REPORT

# 11 YORKVILLE AVENUE

## ENERGY STRATEGY REPORT FOR REZONING AND OFFICIAL PLAN AMENDMENT SUBMISSIONS

**PROJECT#1703153**

**MARCH 8, 2018**

**SUBMITTED TO**


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# EXECUTIVE SUMMARY

This report presents a summary of energy efficiency measures explored for the 11 Yorkville Avenue project located at 11, 17, 19, 21 Yorkville Avenue, & 16, 18 Cumberland Street in Toronto, Ontario. The 62-storey development consists of residential (49,600 $m^2$), amenity (1,600 $m^2$), and retail (3,200 $m^2$) spaces, as well as a mechanical penthouse and 4 levels of below grade parking. The total gross floor area is approximately 55,000 $m^2$, excluding parking areas.

RWDI has explored how differing energy efficiency strategies may be of benefit to the project. The intent of this exploration is to provide strategic energy options for the project, and to address the City of Toronto's "Energy Strategy Terms of Reference," dated July 2016 (Reference Link 1). The overarching goal of this energy strategy is to estimate the steps that should be explored to reduce energy use, ultimately striving towards a net-zero level of performance. Regardless of the decided target level of performance, the strategies identified in this report can act as a roadmap towards enhanced levels of performance.

RWDI has used the energy modelling tool IES Virtual Environment 2017 to develop these results. Note that "actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this standard, changes in energy rates between design of the building and occupancy, and precision of the calculation tool." [ASHRAE 90.1 - 2004, 11.1.4 Informative Note]

The preparation of this energy strategy has identified a number of interesting opportunities, which will continue to be explored by the project's team. However, pursuit of opportunities needs to be balanced with the risks of implementing non-traditional development solutions. Additionally, many of the benefits of the identified opportunities (e.g. reductions in $CO_2e$ emissions) are arguably of greater importance to the City than the developers or end users. As such, the implementation of identified opportunities will likely require a collaborative effort between the developers of this project and the City to de-risk and allow for the implementation of non-traditional development solutions.

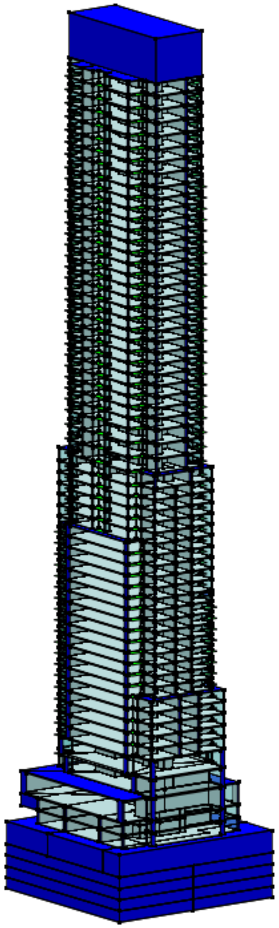

**Figure 1: Energy 3D Model of 11 Yorkville Avenue Project, NE Elevation**

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# INTRODUCTION

## 1.1 CARBON INVENTORIES

More than ever before, climate change and greenhouse gas (GHG) emissions are a priority on the agenda at all levels of government in Canada. The graphs to the right summarize the current targets in Canada, Ontario, and Toronto. Each of these targets are stated in terms of equivalent carbon emissions ($CO_2e$).

For cities, provinces, and countries to operate at established 2050 target carbon budgets will require major changes in the way we all develop, operate, and live. For instance, Ontario has a target of 80% $CO_2e$ reduction by the year 2050, which will equate to a total provincial GHG footprint of 36M tonnes of $CO_2e$. Compare this to Toronto's current total emissions, last reported in 2012, which equate to approximately 21M tonnes of $CO_2e$ – close to 60% of the Province's total targeted 2050 carbon budget.

This energy strategy gives consideration to both the energy and $CO_2e$ intensity of the development site. This is seen as not only an important responsibility, but also a step to align with Ontario's Climate Change Action Plan and potential funding that may be available through the Plan to developments of this scale. The Climate Change Action Plan represents Ontario's five-year climate change action plan and identifies over $6 billion in funding that will be put towards the achievement of Ontario's aggressive GHG targets.

Reference Link 2 to the Ontario Climate Change Action Plan.

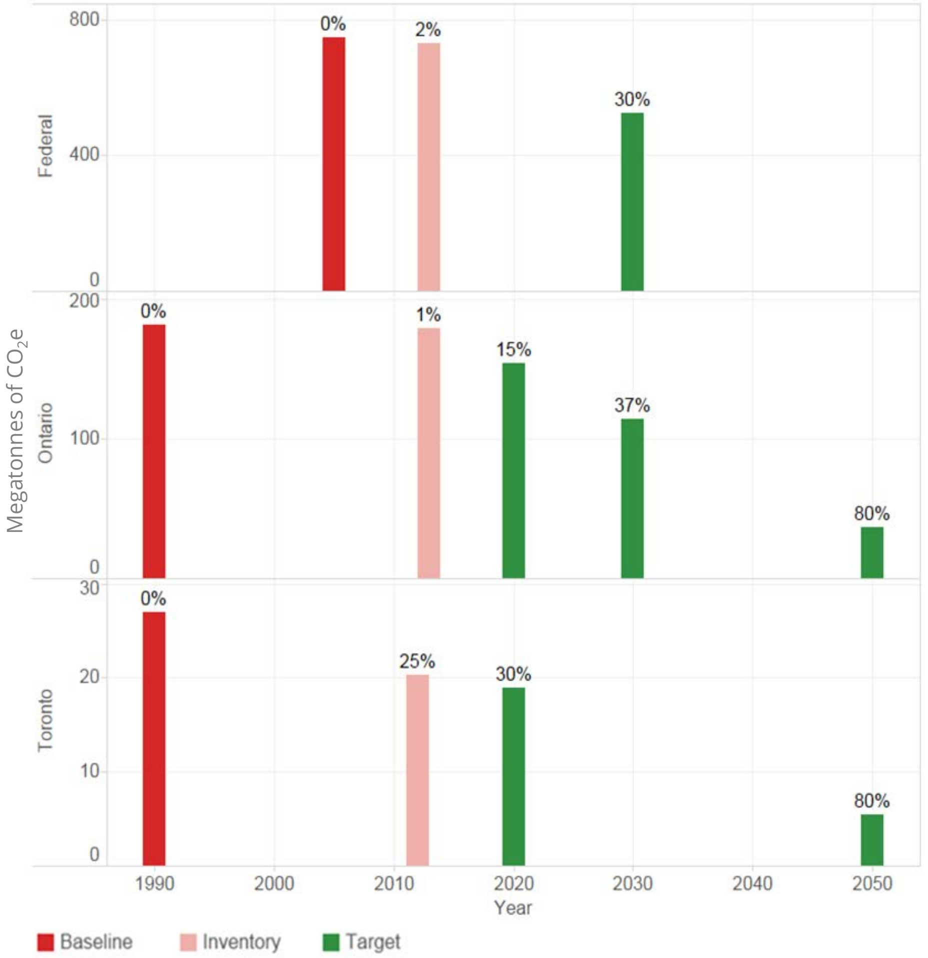



**Figure 2: GHG Emission Baselines, Inventories, and Targets**

The link between a low-energy development and a low-carbon development is the greenhouse gas (GHG) intensity of the fuels consumed. GHG intensity is expressed in equivalent tonnes of carbon per kWh of energy consumed ($CO_2e$/kWh).

Primarily as a result of efforts to retire coal-fired power plants, the GHG intensity of grid-supplied electricity in Ontario has decreased 400% while the GHG intensity of natural gas has remained unchanged. This trend can be seen in the historical $CO_2e$ intensity values for Ontario, which are reported in Canada's annual National Inventory Report, and summarized in Figure 3. (Reference Link 3)

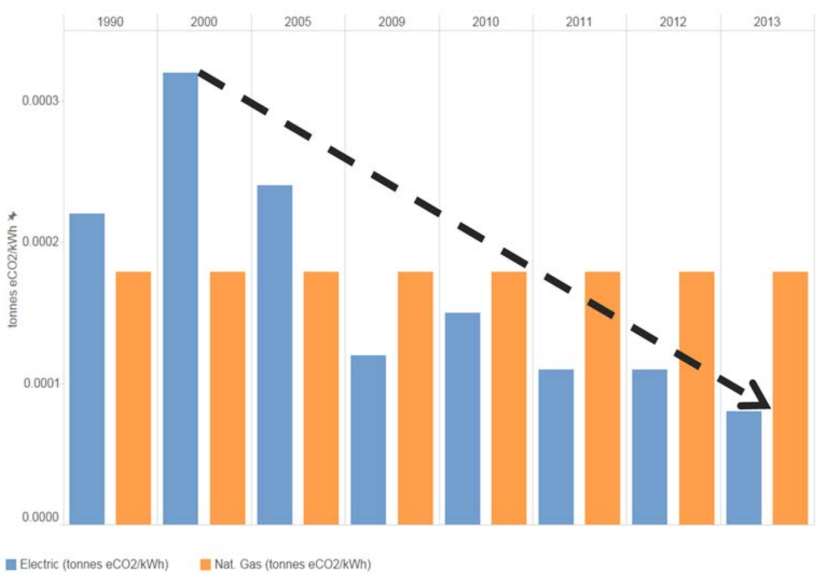



**Figure 3: Historical $CO_2e$ Intensity in Ontario for Electricity and Natural Gas**

The City of Toronto's 2012 GHG inventory, report year 2013, states that buildings are responsible for 48% of the City's total GHG footprint, quantifying the important role of efforts such as this energy strategy in the development of a low-carbon future for Toronto. The inventory further notes that natural gas consumption accounts for 78% of this building-related GHG footprint.

The simple conclusion is that a low-carbon development must now consider using electricity to meet energy demands that have traditionally been met with natural gas – e.g. heating and domestic hot water. However, this conclusion over-simplifies the problem. The challenge is not a technological one – highly efficient electric heating systems exist – rather, the challenge is largely economic. The unit cost of natural gas (approximately \$0.03/kWh) is currently over 5 times less than that of electricity (approximately \$0.15/kWh) and it is expected that this trend will continue into the foreseeable future.

This development will give consideration to electric heating systems, however, these considerations will be balanced with market demands for low operating costs and purchaser demands. Any approach must reflect market realities for developments in the Toronto market.

The following key steps were applied by RWDI in developing this energy strategy:

1. **Create a baseline energy model to provide an estimate of annual energy consumption of the current design;**
2. **Identify the top energy conservation measures (ECMs) that should be considered for the project;**
3. **Quantify the impact these ECMs using an energy model;**
4. **Determine how much renewable energy would be required to address the remaining difference; and**
5. **Make recommendations based on the results of the analysis.**

The identification of ECMs to be explored in this energy strategy was informed by RWDI's extensive experience on similar projects, and in particular a recent engagement sponsored by the Ministry of the Environment and Climate Change (MOECC) and Enbridge Gas. The MOECC initiative took place between November 2016 and January 2017, gathering dozens of professionals experienced in the development, design, and engineering of buildings in Southern Ontario into two integrative design charrettes. The goal of the initiative and charrettes was to determine what it would take for developments to achieve net-zero energy and GHG emissions. RWDI participated in this effort, leading the facilitation of the charrettes and providing input to the final report, which has been published on Sustainable Buildings Canada's web-site (Reference Link 4).

## 1.4 BASELINE PERFORMANCE

The first step in the development of this energy strategy was to establish a baseline performance level ("Baseline Design"), that reflects how the project is expected to perform with the design as it currently stands. Integrated Environmental Solutions – Virtual Environment 2016 (IES-VE) whole building energy simulation software package was used to develop an energy model for this project.

Energy model inputs are based on the architectural drawings, dated March 2018, and mechanical & electrical brief, dated February 2018, that were developed for the Site Plan Control Application. Any inputs that could not be confirmed by the design team at this early stage were assumed to be the same as the NECB 2015 Chapter 8 reference building, as modified by the Ontario Building Code Supplementary Standard SB-10 2017. Appendix A provides a summary of the key model inputs.

To contextualize the Baseline Design, a model was developed that complies with the Ontario Building Code requirements ("OBC Reference"). This analysis found that the **current Baseline Design is performing 1.5% better than the OBC Reference**, as shown in Table 1. The Baseline Design has an energy use intensity (EUI) of 236 ekWh/m$^2$-year.

**Table 1: Energy Use Breakdown, Reference vs. Baseline**

| | OBC Reference (kWh) | Baseline Design (kWh) | Reduction from Reference (%) |
|---|---|---|---|
| Heating | 6,154,900 | 6,669,600 | -3.9% |
| Cooling | 745,400 | 580,400 | 1.3% |
| Lighting | 1,359,100 | 958,000 | 3.0% |
| Fans | 808,300 | 1,384,300 | -4.4% |
| Pumps | 268,900 | 46,600 | 1.7% |
| DHW | 2,618,900 | 2,117,100 | 3.8% |
| Process | 1,241,500 | 1,241,500 | 0.0% |
| **Total Annual Energy (kWh)** | **13,197,000** | **12,997,500** | **1.5%** |
| **Energy Use Intensity (kWh/m$^2$-yr)** | **240** | **236** | |

The Canadian Green Building Council defines a net-zero carbon building as a "highly energy efficient building that produces on-site, or procures, carbon-free renewable energy in an amount sufficient to offset the annual carbon emissions associated with building operations" (Reference Link 5).

To achieve net-zero, a hierarchical approach to high-performance design is applied, as illustrated in Figure 4. Using the current Baseline Design, described previously, the following steps are taken to further reduce the energy consumption of the building:

1. Identify additional passive conservation strategies that should be considered to reduce external loads on the building.
2. Identify additional ways to reduce internal loads and change occupant behavior to conserve energy.
3. Identify additional active conservation strategies to address the remaining loads as efficiently as possible.
4. Make up the remaining difference with renewables.

For the purposes of this analysis, only energy consumed on-site is considered, i.e. distribution losses between the site and generation sources are not included.

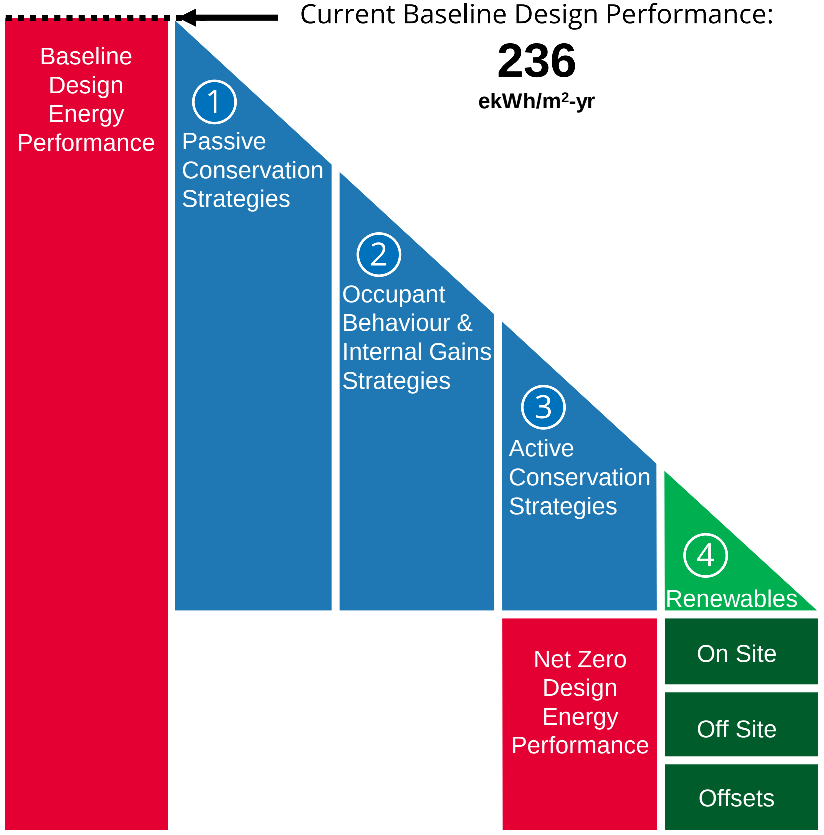



**Figure 4: The path to a net-zero building**

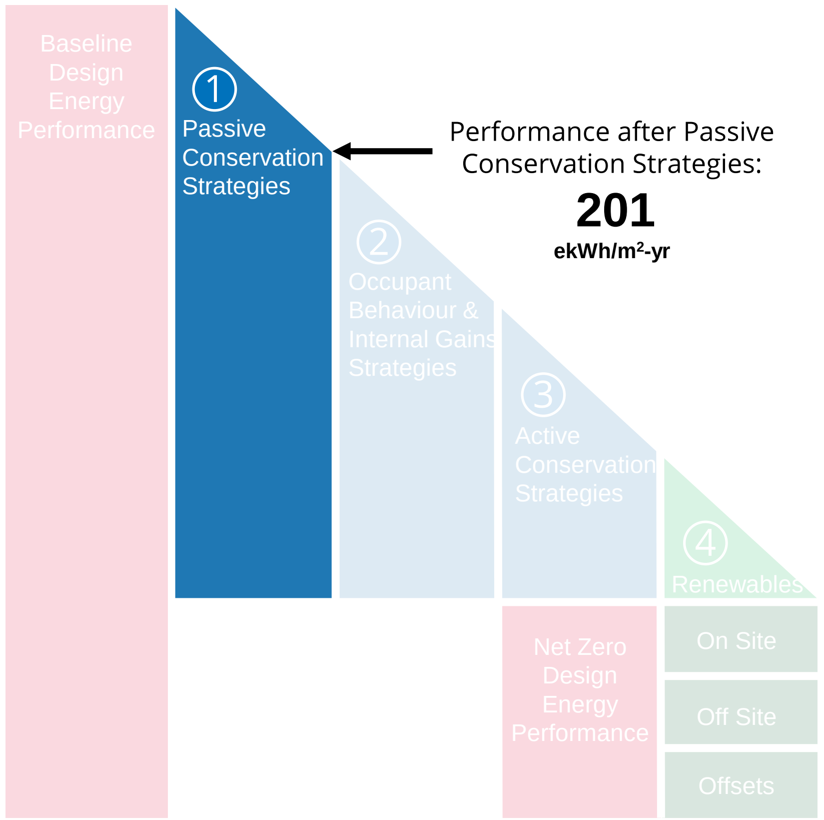
# ENERGY CONSERVATION MEASURES

## 2.1 PASSIVE CONSERVATION STRATEGIES

Passive conservation strategies look to reduce the annual energy consumption of a development by reducing the external loads on the building – i.e. by controlling the heat gains and losses through the building envelope.

The following passive ECMs were identified as priority considerations for this project and included as passive conservation strategies:

- Window-to-wall ratio reduced from 76% to 50%;
- Glazing upgraded to a triple-glazed aluminum frame solution (argon, low-e, thermally broken frame). The USI was improved from1.90 W/m$^2$K to 1.50 W/m$^2$K, and the SHGC was reduced from 0.40 to 0.30;
- Interior spray foam insulation was installed behind all spandrel panels included in the baseline model upgrading them to an effective RSI 1.6 m$^2$K/W (R-9.0 hr-ft$^2$-°F/Btu);
- Podium (retail and amenity) exterior spandrel walls have been replaced with steel framed walls with continuous exterior insulation, an effective RSI 3.6 m$^2$K/W (R-20.4 hr-ft$^2$-°F/Btu); and
- Building infiltration through the envelope has been reduced to the US Army Corps of Engineer's required rate of 1.2 L/s/m$^2$ of exterior envelope area at 75 Pascals.



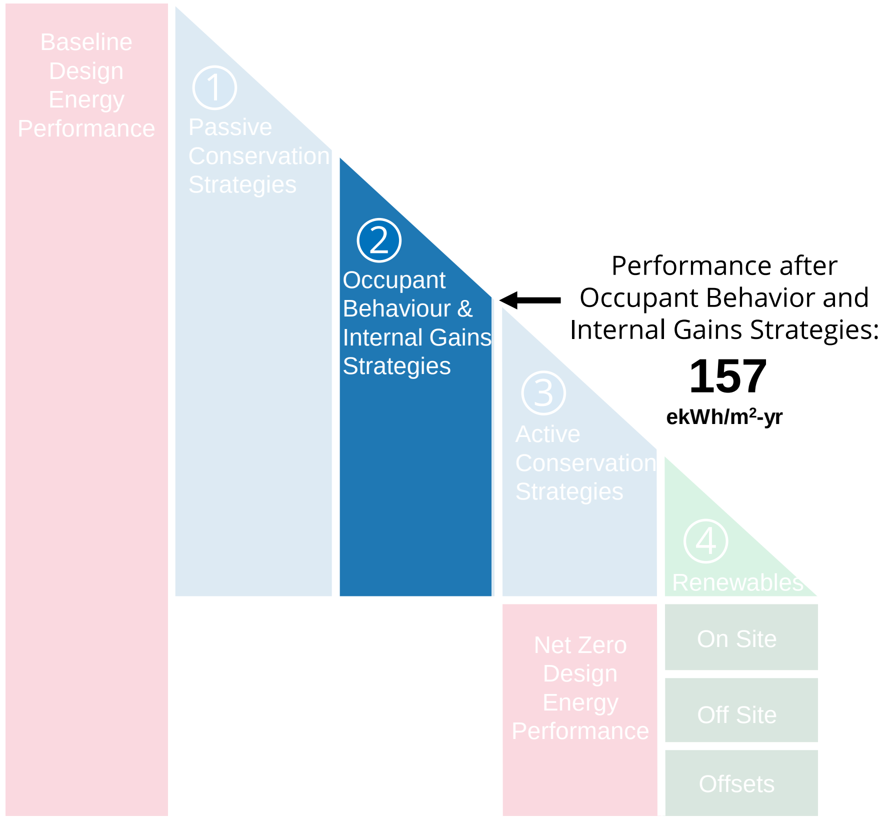
# ENERGY CONSERVATION MEASURES

## 2.2 OCCUPANT BEHAVIOUR & INTERNAL LOADS STRATEGIES

Equipment and occupant loads typically come from appliances, computers, and other powered devices within the residential suites. These loads are difficult to influence as they are decentralized and vary widely depending on the behaviour of individual occupants. Reducing these loads requires both the application of technologies (e.g. occupancy sensors), and behavioural nudges (e.g. educational outreach).

The following ECMs were identified as priority considerations in this category and included as occupant behaviour and internal gains strategies:

- Suite level sub-metering of thermal energy, with smart thermostats;
- Selecting high-performance Energy Star appliances for the residential suites (e.g. washers, dryers, dishwashers, refrigerators);
- Installing kitchen, shower, and lavatory fixtures with flow rates of 3.8, 2.65, and 1.9 LPM, respectively;
- Installing kill-switches at all suite exits to turn off all lights upon exiting; and
- Installing occupancy sensors in the parking garage that reduce lighting levels by 75% when unoccupied.



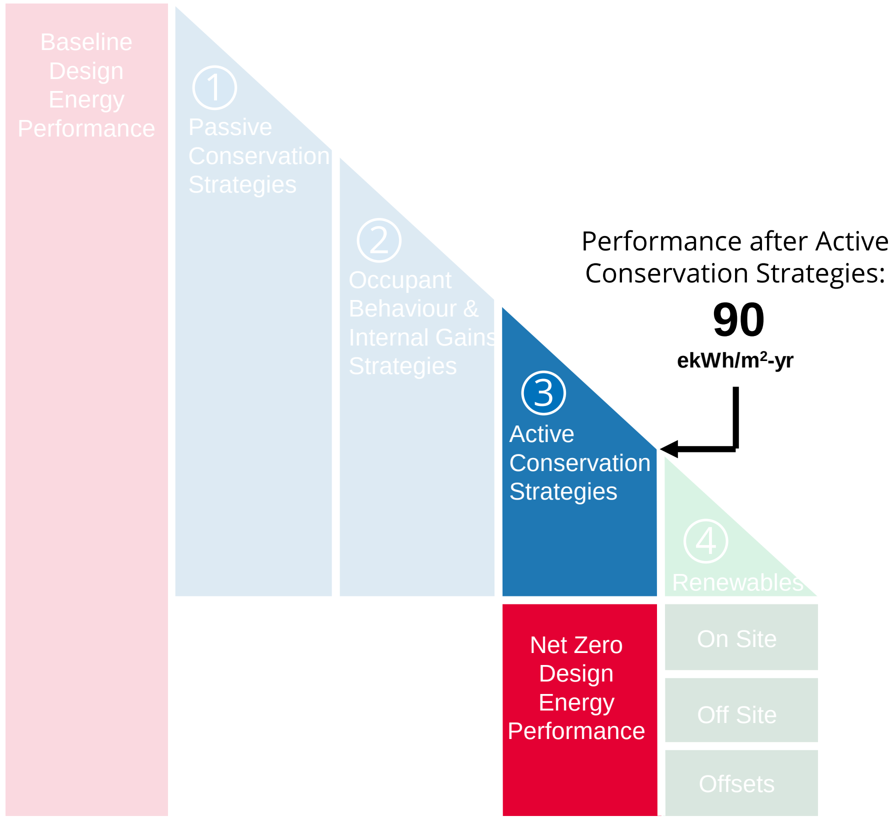
# ENERGY CONSERVATION MEASURES

## 2.3 ACTIVE CONSERVATION STRATEGIES

Active systems use energy from the utility grid to meet energy demands from the building. Common active systems are lights, heaters, fans, air conditioners, and pumps. Typically, reducing the amount of energy used by these active systems is accomplished through one of two broad strategies: increasing efficiency, and reducing use. Reducing use was addressed to the extent deemed feasible in the previous two sections, "passive strategies" and "occupant behaviour and internal gains." As such, this section focuses on increasing efficiency often using enhanced technologies to deliver the same result with less energy.

The following ECMs were identified as priority considerations in this category and included as active conservation strategies:

- Add in-suite energy recovery ventilators (ERVs) to residential units with a sensible effectiveness of 65%;
- Upgrade ERV performance in amenity spaces from 55% to 85% sensible effectiveness;
- Utilize water-source Variable Refrigerant Flow (VRF) system for all residential units and amenity spaces; and
- Add centralized drain water heat recovery to preheat DHW.



## 2.4 RESULTS

The results of these energy conservation and demand management strategies are presented in Figure 5, on the following page. The cumulative strategies achieve a significant reduction in energy consumption over the baseline, reducing the annual EUI from 236 to 90 ekWh/m²-year.

Table 2, below, expresses the results in terms of four key metrics: Energy Use Intensity (EUI), total energy consumption, GHG emissions, and annual energy cost. The building design which includes all cumulative strategies is hereafter referred to as the "Net Zero Design."

<u>GHG Emission Factors</u>
Electricity: 0.050 kg $CO_2$e/kWh
Natural Gas: 0.183 kg $CO_2$e/kWh

<u>Unit Energy Cost</u>
Electricity: $0.1544/kWh
Natural Gas: $0.0267/ekWh

**Table 2: Results of energy conservation and demand management strategies**

| **ECM Packages** | EUI (ekWh/m²) | Total Energy (ekWh) | % Energy Reduction over Baseline | GHG Emission (tonnes $CO_2$e) | % GHG Reduction over Baseline | Energy Cost | Energy Cost Savings over Baseline |
|---|---|---|---|---|---|---|---|
| Baseline Design | 236 | 12,997,600 | - | 1,800 | - | $902,100 | - |
| Performance after Passive Conservation Strategies | 201 | 11,093,400 | 15% | 1,550 | 14% | $767,500 | 15% |
| Performance after Interior Gains & Occupant Behaviour Strategies | 157 | 8,663,500 | 33% | 1,180 | 34% | $629,900 | 30% |
| Performance after Active Conservation Strategies – "Net Zero Design" | 90 | 4,930,800 | 62% | 410 | 77% | $612,700 | 32% |

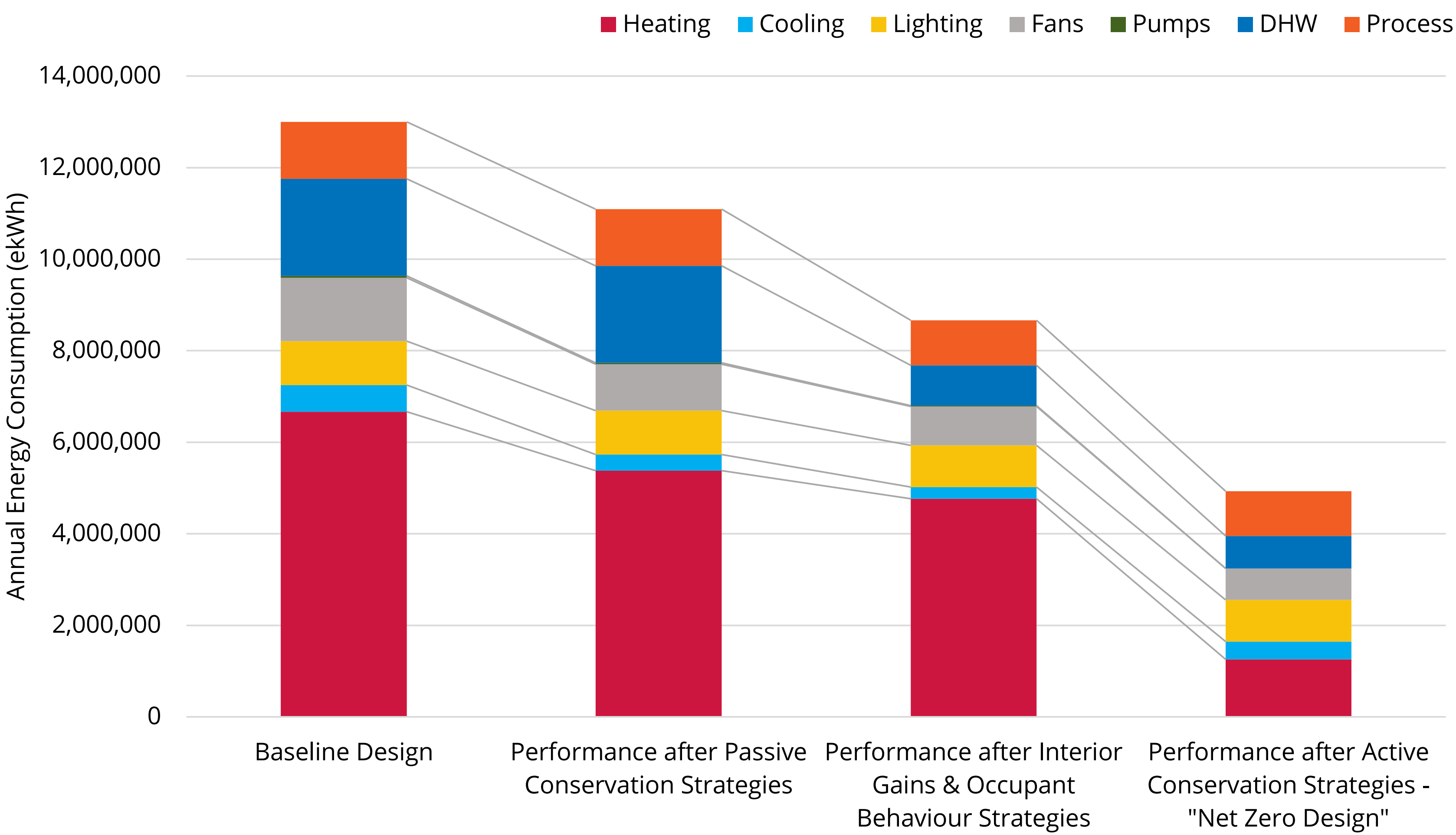



**Figure 5: Results of energy conservation and demand management strategies**

# LOW-CARBON SOLUTIONS

## 3.3 ON-SITE RENEWABLES

After reducing the total energy consumption requirements for the building by 62% over the Baseline Design, this energy strategy now considers the application of renewables to offset the remaining energy use of the Net Zero Design.

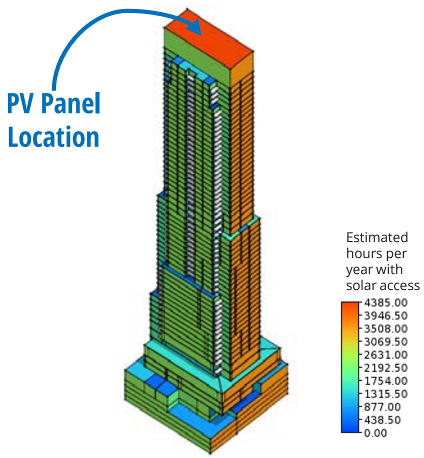
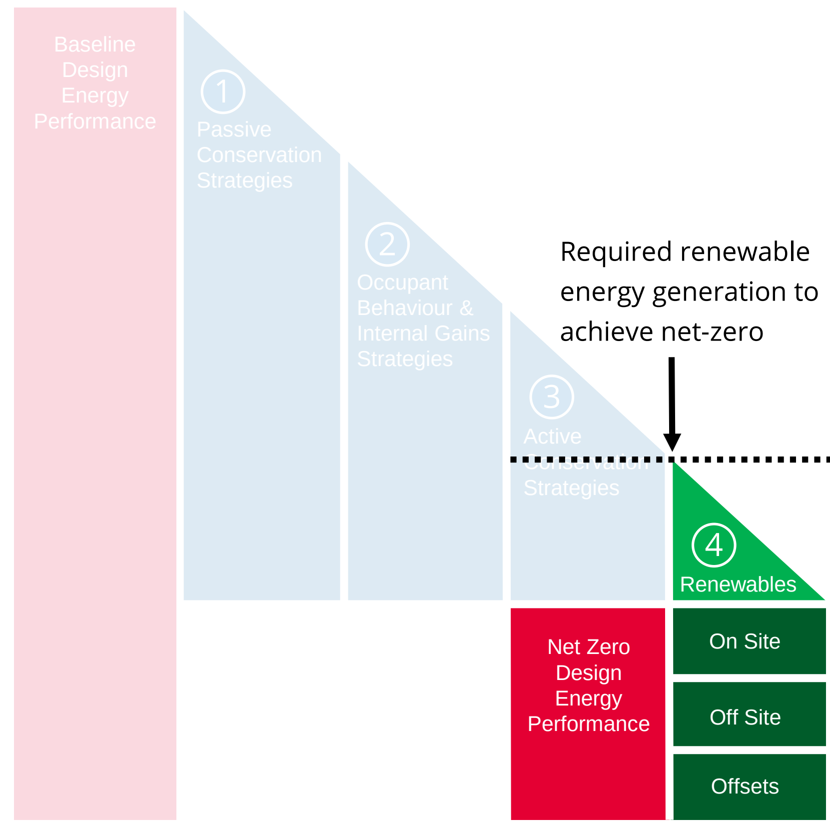



**Figure 6: Solar radiation potential on the building, SW elevation**

Rooftop solar photovoltaic (PV) potential was explored using the National Renewable Energy Laboratory's (NREL) PVWatts Calculator (Reference Link 6). This strategy assigns the mechanical penthouse to hold the solar PV array, for a total area of 560 $m^2$ (see Figure 6).

Using site-specific solar radiation information and the PVWatts calculator it was estimated that 129,200 kWh of energy could be generated on-site, annually. This would only offset 2.6% of the Net Zero Design's total energy use (4,801,000 kWh), and is insufficient to reach a net-zero level of performance using on-site renewable generation.



Although on-site solar PV generation will not generate sufficient energy for the development to reach a net-zero level of performance, off-site carbon offset strategies could also be considered.

The area of solar generation that would be required to fully offset the energy requirement and carbon emissions of the development can be determined by comparing the PV system size to the total energy requirement of the building.

The PVWatts calculator results for on-site solar PV suggest a generation potential of 230 kWh/$m^2$–year in the Toronto climate. The quantity of solar PV required to offset the remaining energy consumption of the Net Zero Design building (4,801,600 kWh) can then calculated by dividing the energy consumption by the generation potential. This equates to a required solar PV system area of 20,900 $m^2$.

This is not an insignificant area, and it would not likely be feasible to install this much solar capacity in downtown Toronto, yet the area is comparable to existing solar farms in rural Ontario. Developments like this could consider taking advantage of Ontario's abundant rural areas – where large-scale solar farms are possible – to achieve the net-zero carbon target of the project, through off-site solar generation. At present, however, there are minimal incentives to encourage developments to consider such large scale strategies, making their pursuit unlikely to be feasible.

**Figure 7: The area of off-site generation required by the development (yellow rectangle) overlaid on the Silvercreek Solar Park, found near Aylmer Ontario (Courtesy of GoogleEarth™).**

# LOW-CARBON SOLUTIONS

## 3.3 DISTRICT ENERGY & CHP

District energy systems (DES) use a centralized plant to generate and distribute energy for many buildings, in the form of thermal energy for heating and cooling, and/or electricity. By collaborating, a group of buildings can find an economy of scale that may provide the following benefits:

1. Increased efficiency at the plant level;
2. Reduced energy consumption by sharing waste thermal energy between buildings with different load profiles;
3. Potential reduction in capital costs;
4. Streamlined maintenance and future equipment upgrades with one central plant instead of several smaller plants; and
5. Flexibility to divide energy generation across a number of energy sources, and add future capacity as required.

Some examples of low carbon intensity energy sources for a DES include a central geothermal field, a combined heat and power plant, deep lake water cooling, and bio-fueled boilers. Importantly, district energy should not be confused with renewable energy or low-$CO_2$e energy sources. Unless the fuel choice at the district central plant has a lower carbon intensity than that which is proposed at the building level, there is no $CO_2$e benefit to considering a district energy approach. In fact, there may be a penalty as a result of distribution losses.

The City of Toronto has a number of existing district energy systems, and encourages building developers and owners to consider collaborating with an existing district system and/or buildings that are "district energy-ready".

Figure 8 illustrates that there are no existing DES near the proposed site, although there is potential for future DES node nearby. As such, it is unlikely that DES will initially be feasible. However, preparing the building to be DES ready may prove to be prudent and should be explored. (Reference Link 7)

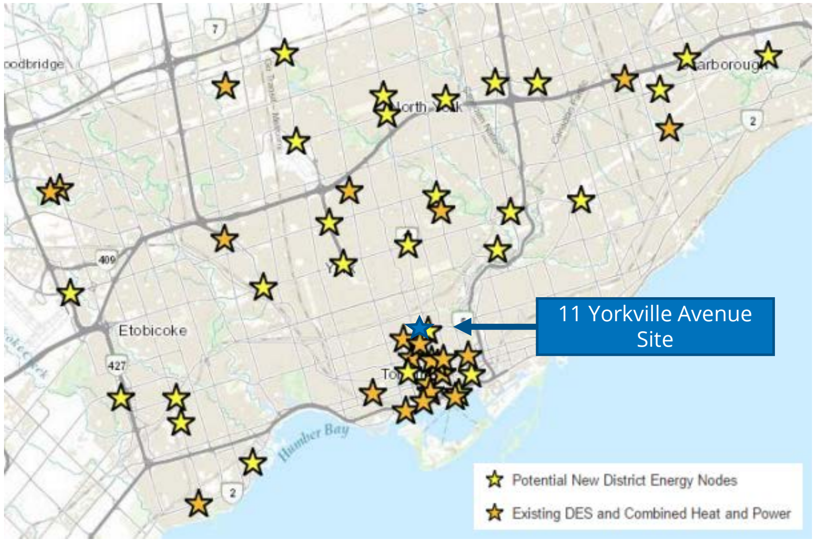



**Figure 8: DES Locations in Toronto**

# RESILIENCY

## 4.1 CLIMATE CHANGE

According to the Resilient Design Institute, "resilient design" is the intentional design of buildings, landscapes, communities, and regions in order to respond to natural and manmade disasters and disturbances, as well as long-term changes resulting from climate change, including sea level rise, increased frequency of heat waves, and regional drought (Reference Link 8).

Other key future weather changes projected by the *Toronto's Future Weather and Climate Driver Study* include:

- Increased temperatures throughout the year;
- Increased frequency and duration of heat waves;
- Increased intensity of major rain events, major storms, and tornados; and
- Increased frequency of freeze-thaw events.

Historically, Toronto has been considered to have a heating-dominated climate, and strategies to reduce energy requirements for heating are typically the most important. Yet, as the climate changes, reducing cooling energy will become increasingly important for Toronto buildings.

**Figure 9: ASHRAE Climate Zones**

Figure 9 shows the ASHRAE Climate Zones in North America. Climate Zones are categorized based on the annual Heating Degree Days (HDDs) that are on average experienced in a given location. While according to ASHRAE, Toronto is located in Climate Zone 6, the Ontario Building Code (OBC) considers Toronto to fall within Climate Zone 5. Further, *Toronto's Future Weather and Climate Driver Study*, found that the annual HDDs are forecasted to continue to decrease, placing Toronto in Climate Zone 4 between 2040 and 2049. (Reference Link 9)

Figure 10, on the following page, shows the historical and forecasted HDDs for Toronto, and demonstrates this shift away from ASHRAE Climate Zone 6.

The development will take several years to be fully realized, and will likely be in operation 40+ years into the future. As such, selected strategies need to be sufficiently robust to meet the needs of today, while flexible enough to adapt to the uncertain future of tomorrow.

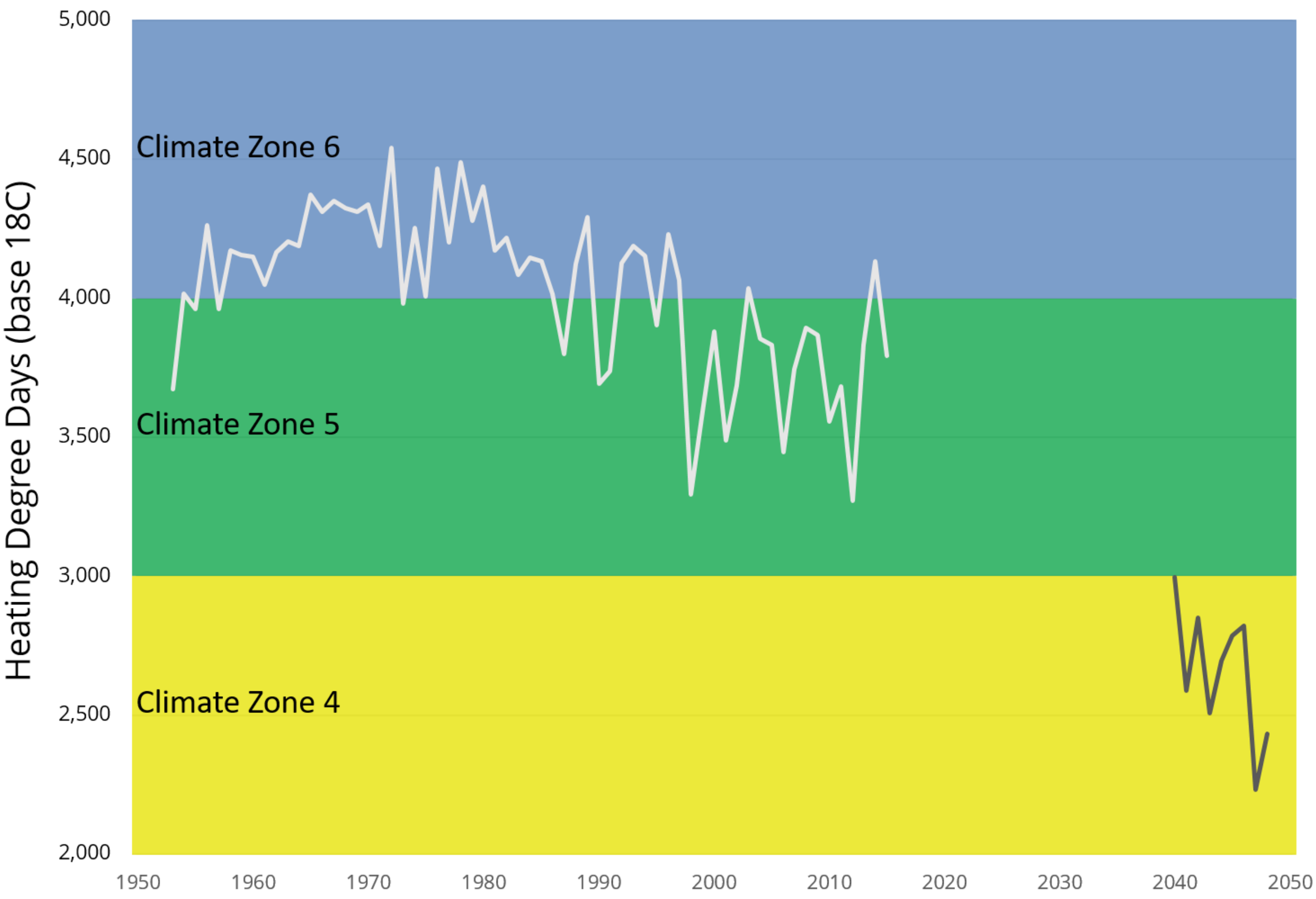



**Figure 10: Historical and Forecasted Heating Degree Days at Toronto Pearson Airport**
(Reference Link 10)

## 4.2 DESIGN CONSIDERATIONS

Climate change will continue to present a new set of challenges to building developments in Toronto. Accordingly, this project's team will be encouraged to consider:

- Back-up power systems, which are suggested to provide at least 72 hours of support for: domestic water (hot & cold), elevator service, space heating, lighting and receptacle power.
- Design solutions that allow the buildings systems to be adapted to future climatic conditions. Examples could include: the ability to add shading devices at a future date, or additional system cooling capacity.
- Enclosure strategies like low window to wall ratios, thermal breaks at balconies, airtightness, and operable windows to improve the thermal comfort and passive survivability of the building.

Working resiliency in the design and equipment selection does of course have an impact on the cost of the building. As a result, it is important to consider the business case for resiliency and how to recoup the investment. This could encompass:

- Higher perceived value because of the resilient features and the ability to market these;
- Lower operating costs (thermal envelope improvements);
- Reduced insurance premiums;
- Increased safety; and
- Easier ability to sell units on higher floors.

**Figure 11: The immediate importance of resilient design was demonstrated in Toronto by the 2013 flooding of downtown streets and buildings (Courtesy of user:Eastmain / Public Domain)**

This luxury high-rise project in New York City could be seen as an exemplar for resilient development.

An increasing focus on resiliency in buildings is demonstrated by the American Copper Buildings, two new high-rise residential buildings in Ney York City – a project by JDS Development Group. The American Copper Buildings were recently featured by the *New York Times* in the first article of their series on resilient building design.

These towers have been designed with resilience as a core design parameter, in response to the recent devastation caused by Hurricane Sandy. Features include:

- Five back-up generators to provide power for emergency services, as well as for the refrigerator and one power outlet in each unit;
- Mechanical equipment installed on the second floor, above the flood elevation; and
- Careful selection of building materials and systems that can accommodate flood water, providing mitigation of potential damage.

By designing for resilience, JDS Development Group is able to protect their building assets against unpredictable future weather events, while attracting good tenants and drawing positive exposure to their firm.

**Figure 12: The American Copper Buildings in New York City (Courtesy of JDS Development Group)**

# CONCLUSIONS & RECOMMENDATIONS

1. Through the implementation of energy conservation measures identified on pages 9, 10 and 11 this energy strategy estimates potential to reduce:
   - Energy use by 62%;
   - GHG emissions by 77%; and
   - Energy cost by 32%.
2. The results presented on page 12 show that the largest potential to reduce energy use and GHG emissions are as results of implementing the identified 'passive' energy conservation measures, e.g. improved thermal resistance of the building envelope, reduced window-to-wall ratio, among others. These passive measures not only present the largest initial opportunity but also are the mostly likely to continue to perform as designed throughout the life of the building.
3. While the potential energy use and GHG emissions reductions are impressive and demonstrate the project's potential to contribute positively towards the City's TransformTO initiative and Province of Ontario's Climate Change Action Plan, the relatively modest energy cost reduction (especially given the investment that would be required to achieve these savings) highlights a key challenge to realizing low-carbon developments in Ontario, which is the cost disparity between natural gas and electricity.
4. It is the team's experience that residents of residential buildings give little regard to the carbon or energy intensity of their investment caring most, if not exclusively, about reducing energy costs. While marketing and education may help to drive market demand, it is likely that incentives or other public subsides would be required for the carbon and energy reductions identified as a possibilities in this energy strategy to actually be realized.
5. Several of the energy conservation measures listed in this strategy have greater marketability because of their visibility and direct link to the resident's utility bills. These include suite level thermal sub-metering and kill switches near the exits. These visible measures give occupants better control of their utility bills and over the use of their space. Moreover, the energy modelling shows that these type of measures can have a significant impact on energy use.
6. While there are currently no established district energy systems near the project site, there appear to be some plans for future district energy in the area. Designing the building to be district energy ready may be prudent, and continued exploration of what these future district energy systems may look like warrants further examination as the design progresses.

# APPENDIX A

## SUMMARY OF PRIMARY ENERGY MODEL INPUTS

The below table provides an overview of the primary energy model inputs for the OBC Reference building, the Baseline Design, and final Net Zero Design model:

| | |
|---|---|
| **Modelled GFA \| Number of Stories** | 55,000m$^2$ (excluding parking) \| 62 above grade, 4 below grade parking levels |
| **Location** | Toronto, Ontario |
| **Primary Space Types** | Residential, Amenity, Retail, Parking |
| **Residential Occupancy Schedule and Set Points** | Occupied Mon-Fri in AM & PM, Sat-Sun all day<br>Heating Set Point: 22°C, Set Back 18°C \| Cooling Set Point 24°C, No Set Back |
| **Non-Residential Occupancy Schedule and Set Points** | Occupied Mon-Fri 8AM to 6PM, Sat 9AM to 5PM, Sun 10AM to 4PM<br>Heating Set Point: 22°C, Set Back 18°C \| Cooling Set Point 24°C, Set Back 26°C |
| **Outdoor Air Rates** | Residential: 47 L/s per Suite \| Non-residential: per ASHRAE 62.1-2013 |

| | OBC Reference | Baseline Design | Net Zero Design |
|---|---|---|---|
| **Envelope** | | | |
| **Typical Exterior Wall Performance** | RSI-3.6 (R-20.4) | RSI-1.1 (R-6.3) | Spandrel RSI-1.6 (R-9.0)<br>Podium RSI-3.6 (R-20.4) |
| **Typical Roof Performance** | RSI-6.4 (R-36.4) | RSI-6.4 (R-36.4) | RSI-6.4 (R-36.4) |
| **Gross Window to Wall Ratio** | 40% | 75% | 50% |
| **Glazing Performance** | USI-1.9 (U-0.33) \| SHGC 0.40 | USI-1.9 (U-0.33) \| SHGC 0.40 | USI-1.50 (U-0.25) \| SHGC 0.40 |
| **Infiltration Rate** | 0.25 L/s-m$^2$ of façade | 0.25 L/s-m$^2$ of façade | 0.22 L/s-m$^2$ of façade |
| **System Level** | | | |
| **Primary HVAC Type** | 4-pipe fan coil | 4-pipe fan coil | VRF, in-suite ERVs |
| **Airside Heat Recovery - Residential** | None | None | 65% sensible, 65% latent |
| **- Non-residential** | 55% sensible, 55% latent | 55% sensible, 55% latent | 85% sensible, 65% latent |
| **Heating** | Hydronic | Hydronic | VRF - Seasonal COP 3.2 |
| **Cooling** | Hydronic | Hydronic | VRF - Seasonal COP 4.2 |
| **Plant Level** | | | |
| **Space Heating Efficiency** | Natural draft boilers: 90% | Condensing boilers: 95% | Condensing boilers: 95% |
| **Space Cooling Performance** | Water-Cooled Chiller: IPLV 0.52 | Water-Cooled Chiller: IPLV 0.35 | Water-Cooled Chiller: IPLV 0.35 |
| **DHW Efficiency** | 90% | Condensing boilers: 95% | Condensing boilers: 95% |
| **Space Level** | | | |
| **Equipment Load** | 5.6 W/m$^2$ (weighted average) | 5.6 W/m$^2$ (weighted average) | 4.4 W/m$^2$ (weighted average) |
| **Lighting Power Density (W/m$^2$)** | Res 5.0 \| Non-res 6.7 \| Parking 1.5 | Res 5.0 \| Non-res 6.0 \| Parking 1.1 | Res 4.8 \| Non-res 6.0 \| Parking 0.8 |
| **DHW Fixture Flow Rates (L/min)** | Lav: 8.35 \| Kitchen: 8.35 \| Shower: 7.6 | Lav: 5.7 \| Kitchen: 5.7 \| Shower: 7.6 | Lav: 1.9 \| Kitchen: 3.8 \| Shower: 2.65 |

# REFERENCE LINKS


1. Energy Strategy Terms of Reference: http://www1.toronto.ca/static_files/CityPlanning/PDF/energy-strategy.pdf
2. Ontario Climate Change Action Plan: https://www.ontario.ca/page/climate-change-action-plan
3. Canada's GHG Inventory: https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=83A34A7A-1
4. Sustainable Buildings Canada's "Roadmap to Net Zero" Summary Report: http://sbcanada.org/wp-content/uploads/2017/04/Roadmap-to-Net-Zero-Summary-Report-.pdf?x41824
5. CaGBC Zero Carbon Framework: http://www.cagbc.org/cagbcdocs/NetZero/2016_CaGBC_Zero_Carbon_Framework_Exec_Summary.pdf
6. National Renewable Energy Lab (NREL) PVWatts Calculator: http://pvwatts.nrel.gov/
7. City of Toronto District Energy Guideline: https://www1.toronto.ca/City%20Of%20Toronto/Environment%20and%20Energy/Programs%20for%20Businesses/BBP/PDFs/District%20Energy%20Ready%20Guideline_October%202016.pdf
8. Resilient Design Institute: http://www.resilientdesign.org/
9. Toronto's Future Weather and Climate Driver Study: http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=b8170744ee0e1410VgnVCM10000071d60f89RCRD
10. RWDI White Paper "Modelling Weather Futures": http://rwdi.com/assets/factsheets/Modelling-weather-futures.pdf