REPORT

895 LAWRENCE AVENUE EAST

ENERGY STRATEGY REPORT: ISSUED FOR ZONING BY-LAW AMENDMENT

PROJECT #2003091
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SUBMITTED TO

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EXECUTIVE SUMMARY

RWDI was retained by First Capital Realty Inc. (First Capital) to prepare an energy strategy report for the 895 Lawrence Avenue East development in Toronto, Ontario. The development consists of two multi-unit residential towers with 6 podium levels and at-grade commercial retail (see Figure 1). The proposed total gross floor area (excluding below-grade parking) is 42,101 m^2.

This report was completed to support the Zoning By-Law Amendment submission, as required by the City of Toronto (Reference Link 1). A more detailed Design Development Stage Energy Efficiency Report will be conducted during the Site Plan Control Application stage.

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 at an early stage, and to identify the steps that should be explored to reduce energy use, ultimately striving towards a near-zero emissions level of performance.

This report should act as a roadmap towards enhanced levels of performance. Particular focus was placed on the absolute performance targets of the Toronto Green Standard Version 4 for total building energy use, thermal energy demand, and greenhouse gas emissions. In addition to energy saving strategies, this report has provided recommendations on how to implement climate resilient design to account for the expected changes in the local microclimate.

This energy strategy identifies a number of interesting opportunities that will continue to be explored by the project team. However, pursuit of opportunities will need to be balanced with the risks of implementing non-traditional development solutions. 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 the less-conventional development solutions.

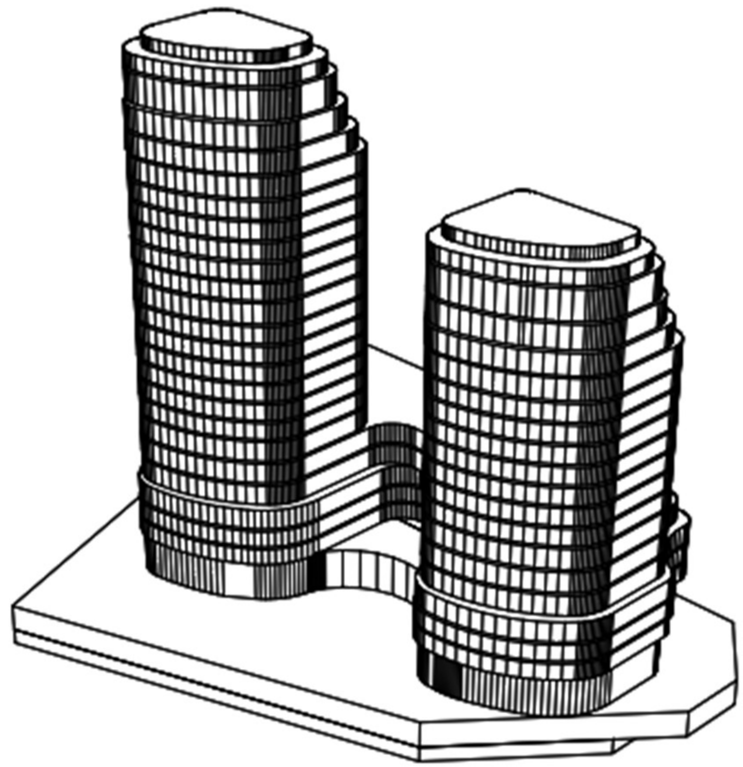

Figure 1: Model of proposed 895 Lawrence Avenue East project

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1. INTRODUCTION

1.1 PLANNING FOR A SUSTAINABLE FUTURE

More than ever before, climate change and greenhouse gas (GHG) emissions are a priority on the agenda at all levels of government in Canada. In October 2019, the City of Toronto declared a climate emergency, accelerating its commitment to becoming net-zero before 2050. The City's GHG emission reduction targets are shown in Figure 3 on the following page.

In 2017, buildings in Toronto were responsible for 7.9 million tonnes of equivalent carbon emissions (CO_2e), as reported in the TransformTO Implementation Update (Reference Link 2). This represents 52% of the City's GHG emission inventory and quantifies the important role that buildings will play in Toronto's goal to become a low-carbon city.

Further, the Implementation Update notes that natural gas consumption accounts for 94% of building-related emissions (see Figure 2). The link between a low-energy development and a low-carbon development is both the efficiency of the building and the GHG intensity (i.e., CO_2e/kWh) of the fuels consumed. Over the next 20 years in Ontario, the GHG intensity of natural gas is projected to be 2.3 times that of electricity as a result of electricity being generated primarily using non-GHG emitting energy sources.

This energy strategy report will explore opportunities for the proposed development to reduce its energy use and GHG emissions. The focus on carbon will be balanced, however, by the economic challenge presented by the fuel-cost disparity: the cost of electricity is over five times greater than that of natural gas.

Beyond GHG emissions, it is important to consider that buildings designed today will have to accommodate an alternative climate future. Renewable energy and climate resilience will have to become part of the design process.

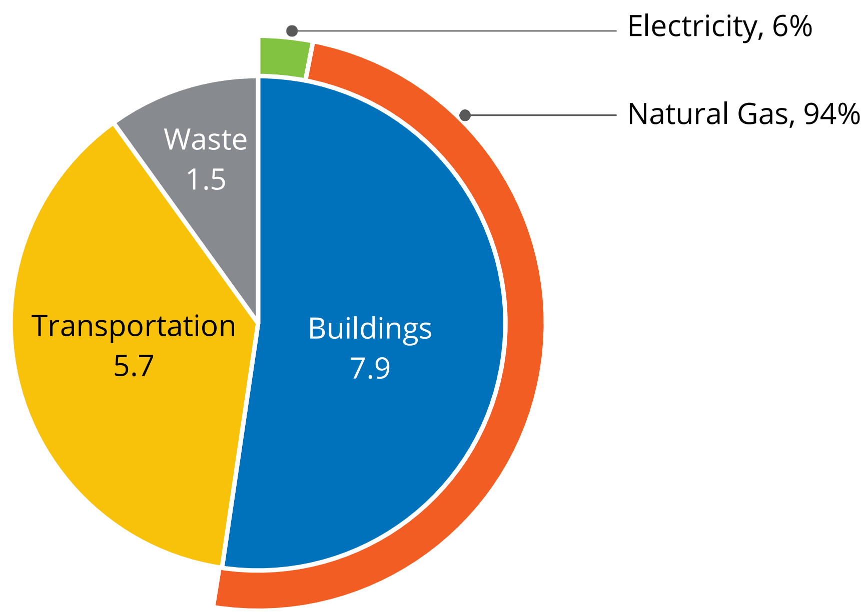


Figure 2: City of Toronto GHG Emissions in 2017 (in million tonnes CO_2e)

1.2 TORONTO GREEN STANDARD

The Toronto Green Standard (TGS) Version 4 and Zero Emissions Building Framework outline the sustainable design requirements for all new developments in Toronto (Reference Link 3). The energy efficiency requirements of TGS are aligned with the City of Toronto's 2050 GHG emission reduction targets (see Figure 3), ensuring that low-carbon design principles are integrated into new developments.

There are three tiers of performance under TGS V4. Tier 1 is a minimum requirement for all new planning applications, while Tiers 2 through 3 incentivize higher performance on a voluntary basis. The Tiers are projected to become increasingly stringent over the next six years as the TGS is renewed, shown in Table 1, with the next renewal taking place in 2025.

As the proposed design progresses, additional energy modelling will be required to ensure alignment with the absolute performance targets in effect at the time of the development's Site Plan Control Application submission.

Table 1: City of Toronto's TGS plan for energy targets

	Tier 1	Tier 2	Tier 3
	Minimum Performance	Incentivized Higher Performance	
Current (V4)	V4 Tier 1	V4 Tier 2	V4 Tier 3
2025 (V5)	V4 Tier 2	V4 Tier 3	
2028 (V6)	V4 Tier 3		

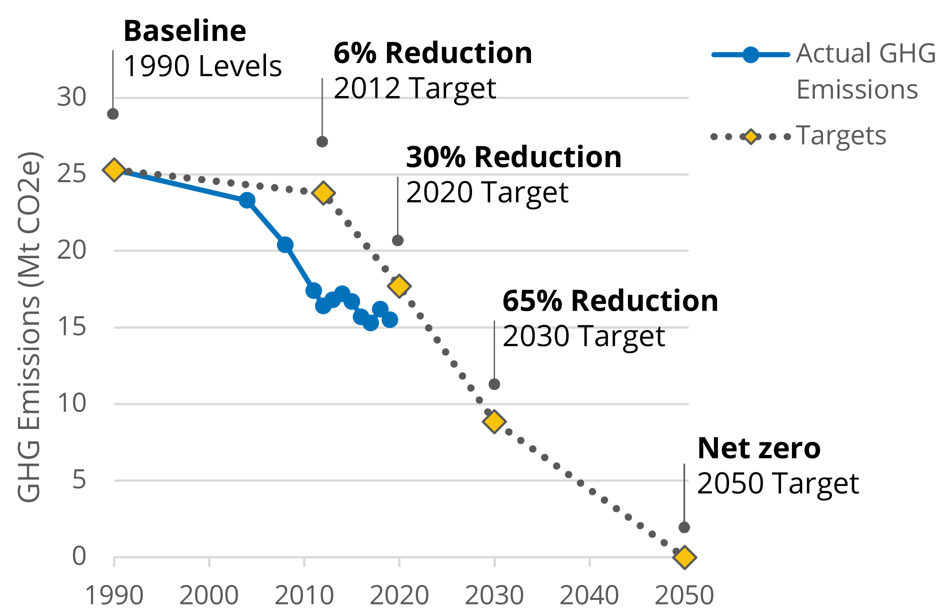


Figure 3: City of Toronto GHG Emissions and Targets

1.3 TGS PERFORMANCE METRICS

There are three metrics used by the TGS to indicate a building's absolute energy performance:

- **Total energy use intensity (TEUI)**: This metric measures the energy consumed by the building each year (in ekWh) normalized by the conditioned floor area (in m^2). A lower TEUI indicates a more energy efficient building.
- **Thermal energy demand intensity (TEDI):** This metric measures the annual heating energy required for a building to maintain a stable, pre-defined interior temperature (in kWh) normalized by the conditioned floor area (in m^2). A lower TEDI is achieved by designing a high-performance building envelope and using energy recovery ventilation units.
- **Greenhouse gas intensity (GHGI):** This metric looks at the annual GHG emissions of a building (in kg CO_2e) based on the current-year fuel-specific emission factors, normalized by the conditioned floor area (in m^2). This metric encourages the use of highly efficient, lower-carbon emitting fuels.

TGS V4 identifies performance targets at each Tier, based on the following building use types: High Rise Residential, Mid Rise Residential, Commercial Office, or Commercial Retail. Energy performance targets for this development have been calculated using an area-weighted average of the relevant building use types. The resulting targets for the development are listed in Table 2; these targets have been used for the development of this energy strategy.

Table 2: TGS V4 Energy Performance Targets for 895 Lawrence Avenue East

	TEUI (ekWh/m^2)	TEDI (kWh/m^2)	GHGI (kg CO_2e/m^2)
Tier 1	134	50	15
Tier 2	100	30	10
Tier 3	75	15	5

1.4 METHODOLOGY

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

1. **Develop and utilize archetype energy models** representative of the proposed project. The proposed development is comprised of the following building archetypes, as shown in Figure 4:
    1. High Rise Residential
    2. Commercial Retail
    3. Parking
2. **Identify the top Energy Conservation Measures (ECMs)** that should be considered for the project to achieve three levels of performance:
    - I. Baseline Performance – equal to Tier 1 of TGS V4;
    - II. High Performance – equal to Tier 2 of TGS V4; and
    - III. Near-zero Emissions – equal to Tier 3 of TGS V4.

    Quantify the impact of these ECMs on site-wide energy and greenhouse gas emissions.
3. **Consider low-carbon opportunities for the project,** including on-site renewable energy and district thermal energy networks.
4. **Make recommendations based on the results of the analysis.**

This energy strategy was prepared using the preliminary density and built form concepts using '895 Lawrence Ave East_ZBA Progress Set_220609' dated June 9th, 2022. RWDI has used the energy modelling tool IES Virtual Environment 2021 to develop this analysis. A summary of the energy modeling inputs can be reviewed in Appendix A.

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 - 2016, 11.2 Informative Note].

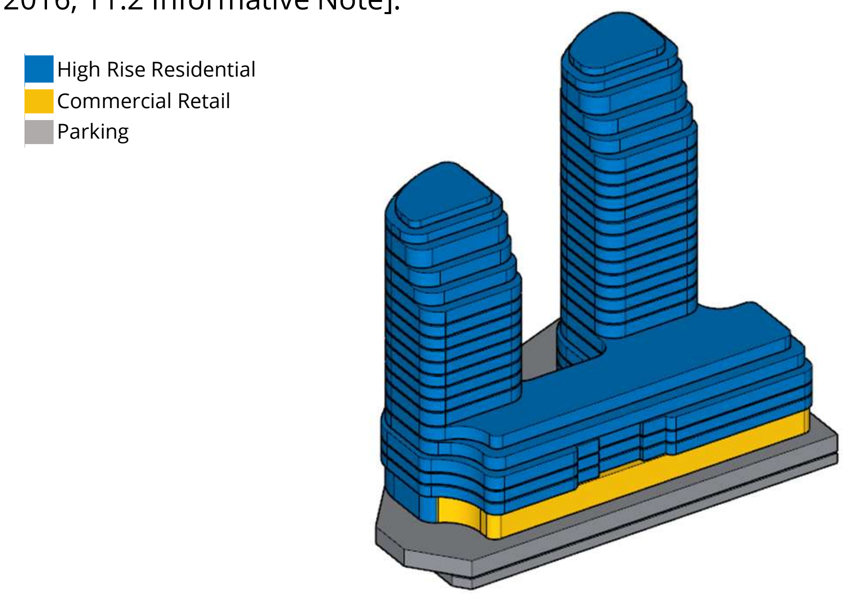


Figure 4: Project Geometry with Modelled Archetypes

2. PROJECT ANALYSIS

2.1 BASELINE PERFORMANCE: ENERGY CONSERVATION MEASURES AND RESULTS

To receive approval of the site plan control application, the project must at a minimum comply with the energy performance targets of TGS V4 Tier 1 across all three performance metrics: TEUI, TEDI, and GHGI. This is therefore considered the baseline level of performance for the development.

A package of design strategies and energy conservation measures has been employed in the energy model to achieve this baseline performance. The energy conservation measures included in this package have been selected to prioritize low-cost upgrades and best practice design in Ontario. The results for each of the TGS metrics are shown in Figure 5, below.

The key strategies in this package are:

1. Implement heat pump water heaters in residential settings.
2. Optimize window placement to achieve a gross window-to-wall ratio of 40% in high-rise residential buildings.
3. In high-rise residential, achieve overall thermal performances for opaque assemblies of R-12 and glazed assemblies of USI-1.7 through the implementation of hybrid window wall systems and thermally broken balconies.
4. Upgrade Residential in-suite ventilation units to ERV with 75% sensible and 70% latent effectiveness. Switch Retail systems to dedicated outdoor air systems with zone-level fan coil units with ventilation using ERVs.
5. Implement corridor pressurization rates no more than 20 CFM per door in the High-Rise Residential typology.

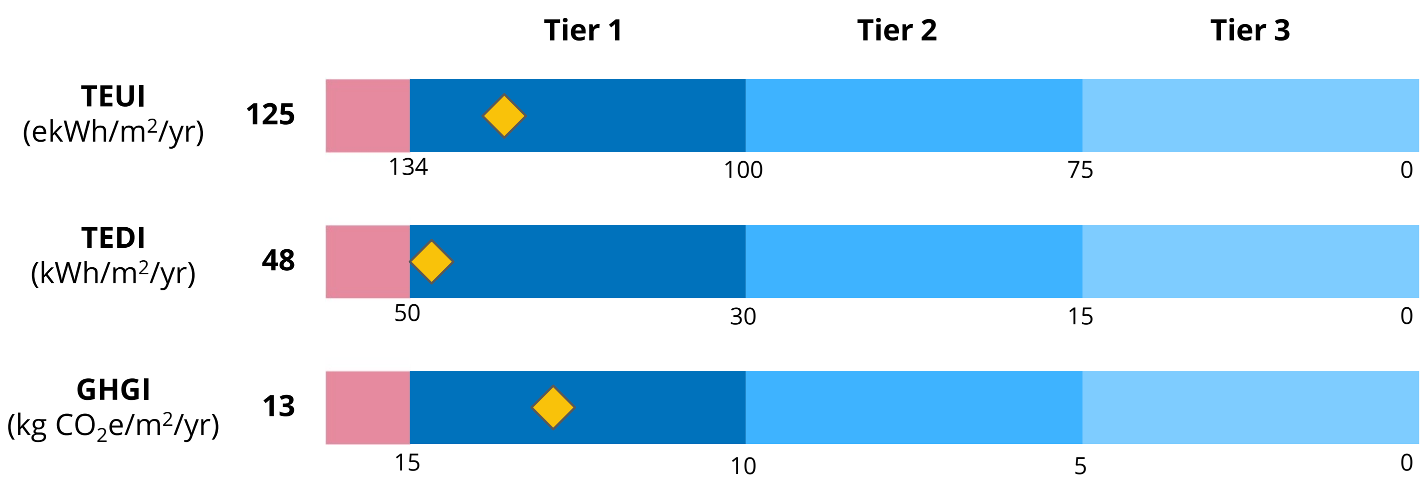


Figure 5: Baseline Performance Package Results

2.2 HIGH PERFORMANCE: ENERGY CONSERVATION MEASURES AND RESULTS

Performance beyond TGS Tier 1 is incentivized through partial development charge refunds. Reaching the energy performance targets of Tier 2 across all performance metrics will require the building design to implement innovative passive and active energy conservation measures. A development that achieves the Tier 2 targets is therefore considered High Performance.

A package of design strategies and energy conservation measures has been employed in the energy model to demonstrate this high performance. The results for each of the TGS metrics are shown in Figure 6, below.

The key strategies in this package are:

1. Improve the building envelope to achieve R-30 in both residential typologies and R-12 in Commercial Retail.
2. Upgrade Residential in-suite ventilation units to ERV with 80% sensible and 70% latent effectiveness.
3. Implement triple-glazed windows with performance of USI-1.4 or better in residential settings.
4. Reduce infiltration to ~0.6 ACH @ 50 Pa in residential building types.
5. Implement VRF heating and cooling in the Retail typology.
6. Reduce corridor pressurization rates to 13 CFM per door in the High-Rise Residential typology.

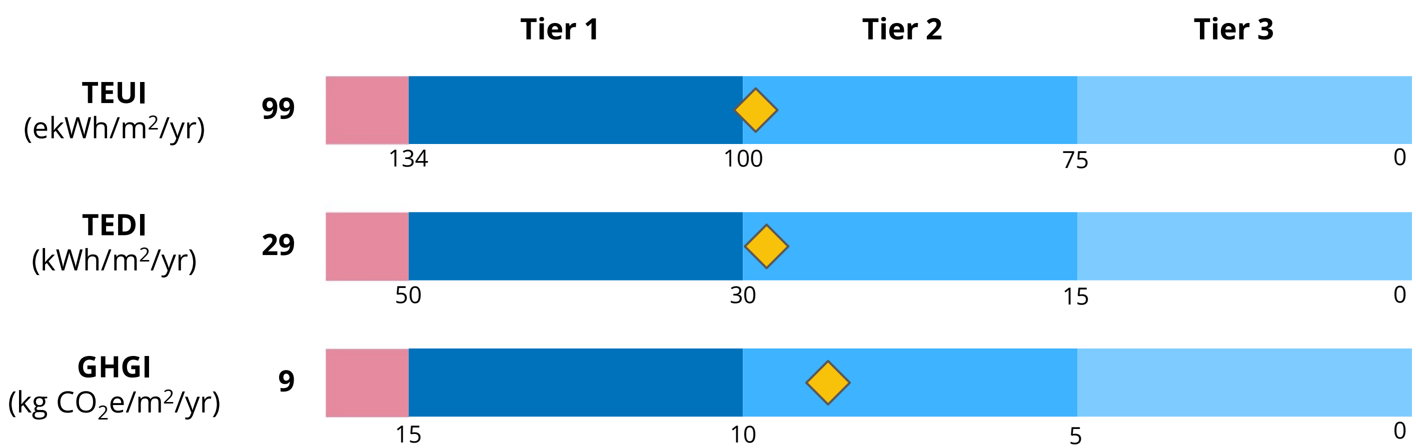


Figure 6: High Performance Package Results

2.3 NEAR-ZERO EMISSIONS: ENERGY CONSERVATION MEASURES AND RESULTS

Moving the building design toward a near-zero emissions level of performance requires fuel-shifting away from natural gas in favour of Ontario's low-carbon electricity grid. In addition, energy efficiency measures must be considered a priority in all aspects of the building design to reach the TGS Tier 3 targets. This level of performance would position the development as a leader in decarbonization in Ontario.

A package of design strategies and energy conservation measures has been employed in the energy model. The results for each of the TGS metrics are shown in Figure 7, below.

The key strategies in this package are:

1. Electrify the heating and cooling systems in each building typology by implementing high-performance air-source VRF and air-source heat pumps with electric backup heat.
2. Maximize the building envelope performance with a focus on air tightness in enclosure details and during construction.
3. Design Retail ventilation systems to maximize distribution of fresh air to the occupied zone using displacement ventilation.
4. Preheat domestic hot water (DHW) using a drain water heat recovery system in the Mid-Rise Residential typology.
5. Reduce corridor pressurization rates to 10 CFM per door in the High-Rise Residential typology.

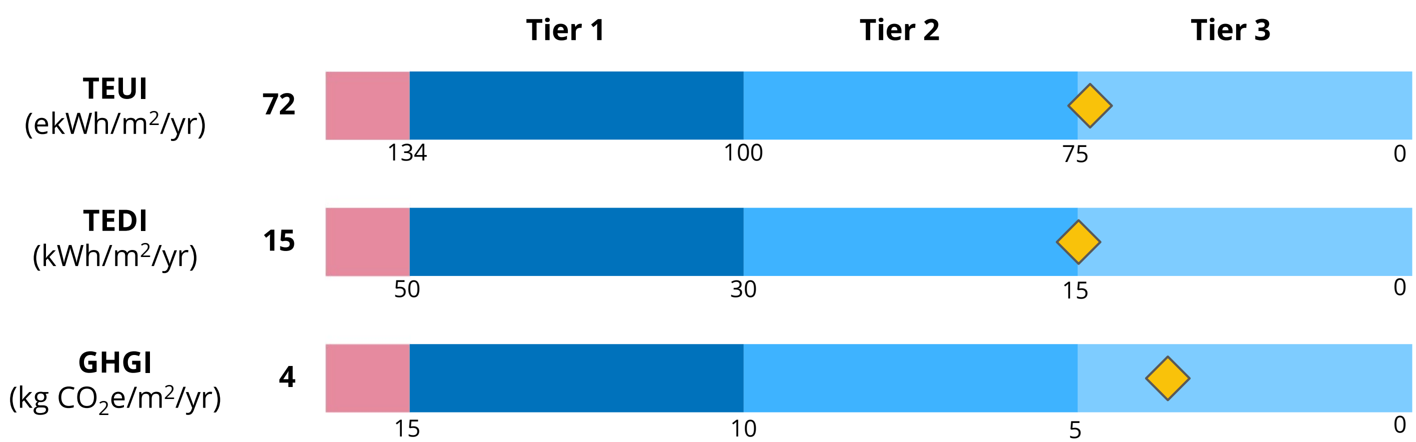


Figure 7: Near-Zero Emissions Package Results

2. PROJECT ANALYSIS

2.4 LIFE CYCLE ANALYSIS: METHODOLOGY AND RESULTS

Version 4 of the Toronto Green Standard requires a Life Cycle Analysis (LCA) of the project to identify opportunities to reduce embodied carbon. Therefore, a lifecycle analysis encompassing project life cycle phases A1-A5 was carried out to estimate material emissions for the project. This analysis was carried out using the OneClick LCA Net Zero Carbon analysis tool and assuming conventional construction methods for the building. Key assumptions for the analysis include using conventional building materials and assemblies such as concrete structure and underground parking, aluminum cladding, window wall, and curtain wall systems. The results from this analysis were then scaled based on the project GFA metrics to estimate the overall emissions. The results of the analysis based on space type and LCA phase are shown in Figure 8 and Table 3.

A first important finding, as shown in Figure 8, is that the parking area makes up a disproportionately large amount of the building emissions as a result its large concrete and rebar makeup. A second important finding is that the total carbon associated with phases A1-A5 is 6,450 tonnes (153 kg/m^2 of conditioned floor area), which corresponds to 12 to 41 years of operational carbon emissions for Tiers 1 and 3, respectively. Therefore, identifying methods to reduce these emissions is critical to reducing the environmental impact of this project. Key strategies for these reductions include reducing underground parking, using low-emission concrete (such as increasing slag to 30%), and replacing aluminum façade framing with wood. Additional LCA results are presented in Figure 9 on the following page.

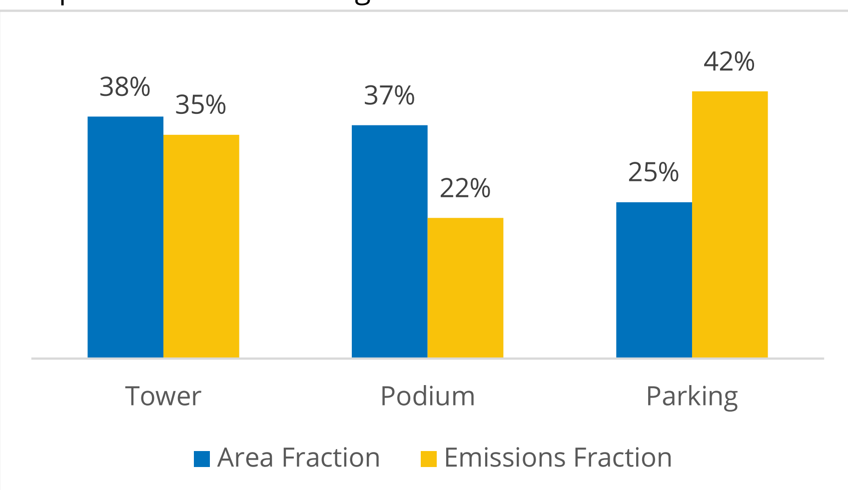


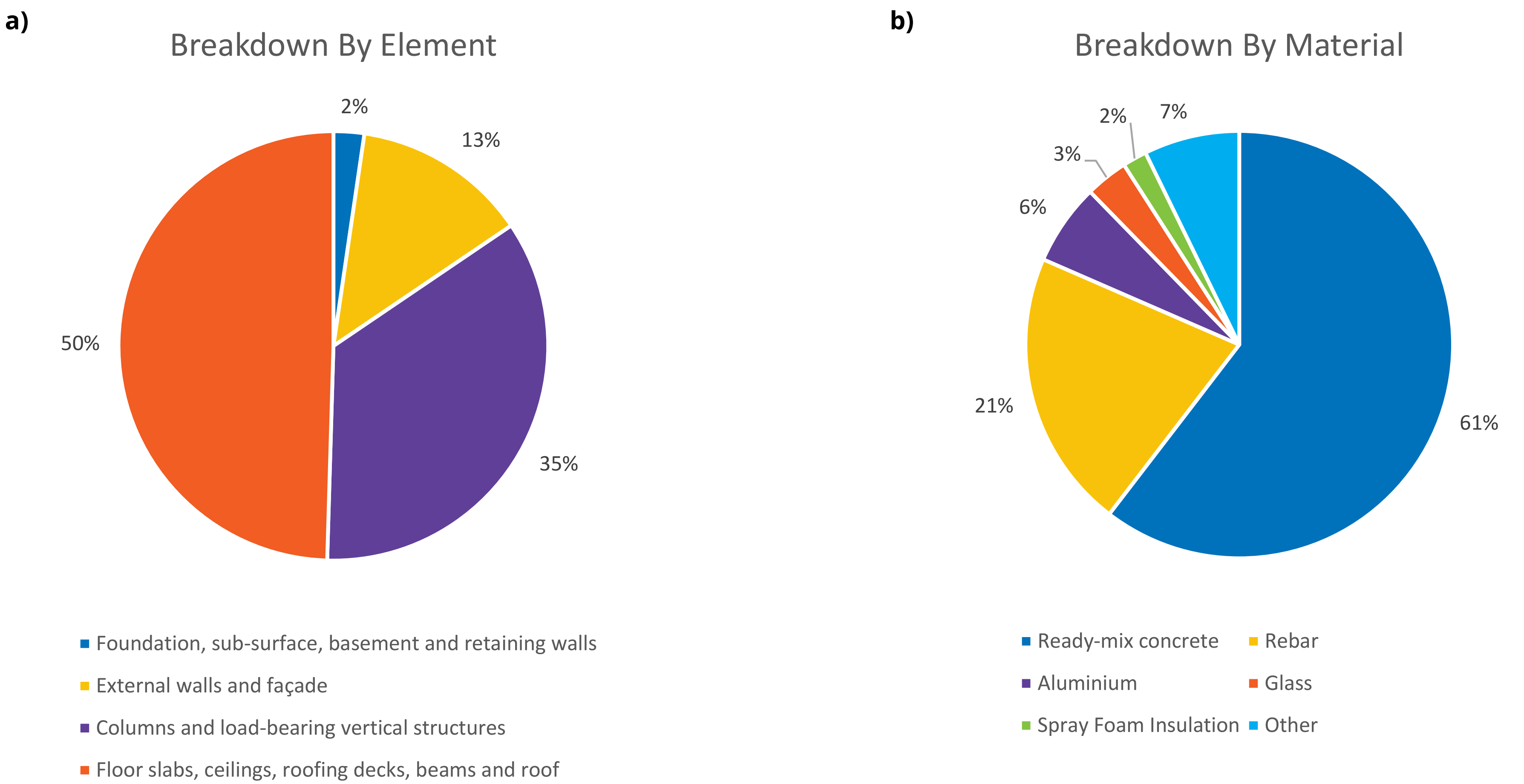
Figure 8: Project Phase A1-A5 Emissions Breakdown by Space Types

Project Phase (Tonnes CO2e)	Tower	Podium	Parking	Total
A1-A3: Construction Materials	2,976	703	1,885	5,564
A4: Transportation to site	329	61	239	629
A5: Construction	139	33	85	256
Total	**3,443**	**798**	**2,209**	**6,450**

Table 3: Project Phase A1-A5 Emissions Breakdown by Phase

2.4 LIFE CYCLE ANALYSIS: METHODOLOGY AND RESULTS

Figure 9: a) Breakdown of Development Phase A1-A5 Emissions by Building Element, b) Breakdown of Development Phase A1-A5 Emissions by Material



2.5 FINANCIAL PROJECTIONS

The improved performance packages offer operational cost savings that must be balanced against associated increased initial cost. To begin assessing this balance, annual operating costs that account for changes from electricity, natural gas, and carbon pricing and emission factors (Reference Link 4) were estimated for a 20-year period. Electricity and natural gas prices were assumed to escalate at 3% per year, and carbon prices followed the Federal framework (Reference Link 5) to 2030 and then were assumed constant. The results are shown in Figure 10.

As shown in Figure 10, both improved packages offer costs savings compared to the baseline in each year. At the onset of the project, the high-performance and near-zero emissions packages offer 11% and 17% annual cost-savings relative to the baseline, respectively. In the 20th year, these savings are 12% and 19%, respectively. The increase in savings for the near-zero case occurs because the carbon cost over the lifetime of the project increases. For example, in the baseline the carbon cost is 4% in the first year and increases to 11% in the 20th year.

While this assessment is preliminary, it supports that both improved performance packages will consistently offer energy and carbon cost savings. In addition, since we conservatively assumed carbon pricing remains flat from 2030, systems that minimize carbon will offer further savings if prices escalate.

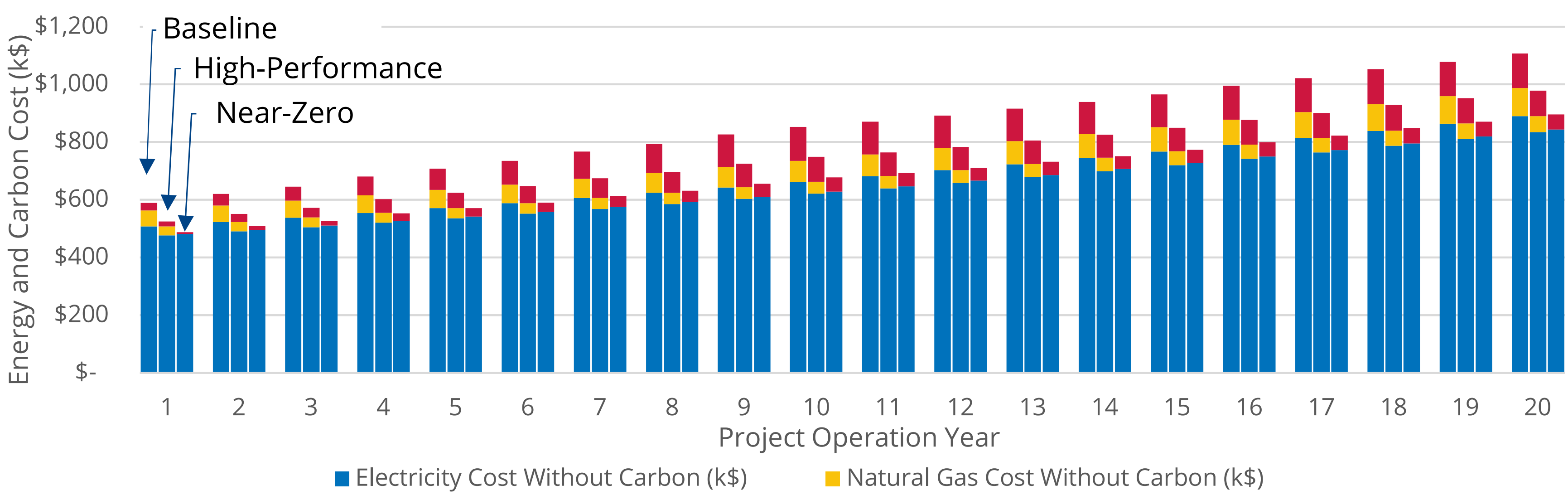


Figure 10: Operating Cost Projections

2.6 ENERGY AND EMISSIONS PROJECTIONS

The results from the energy conservation and demand management strategies presented in Sections 2.1 to 2.3 are visualized on the following pages. The detailed assumptions used for each package are listed in Appendix A.

The energy use intensity (EUI) of each ECM package is shown broken down by end-use for the development in Figure 11. As shown in Figure 11, the high-performance and near-zero packages offer total EUI savings of 21% and 42%, respectively, which are primarily from reduced heating energy use through improved passive building performance and system efficiency.

Given the disparity in emissions for electricity and natural gas, a similar breakdown for GHG emissions for each end use is shown in Figure 12 to illustrate emissions reductions. In this analysis, projected 20-year average GHG emission intensities for each fuel source were used instead of the SB-10 requirements used for the TGS metrics analysis. As shown in Figure 12, using the high-performance and near-zero emissions packages offer emission reductions of 28% and 60%, respectively, which are a result of reduced energy consumption for both packages, and fuel shifting for the near-zero emissions package.

Visualizations of the analysis results are shown in Figure 13, broken down by space type. Table 4 summarizes other outputs.

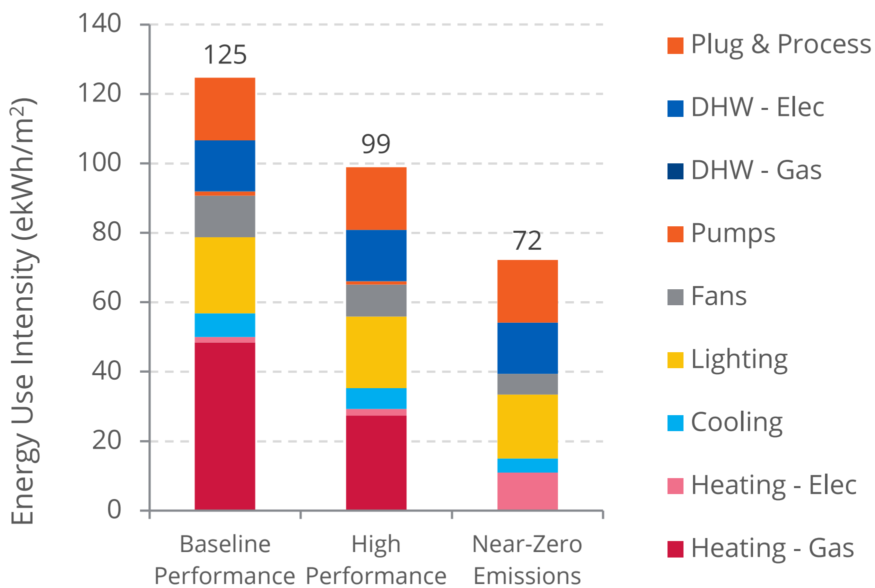


Figure 11: Energy End-Use Breakdown

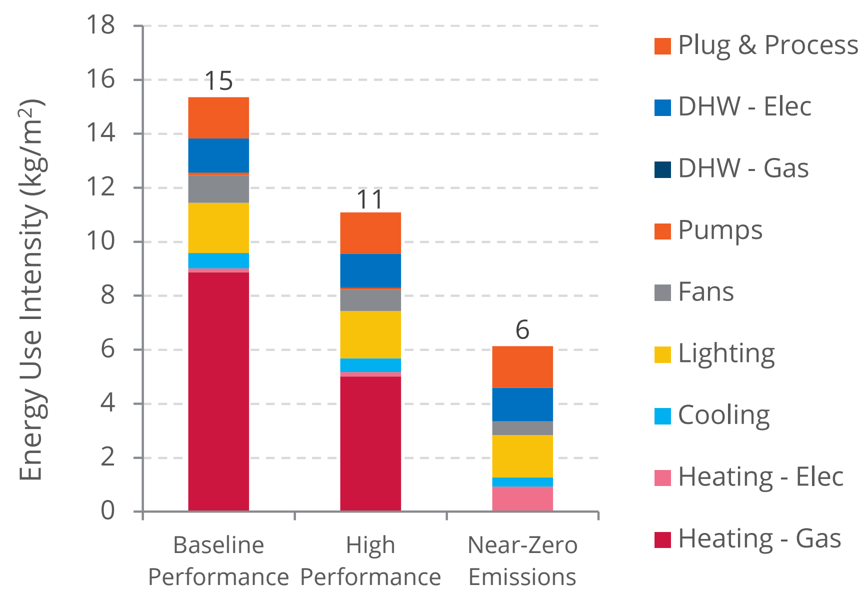
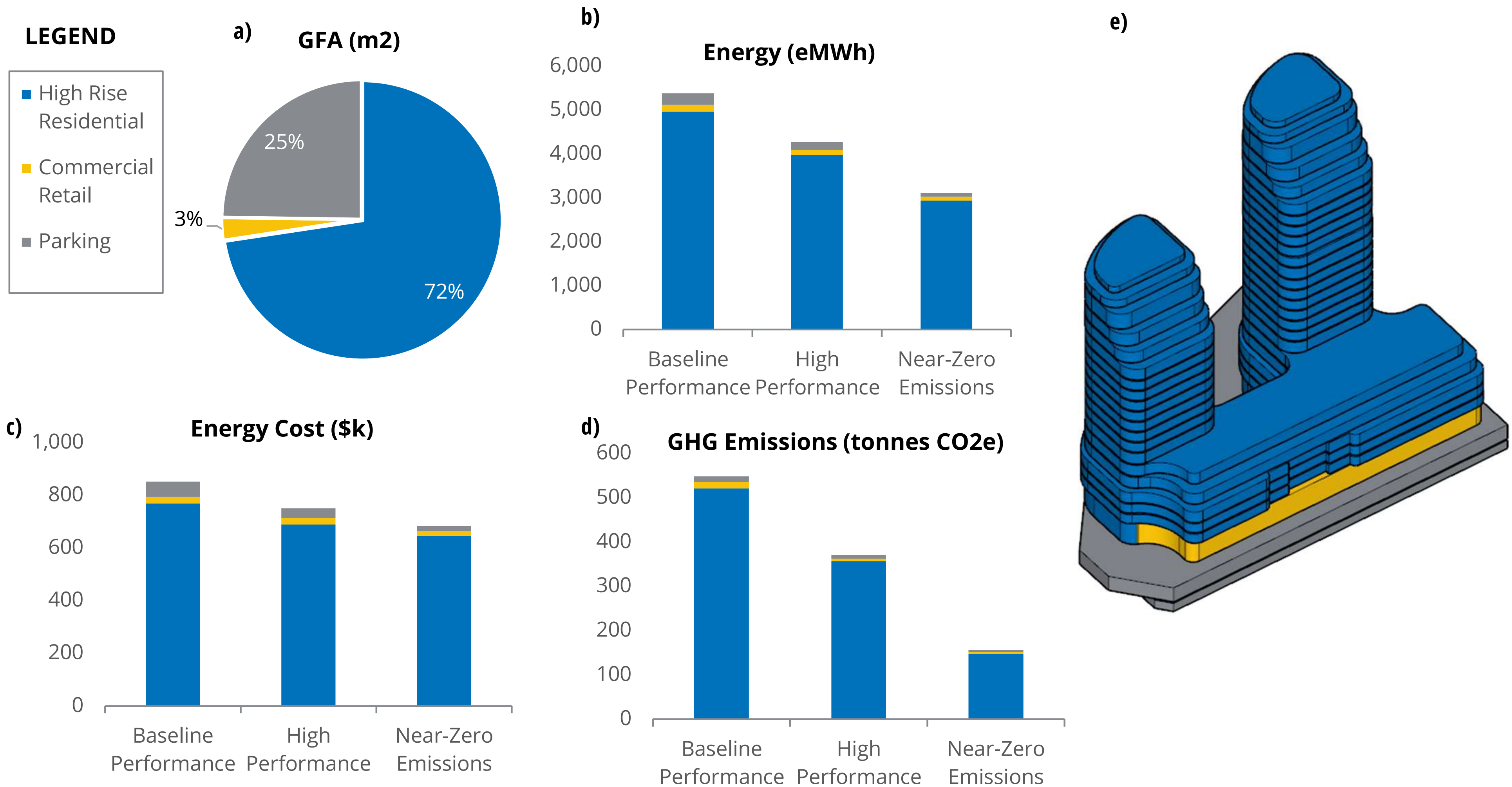


Figure 12: Projected Emission Intensity End-Use Breakdown

2.7 SUMMARY OF RESULTS

Figure 13: a) Breakdown of Development Site Gross Floor Area by Archetype, b) Energy Results, c) Energy Cost Results, d) GHG Emissions Results, e) Modelled Geometry by Archetype



2.7 SUMMARY OF RESULTS

Table 4: Site-level Performance Results

Performance Metric	Unit	Baseline Performance	High Performance	Near-Zero Emissions
TGS V4 Performance Tier		Tier 1	Tier 2	Tier 3
Total Energy	ekWh	5,249,700	4,162,000	3,038,600
TEUI	ekWh/m^2/yr	125	99	72
Energy Savings	%	--	21%	42%
TEDI	kWh/m^2/yr	48	29	15
TEDI Savings	%	--	40%	69%
Current-Year Electricity Emission Factor	kg CO_2e/kWh		0.05	
Current-Year Natural Gas Emission Factor	kg CO_2e/kWh		0.183	
GHGI	kg CO_2e/m^2	13	9	4
GHGI Savings	%	--	32%	72%
Energy Cost	$	831,000	732,000	667,000
Energy Cost Savings	%	--	12%	20%

3.1 ON-SITE RENEWABLES

After reducing the total energy consumption of the development by 42% in the Near-Zero Emissions model, as compared to the Baseline Design, this energy strategy now considers the application of renewables to offset the remaining energy use.

Rooftop solar photovoltaic (PV) potential was explored using the National Renewable Energy Laboratory's (NREL) PVWatts Calculator (Reference Link 6). Given the early design stage of this project, which we assume allows for the prioritization of PV mounting on rooftops, the analysis assumed that 90% of high-rise residential and commercial building roofs are used for PV mounting, resulting in an array size of 735 m^2 (Figure 14). Using site-specific solar radiation information and the PVWatts calculator, it was estimated that 182,280 kWh of energy could be generated on-site annually. While this generation is significant, it would only offset 6% of the Near-Zero Emissions modelled total energy use (3,038,600 kWh) and is therefore insufficient to reach a net-zero level of performance using on-site renewable generation. Therefore, off-site renewables are discussed next.

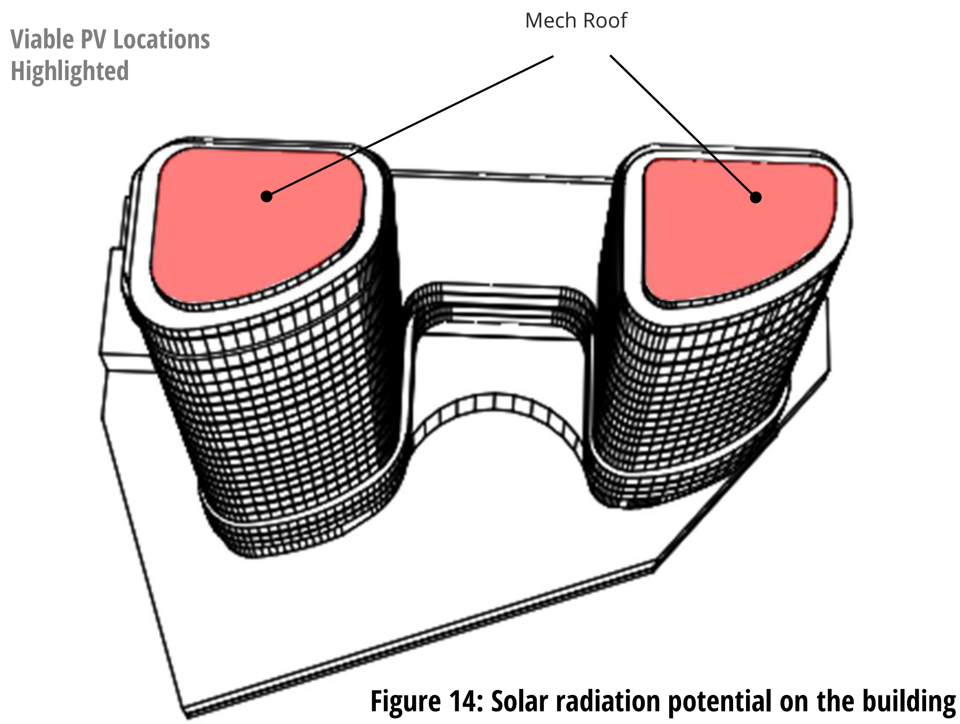


Figure 14: Solar radiation potential on the building

3.2 OFF-SITE RENEWABLES

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 248 kWh/m^2–year in the Toronto climate. The quantity of solar PV required to offset the remaining energy consumption of the Near-Zero Emissions model (2,856,320 kWh) can then be calculated by dividing the energy consumption by the generation potential. This equates to a solar PV system area of 11,517 m^2.

This is not an insignificant area, and it would not likely be feasible to install this much solar capacity in downtown Toronto as the area is comparable to existing solar farms in rural Ontario. An example of such a solar farm is presented in Figure 15. Developments like this could consider taking advantage of Ontario's abundant rural areas where large-scale solar farms are possible to achieve a net-zero carbon level for 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.

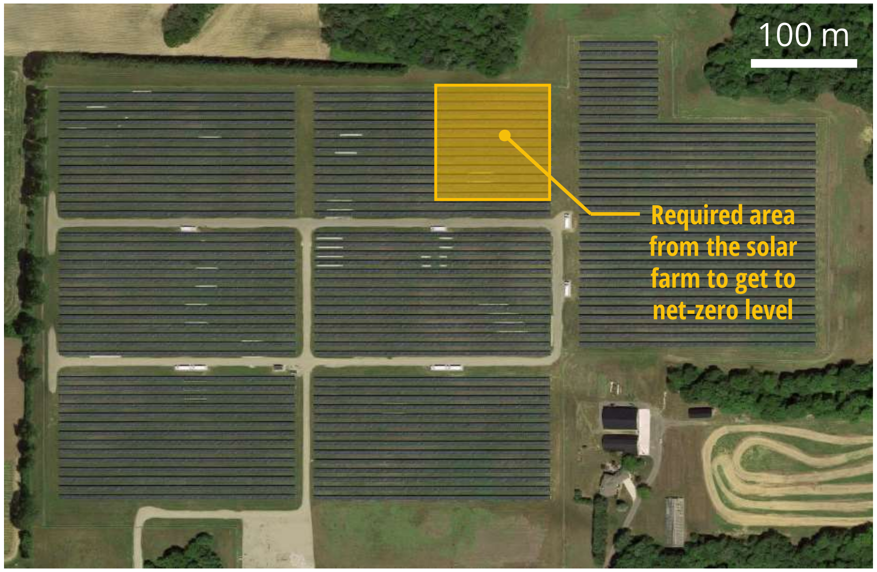


Figure 15: The area of off-site generation required by the development (yellow rectangle) overlaid on the Silvercreek Solar Park, found near Aylmer Ontario (image Courtesy of Google Earth™).

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.

There are number of existing district energy systems in Toronto, and the City encourages building developers and owners to consider collaborating with an existing district system and /or buildings that are "district energy-ready" (Reference Link 7). For example, 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. As such, the selection of supply and return temperatures for heating/cooling equipment in the development should be carried out to maintain compatibility with each of these systems.

Importantly, district energy should not be confused with renewable energy or low-CO_2e 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_2e benefit to considering a district energy approach. In fact, there may be a penalty as a result of distribution losses.

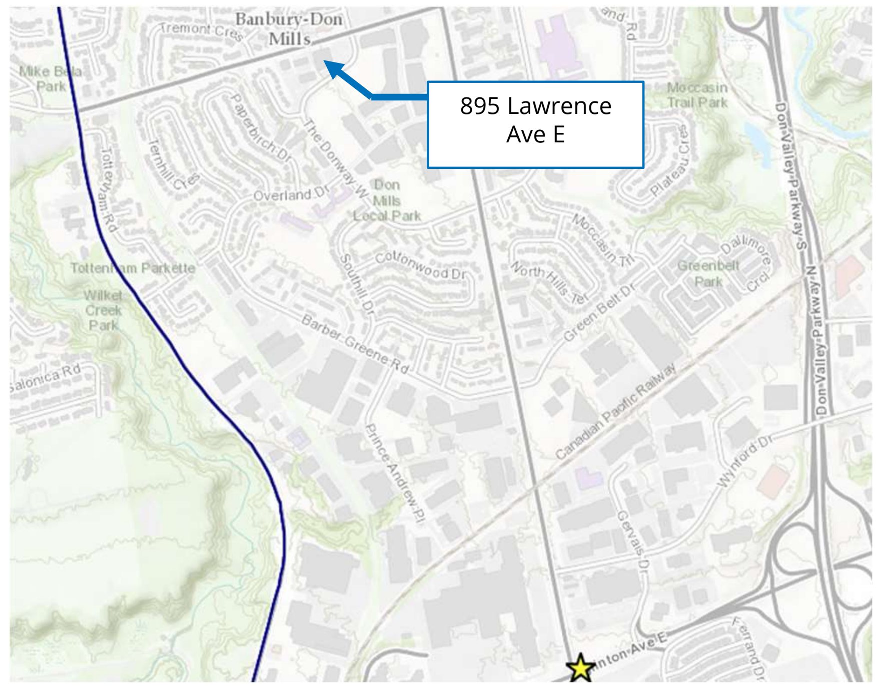


Figure 16: Nearby DES Infrastructure

3.4 EMBODIED CARBON

As stated earlier in Section 1.1, the TransformTO Implementation Update lists buildings as responsible for 52% of the GHG emissions in Toronto in 2017. It is particularly important to note, however, that this GHG inventory only considers the operational GHG emissions of the building, and does not account for the emissions associated with the construction of buildings – known as the "embodied carbon".

The UN Environment 2018 Global Status Report calculated that building materials and construction were responsible for 11% of global GHG emissions in 2017, listed as 'Construction industry' in Figure 17 (Reference Link 8). Therefore, it is critical to take a look at both low-carbon design and low-carbon operation in any new development.

There are a multitude of design options available for the design team to reduce the overall embodied carbon of the development. Some strategies include:

1. Evaluating the structural design strategy of the buildings to optimize for minimal embodied carbon. Consider using structural timber when local FSC-certified wood is available.
2. Replacing portland cement with supplementary cementitious materials, such materials include fly ash or ground granulated blast furnace slag (GGbF).
3. Using materials with a high recycled content or materials that are easy to recycle when the building has reached end-of-life.
4. Using materials that have been sourced locally to decrease carbon emissions from transport.

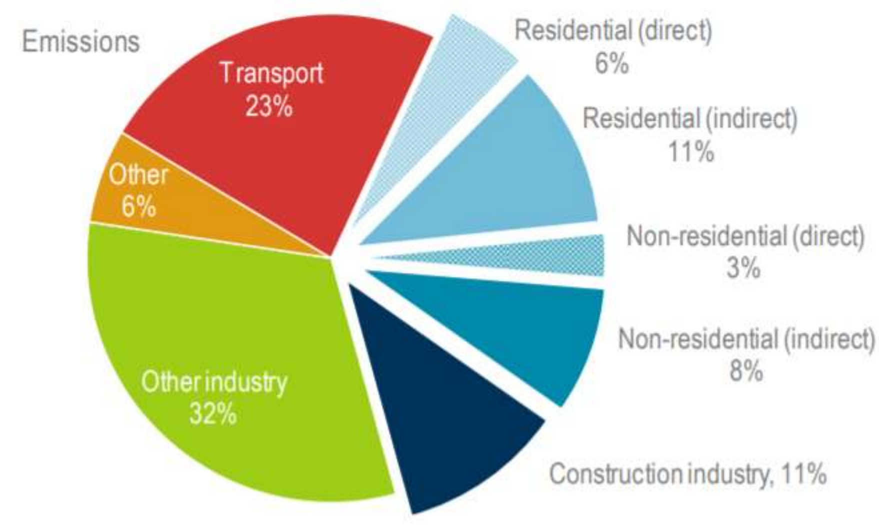


Figure 17: Global GHG Emissions by Sector, 2017

3.5 LOW-CARBON TRANSPORTATION

Electric Vehicles (EVs) can offer significant reductions in CO_2e emissions as compared to conventional internal combustion vehicles, especially in Ontario given the low CO_2 intensity of Ontario's electricity. As shown in Figure 18 for multiple EV types, CO_2e emissions per kilometer can be reduced by approximately 95% for a vehicle of the same type (e.g., full-sized sedan), which exemplifies the importance of adopting EVs on a societal level.

Given recent and future increases in EV adoption, it is critical to consider infrastructure to support EVs at the building level and this infrastructure typically comes in the form of EV charging stations. In the mandatory tier of TGS V4 (Tier 1), at least 25% of parking spaces in residential buildings must have adjacent energized outlets that support level 2 EV charging (208-240 VAC with 40-amp breakers) and 100% of spaces must permit the future installation of energized outlets (e.g., installation of cable raceways). In non-residential buildings, at least 5% of spaces require adjacent energized outlets. In Tiers 2 and above, 100% of residential parking spaces require these energized outlets.

While the mandatory target in TGS may seem ambition, a study carried out by The Atmospheric Fund (TAF) showed that the EV adoption targets set by Transform TO and Toronto's EV strategy will result in 75% of building residents facing significant barrier to adopting EVs if only 25% of spaces are equipped with EV charging infrastructure (Reference Link 9). TAF also found that the cost of installing EV infrastructure during building construction was an order of magnitude lower than installing it as a retrofit. Therefore, and in line with requirements set in jurisdictions such as Richmond and Vancouver BC, considering the installation of EV infrastructure at 100% of parking spaces is recommended.

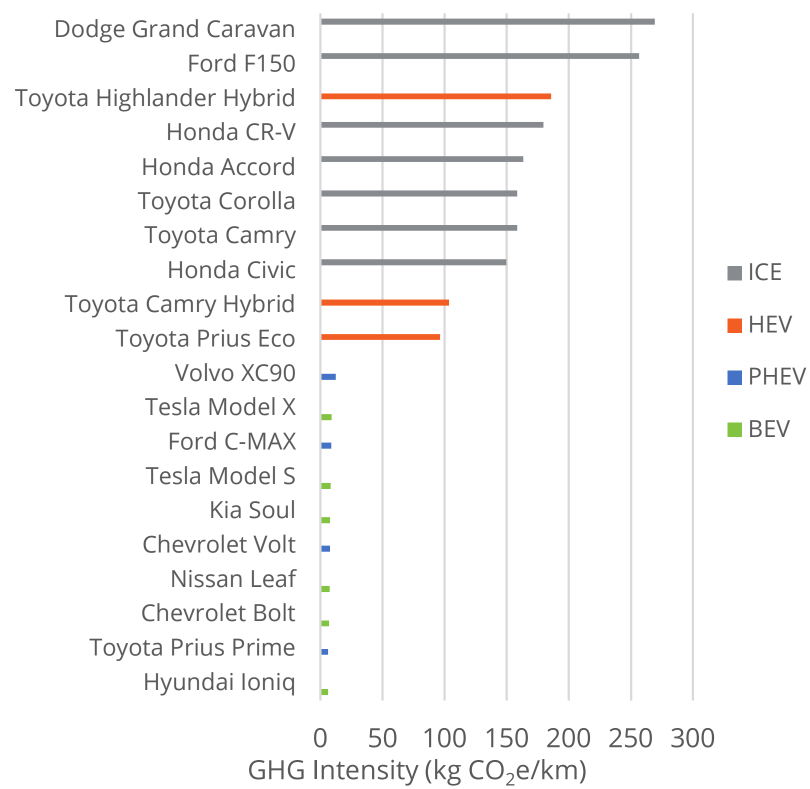


Figure 18: GHG Intensities of Internal Combustion Engine (ICE) Vehicles, Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV), and Battery Electric Vehicles (BEV) (Reference Link 10)

4. RESILIENCY

4.1 CLIMATE CHANGE

Historically, Toronto has been considered to have a heating-dominated climate, categorized in ASHRAE Climate Zone 6. In the last 20 years, however, Toronto's climate has changed – the number of annual heating degree days (HDDs) has reduced below 4,000. With this weather, Toronto has been recategorized into ASHRAE Climate Zone 5.

Further, the City of Toronto's *Future Weather and Climate Driver Study* predicts that climate change will continue to present a new set of challenges to building developments in Toronto (Reference Link 11). Some of the climatic changes include:

- Increased temperatures throughout the year. This means both an increased number of Cooling Degree Days above 18°C, and an increased frequency and duration of heat waves;
- Increased temperatures throughout the year will also result in a decreased number of Heating Degree Days below 18°C;
- Increased intensity of major rain events; and
- Increased frequency of freeze-thaw events.

As the annual HDDs are forecasted to decrease, Toronto could shift into ASHRAE Climate Zone 4 between 2040 and 2049. The historical and forecasted heating degree days for Toronto Pearson International Airport are is shown in Figure 19, showing the shift from Climate Zone 6 to Climate Zone 4.

A study by RWDI demonstrated that as the climate changes, controlling summer overheating will become increasingly important for occupant comfort in Toronto buildings (Reference Link 12). Designing modular mechanical systems to allow for future increased cooling capacity can help alleviate the increased risk of overheating and occupant discomfort.

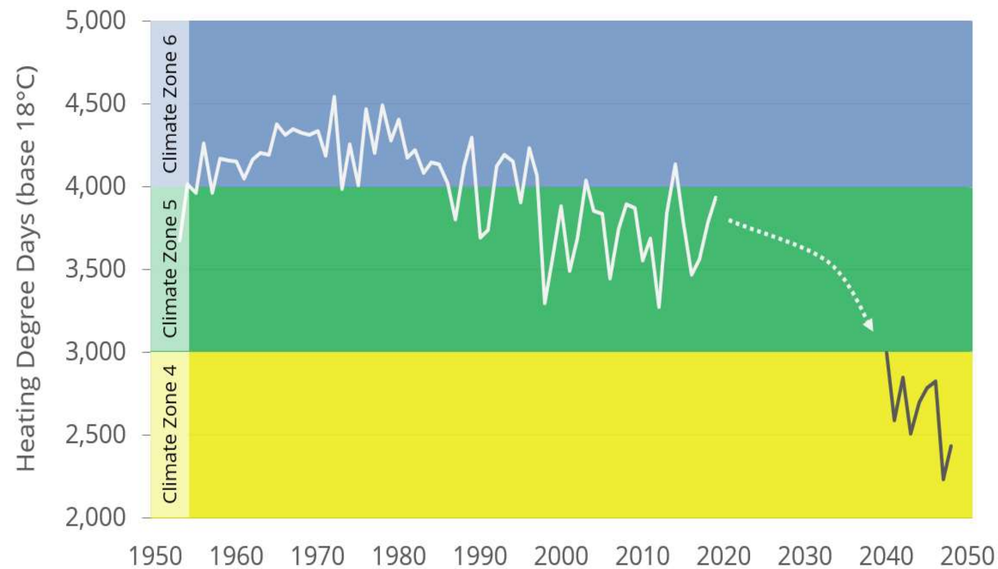


Figure 19: Historical and Forecasted Heating Degree Days at Toronto Pearson International Airport

4.2 DESIGN CONSIDERATIONS

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 man-made 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 13).

To better the prepare for the forecasted changes to Toronto's climate, 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.
- Building materials selected for durability during flooding events, and buildings designed to operate despite water incursion from major rain events, forecasted to become more frequent (shown in Figure 20).

Working resiliency in the design and equipment selection inevitably has 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 from thermal envelope improvements;
- Reduced insurance premiums; and
- Increased safety.

Figure 20: Flooding of Downtown Toronto Streets in 2013 (Courtesy of user:Eastmain / Public Domain)

CONCLUSIONS AND RECOMMENDATIONS

1. To meet the absolute energy performance targets of TGS V4 Tier 1, the building design will need to include a combination of best practice measures, envelope upgrades and mechanical system upgrades. Additional modelling will be required as the design progresses to ensure continued alignment with these targets.

2. A detailed financial analysis is required to determine the economic practicality of the high-performance and near-zero emissions packages. While both packages demonstrate the project's potential to contribute positively towards the City's TransformTO initiative and offer notable annual energy and carbon cost reductions, especially as carbon prices increase for the near-zero package, careful balancing against initial cost is required to overcome the cost disparity between natural gas and electricity. An investigation into potential financial incentives for these packages, including partial development charge refunds, grants, loans and other financial supports, and savings associated with the reclaim of mechanical spaces when applying district systems is recommended as part of this analysis.

3. The emissions associated with conventional concrete use in the building structure contribute significantly to the lifecycle emissions of the project. As such, consideration of embodied carbon and methods to reduce embodied carbon should be carried out at the earliest design stages. The selection of alternative materials and building forms that minimize concrete use are recommended.

4. Energy conservation measures related to occupant behaviour can have significant impact on the building energy use, but are challenging to predict in an energy model. These measures, including suite-level thermal sub-metering and kill switches near exits, can have greater marketability because of their visibility and direct link to the residents' utility bills. These visible measures give occupants better control of their utility bills and over the use of their space.

6. REFERENCE LINKS

1. Energy Strategy Terms of Reference: https://www.toronto.ca/wp-content/uploads/2018/01/9446-CEP-Energy-Strategy-Terms-of-Reference-Jan-2018.pdf
2. TransformTO Implementation Update: https://www.toronto.ca/wp-content/uploads/2019/06/97ee-DS-19-0150_TransformTO_Report_digital_final_reducedSize_June28update.pdf
3. City of Toronto Zero Emissions Buildings Framework: https://www.toronto.ca/wp-content/uploads/2017/11/9875-Zero-Emissions-Buildings-Framework-Report.pdf
4. Ontario Emission Factor Projections: https://taf.ca/wp-content/uploads/2021/11/20211116_TAF_Emissions-Factors-Guidelines.pdf
5. Federal Carbon Pricing Framework: https://www.canada.ca/en/environment-climate-change/news/2020/12/a-healthy-environment-and-a-healthy-economy.html
6. National Renewable Energy Lab (NREL) PVWatts Calculator: http://pvwatts.nrel.gov/
7. District Energy Map in Toronto: https://www.arcgis.com/home/webmap/viewer.html?webmap=4e58774223774e4c8afaf96473f99706
8. UN Environment 2018 Global Status Report: https://wedocs.unep.org/bitstream/handle/20.500.11822/27140/Global_Status_2018.pdf?sequence=1&isAllowed=y
9. TAF Feedback on TGS v4: https://taf.ca/wp-content/uploads/2021/06/Toronto-GDS-v.4-Recommendations.pdf
10. GHG Intensity of Different Vehicles: https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2018/market-snapshot-how-much-co2-do-electric-vehicles-hybrids-gasoline-vehicles-emit.html
11. Toronto's Future Weather and Climate Driver Study: https://www.toronto.ca/legdocs/mmis/2012/pe/bgrd/backgroundfile-51653.pdf
12. RWDI White Paper "Modelling Weather Futures": https://rwdi.com/assets/factsheets/Modelling-weather-futures.pdf
13. Resilient Design Institute: http://www.resilientdesign.org/

APPENDIX A

SUMMARY OF ENERGY MODEL INPUTS

APPENDIX A

SUMMARY OF PRIMARY ENERGY MODEL INPUTS

The primary energy model inputs for the **High-Rise Residential Building** are shown below:

Modelled Area | Description	42,101 m² Residential High-Rise | 13,854 m² Parking
Location | Climate	Toronto, Ontario | Toronto CWEC
Primary Space Types	Residential, Amenities
Occupancy Schedule	Residential: NECB Schedule G | Non-Residential: NECB Schedule C
Set Points	Heating Set Point: 22°C, Set Back 18°C | Cooling Set Point 24°C, Residential: No Setback; Non-Residential: Set Back to Off
Fuel Emissions Intensities	Electricity = 0.050 kg/kWh | Natural Gas = 0.1832 kg/kWh

	Tier 1 v4	Tier 2 v4	Tier 3 v4
TEDI (kWh/m²)	49 (50)	29 (30)	15 (15)
TEUI (kWh/m²)	119 (135)	95 (100)	70 (75)
GHGI (kg CO2e/m²)	13 (15)	9 (10)	4 (5)
Envelope			
Typical Exterior Wall Performance	RSI-2.11 (R-12.0)	RSI-5.28 (R-30.0)	RSI-7.4 (R-42.0)
Typical Roof Performance	RSI-6.9 (R-39.2)	RSI-6.9 (R-39.2)	RSI-6.9 (R-39.2)
Gross Window to Wall Ratio	40%	28%	28%
Glazing Performance	USI-1.7 | SHGC 0.35	USI-1.4 | SHGC 0.35	USI-0.9 | SHGC 0.35
Infiltration Rate	0.25 L/s-m² of total façade (0.71 ACH @ 50 Pa)	0.225 L/s-m² of total façade (0.64 ACH @ 50 Pa)	0.225 L/s-m² of façade (0.64 ACH @ 50 Pa)
System Level – Residential			
Primary HVAC Type	DOAS 4-Pipe Fan Coil	DOAS 4-Pipe Fan Coil	Air Source Variable Refrigerant Flow (VRF)
Airside Energy Recovery	In-suite ERVs, 75% sensible, 70% latent Electric OA Preheat to -5C	In-suite ERVs, 80% sensible, 70% latent Electric OA Preheat to -5C	In-suite ERVs, 85% sensible, 70% latent Electric OA Preheat to -5C
Heating	Hydronic Coils | Electric Preheat	Hydronic Coils | Electric Preheat	VRF – Design Condition COP 4.4
Cooling	Hydronic Coils	Hydronic Coils	VRF – Design Condition COP 5.1
Outdoor Air Rates (per Unit)	26.3 L/s, plus 9.3 L/s corridor pressurization	26.3 L/s, plus 6.1 L/s corridor pressurization	26.3 L/s, plus 4.7 L/s corridor pressurization
Fan Power (W/CFM)	ERV: 0.5 | FC: 0.3 (multi-speed)	ERV: 0.5 | FC: 0.3 (multi-speed)	ERV: 0.5 | FC: 0.3 (multi-speed)
System Level – Amenities and Aux Spaces			
Primary HVAC Type	DOAS 4-Pipe Fan Coil	DOAS 4-Pipe Fan Coil	Air Source Variable Refrigerant Flow (VRF)
Airside Energy Recovery	75% sensible, 70% latent Electric OA Preheat to -5C	80% sensible, 70% latent Electric OA Preheat to -5C	In-suite ERVs, 85% sensible, 70% latent Electric OA Preheat to -5C
Heating	Hydronic Coils | Electric Preheat	Hydronic Coils | Electric Preheat	VRF – Design Condition COP 4.4
Cooling	Hydronic Coils	Hydronic Coils	VRF – Design Condition COP 5.1
Outdoor Air Rates	Meet but not exceed ASHRAE 62.1-2013	Meet but not exceed ASHRAE 62.1-2013	Meet but not exceed ASHRAE 62.1-2013
Fan Power (W/CFM)	ERV: 0.5 | FC: 0.3 (multi-speed)	ERV: 0.5 | FC: 0.3 (multi-speed)	ERV: 0.5 | FC: 0.3 (multi-speed)
Plant Level			
Space Heating Efficiency	Condensing boiler: 95% seasonal	Condensing boiler: 95% seasonal	N/A
Space Cooling Performance	VFD Centrifugal Chiller: COP 6.5 Cooling tower with VSD speed fan	VFD Centrifugal Chiller: COP 6.5 Cooling tower with VSD speed fan	N/A
DHW Efficiency	Heat Pump Water Heater – Seasonal COP 2.8	Heat Pump Water Heater – Seasonal COP 2.8	Heat Pump – seasonal COP 2.8
Space Level			
Equipment Load	4.3 W/m² (weighted average)	4.3 W/m² (weighted average)	4.3 W/m² (weighted average)
Lighting Power Density (W/m²)	Res: 5.0 | Non-Residential: 5.8	Res: 5.0 | Non-Residential: 5.8	Res: 5.0 | Non-Residential: 5.8
DHW Fixture Flow Rates (W/occ)	Res: 500 | Non-Residential: 40	Res: 500 | Non-Residential: 40	Res: 500 | Non-Residential: 40
Drain Water Heat Recovery (%)	No	No	No

APPENDIX A

SUMMARY OF PRIMARY ENERGY MODEL INPUTS

The primary energy model inputs for the **Commercial Retail Building** are shown below:

Modelled Area | Description	1,471 m² | As part of Building
Location | Climate	Toronto, Ontario | Toronto CWEC
Primary Space Types	Retail
Occupancy Schedule	NECB Schedule C
Set Points	Heating Set Point: 22°C, Set Back 18°C | Cooling Set Point 24°C, Set Back to Off
Fuel Emissions Intensities	Electricity = 0.050 kg/kWh | Natural Gas = 0.1832 kg/kWh

	Tier 1 v4	Tier 2 v4	Tier 3 v4
TEDI (kWh/m²)	33 (40)	22 (25)	14 (15)
TEUI (kWh/m²)	104 (120)	74 (90)	60 (70)
GHGI (kg CO2e/m²)	10 (10)	4 (5)	3 (3)
Envelope			
Typical Exterior Wall Performance	RSI-1.6 (R-9)	RSI-2.11 (R-12)	RSI-6.16 (R-35.0)
Typical Roof Performance	N/A	N/A	N/A
Gross Window to Wall Ratio	70%	33%	33%
Glazing Performance	USI-2.0 | SHGC 0.35	USI-2.0 | SHGC 0.35	USI-1.4 | SHGC 0.35
Infiltration Rate	0.25 L/s-m² of façade (0.27 ACH @ 50 Pa)	0.25 L/s-m² of façade (0.27 ACH @ 50 Pa)	0.25 L/s-m² of façade (0.27 ACH @ 50 Pa)
System Level			
Primary HVAC Type	DOAS 4-Pipe Fan Coil Unit	DOAS Air-source Variable Refrigerant Flow (VRF)	DOAS Air-source Variable Refrigerant Flow (VRF)
Airside Energy Recovery	65% sensible 55% latent | Electric Preheat	75% sensible 55% latent | Electric Preheat	80% sensible 70% latent | Electric Preheat
Heating	Hydronic Coils	VRF – Design Condition COP 4.0	VRF – Design Condition COP 4.0
Cooling	Hydronic Coils	VRF – Design Condition COP 4.8	VRF – Design Condition COP 4.8
Outdoor Air Rates	Per ASHRAE 62.1-2013 | Effectiveness 0.8	Per ASHRAE 62.1-2013 | Effectiveness 0.8	Per ASHRAE 62.1-2013 | Effectiveness 1.0
Fan Power (W/CFM)	ERV SF: 1.0 | FCU: 0.5 (multi-speed)	ERV SF: 1.0 | FCU: 0.5 (multi-speed)	ERV SF: 1.0 | FCU: 0.5 (multi-speed)
Plant Level			
Heating	Condensing boiler, 95% efficiency	Electric back-up to VRF, 100% efficiency	Electric back-up to VRF, 100% efficiency
Cooling	VFD Centrifugal Chiller: COP 5.5 Cooling tower with two-speed speed fan	N/A	N/A
DHW Efficiency	Condensing boiler, 95% efficiency	Condensing boiler, 95% efficiency	Heat Pump Water Heater – Seasonal COP 2.8
Space Level			
Equipment Load	1.9 W/m² (weighted average)	1.9 W/m² (weighted average)	1.9 W/m² (weighted average)
Lighting Power Density	8.9 W/m² (weighted average)	8.9 W/m² (weighted average)	8.9 W/m² (weighted average)
DHW Fixture Flow Rates	40 W/Occ	40 W/Occ	40 W/Occ
Drain Water Heat Recovery (%)	N/A	No	No

APPENDIX A

SUMMARY OF PRIMARY LCA MODEL OUTPUTS

The primary LCA model inputs are shown below:

Modelled Area | Description	21,435 m^2 Tower| 20,666 m^2 Podium | 13,854 m^2 Parking
Location	Toronto, Ontario
LCA software	One Click LCA
Lifecycle Stages	Upfront Carbon A1-5

	Description	Material	Global Warming Potential
Tower			
Foundation, sub-surface, basement and retaining walls	Concrete w/ Steel Rebar	Concrete 3001-4000 psi 0% Slag 0% Ash	451 kgCO2e/m^3
		Steel Rebar (0.375-2.257)	7725 kgCO2e/m^3
External walls and façade	Window Wall System + Aluminum Cladding	Double Pane Glass (IGU)	50.9 kgCO2e/m^2
		Aluminum Cladding + Extrusions	3013 kgCO2e/m^3
		Batt and Semi-Rigid Insulation	40 kgCO2e/m^3
Columns and load-bearing vertical structures	Concrete w/ Steel bar	Concrete 3001-4000 psi 0% Slag	451 kgCO2e/m^3
		Steel Rebar (0.375-2.257)	7725 kgCO2e/m^3
Floor slabs, ceilings, roofing decks, beams and roof	Concrete w/ Steel Rebar	Concrete 3001-4000 psi 0% Slag	451 kgCO2e/m^3
		Steel Rebar (0.375-2.257)	7725 kgCO2e/m^3
Podium			
External walls and façade	Curtain Wall + Brick Construction + Aluminum Cladding	Double Pane Glass (IGU)	50.9 kgCO2e/m^2
		Aluminum Cladding + Extrusions	3013 kgCO2e/m^3
		Brick & Mortar	233 kgCO2e/m^3
		Spray Foam Insulation	3517 kgCO2e/m^3
		Batt and Semi-Rigid Insulation	40 kgCO2e/m^3
Columns and load-bearing vertical structures	Concrete w/ Steel Rebar	Concrete 3001-4000 psi 0% Slag	451 kgCO2e/m^3
		Steel Rebar (0.375-2.257)	7725 kgCO2e/m^3
Floor slabs, ceilings, roofing decks, beams and roof	Concrete w/ Steel Rebar	Concrete 3001-4000 psi 0% Slag	451 kgCO2e/m^3
		Steel Rebar (0.375-2.257)	7725 kgCO2e/m^3
Parking			
Columns and load-bearing vertical structures	Concrete w/ Steel Rebar	Concrete 3001-4000 psi 0% Slag	451 kgCO2e/m^3
		Steel Rebar (0.375-2.257)	7725 kgCO2e/m^3
Floor slabs, ceilings, roofing decks, beams and roof	Concrete w/ Steel Rebar	Concrete 3001-4000 psi 0% Slag	451 kgCO2e/m^3
		Steel Rebar (0.375-2.257)	7725 kgCO2e/m^3

Zero Carbon Building Version 2

Embodied Carbon Reporting Template

March 10, 2020

1. INTRODUCTION

The purpose of this reporting template is to outline the information that is required to be submitted in the embodied carbon report that is required for ZCB-Design v2 certification. Projects may complete this template or provide a custom report that meets the information needs specified herein.

Projects pursuing ZCB-Performance v2 certification that complete a retrofit of structural or envelope materials in the performance year must also use this template to guide the reporting of embodied carbon associated with the retrofit project.

2. GENERAL INFORMATION

Please provide the following general information about the project.	
Project Name	Baseline Building Archetype Model
Embodied Carbon Assessor	Huda Alkhatib
Firm	RWDI
Date of Assessment Completion	June 3rd 2022
Software & Version Number	One Click LCA
Project Life	☒ 60 year
Assessment Timing (check all that apply)	☒ Schematic Design ☐ Design Development ☐ Construction Documents
Please confirm that the analysis includes all structural and envelope components (“mandatory materials”) by checking the applicable boxes to the right.	☒ Footings and foundations ☒ Complete structural wall assemblies (cladding to finish) ☒ Structural floors and ceilings (no finishes) ☒ Slab on grade ☒ Roof assemblies ☐ Stairs ☒ Parking structure (not including surface parking)
Please list any additional materials that are included at the applicant’s discretion.	None.

3. CARBON EMISSIONS FOR EACH LIFE-CYCLE STAGE

Provide the following breakdown by life-cycle stage. If the software used does not provide values for every stage, leave the missing ones blank.

Life-cycle Stage				Carbon Emissions from Mandatory Materials (kg CO_2e)	Carbon Emissions from Optional Materials (kg CO_2e)
Upfront	Product	A1	Raw Material Supply	A1-A3: 20,988,639.37	
		A2	Transport (to factory)		
		A3	Manufacturing		
	Construction	A4	Transport (to site)	A4: 2,241,490.49	
		A5	Construction & Installation	A5: 977,660.39	
			Total Upfront Carbon	**24,207,790.25**	
Use		B1	Use		
		B2	Maintenance		
		B3	Repair		
		B4	Replacement		
		B5	Refurbishment		
			Total Use Stage Embodied Carbon		
End of Life		C1	Demolition		
		C2	Transport (to disposal)		
		C3	Waste Processing		
		C4	Disposal		
			Total End of Life Carbon		
Optional, does not need to be offset:					
Beyond the Life-cycle		D	Reuse		
		D	Recycling		
		D	Energy Recovery		
			Total Beyond the Life-cycle Carbon		

3.1 Contribution Analysis

Please provide a contribution analysis, broken out to the best of your ability by either material type or building assembly type. The list must include the top 10 contributing items at a minimum (concrete can only count as one, although multiple mix types can be listed separately).

Material or Building Assembly	Carbon Emissions (kg CO_2e)
Concrete, 3001-4000 psi (20.69-27.58 MPa), 0% ash, 0% slag, 4000-00-FA/SL (National Ready Mixed Concrete Association, industry wide) EPD#: EPD10046	14,064,522.52
Reinforcement steel, McMinnville mill (OR), ASTM A1035, 0.375-2.257 in (Cascade Steel) EPD#: SCS-EPD-04335	4,406,256.67
Thermally improved aluminum extrusions (profiles), anodized (Aluminum Extruders Council (AEC)) EPD#: 11240237.102.1	2,509,169.49
Double pane insulated glass unit (IGU) with one spacer. (Vitro Architectural Glass (2017) EPD#: EPD-062, issue 6	980,686.83
Spray foam insulation, 1.02in. EPD#: CP121	363,243.94
Aluminium curtain walls, 37 kg/m2 (AluQuébec) EPD#: 2622-3967	206,642.96
Rock wool insulation board. 1-8 in (25.4-203 mm), 4.1 lb/ft3 (65 kg/m3), CAVITYROCK (Rockwool North America) EPD#: 4789092768.101.1	105,256.69
Gypsum plaster board, regular, generic, 6.5-25 mm (0.25-0.98 in)	52,608.49
Cement mortar, 0.834 lb/ft2, 80.03 lb/ft3 (TCNA) EPD#: 4787109018.102.1	50,187.54
Clay brick, 3.625 x 2.25 x 7.625 in, 37.1% fly-ash (CalStar Products)	12,820.02

3.2 Reduction Measures Considered

Please provide a list of embodied carbon reduction measures considered, as well as the associated embodied carbon reduction potential of each.

Description of Embodied Carbon Reduction Measure	Reduction Potential (kg CO_2e)
Change Concrete used to Concrete, 3001-4000 psi (20.69-27.58 MPa), 30% slag, 4000-30-SL (National Ready Mixed Concrete)	3,467,403.46
Change Spray Foam Insulation to Mineral Wool Insulation	359,828.20

4. IMPACT AND INNOVATION

4.1 Impact and Innovation - 20% Reduction in Embodied Carbon

ZCB-Design projects pursuing the Impact and Innovation strategy of demonstrating an embodied carbon reduction of at least 20% must provide the following information.

Please provide a summary description of the embodied carbon reduction measures that were implemented.
The reduction measures taken to reduce the embodied carbon were to replace the concrete used in the whole building with concrete that contains 30% slag and replace the spray foam insulation with mineral wool insulation. The concrete change resulted in a total building embodied carbon reduction of 19% and the insulation change resulted in an additional 2% reduction. The combined reduction is 21%.

Please explain how the baseline building and the proposed building have equivalent operational energy use, floor area, functional space use, and building shape/orientation.
The concrete and insulation that were chosen in the proposed building have similar characteristics (strength, r-values) to the baseline materials. Therefore, no changes occurred to the operational energy use, floor area, functional space use, and building shape/orientation.

Please provide a summary of the embodied carbon reductions achieved.							
Life-cycle Stage				Baseline ($kg\ CO_2e$)	Proposed ($kg\ CO_2e$)	Percent Reduction
Upfront	Product	A1	Raw Material Supply	A1-A3: 20,988,639.37	16,247,180.65	23%
		A2	Transport (to factory)			
		A3	Manufacturing			
	Construction	A4	Transport (to site)	A4: 2,241,490.49	2,222,655.00	1%
		A5	Construction & Installation	A5: 977,660.39	763,641.83	22%
			Total Upfront Carbon	**24,207,790.25**	**19,233,477.48**	**21%**
Use		B1	Use			
		B2	Maintenance			
		B3	Repair			
		B4	Replacement			
		B5	Refurbishment			
			Total Use Stage Embodied Carbon			
End of Life		C1	Demolition			
		C2	Transport (to disposal)			
		C3	Waste Processing			
		C4	Disposal			
			Total End of Life Carbon			

4.2 Impact and Innovation - Net Upfront Carbon Emissions Equal to or Less Than Zero

ZCB-Design projects pursuing the Impact and Innovation strategy of demonstrating upfront carbon emissions equal to or less than zero must provide the following information.

Please provide a description of any strategies for carbon storage (sequestration) in the building materials and provide the associated reduction in upfront carbon emissions (life-cycle stages A1-A5).		
Description of Carbon Storing Material	**Amount of Material (kg)**	**Carbon Storage (kg CO_2e)**
N/A	N/A	N/A

Please provide the upfront carbon demonstrating it is less than or equal to zero.		
Upfront Carbon (kg CO_2e)	**Total Carbon Storage (kg CO_2e)**	**Net Upfront Carbon (kg CO_2e)**
N/A	N/A	N/A