  - *Gap between Modelled and Actual Metered Energy Use:* On average, the energy usage of the five buildings was 18% higher than modeled. This difference was expected because in EPL's experience, normalizing energy data (either the model or the actual use) is crucial to valid comparison.[1]
  - *Gap between Modelled and Normalized Metered Energy Use*: On average, the normalized energy usage of the buildings was 9% less than modeled.

- **Tenant Energy Usage and Building Operations are Key Factors in Performance Gap between Modeled Energy Usage and Normalized Energy Usage in Commercial Buildings:** We found that tenant energy consumption and building operations played a significant role in the difference between modelled and normalized building energy usage:

[1] The multi-unit residential building study – prepared in parallel with this commercial building study – also compared modeled energy use with metered energy use for a sample of buildings. In that case, the energy models were calibrated with the year's actual weather data to improve the validity of the comparison. This was not possible for this study of commercial office buildings because EPL did not have direct access to the energy models; simply the outputs.

- *Atypical/exceptional tenant use:* High-consuming tenants (such as those with data centres) can result in overall building consumption being higher than anticipated. This can appear to be a ”gap” between modeled and actual performance. Normalizing for this exceptional use addresses this gap.
- *Building Operation:* Data from two recently-constructed buildings shows that it can take time for optimal performance to be achieved at a new building, and that a post-occupancy commissioning program can help accelerate this. In EPL’s experience, the time lag to achieve optimal performance can be due to several reasons, including the reality that buildings are typically occupied concurrent with construction still being completed, and the “organized chaos” of building occupancy when operators’ attention is on getting tenants into the building on schedule, as opposed to optimizing performance.
- *Modeling is basically accurate for Commercial Buildings:* The fact that the normalized energy usage of the buildings assessed in this report outperformed their models aligns with EPL’s experience that new office buildings can perform as well as, or better than, their models predict. Said another way, office buildings designed for high performance (e.g. efficient lighting and HVAC systems) are capable of achieving high performance.

1. Introduction

Energy Profiles Limited (EPL), along with Urban Equation and EQ Building Performance, was engaged by Sidewalk Labs to undertake a study of the performance of commercial office buildings in Canada to help lay a foundation for setting building energy performance targets, developing energy modeling guidelines, and ultimately designing buildings in Sidewalk Toronto-led developments.

1.1 About EPL's Database

EPL tracks whole-building utility data for thousands of client buildings across North America, including hundreds of commercial office buildings. EPL also has data from thousands of submeters in hundreds of commercial office buildings.

EPL has "raw" energy data for more than 450 office buildings in Canada. In order to develop normalized energy performance metrics[2], additional building characteristics such as gross floor area and occupancy are needed. EPL calculates normalized energy metrics for 156 office buildings in Canada, including 53 in the Greater Toronto Area (GTA).

The following tables summarize the physical characteristics of the 156 Canadian office buildings for which EPL calculates normalized energy-performance metrics.

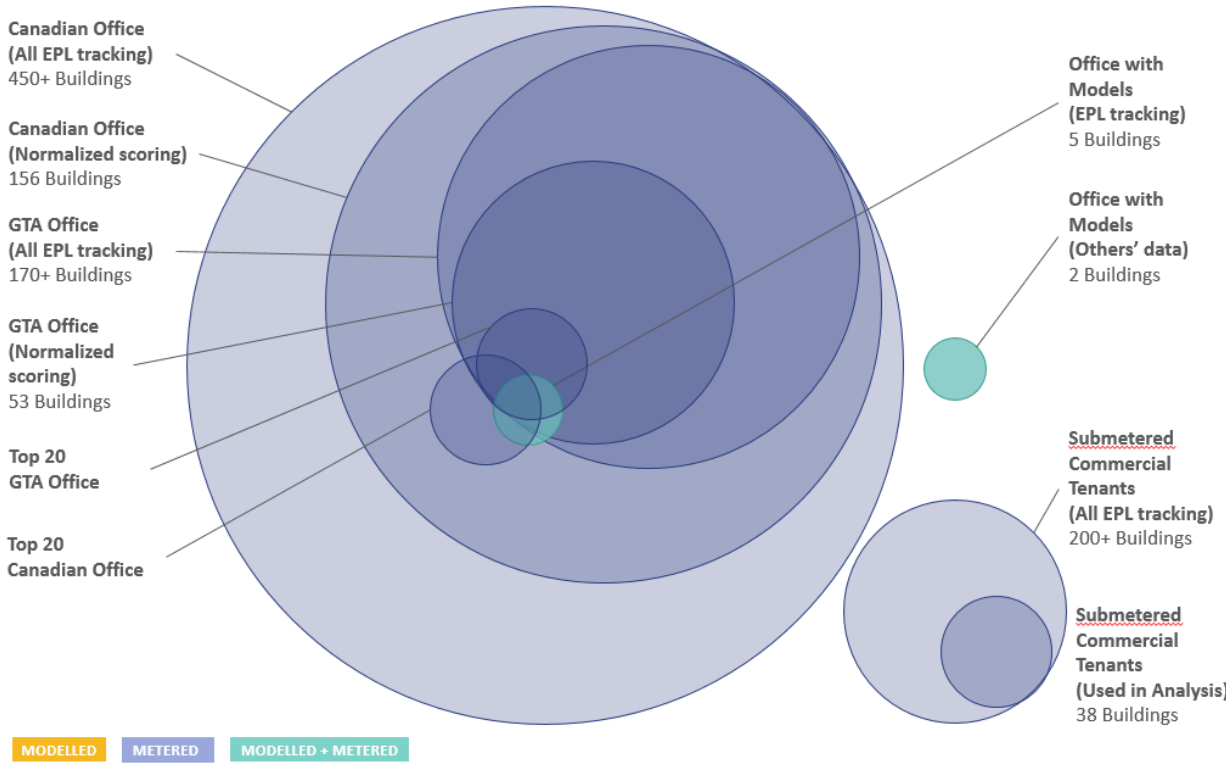
Gross Floor Area (m2)		
Range		Mean
2,287	255,069	29,699

Age (years)		
Range		Mean
3	106	31

Number of Floors		
Range		Mean
1	69	13

The following chart shows the various datasets referenced in this report and the relationships between them.

[2] See Section 3 below for a discussion of these metrics and how they are calculated.



All energy data and performance metrics presented in this report are for calendar year 2017.

2. In-Suite Tenant Electricity Loads

Given that tenant in-suite consumption can form a substantial portion of whole-building energy use, tenant loads and behaviour are important to delivering high-performance buildings. We therefore present here a snapshot into typical tenant in-suite loads in commercial buildings.

2.1 Typical Office Tenant Loads

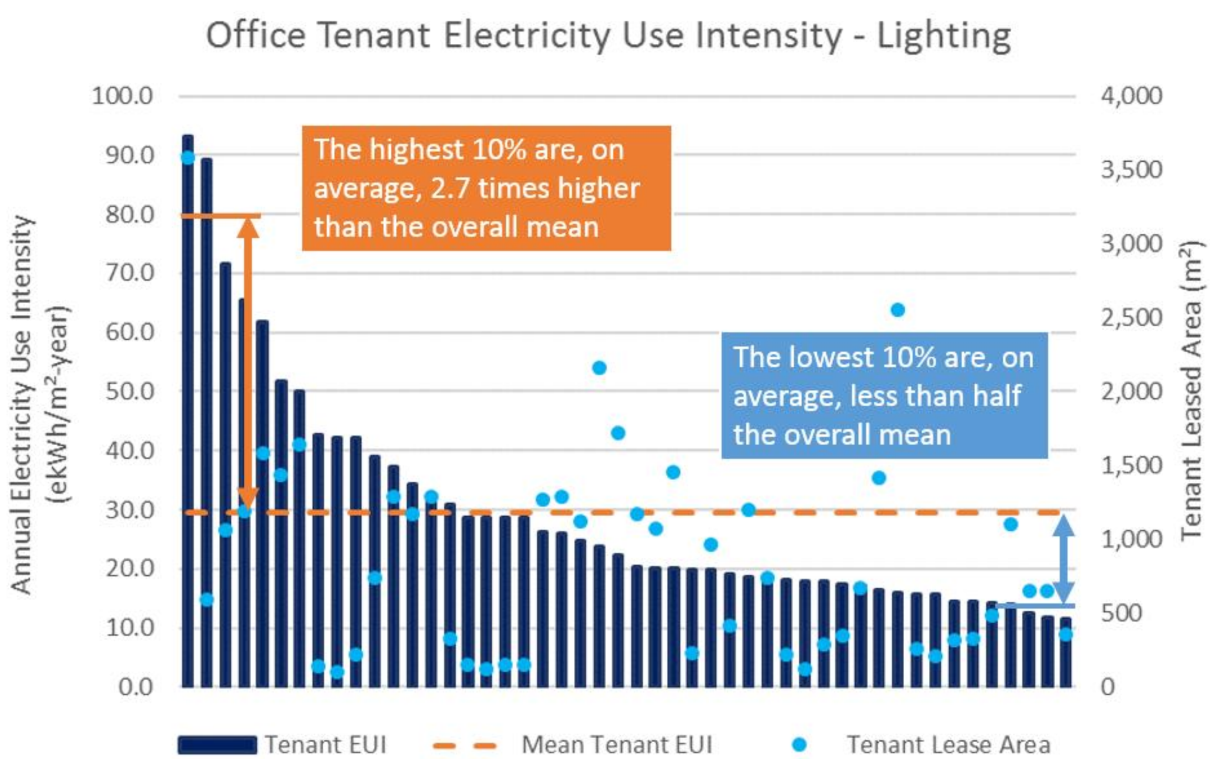
EPL's database contains data from thousands of submeters in hundreds of commercial office buildings. For some tenants, only lighting is submetered; for others, just plug loads; and for yet others, both are submetered. We present data for those three groups below. In all three submetering scenarios, there is a large range of electricity use intensity (energy use per square foot).

In-suite Lighting Loads

The following table summarizes the range of in-suite, submetered lighting loads from about 50 office tenants in EPL's database. It is worth noting that emergency lighting (typically at least 10% of the connected lighting load) is generally not captured by submeters, since it tends to be fed from different circuits.

Office Tenant Electricity Use Intensity - Lighting	kWh/m2-yr	kWh/ft2-yr
Minimum	11	1.1
Lowest 10% (mean)	13	1.2
Median	23	2.1
Mean	38	3.5
Highest 10% (mean)	134	12.5
Maximum	351	32.7

The following chart shows the range of tenant lighting EUIs, compared to the size of their suites. There is no indication that larger or smaller suites result in higher or lower EUIs.



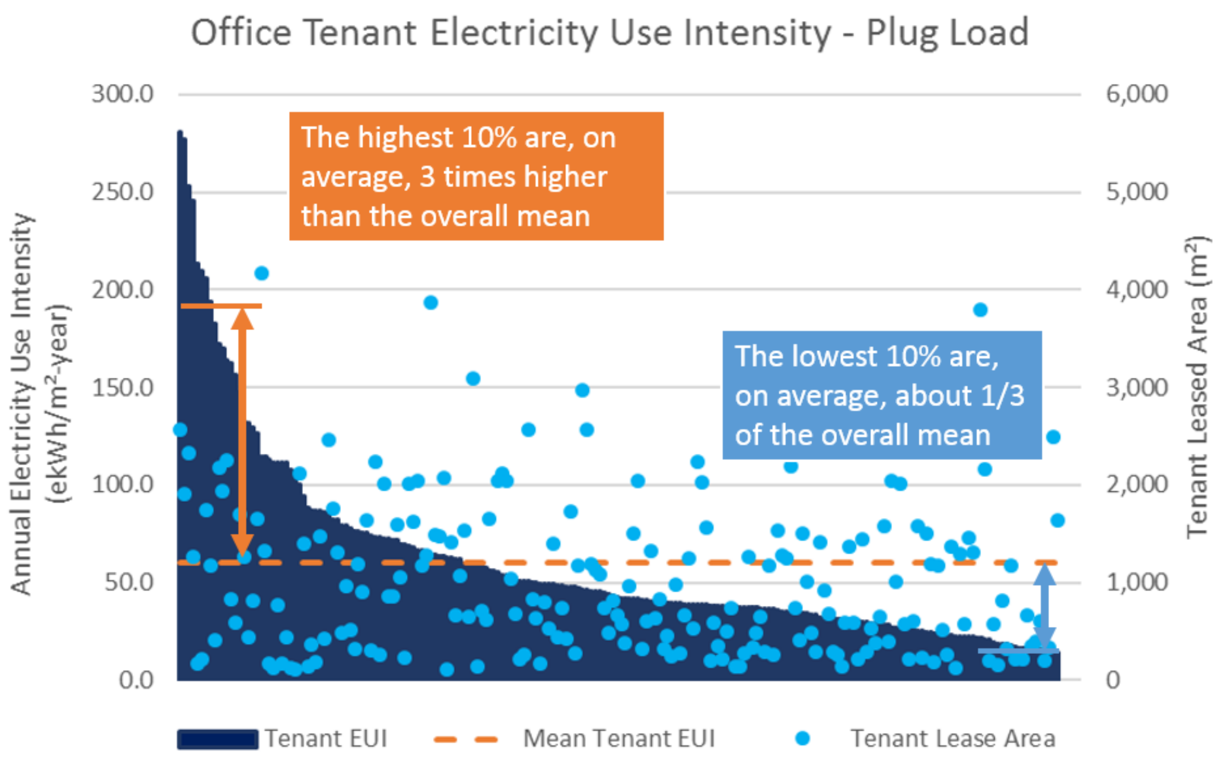
While we do not have the details of all the buildings represented in this dataset, we can confirm that at least half of tenants shown here – including many in the top half – have fluorescent T8 lighting, as opposed to newer LEDs.

In-suite Plug Loads

The following table summarizes the range of in-suite, submetered plug loads from about 210 office tenants in EPL's database.

Office Tenant Electricity Use Intensity - Plug Loads	kWh/m2-yr	kWh/ft2-yr
Minimum	14	1
Lowest 10% (mean)	18	2
Median	43	4
Mean	67	6
Highest 10% (mean)	237	22
Maximum	703	65

The following chart shows the range of tenant plug load EUIs, compared to the size of their suites. There is no indication that larger or smaller suites result in higher or lower EUIs.



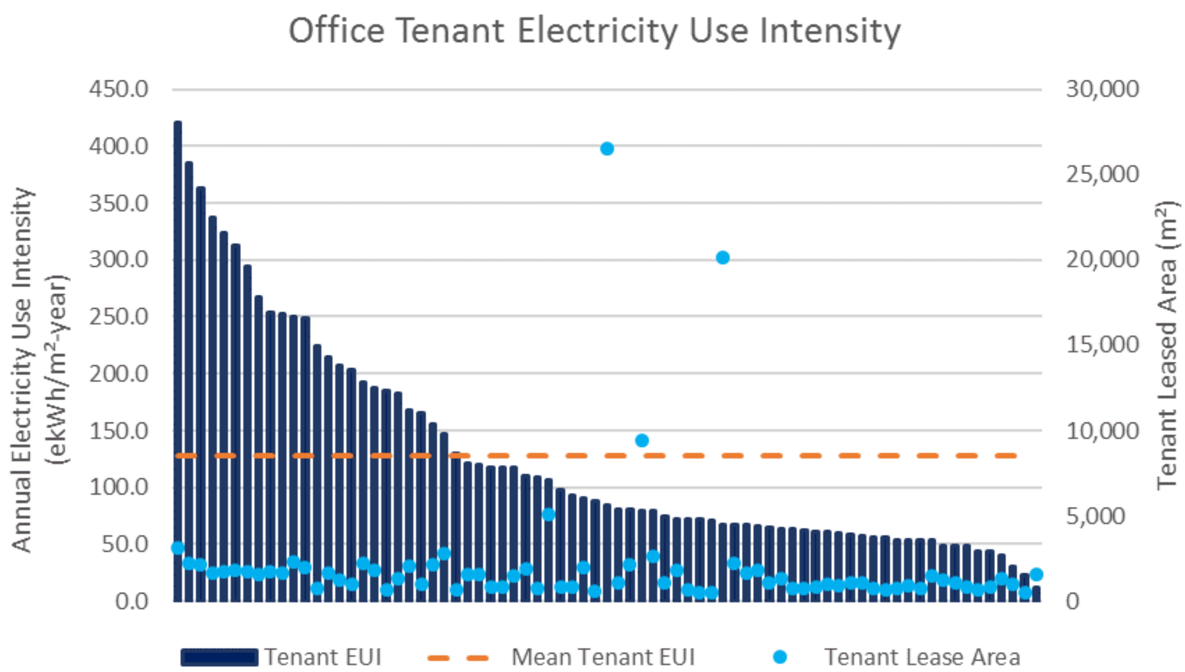
Tenants with the highest consumption (the top 10%) likely have some form of high-intensity computing – i.e. non-submetered data centres.

In-suite Combined Lighting and Plug Loads

The following table summarizes the range of in-suite office electricity loads from about 75 submetered tenants we know capture both lighting and plug loads, combined.

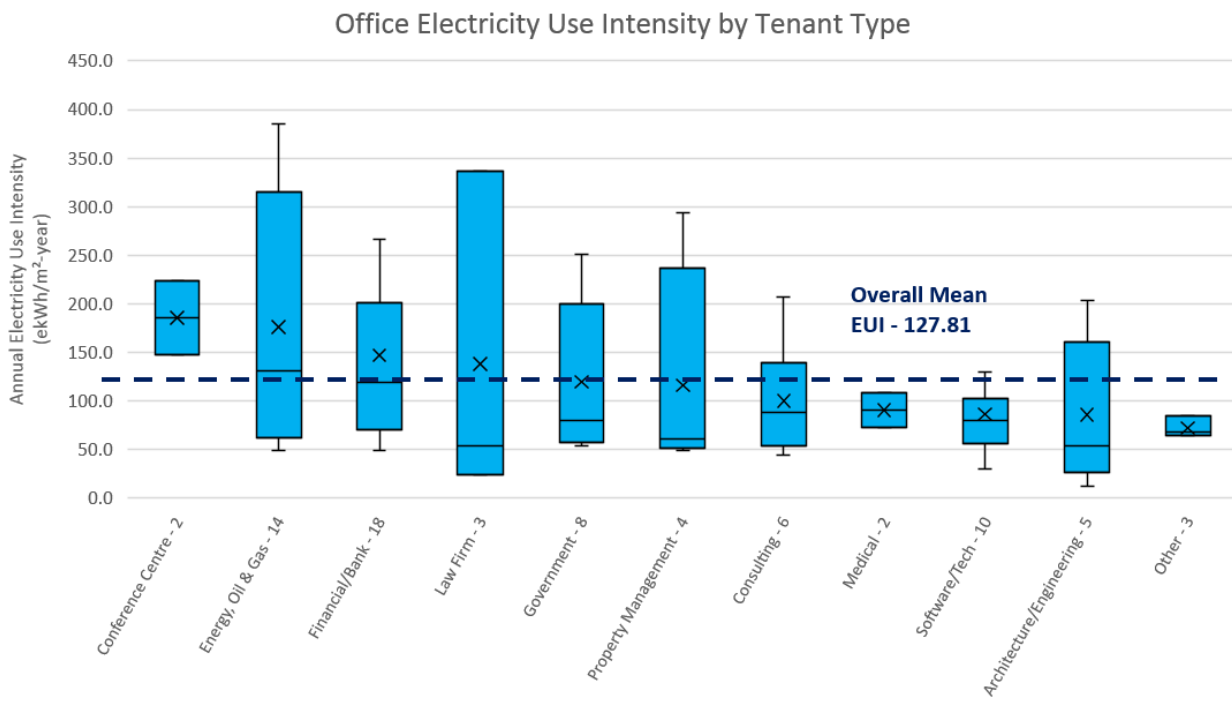
Office Tenant Electricity Use Intensity	kWh/m2-yr	kWh/ft2-yr
Minimum	12	1.2
Lowest 10% (mean)	36	3.4
Median	84	7.8
Mean	128	11.9
Highest 10% (mean)	290	27.0
Maximum	420	39.0

The following chart shows the range of tenant EUIs, compared to the size of their suites. There is no indication that larger or smaller suites result in higher or lower EUIs[3].



Office tenant "type" is not currently a datapoint consistently tracked in EPL's database, but we have grouped these 75 tenants into a dozen categories. The following chart shows the averages and range of EUIs for each type.

[3] The distribution is a bit different for this dataset than for the separate lighting and plug load data above. If the four large tenant spaces (more than 5,000 m2), which all have moderate EUIs, are excluded there is a weak trend for larger office spaces to have higher EUIs.

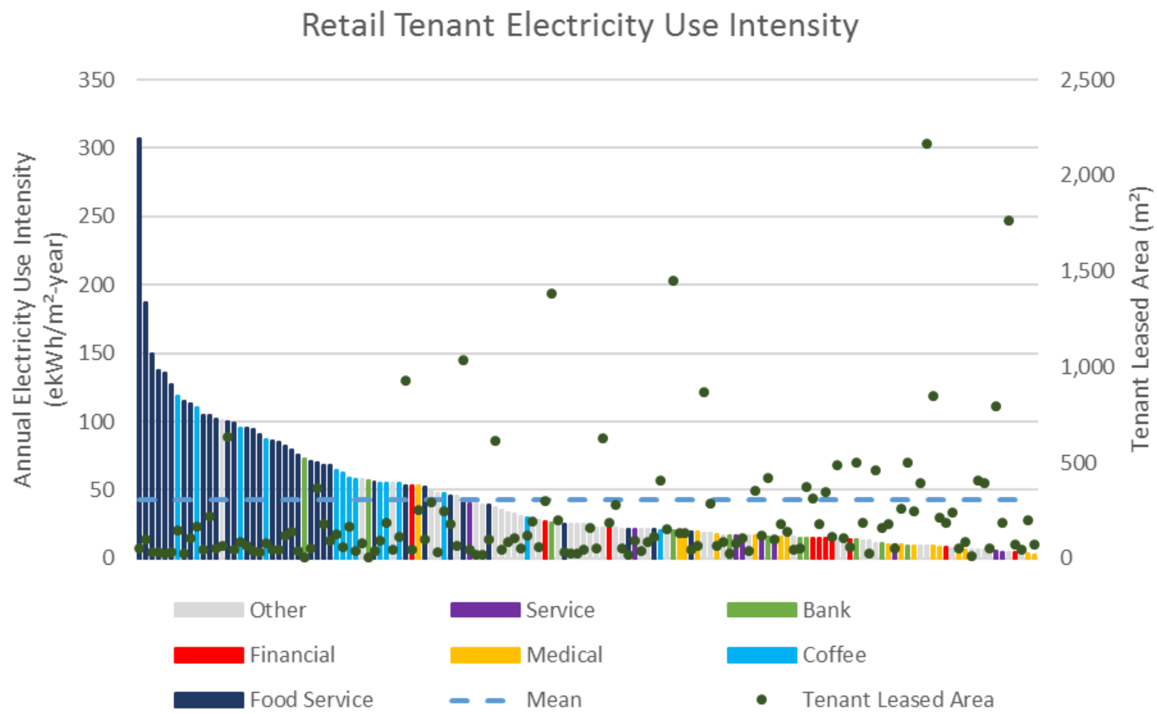


Most tenant types have a wide range of in-suite consumption. Without detailed information about these tenant spaces and the goings-on within them, it is impossible to say with any certainty why similar tenants' energy use ranges so widely. But many factors could contribute: the number of occupants, the hours they work, the amount and type of equipment they use, the type of lighting and lighting controls in place, whether there are other non-office uses within the space (conference facilities, showrooms, data centres, etc). In addition, we suspect that tenants with the highest consumption (the top 10%) likely have some form of high-intensity computing – i.e. non-submetered data centres. There is no relationship between tenant in-suite EUI and the NEUI of the buildings housing those tenants.

2.2 Typical Retail Tenant Loads in Office Buildings

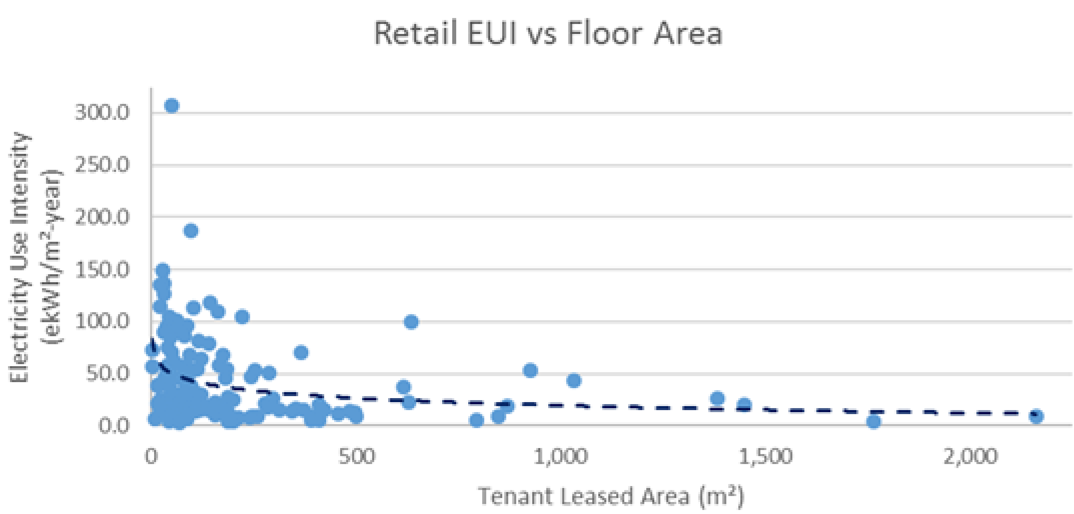
EPL also tracks submeter data for hundreds of retail tenants in office and mixed-use buildings. These tenants are somewhat easier to categorize. The following table and chart summarize the range of in-suite retail electricity loads from a subset of those submeters.

Retail Tenant Electricity Consumption (kWh/ft²-year)				
Load Type	Minimum	Mean	Median	Maximum
Food Service	19.1	97.6	92.5	307.4
Coffee	20.4	66.2	58.7	118.5
Bank	9.4	24.7	15.7	72.7
Medical	2.7	15.1	15.5	52.9
Overall	2.7	42.4	24.0	307.4



Unlike with office tenants, the size of a retail tenant's space does seem to be significant to the tenant's EUI. For example, two restaurants in an office building might serve similar numbers of meals in a day - consuming similar amounts of electricity - while occupying very different footprints. The restaurant with the larger space has a lower EUI.

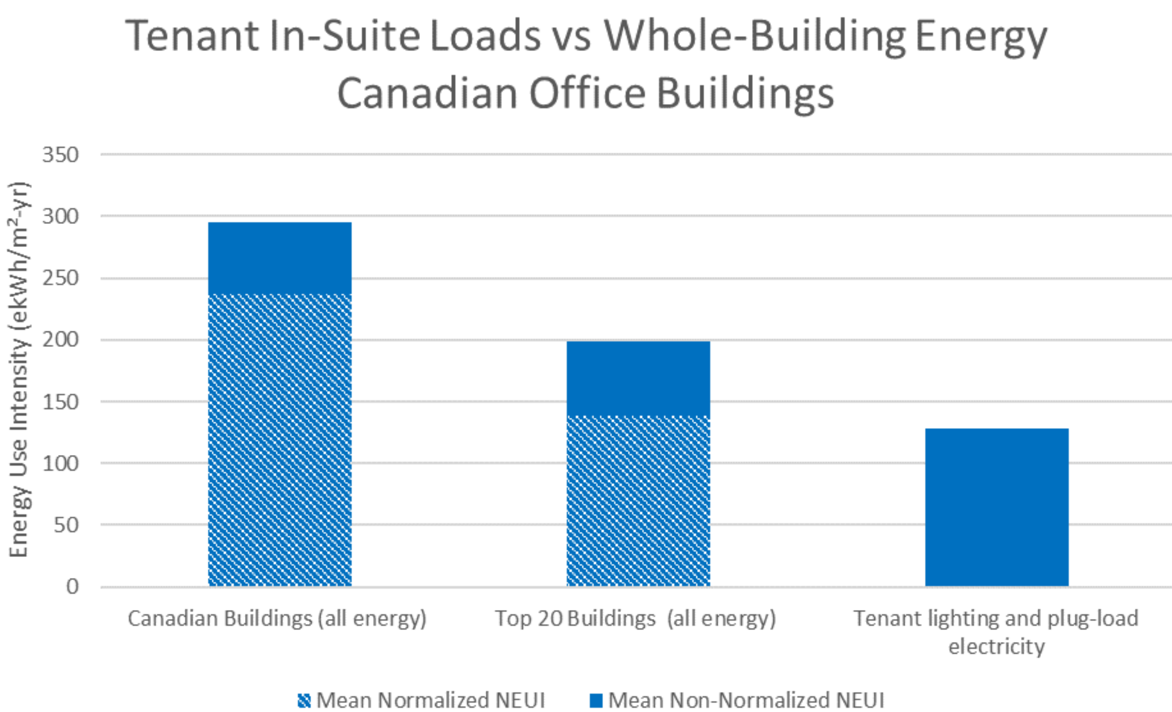
The following chart shows retail electricity intensity plotted against floor area. Larger suites clearly tend to have lower EUIs, but there remains a large spread among small retail spaces. The trend is similar for both food service tenants and non-food service. This pattern differs from that found in the office tenant data, where there was a wide range across all suite sizes.



We conclude that energy use intensity based solely on floor area is of limited value for target-setting in retail space. To address this fact, some shopping centre managers have begun to use other metrics for comparing energy performance of their buildings or tenant suites. For example, EPL tracks energy use per dollar of monthly sales as a metric for one local shopping centre. Given the limited volume of data using these metrics and how recently they have been applied, we cannot yet draw any useful conclusions from/about them.

2.3 Impact of Tenant Use on Building Performance

It is useful to compare the scale of these submetered tenant in-suite loads to whole-building energy use. The following chart and table show the average tenant lighting and plug loads from Section 2.1 to the average normalized energy use intensity (NEUI) of Canadian office buildings. (For those unfamiliar with NEUI, the metric is explained in the next section.)



Data Source		ekWh/m2-yr	ekWh/ft2-yr
Canadian Buildings (all energy)	Mean, non-normalized EUI	295	27.4
	Mean NEUI	237	22.0
Top 20 Buildings (all energy)	Mean, non-normalized EUI	199	18.5
	Mean NEUI	139	12.9
Canadian Tenants	Mean tenant lighting electricity	38	3.5
	Mean tenant plug-load electricity	67	6.0
	Mean combined tenant lighting and plug electricity	128	11.9

The comparison shows how large a component of whole-building energy in-suite tenant use can be – and how small the owner/developer/landlord's "sphere of influence" can sometimes be. The average submetered, in-suite tenant electricity use from EPL's database is almost as much as the average whole-building energy use of the Top 20 buildings. Clearly, the tenant in-suite use in the highest-performing buildings must be much less than average (otherwise, they could not have achieved this high level of performance).

3. Normalized Energy Performance of Commercial Office Buildings

Raw, non-normalized energy usage data is of little value to commercial property owners and managers in tracking their building's performance over time and comparing it to that of its peers, because building energy use is affected by factors that vary over time and from building to building, including weather and occupancy. EPL therefore calculates and tracks normalized performance metrics for its client buildings using standard industry methodologies. Those methodologies are the best available approach to accounting for operational variances between buildings, and in our experience provide a good metric for comparing and assessing performance.

Similarly, raw non-normalized energy use data cannot usefully be compared to output from design-stage energy models, since those are typically based on default assumptions of weather and occupancy. As a result, non-normalized energy use intensity is not a useful form of operational or outcome-based performance target for new construction.

3.1 Metrics Presented in this Report

This report uses three different building benchmarking metrics to evaluate building performance.

Non-Normalized Energy Use Intensity (EUI)

This metric is simply the sum of the total annual energy use (in equivalent kWh/year) divided by the gross leasable floor area (GLA, in m^2 or ft^2). Leasable area is the area on which tenants' rent is calculated and thus the area figure most commonly known and used by commercial property managers.

Normalized Energy Use Intensity (NEUI)

The NEUI is also expressed as ekWh/m^2-year. It is based on a methodology developed by the Real Property Association of Canada (REALPAC). It accounts for gross floor area (GFA), location (weather) and exceptional, submetered energy use (generally retail or data centres), plus occupant-dependant variables (occupant density - people per ft2, vacancy - unoccupied floor area, and operating hours). In simplistic terms, individual factors (values between zero to one) are calculated for each variable and then multiplied by the non-normalized EUI to arrive at a NEUI. The REALPAC definitions of these factors are based on the ENERGY STAR definitions (see below), resulting in consistent metrics being used across the industry.

EPL calculates a NEUI for 156 office buildings in Canada. For comparison, the average NEUI of that dataset is about 237 ekWh/m^2-year (22.0 ekWh/ft^2-year), whereas the average non-normalized EUI for that same dataset is about 295 ekWh/m^2-year (27.4 ekWh/ft^2-year) – roughly 25% higher.

ENERGY STAR

ENERGY STAR is a widely-used, independent benchmark that illustrates how efficiently a given building uses energy relative to similar buildings. The ENERGY STAR scoring system normalizes a building's energy performance based on a number of factors including number of occupants, hours of operation and weather, and ranks it relative to a representative data set of the country's buildings. A score between 1 and 100 is assigned to the building based on its ranking. A score of 50 is intended to denote average energy performance.

ENERGY STAR was developed by the US EPA, but is managed for Canadian buildings by Natural Resources Canada. In Canada, scores are based on a comparison to the Survey of Commercial and Institutional Energy Use (SCIEU) updated every few years by Statistics Canada. General background information about the calculation of ENERGY STAR scores can be found in the EPA's Technical Reference document, and a similar document from NRCan provides specifics of scoring for office buildings in Canada.

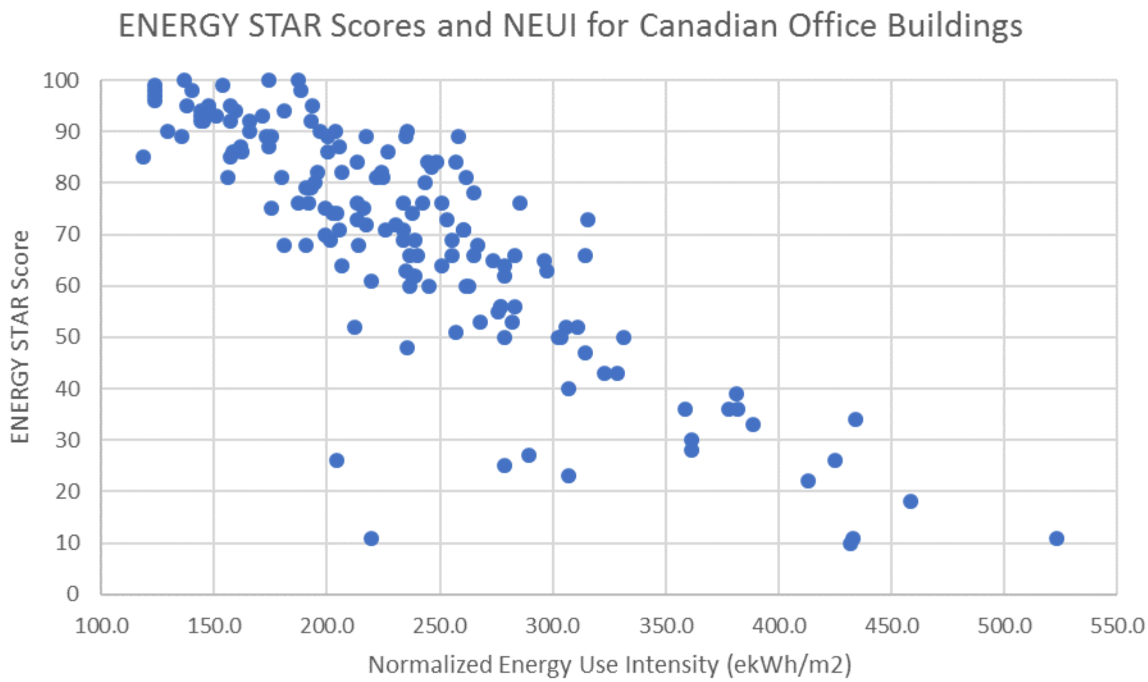
The average ENERGY STAR score of the 156 Canadian office buildings in EPL's database is about 70. Given that the average building in Canada is intended to have a score of 50, this indicates that the buildings within EPL's database perform better than the Canadian average. This is to be expected, given that many of the buildings in that dataset are owned and managed by organizations that are focused on sustainability and energy performance.

Natural Resources Canada (NRCan), who manages ENERGY STAR in Canada, recently implemented changes in the scoring for commercial office buildings. Those changes, which included a revision to how data centres are treated, were enacted in February 2018. (The EPA enacted similar scoring changes for US buildings in August 2018.) The average building in EPL's database saw its score drop by about 11 points on average. The scores presented in this report, even though they are based on 2017 utility data, use the current (i.e. new) scoring methodology.

NEUI vs ENERGY STAR

NEUI and ENERGY STAR normalize for the same factors, in similar ways. EPL uses both metrics to evaluate the performance of client buildings. NEUI tends to be more useful for evaluating performance at the very highest levels – beyond an ENERGY STAR score of 100.

The following chart shows ENERGY STAR scores and NEUIs for these 156 buildings. There is a strong, though not perfect, correlation between the metrics. As described above, the two systems normalize for the same factors, in similar ways.



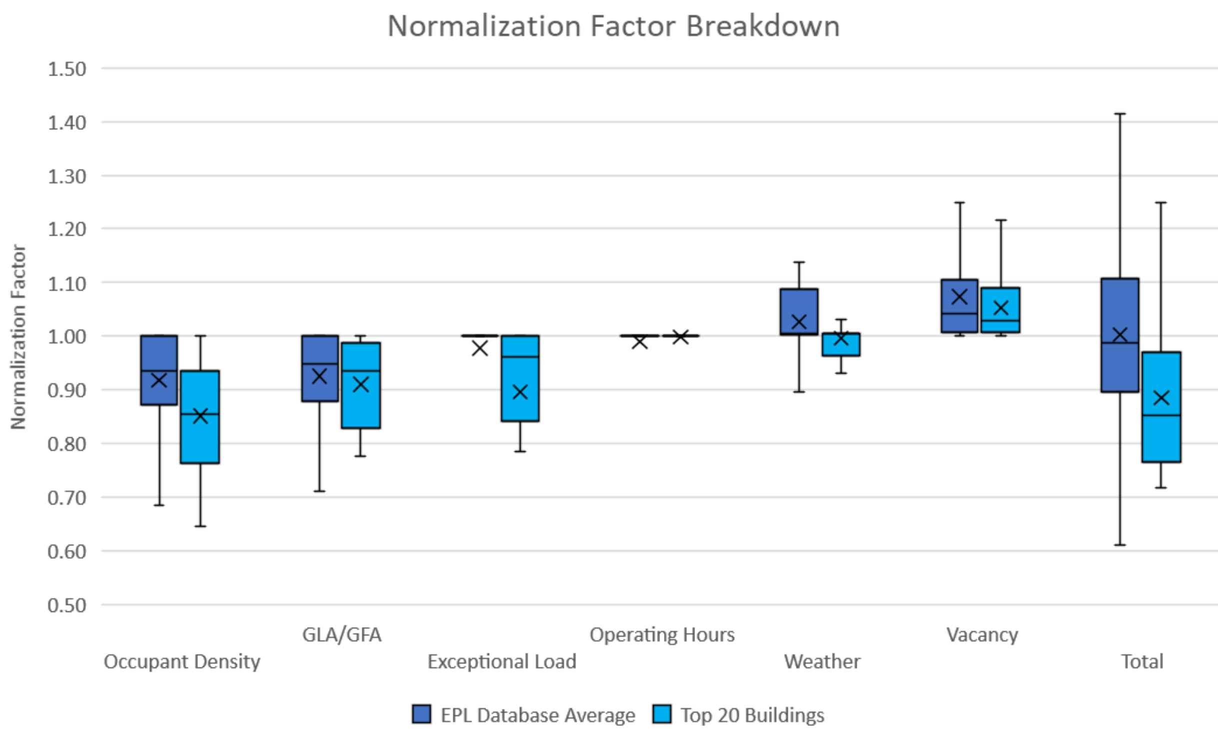
3.2 Normalization Factors (NEUI)

As described above, the calculation of both NEUIs and ENERGY STAR scores involves normalization for several factors. We examined the NEUI calculations of buildings in EPL's database in order to answer these questions:

- How material is each normalizing factor?
- How do the "baseline" values for each normalization factor compare to similar numbers found in industry standards, such as the Toronto Green Standard?
- From where are the underlying normalization inputs typically obtained?

As mentioned above, EPL calculates a NEUI for 156 office buildings in Canada. The average non-normalized EUI of that dataset is about 25% higher than the average NEUI.

The following chart summarizes the contribution of each normalization factor to the NEUI calculations for office buildings in EPL's database. These factors are discussed in more detail below.



GLA vs GFA

As mentioned above, EPL uses gross leasable area (GLA) to calculate non-normalized EUIs, but gross floor area (GFA) to calculate normalized EUIs. GFA is the standard, industry-accepted measure of floor area for energy benchmarking and it is also the value typically used in design-stage energy models, but commercial property managers often do not have a "true" GFA number on hand. Leasable area is the more readily available measure.

For the Canadian buildings in EPL's database that have both values, GFAs are on average 17% higher than GLAs. The average normalization factor for GLA vs GFA is about 0.925.

GLAs are typically based on third-party measurements, standardized according to BOMA guidelines. GFAs typically need to be measured from drawings. ENERGY STAR's guidelines are considered the standard for GFA.

Weather

Buildings can be expected to use more energy when it is hotter or colder than average and less when it is milder. Comparing the performance of buildings over time and in different regions therefore requires weather-based normalization.

The average 2017 weather normalization factor for Canadian office buildings in EPL's database is 1.03 and the average for the Top 20 is 0.997.

The following table summarizes the weather data used in various normalizations and modeling. In all cases, data from the closest available weather station is used.

Weather Data Baseline	
Source	Data Source
NEUI normalization	2009 temperatures
ENERGY STAR normalization	30-year average temperatures
Toronto Green Standard modeling	30-year average temperatures

Submetered Exceptional Use

Some office buildings have tenants with operations that require exceptional amounts of energy, well beyond that of a normal office building tenant. The NEUI methodology allows for adjustments for these exceptional uses if they are submetered. In general, data centres (housing enterprise-scale computing, as distinct from typical server rooms), retail space and rooftop telecommunications gear (i.e. cell towers) are treated as exceptional uses.

The average Canadian office building in EPL's database has 11 ekWh/m2 (1.0 ekWh/ft2) of submetered exceptional tenant use. The Top 20 buildings have on average 32 ekWh/m2 (2.9 ekWh/ft2) of exceptional use. The average normalization factor for Submetered Exceptional Use for Canadian office buildings in EPL's database is about 0.978, and that for the Top 20 is about 0.905.

Occupant Density

A building with more occupants can be expected to use more energy. Both NEUI and ENERGY STAR therefore normalize for occupant density. The average occupant-density normalization factor for Canadian office buildings in EPL's database is 0.918 and the average for the Top 20 is 0.852.

The following table compares actual, average occupant densities to industry baselines/standards.

Occupant Density		
Source	People/1000 ft2	ft2/person
All office buildings in EPL database	3.5	286
Top 20 buildings in EPL database	4.6	217
REALPAC NEUI baseline	2.3	435
Toronto Green Standard baseline	4.7	213

Determining the number of occupants in an office building can be challenging. Property managers commonly provide desk counts, or numbers from tenant surveys or tenant-appreciation event planning.

Vacancy

A partially vacant building can be expected to use less energy than a fully occupied one. NEUI therefore normalizes for vacancy, and ENERGY STAR has provisions and guidelines for doing so as well. The average occupant-density normalization factor for Canadian office buildings in EPL's database is 1.07 and the average for the Top 20 is 1.05. Vacancy normalization accounts for about 22% of the difference between the average non-normalized EUI and the average NEUI in EPL's database.

The following table compares actual, average vacancy rates to industry baselines/standards.

Vacancy Rate	
Source	Value (%)
All office buildings in EPL database	13%
Top 20 buildings in EPL database	10%
REALPAC NEUI baseline	0%
Toronto Green Standard baseline	0%

Property managers typically keep very good records of the leasing situation at their buildings. That is, they know exactly what portion of the building is vacant at any given time. However, for energy normalization purposes, “vacant” space should include “leased, but unoccupied” space in addition to “unleased” space. Determining the appropriate value for use in normalization generally requires some discussion with the property manager.

Operating Hours

A building operating longer-than-average hours can be expected to use more energy. Both NEUI and ENERGY STAR therefore normalize for operating hours. In practice, however, few office buildings can be reasonably deemed to operate much longer than average, and therefore, the impact of operating hour normalization tends to be negligible. The average operating-hour normalization factor for Canadian office buildings in EPL’s database is 0.990 and the average for the Top 20 is 0.998.

The following table compares actual, average operating hours to industry baselines/standards.

Weekly Operating Hours	
Source	Value (hours)
All office buildings in EPL database	66.5
Top 20 buildings in EPL database	65.2
REALPAC NEUI baseline	65.0
Toronto Green Standard baseline	"As Designed"

Determining a standardized or consistent number of weekly operating hours is very challenging. ENERGY STAR has guidelines on this topic, but they tend to be difficult for property managers to interpret or apply. In that light, in 2018 NRCan set a default of 65 hours for office buildings in Canada for ENERGY STAR calculations.

4. Performance of Top Office Buildings

As Sidewalk Toronto works towards energy-performance targets, it is helpful to understand the current market context. How do the best “market” office buildings perform? How does that compare to the Canadian average? What makes those buildings perform well? Is even better performance achievable?

4.1 Defining “Top” Performance

For the purposes of this report, we define “top” performance as the twenty buildings with the lowest NEUI (which are generally also the buildings with the highest ENERGY STAR scores).

As previously described in this report, EPL tracks normalized energy performance metrics for 156 office buildings in Canada. The average NEUI for these buildings in Canada is 237 ekWh/m2-year (22.0 ekWh/ft2-year), and the average ENERGY STAR score is 70. These buildings outperform the Canadian market overall, considering the average Canadian office building should have (by definition) an ENERGY STAR score of 50. The clients for whom EPL tracks data tend to be more focused than average on energy performance, and their buildings could be expected to perform better than average.

The highest-performance buildings in EPL's database (the ones with the best NEUIs and ENERGY STAR scores) *are* representative of the best commercial office buildings in the country. One indication of this is that when Natural Resources Canada opened up ENERGY STAR Certification in Canada this year, EPL was responsible for 45 of the first 73 buildings to achieve it.

That said, as discussed later in this report, we know of a small number of "bleeding edge" office buildings that perform considerably better than even the best buildings in the EPL database. Those buildings are either government- or privately-owned and occupied. They could be considered "marquee" projects in that there was an intention to push well beyond industry norms and "make a statement". And while they are representative of what is possible in current building performance, they are not representative of what the market finds commercially viable.

4.2 Energy Performance

The following subsections describe the performance of the "top-tier" buildings in EPL's database – first across Canada, then in the GTA.

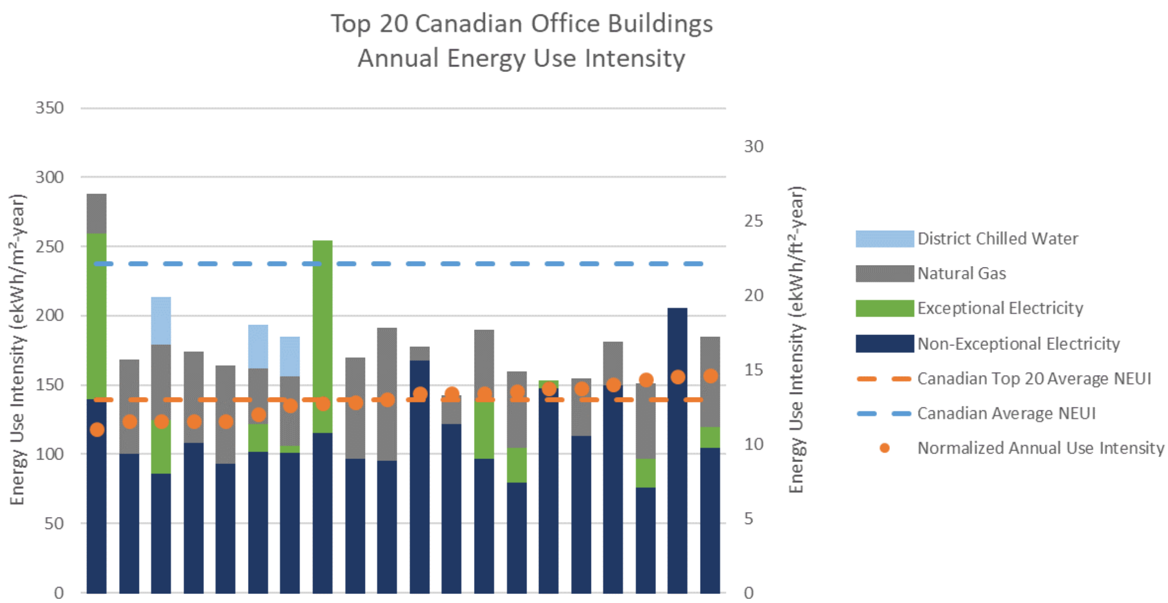
Canada

The twenty top-performing Canadian office buildings in EPL's database have an average NEUI of 139 ekWh/m^2-year (12.9 ekWh/ft^2-year), 41% lower than the average of EPL's Canadian dataset. For comparison this is not far off the Toronto Green Standard Tier 2 modeled performance target of 130 ekWh/m^2 (12.1 ekWh/ft^2) for new construction. The average ENERGY STAR score for these Top 20 buildings is 94[4]; 24 points better than the average of Canadian buildings in EPL's database.

We do not have access to a NEUI (calculated using the REALPAC methodology) for the two bleeding edge buildings, Manitoba Hydro Place and A Grander View. But their actual energy use is reported to be around 75 ekWh/m^2-year (7.0 ekWh/ft^2-year), 46% lower than that of the "top-tier" buildings in EPL's database and 68% lower than the Canadian average. These two buildings feature design elements and technologies not found in even the best "market" buildings. While this level of performance is technically possible, it is not representative of what the commercial market currently considers viable.

The following chart shows the Top 20 Canadian office buildings ranked by NEUI, overlaid with non-normalized energy use intensity (broken down by energy source).

[4] The average ENERGY STAR score for these twenty buildings prior to NRCan's February 2018 scoring changes was 98.

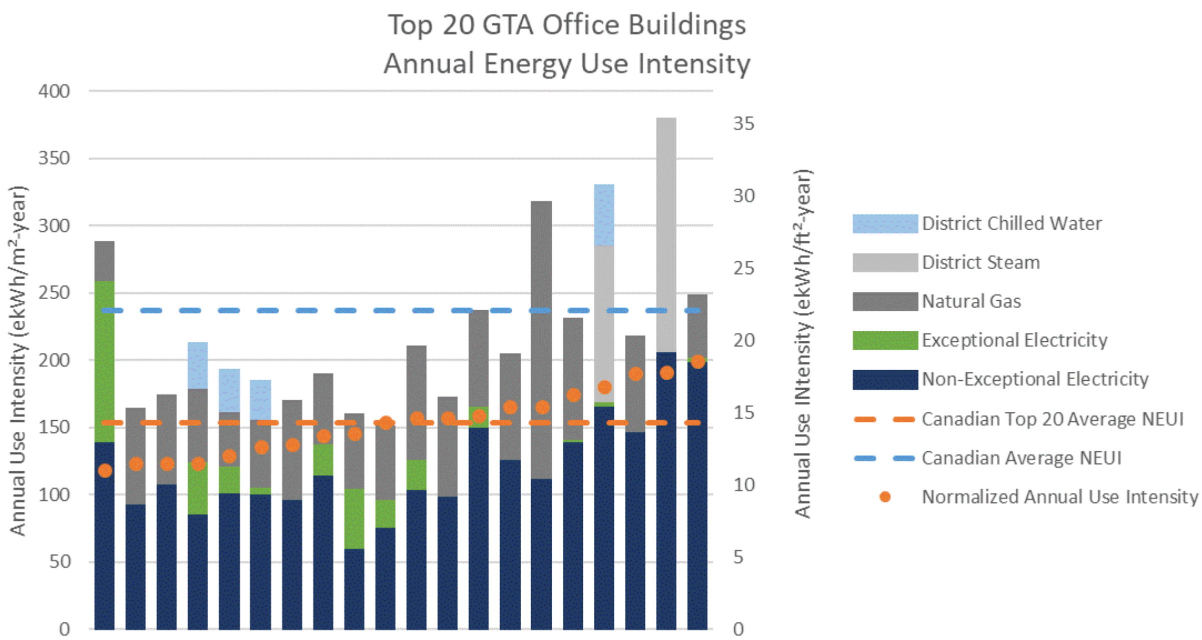


The average non-normalized EUI for these buildings is 199 ekWh/m^2-year (18.5 ekWh/ft^2-year) – considerably higher than their average normalized performance (NEUI). Highlighted in green above is "exceptional" electricity – tenant data centres, etc – that is excluded in the NEUI calculation. This excluded, exceptional use is the largest component of the variation between these NEUIs and the non-normalized EUIs.

Greater Toronto

The twenty top-performing GTA office buildings in EPL's database have an average NEUI of 154 ekWh/m^2-year (14.3 ekWh/ft^2-year) and an average ENERGY STAR score of 89.

The following chart shows the Top 20 GTA office buildings ranked by NEUI, overlaid with non-normalized energy use intensity (broken down by energy source).



4.3 Characteristics of Top 20 Office Buildings

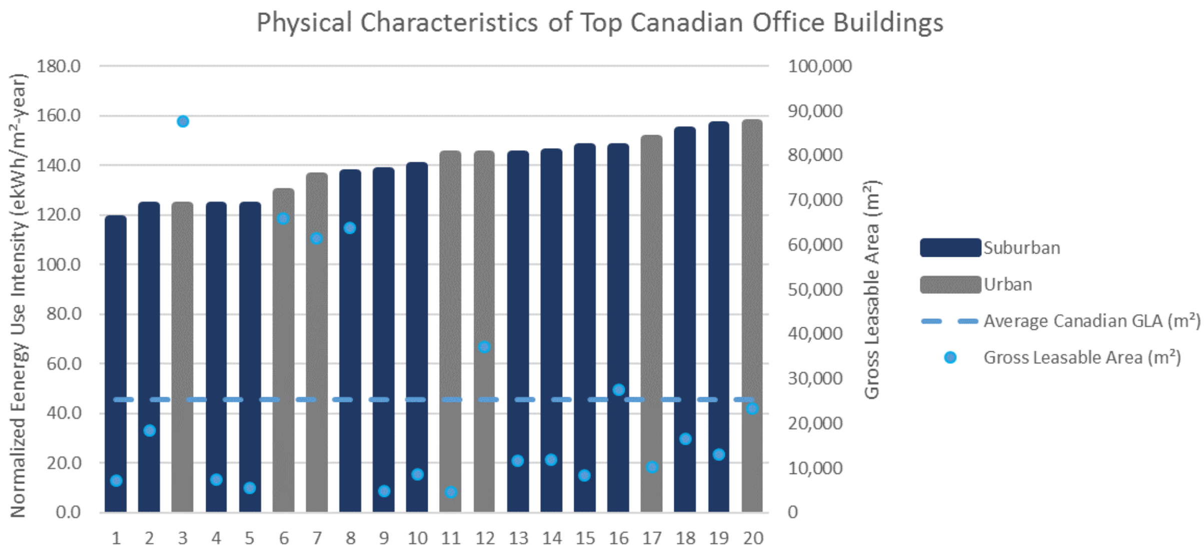
We "dug deeper" into the 20 top-performing tier Canadian office buildings in the EPL database to identify their common characteristics. We focused on the buildings for which we had substantial, in-depth information such as interval electricity data, submeter data and energy audit reports.

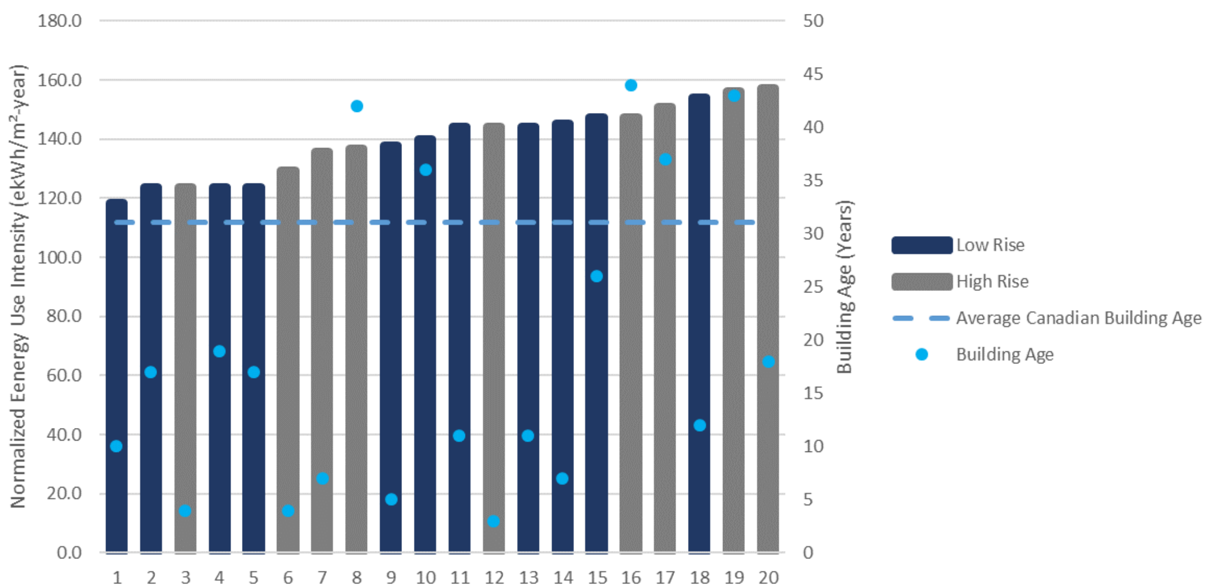
Physical Characteristics

There are no obvious patterns in the physical characteristics of the top-performing buildings in EPL's database. That is, they are more different than they are similar. Or, put another way, there is no sign that a building need be new or conform to a certain mould in order to achieve a high level of performance.

- Some are big (over 50,000 m2) and some are small (under 10,000 m2)
- Some are tall (over 20 floors) and some are low-rise (less than 5 floors)
- Some are new (less than 5 years) and some are old (more than 30 years)
- About half are urban and the other half suburban
- Many are located in Ontario, but four other provinces are represented

In the Top 20, the five oldest (about 40 years old, on average) consume less than 10% more than the five newest (about 5 years old, on average).





Systems and Input Energy Sources

The highest-performance buildings in the EPL database also feature a wide range of systems and input energy sources. There are, however, some common patterns to be gleaned:

- Virtually all have ventilation systems separated from heating and cooling systems, at some level. While not unique to high-performance buildings, this attribute is widely recognized as important for HVAC energy efficiency, allowing the two systems to be controlled based on their respective demands. Most have dedicated fresh air fans feeding individual zones or floors (as opposed to having air-conditioning fans supply fresh air). Some – but not all – have ventilation heat-recovery systems. Many make use of CO_2 sensors to control ventilation based on demand.

- Virtually all have some level of compartmentalized HVAC, as opposed to more centralized systems – for example, zone-level heat-pumps or floor-by-floor compartmental air-handling units. Breaking up HVAC systems into smaller zones allows for a finer degree of equipment scheduling and control.

Operations and Management

We note that the top-tier buildings share common characteristics in the realm of operations and maintenance. In our opinion, these factors contribute to the high performance of these buildings, relative to the average of the dataset.

- Each is managed by a top-class organization, with programs and policies around building performance.
- Most are participants in some form of data-driven BAS and submeter analytics (i.e. "monitoring-based commissioning") program.
- Most have extensive submetering in place, used for cost allocations and data/performance analytics.
- Those with substantial exceptional tenant loads - such as data centres - have those submetered and excluded from their normalized EUIs.

5. Performance of Heat-Pump Office Buildings

We understand that, as Sidewalk Toronto and their team evaluate prospective systems for district-level energy supply and building-level energy distribution, many of the most promising system types involve heat pumps. For that reason, we have explored – and present here – the performance of heat-pump buildings in the EPL database.

5.1 What we Mean by Heat Pumps

Heat pumps can feature in building HVAC systems in a variety of configurations. The chillers used for air-conditioning in many commercial office buildings are a form of heat pump. However, when the term "heat pump" is used in HVAC terms, it typically signifies that those machines are also used for heating. The primary form of HVAC system found in office buildings in EPL's database features zone-level (aka "terminal") water-source heat pumps located in the ceiling above tenant spaces. This type of heat pump is generally served by a central condenser water loop with excess heat rejected through a closed-loop cooling tower and heat injected, when required, by gas-fired boilers.

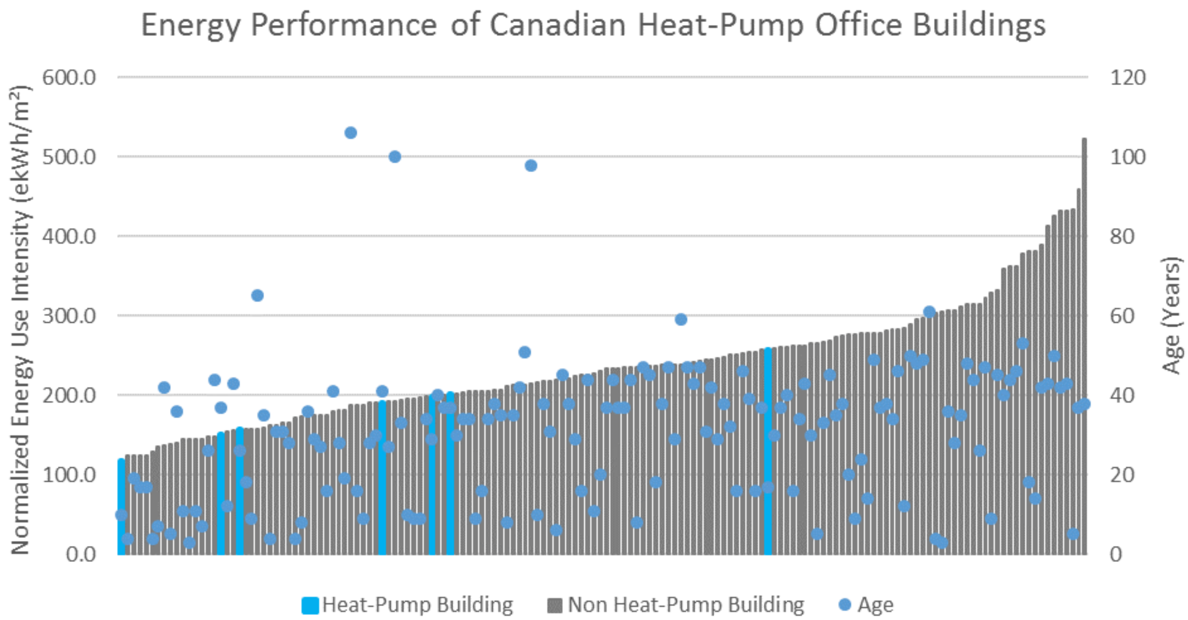
The prototypical Canadian office building with water-source heat-pumps is of modest size (less than 20,000 m2), but has more than a handful of floors, and was built in the 1980s or 90s. This system type has been less common since that era. We suspect that this is mainly due to changing utility costs (more expensive electricity and less expensive natural gas), but other factors likely also contribute: the difficulty of accessing heat pumps above tenant spaces, noise, etc.

It is rare for a very large building to use heat pumps (heat pumps have generally been considered a low-cost system option, not suitable for large, Class A buildings), but also rare for low-rise buildings to use them (packaged rooftop units tend to be preferred for low-rise). Given their typical vintage, heat pump buildings often have standalone zone-level controls; that is, the heat pumps themselves are often not controlled by a central automation system.

5.2 Energy Performance

In part because they tend to be older and not "top class" buildings, most of the heat-pump buildings in EPL's database have modest energy performance.

However, there are a handful of exceptions to this rule. The highest-performance building in EPL's database, from a NEUI perspective, uses heat pumps. And there are two others with NEUIs below 160 ekWh/m^2-year (15 ekWh/ft^2-year).



Based on our review, we have identified two primary characteristics of high-performance heat-pump buildings:

- Their zone-level controls are integrated with the central automation system.
- They are run by a top-class management team, focused on energy efficiency.

While there is only one such example in this dataset, in our opinion and experience (rather than based on our data), heat pumps tend to be particularly well suited to mixed-use developments, where waste heat from office and retail spaces can be used seasonally in residential units.

6. Modeled vs Actual Office Building Performance

EPL currently has access to design-phase energy modeling data[5] from five recently-constructed, high-performance office buildings for which we also track actual utility consumption and performance. For reference, we have also included publicly-available data for two other buildings, recognized as among Canada's highest-performing office buildings.

[5] In contrast to the multi-unit residential building study – prepared in parallel with this commercial building study – we did have access to the models themselves and could not "calibrate" them to actual operating conditions. Instead, as described below, we compared the model data to the normalized, metered (actual) energy use.

It is important to note that these design-stage models were created for a variety of purposes: for example, making design decisions, or complying with building codes or LEED®. But none of them was created with the specific intention of predicting the actual consumption of the finished building. The energy modelers we spoke to as part of this assessment were quick to point out the enormous difference in the effort behind a LEED compliance model and an in-depth model associated with an energy guarantee.

6.1 Physical Characteristics of Included Buildings

EPL Client Buildings

The five buildings chosen from EPL's database for this analysis:

- Are all new. They were constructed within the last seven years.
- Are all large. They have gross floor areas of more than 40,000 m^2 and are over 25 stories tall.
- Are high-performers. They have an average, actual normalized energy use intensity (NEUI) of 139 ekWh/m^2-year (12.9 ekWh/ft^2-year) – about 41% lower than the national average. Coincidentally, this is the same average performance as the Canadian "Top 20" (see Section 3.2).

Other Canadian Buildings

The following are the physical characteristics of the two other Canadian high-performing (bleeding edge) office buildings included:

- Manitoba Hydro Place ("Building 4" in the charts below) is a 21-storey, 65,000 m2 office tower in Winnipeg, Manitoba, completed in 2009. Its construction costs, at about \$470/ft^2 (2018 dollars) were considerably higher than average, even for Class A office construction (~\$300-\$350/ft^2). In addition to many traditional energy efficiency elements, its design and systems include several unique (and expensive) features:
    - A double façade and solar chimney
    - Ground-source heat pumps
    - Humidification via an atrium water feature integrated into the ventilation systems

See these case studies for further details:

- "High Performing Buildings" magazine article
- IISBE Canada case study

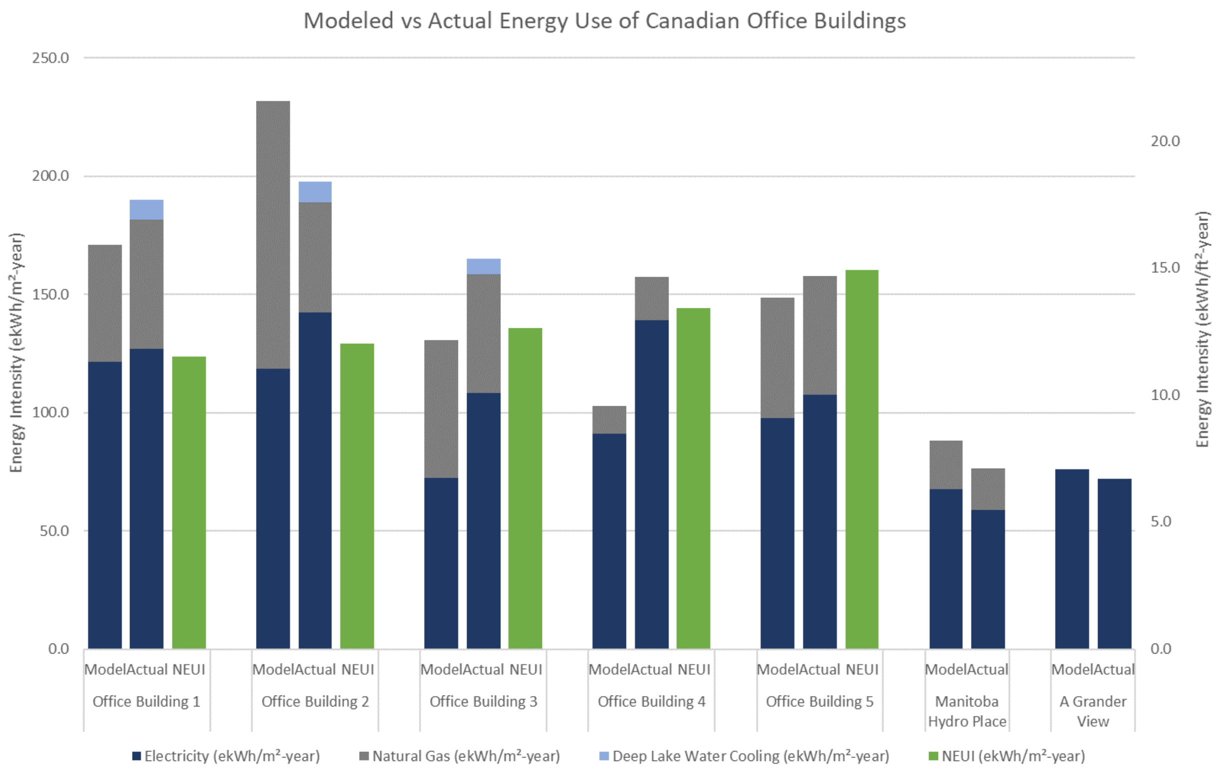
- A Grander View ("Building 5" in the charts below) is a 3-storey, 2,050 m2, wood-frame office building in Kitchener, Ontario, completed in 2009. It was selected in part because of its variable-refrigerant flow (VRF) HVAC systems. Its construction costs, at about \$300/ft^2 (2018 dollars) were also higher than average for this scale of building (~\$200-\$250/ft^2). Its design and systems include these uncommon aspects:
    - An unusually narrow footprint, optimized for daylighting
    - A much higher-performance-than-usual building envelope
    - Earth tubes for ventilation pre-conditioning
    - Solar photovoltaic electricity generation

See these case studies for further details:

- "High Performing Buildings" magazine article
- IISBE Canada case study

6.2 Overall Energy Performance

The following chart shows the modeled and actual EUIs of these five buildings, broken down by input energy type. Also included, for the three buildings from EPL's dataset, is the NEUI.



With the exception of Building 4 (incidentally the newest of the seven), the NEUI for these buildings is close to or below the modeled EUI.

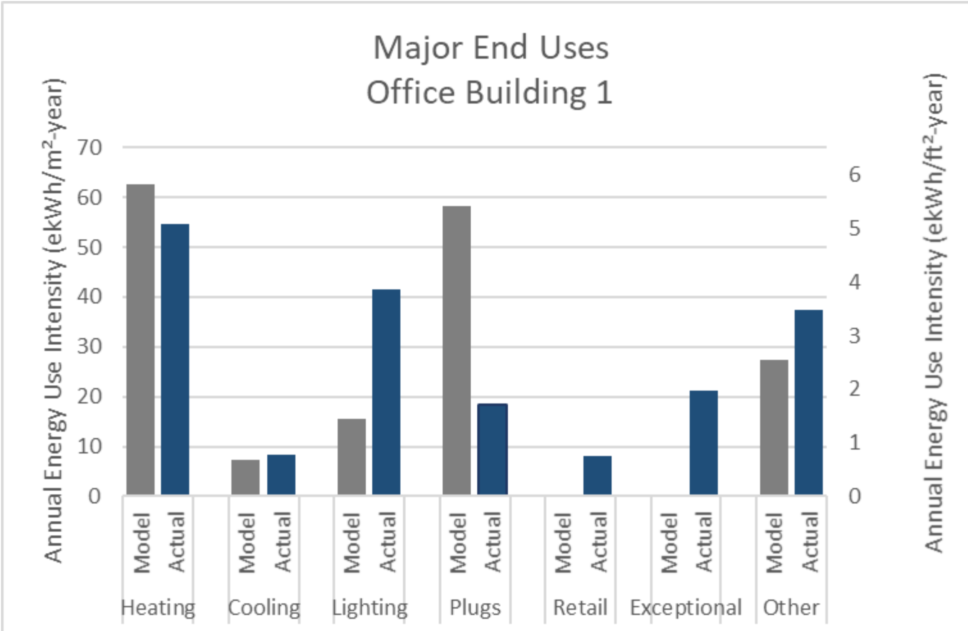
6.3 End-Use Analysis

Substantial data is available in EPL's database of the actual end-use consumption for three of these buildings. Comparing as-modeled and as-submetered data is a particular challenge, however, since the end-use categories rarely align. For example, base-building HVAC equipment – fans, pumps, etc. – is often not submetered (and it therefore categorized as "other" in this analysis), and energy models do not usually differentiate between office and retail loads.

We have attempted to align these end uses as well as possible. The following charts summarize the as-modeled vs as-metered end-use breakdowns for the three buildings for which we have sufficient data.

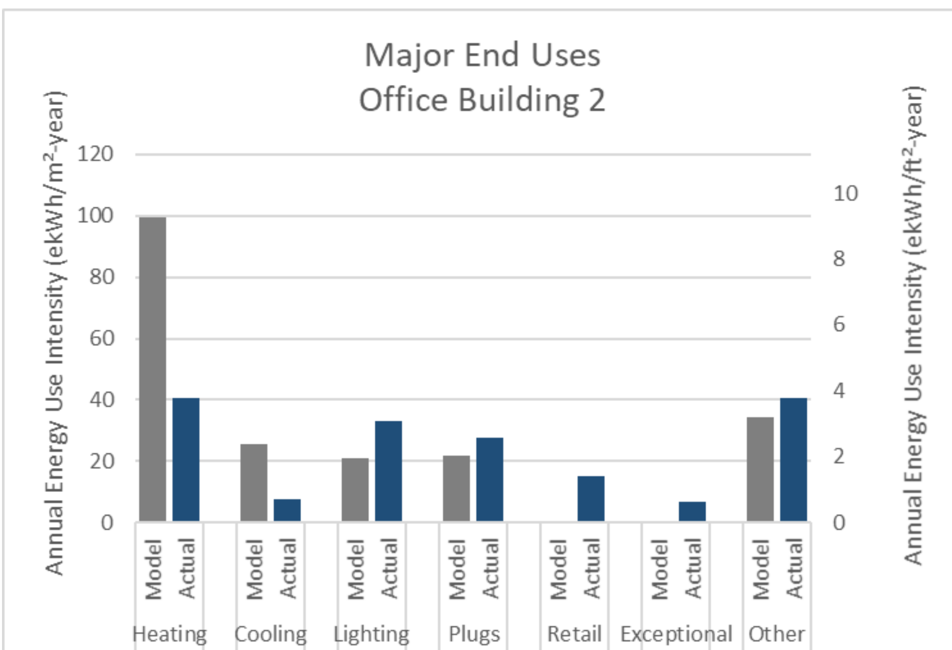
Building 1

Building 1 appears to use considerably more electricity for lighting than modeled, but much less for plug loads. It has material "retail" and "exceptional" uses that may not have been contemplated in the model. Its other end uses appear to align reasonably well.



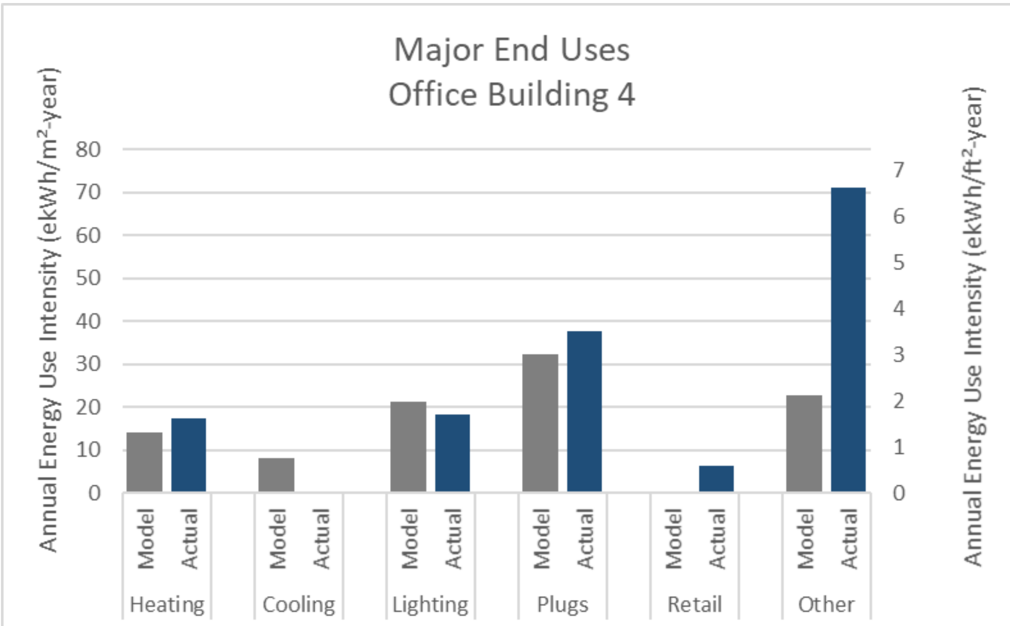
Building 2

Building 2 appears to use much less energy for heating and cooling than modeled, potentially because of more-effective-than-projected heat-recovery or demand-control ventilation systems. It also has material "retail" and "exceptional" uses that may not have been contemplated in the model. Its other end uses appear to align reasonably well.



Building 4

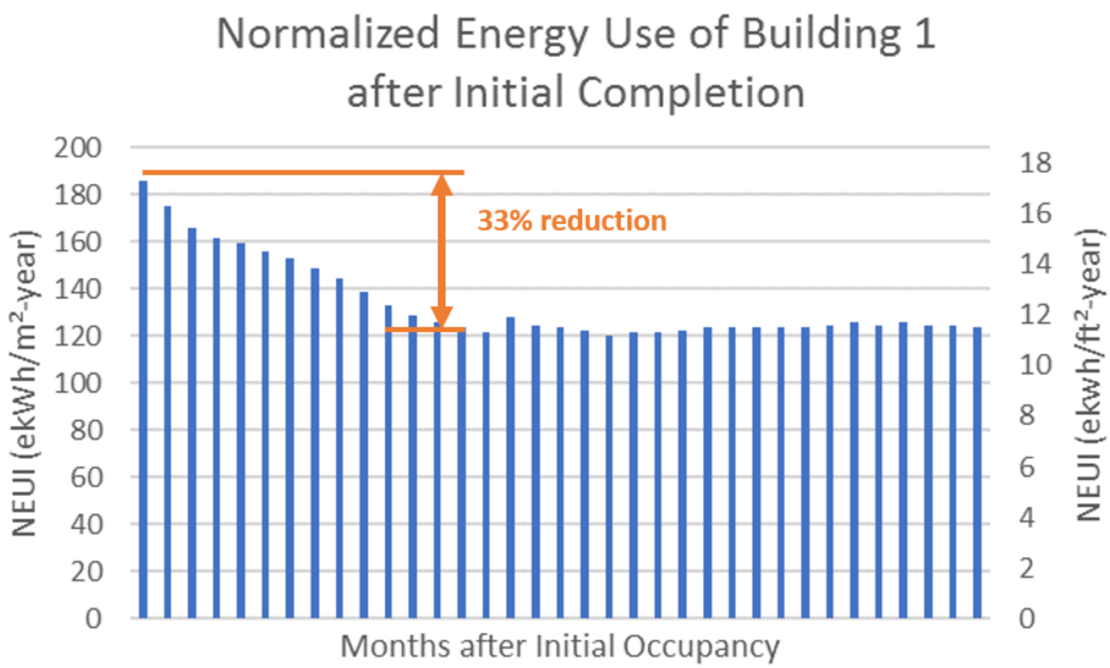
Building 4 does not have its cooling system submetered. That end use is therefore included under "other" in the actual loads. Its submetered end-uses appear to align reasonably well with the model. Virtually all of the difference between its as-modeled and actual performance seems fall under the "other" category, and may therefore be related to base-building systems such as HVAC or unmetered loads.



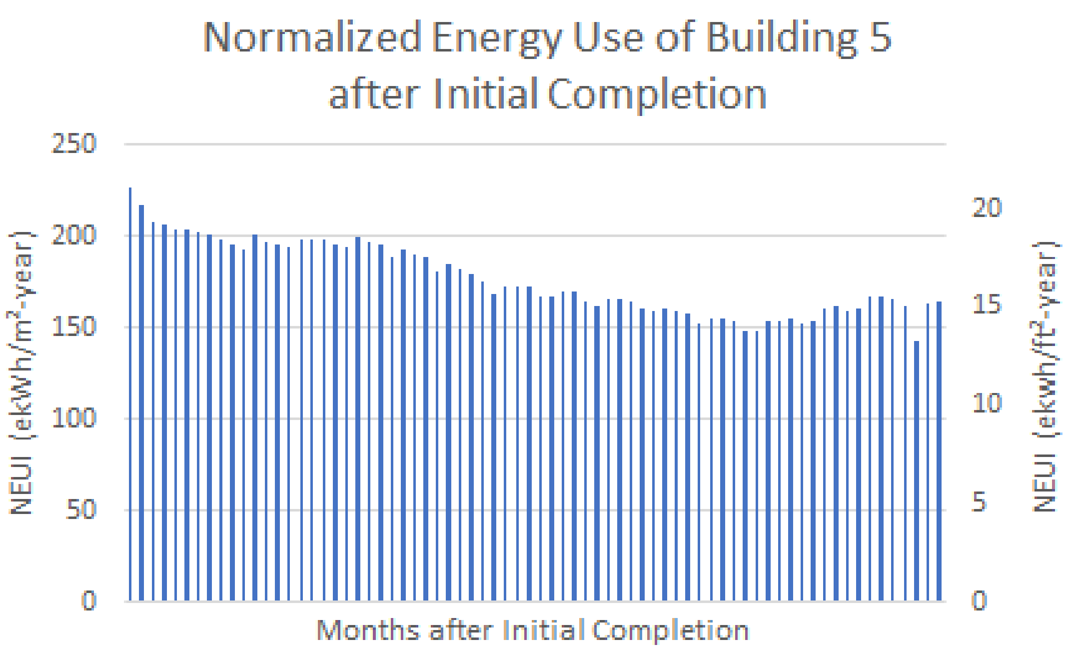
6.4 Post-Occupancy Improvements

EPL has performance data for some of these buildings since they were first constructed. The trends indicated in the following charts suggests that it took one to two years – and a focused, post-occupancy commissioning process – for performance to improve to current levels.

Building 1 had a NEUI of around 190 ekWh/m2-year shortly after its completion – higher than its model projected. It took more than a year for performance to improve to its current level – considerably better than modeled. EPL was involved in a monitoring-based commissioning process for the first few years of this building's existence, and in our opinion, a large part of that performance improvement was due to the operational improvements instituted during that time.



Building 5 had an initial, post-completion NEUI of around 220 ekWh/m2-year, and it took several years for performance to improve to its current level (close to that modeled). There has not been an ongoing commissioning program in place at this building, and one might infer that – at least in part – this is why it took longer for performance to improve.



It is difficult to know how widely applied ongoing, monitoring-based commissioning is. EPL is delivering this type of service to about 50 Canadian office buildings – only a fairly small portion the hundreds of buildings in our client portfolio. In the wider Canadian office market, we suspect that fewer than 5% have any form of ongoing commissioning program in place.

6.5 Conclusions

The available dataset is small, making it difficult to draw detailed conclusions. However, based on the data above, and on our experience, it is generally possible for a new office building to perform as well as, or better than, projected by its design-stage energy model. The biggest gaps between as-modeled and actual performance tend to fall within the realm of operations and exceptional loads (i.e. retail and data centres).