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1800 Shepard Ave. East
Energy Strategy

For

The Cadillac Fairview Corporation Ltd.

Project Location
1800 Sheppard Avenue East, Toronto, On

Footprint Project Number
16674-00

Date
04-03-2022

Prepared by

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Executive Summary

The following report presents the findings of the energy study performed for The Cadillac Fairview Corporation Ltd. concerning the proposed mixed-used development located at 1800 Shepard Ave. E Street.

The purpose of this report is to provide an energy strategy that will help the proposed building design to achieve the compliance with Toronto Green Standards (TGS), and explore the opportunities toward achieving net zero development.

This report is in support of a Zoning Bylaw Amendment application.

Considering the upcoming changes to the Toronto Green Standards, this report assumes that the SPA application will be submitted after TGS Version 4 takes effect in May 2022.

PROPOSED DEVELOPMENT

The proposed development is comprised of:

- 3 Residential Towers: C1, C2, R1
- Total Residential GFA: 1,122,591 sf (104,292 sm)
- Total number of residential units:
    - R1: 550
    - C1: 506
    - C2: 360
- Total number of Floors:
    - R1: 58
    - C1: 48
    - C2: 38

ENERGY CONSERVATION DESIGN FEATURES

The design assumptions were determined from information available and with the intent of meeting the energy requirement of Toronto Green Standard (TGS) V4 Tier 1 as a minimum Code requirement and with the goal to strive for a higher level of energy performance. The detailed energy model inputs can be found in Appendix A. The following **E**nergy **C**onservation **M**easures (ECMs) are recommended in this proposed building design:

- Opaque envelope performance with overall R-8 effective (including thermal bridging) for walls and R-30 roofs;
- Exposed floors with effective R-20
- Insulated floors (Parking) with effective R-20
- Glazing performance: U-0.34 and 0.34 SHGC;
- 45% Window to Wall Ratio (WWR);
- Corridor Ventilation 30 CFM/Suite

- In suite ventilation energy recovery provided for dwelling units - 65% effective;
- Low flow lavatories, showerheads and faucets;
- Water source heat pump system;
- High efficiency condensing boilers;
- Variable speed control on all fans and pumps.
- High efficiency condensing gas-fired service water heater for the residential suites: 96% efficiency

ENERGY PERFORMANCE

The energy use intensity (EUI) of the proposed design is 124.1 ekWh/sm, meeting (TGS) V4 Tier 1 targets for total EUI, TEDI and GHG emissions.

- TEUI (ekWh/sm): 124.1
- TEDI (ekWh/sm): 34.1
- GHGI (kgCO2e/sm): 14.1

- Emissions determined from SB-10 2017 Table 1.1.2.2
- Using current average prices: Electricity $0.16/kWh and Natural Gas = $0.256/m^3

Additional Energy Conservation Measures (ECMs) have been applied to the proposed design in order to reduce the overall energy consumption and to achieve compliance with the different TGS V4 tiers. A detailed list of ECMs and energy analysis summary are provided in Appendix B.

Three (3) mechanical design options have been considered as part of the analysis:

- Option 1: Water Source Heat Pump (WSHP) system (DX cooling, backup boilers, cooling towers)
- Option 2: Ground Source Heat Pump (GSHP) system

The implemented ECMs will vary with the different options, considering that HVAC system efficiency will increase between the options (GSHP is more efficient than WSHP).

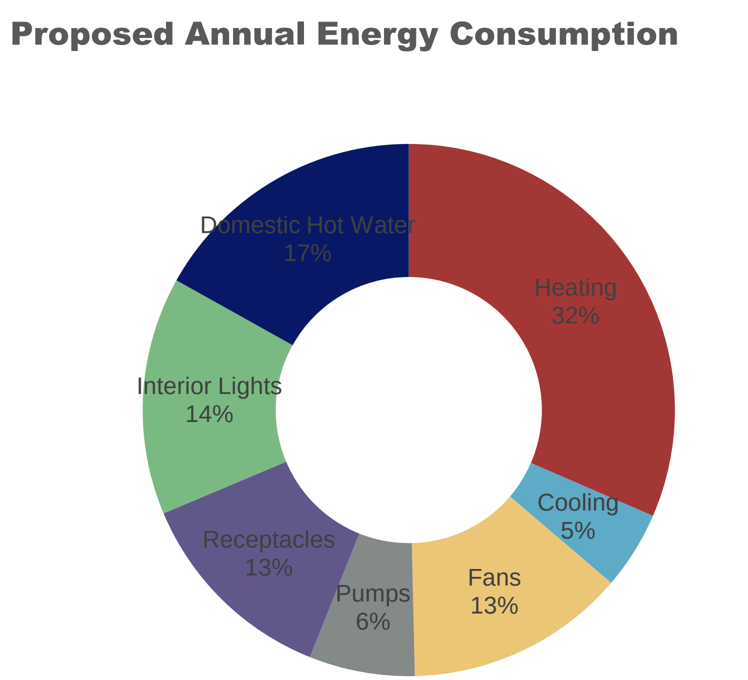
Thermal Energy Demand Intensity (TEDI) is not impacted by the mechanical system efficiency and type; so improving the envelope and the ventilation efficiency will be required to achieve the TEDI target regardless of the HVAC system performance.

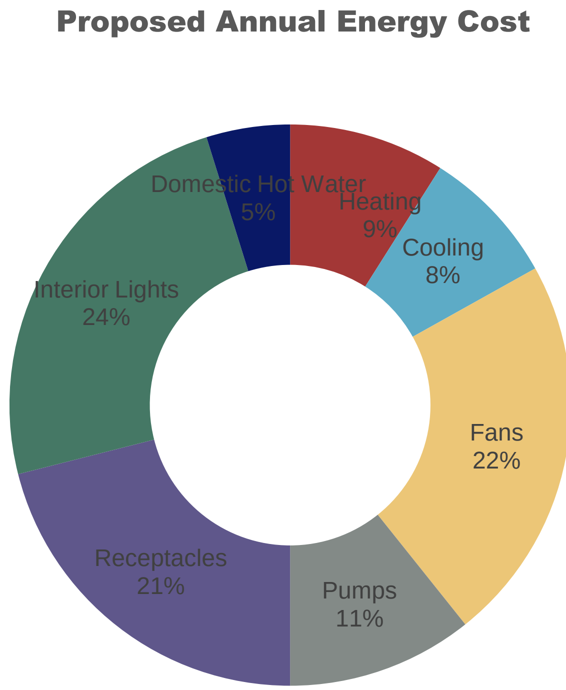
Results Summary

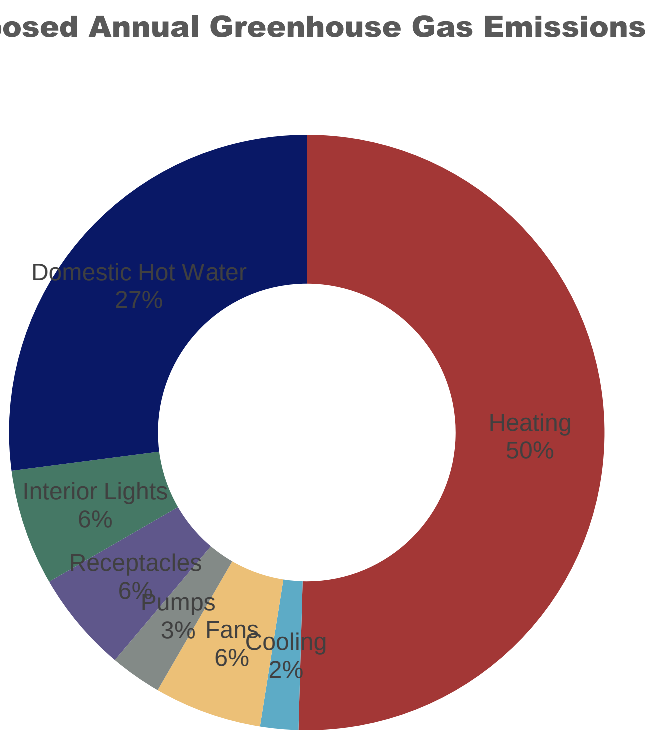
Table 1: ECMs Analysis Summary

Design Case	Description	TEUI (kWh/m²)	TEDI (kWh/m²)	GHGI (kg eCO2/m²)	Energy Savings	Cost Savings	GHG Savings
Proposed Tier 1	As per ECM Summary	124.1	34.1	14.1	-	-	-
Proposed Tier 2	As per ECM Summary	81.8	25.4	7.9	34.1%	5.2%	44.2%
Proposed Tier 3	As per ECM Summary	48.6	16.5	2.4	54.1%	7.1%	79.8%

Refer to Appendix C for a detailed list of all ECMs considered.




Proposed Annual Energy Cost
Domestic Hot Water
5%
Heating
9%
Cooling
8%
Fans
22%
Pumps
11%
Receptacles
21%
Interior Lights
24%


Proposed Annual Greenhouse Gas Emissions
Domestic Hot Water
27%
Heating
50%
Interior Lights
6%
Receptacles
6%
Pumps
3%
Fans
6%
Cooling
2%

Base Building Design Description

MASSING & ORIENTATION

The nature of the site and purpose of the proposed development lends itself to a large amount of occupied perimeter spaces.

DAYLIGHTING

The proposed building's form and function promote daylighting mainly for residential units, as all units have exterior glazed exposure.

THERMAL PERFORMANCE

The envelope thermal performance values have been estimated based on previous projects with the intent of meeting the 2017 Ontario Building Code SB-10 requirements.

- Exterior wall with R-8 effective performance including thermal bridging. Exterior walls were assumed to consist of spandrel panel with back pan insulation and interior insulation between the studs.
- Roof/Soffit/Parking Garage plenum: R-50
- Glazing System U value is 0.34 Btu/h sf °F. Overall U value is estimated based on typical curtain wall sizes.

LIGHTING

The baseline lighting targets are set to be 25% better than the 2017 Ontario Building Code SB-10 requirements. LED lighting fixtures are required in the proposed design to achieve these lighting power density targets.

APPLIANCES

All in-suite appliances have been set to ENERGY STAR® minimum requirements.

HEATING AND COOLING

Heat Pump

Two heat pump systems have been considered in this study; Water Source Heat pump (WSHP) and Ground Source Heat Pump (GSHP). WSHPs are used to provide local space conditioning using DX coils for cooling and hot water coils for heating.

For the WSHP, heating and cooling are provided by condensing water loop connected to high efficiency natural gas hot water heaters and fluid coolers.

For the GSHP, the building HVAC will exchange energy with the ground which typically have a constant temperature after specific depth.

VENTILATION

Dwelling unit ventilation is provided by in suite energy recovery ventilators, whereas lobby and amenity ventilation as well as corridor pressurization is provided by a hydronic make up air unit.

Amenity and corridor ventilation accounts for over 30% of the total proposed design ventilation. Measures to reduce the corridor ventilation load are explored in Appendix B.

The ventilation is provided by MUAs connected to fan coil systems, the proposed model is assumed to have energy recovery wheel with 65% effectiveness.

DOMESTIC HOT WATER

Domestic hot water is provided by high efficiency condensing domestic water heaters. Low flow fixtures have been incorporated into the proposed design. Opportunity to further reduce the domestic hot water load is assessed as an conservation measure.

Energy Conservation Measures

Energy conservation measures were determined by first examining where the proposed building design loads could be reduced. Many load reduction measures have been incorporated into the proposed design: good envelope performance, ventilation energy recovery in residential suites, and low flow plumbing fixtures. The following items provide the most opportunity for further load reduction:

- Glazing
- Domestic Hot Water
- Corridor Ventilation
- Building Air Tightness
- Mechanical System Type

The proposed energy measures and additional measures will be analyzed during detailed design; in order to ensure that final selected ECMs are applicable to the project and economically feasible.

GLAZING

Reduced Glazing Area

Heat loss and heat gains through glazing are major contributors to heating and cooling loads. Reducing the total glazed area is the most cost effective way to reduce energy consumption. Designing to achieve a 40% window to wall ratio is ideal from an energy perspective as this helps reduce cooling loads and heating losses, while allowing enough glazing area to maintain daylighting and sufficient heat gain during bright winter and shoulder season days.

Improved Window Performance

Three glazing performance measures were analyzed:

- Conventional double glaze system with lower solar heat gain coefficient (SHGC);
- High-performance double glaze system (lower U-value) with higher SHGC to allow more passive heating
- Triple glaze system (lower U-value) with higher SHGC to allow more passive heating

There is a trade-off between heating and cooling loads, as reduced solar heat gain increases heating loads. The cost of electricity is much higher than natural gas, so reducing the solar heat gain coefficient will reduce energy costs far more than energy and emissions. Reducing solar heat gain coefficients is achieved through various low-e coatings and is less expensive than improving both U-value and solar heat gain coefficient. Window U-value improvements are achieved through increasing the number of panes (i.e. triple glazed) or increasing the thermal break of aluminum frames.

DOMESTIC HOT WATER

Lower Flow Fixtures

Low flow water fixtures, such as 1.9 Litre per minute (LPM) lavatory faucets and 3.8 LPM kitchen sinks should have negligible incremental capital costs and will reduce the domestic hot water load by 48%.

Drain Water Heat Recovery

Utilizing drain water recovery entails separating toilet drain piping to capture waste heat from lavatories, showers and sinks. The savings are estimated using a recovery effectiveness of 30%. Incremental costs are estimated at $500/dwelling unit.

Low flow fixtures conflict with this strategy, as separating the plumbing makes it more difficult to achieve proper waste flushing. Lower flow fixtures are a more feasible measure to reduce the total domestic hot water load.

Solar Domestic Water Heaters

Solar domestic water heaters were analyzed as an alternative to photovoltaics serving the electrical load of the building.

The solar domestic water heater was run in conjunction with lower flow fixtures to reduce initial system sizing and costs. System loads and sizing would need to be calculated during detailed design. Additionally, space restraints might not allow for backup and storage equipment or the solar collectors.

Electric Domestic Water Heaters

Electric domestic water heaters were analyzed as an alternative to **N**atural **G**as (NG) heaters as a measure to achieve greenhouse gas emissions required by Tier 4

CORRIDOR VENTILATION

Ventilation Energy Recovery

Ventilation energy recovery is incorporated in the dwelling units of the base design case; however, corridor make up air represents over 30% of the total ventilation provided. Ducting the exhaust air back to these units is typically not practical. The additional cost of incorporating energy recovery on the corridor ventilation units would be substantial considering the additional space and ductwork required. It is recommended that alternative strategies also be investigated to reduce the load of the corridor ventilation air.

GROUND SOURCE HEAT PUMPS (GEOTHERMAL)

Ground source heat pumps use the mass of the earth to improve the performance of a vapour compression refrigeration cycle which can heat in winter and cool in summer. Glycol is passed through vertical or horizontal piping loops between the building and the ground. The fluid absorbs heat from the ground in winter months and rejects heat to the ground in the summer months. The soil remains at a relatively constant temperatures and essentially serves as a highly efficient heat rejection medium.

Since this would be below the below grade building levels, the construction of the geothermal field would need to be coordinated with the overall building construction plan and may extend the construction schedule.

Integrating geothermal into the building is typically done in two ways. The heat can be transferred with a water-to-water heat pump (centralized system) or multiple water-to-air heat pumps (distributed system). Multi-unit residential buildings utilize distributed heat pump systems as typically the mechanical designs are already distributed systems i.e. fan coils.

It is important to note that ground source heat pumps shift the primary source of heating energy from natural gas to electricity. The discrepancy between the cost of electricity and the cost of natural gas results in a discrepancy between energy and energy cost savings. Current average electricity cost is ~ \$0.16/kWh, whereas the average natural gas costs is (\$0.25/m^3). Therefore energy cost savings will be far less significant than energy savings when compared to a natural gas heated reference building.

The incremental geothermal system capital costs and discrepancy in utility costs due to switching from natural gas to electric heating make it imperative that the base building heating and cooling loads are reduced as much as possible. There is potential to see cost benefits associated with ground source heat pumps when the overall building loads have been reduced first.

There is no cost benefit to ground source heat pumps as an individual measure; however, combined with decreased glazing area, improved glazing performance, as well as solar strategies that reduce the ventilation and domestic water heating load, ground source heat pumps play a key role in achieving lower energy use intensities.

COMBINED HEAT & POWER

Combined heat and power systems (CHP) are on site electricity production systems that are specifically designed to recover waste heat from the electricity production process for the use in heating, cooling, or process applications. A properly designed CHP plant can be twice as efficient as a typical fossil fuel power plant, converting up to 80% of the energy from input fuel into electricity and useful heat.

The most successful applications for CHP involve projects where the demands for electricity and heat align. Projects with central heating and cooling plants such as university campuses, provide a good match for CHP systems because an infrastructure for distributing the heating and cooling already exist and there is generally a continuous or large demand for simultaneous electricity and heat. When electricity and heating demands are not in synchronization, the efficiency and feasibility of a CHP is reduced. Increasing the carbon emission associated with CHP design for this application will significantly reduces the chance to meet TGS V3 targets and therefore not recommended for this project.

PHOTOVOLTAICS

Photovoltaic (PV) cells capture sunlight to generate electricity. PV cells, or solar cells, are arranged together in a module to collect sunlight and convert it into usable electricity. The electricity can be used as a partial or complete supply for a building’s electricity needs. Excess electricity can be relayed back to the electricity grid or stored in batteries. Larger area modules with the same efficiency will produce more electricity. PV cells are most efficient in direct sunlight and lose efficiency with shading, dirty surfaces, and heating of the cells. Therefore, the location and orientation of the panels affects their output.

The proportion of proposed building area to total site area limits the potential for onsite electricity production through PV. Considering this project limitation, it is more beneficial to integrate other solar strategies such as solar domestic hot water.

Results Summary Energy Conservation Measures

Please refer to Appendix B to review the ECM table.

TORONTO GREEN STANDARD TIER 1

Water Source Heat Pump System

- Exterior walls with effective R-8 (including thermal bridging)
- Built-up roof with effective R-50
- Below grade walls with effective R-20
- Exposed floors with effective R-30
- Insulated Floor (Parking & Level 1) effective R-20
- Glazing performance: U-0.34 (including center of glass and frame) and 0.30 SHGC
- 40% Window to Wall Ratio (WWR)
- Corridor Ventilation of 30 CFM/Suite
- Install Demand Control Ventilation (DCV) in commercial spaces and amenities
- In-suite ventilation energy recovery provided for dwelling units: 75% sensible and 70% latent effectiveness
- Heat Pump heating COP 3.0, cooling EER 13
- Multi-speed Heat Pump ECM Fan motors
- Recue Lighting Power Densities (LPD) 25% below 2017 Ontario Building Code SB-10 requirements value

TORONTO GREEN STANDARD TIER 2

Tier 1 Plus

Ground Source Heat Pump System

- Exterior walls with effective R-13 (including thermal bridging)
- Built-up roof with effective R-50
- Below grade walls with effective R-25
- Exposed floors with effective R-30
- Insulated Floor (Parking & Level 1) effective R-20
- Glazing performance: U-0.25 (include center of glass and frame) and 0.4 SHGC
- 30% Window to Wall Ratio (WWR)
- Corridor Ventilation of 30 CFM/Suite

- Reduced Infiltration by 15%
- Install Demand Control Ventilation (DCV) in commercial spaces and amenities
- In-suite ventilation energy recovery provided for dwelling units: 75% sensible and 70% latent effectiveness
- Natural Gas DHW system 96%
- Reduce service water demand 48% below NECB 2015, by installing low-flow water fixture or drain water recovery
- Heat Pump COP 4.0, EER 16.8

TORONTO GREEN STANDARD TIER 3

Tier 2 Plus

Ground Source Heat Pump System

- Exterior walls with effective R-20 (including thermal bridging)
- Built-up roof with effective R-50
- Exposed floors with effective R-30
- Below grade walls effective R-25
- Insulated Floor (Parking & Level 1) effective R-20
- Reduce air leakage 15% below the air-leakage level required by the NECB 2015 requirements
- Glazing performance: U-0.21 (include center of glass and frame) and 0.35 SHGC
- 30% Window to Wall Ratio (WWR)
- Corridor Ventilation 15 CFM/Suite,
- Install Demand Control Ventilation (DCV) in commercial spaces and amenities
- In-suite ventilation energy recovery provided for dwelling units: 75% sensible and 70% latent effectiveness;
- Recue Lighting Power Densities (LPD) 50% below NECB 2015 requirements values
- Use Air Source Heat Pump DHW system with COP-2.1
- Reduce service water demand 48% below NECB 2015, by installing low-flow water fixture or drain water recovery
- Heat Pump COP 4.0, EER 16.8
- Elevator consumption reduced by 25%

Energy Resilience

Standard practice for multi-unit residential buildings is to provide backup power systems that cover all life safety requirements and base buildings loads such as pressurization fans, boilers, sump pumps and domestic hot water systems. Diesel generators are more common than natural gas generators since natural gas generators cost approximately double and are larger than their diesel counterparts are.

Additionally natural gas generators above 350kW have difficulty meeting the 15-second maximum time allowance for life safety equipment to come back on. Multiple or twin generators could address this concern. The benefits of natural gas generators are lower NO_X emissions as well as a constantly available fuel supply that does not have to be delivered.

The distribution and sizing of the backup systems will need to consider Ministry of Environment and Climate Change requirements for NO_X emissions. Typically, the generators must be located at higher levels such as a penthouse to satisfy the emissions requirements. A typical design for this development would locate a single generator at the top of the building.

Appendix A: Energy Modelling Assumptions

MODEL SUMMARY

Project Title	**1800 Shepard Ave. E**
Date	**04/03/2022**
Location	**Toronto**
Software	**eQuest 3.65 7173 DOE 2.2**
Weather File	**CAN_ON_Toronto-City.Centre.715080_CWEC2016.BIN**

BUILDING SUMMARY

Project Size	**1,122,591 sf**
Total Number of Residential Units	**1416**

OPAQUE ENVELOPE

	Design	
	Description	**Performance**
Overall Wall	Curtain/window wall/EIFS combined	R-8
Roof/Exposed Floor	TBD	R-20

GLAZING

	Design	
	Description	**Performance**
U-value (effective)	Preliminary Design Information	0.34
SHGC		0.34
Window-to-Wall Ratio		40%

INTERIOR LIGHTING

	Design	
	Description/Controls	LPD (W/sf)
Amenity & Lobby	Targets per SB-10 2017	0.90
Corridor		0.56
Dwelling Unit		0.46
Locker		0.39
Mechanical / Electrical		0.36
Parking Garage		0.12
Stairs		0.49
Office		0.79
Conference / meeting / multi-purpose		0.82
Storage		0.53

ELECTRICAL

	Design	
Load	Description	Power or Power Density
Amenity & Lobby	ASHRAE default per space type	0.09 W/sf
Dwelling Unit	Energy Star® appliances	0.46 W/sf
Miscellaneous Fans and Pumps	Preliminary estimate Total power de rated for varying schedules	22 kW
Elevator		259 kW

WATER-SIDE

	Design Description Performance
Water Source Heat Pump Loop	Natural gas condensing boilers, 92.5% thermal efficiency Setpoints (supply/return): 68 / 86 °F Pump Power: 15 w/gpm (includes primary and secondary)
Domestic Hot Water	Natural gas condensing water heaters, 96% thermal efficiency Supply Temperature: 140F Modelled Peak Lavs 3.8 LPM | Showers 5.7 LPM | Kitchen sink 5.7 LPM Residential : 72.8 gpm

AIR-SIDE HVAC

	Design Description Performance
MUAs - Residential Corridors, main lobby and amenities	DOAS Supplying tempered ventilation air at 30 cfm per suite to corridors and lobbies Supply Fan kW/cfm: 0.0009 with Variable Speed Fan Hydronic Heating & DX Cooling
MUAs - Office Fancoil and ERVs Condo	Ventilation Provided in accordance with ASHRAE 62.1-2010 directly to suite via ERV 1 bedroom 50 cfm | 2 bedroom 75 cfm | 3 bedroom 100 cfm ERV Performance Energy Recovery: 65% Sensible, 60% latent effectiveness Fans: ECM motors, 0.0006 kW/cfm WLHP units Performance COP: 3.8, EER: 14 Fans: Two Speed with ECM motors Constant speed kW/cfm: 0.0003 Exhaust Fans: Washroom: 30 Watts Kitchen Hood: 50 Watts Dryer: 50 Watts

Heating Only Spaces Hot Water Force Flow Heaters	Fan Coil Performance Fans: Constant volume, with ECM motors kW/cfm: 0.00015 65 °F Heating Setpoint

Appendix B: Energy Conservation Measures Summary

ECM Description	WWR %	Wall Insulation (Effective)	Roof Insulation	Infiltration Improvement	Glazing U-Value (Effective)	Glazing SHGC	Corridor Pressurization (cfm/door)	ERV Sensible Eff	ERV Latent Eff	DHW Improvement	Boiler Eff	Chiller Eff kW/ton	Lighting Improvement	Plug Loads Improvement
ECM-A-01	40%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-02	30%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-03	50%	R-8	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-04	50%	R-13	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-05	50%	R-20	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-06	50%	R-5	R-50	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-07	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-08	50%	R-5	R-30	15%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-09	50%	R-5	R-30	50%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-10	50%	R-5	R-30	0%	U-0.478	0.30	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-11	50%	R-5	R-30	0%	U-0.478	0.35	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-12	50%	R-5	R-30	0%	U-0.354	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-13	50%	R-5	R-30	0%	U-0.354	0.30	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-14	50%	R-5	R-30	0%	U-0.354	0.35	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-15	50%	R-5	R-30	0%	U-0.21	0.25	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-16	50%	R-5	R-30	0%	U-0.21	0.30	40	65%	60%	0%	91%	0.78	15%	0%
ECM-A-17	50%	R-5	R-30	0%	U-0.21	0.35	40	65%	60%	0%	91%	0.78	15%	0%
ECM-M-01	50%	R-5	R-30	0%	U-0.478	0.25	30	65%	60%	0%	91%	0.78	15%	0%

ECM Description	WWR %	Wall Insulation (Effective)	Roof Insulation	Infiltration Improvement	Glazing U-Value (Effective)	Glazing SHGC	Corridor Pressurization (cfm/door)	ERV Sensible Eff	ERV Latent Eff	DHW Improvement	Boiler Eff	Chiller Eff kW/ton	Lighting Improvement	Plug Loads Improvement
ECM-M-02	50%	R-5	R-30	0%	U-0.478	0.25	15	65%	60%	0%	91%	0.78	15%	0%
ECM-M-03	50%	R-5	R-30	0%	U-0.478	0.25	40	75%	70%	0%	91%	0.78	15%	0%
ECM-M-04	50%	R-5	R-30	0%	U-0.478	0.25	40	85%	80%	0%	91%	0.78	15%	0%
ECM-M-05	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	30%	91%	0.78	15%	0%
ECM-M-06	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	50%	91%	0.78	15%	0%
ECM-M-07	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	93%	0.78	15%	0%
ECM-M-08	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	95%	0.78	15%	0%
ECM-M-09	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.66	15%	0%
ECM-M-10	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.57	15%	0%
ECM-E-01	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	25%	0%
ECM-E-02	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	50%	0%
ECM-E-03	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	10%
ECM-E-04	50%	R-5	R-30	0%	U-0.478	0.25	40	65%	60%	0%	91%	0.78	15%	25%
Tier-1-01	40%	R-8	R-50	0%	U-0.354	0.25	30	75%	70%	0%	93%	0.66	25%	0%
Tier-1-02	40%	R-8	R-50	0%	U-0.354	0.30	30	75%	70%	0%	93%	0.66	25%	0%
Tier-1-03	40%	R-13	R-50	0%	U-0.354	0.35	30	75%	70%	0%	93%	0.66	25%	0%
Tier-1-04	40%	R-13	R-50	0%	U-0.354	0.25	30	75%	70%	0%	93%	0.66	25%	0%
Tier-1-05	40%	R-13	R-50	0%	U-0.354	0.30	30	75%	70%	0%	93%	0.66	25%	0%
Tier-1-06	40%	R-8	R-50	0%	U-0.354	0.35	30	75%	70%	0%	93%	0.66	25%	0%
Tier-2-01	30%	R-8	R-50	15%	U-0.21	0.25	30	75%	70%	30%	95%	0.57	50%	10%
Tier-2-02	30%	R-8	R-50	15%	U-0.21	0.30	30	75%	70%	30%	95%	0.57	50%	10%
Tier-2-03	30%	R-13	R-50	15%	U-0.21	0.35	30	75%	70%	30%	95%	0.57	50%	10%
Tier-2-04	30%	R-13	R-50	15%	U-0.354	0.25	30	75%	70%	30%	95%	0.57	50%	10%
Tier-2-05	30%	R-13	R-50	15%	U-0.354	0.30	30	75%	70%	30%	95%	0.57	50%	10%
Tier-2-06	30%	R-13	R-50	15%	U-0.354	0.35	30	75%	70%	30%	95%	0.57	50%	10%
Tier-2-07	30%	R-13	R-50	15%	U-0.21	0.25	30	75%	70%	30%	95%	0.57	50%	10%
Tier-2-08	30%	R-13	R-50	15%	U-0.21	0.30	30	75%	70%	30%	95%	0.57	50%	10%
Tier-2-09	30%	R-13	R-50	15%	U-0.21	0.35	30	75%	70%	30%	95%	0.57	50%	10%
Tier-3-01	30%	R-13	R-50	15%	U-0.21	0.25	30	75%	70%	30%	95%	0.57	50%	25%
Tier-3-02	30%	R-13	R-50	15%	U-0.21	0.30	30	75%	70%	30%	95%	0.57	50%	25%
Tier-3-03	30%	R-20	R-50	15%	U-0.21	0.35	30	75%	70%	30%	95%	0.57	50%	25%

ECM Description	WWR %	Wall Insulation (Effective)	Roof Insulation	Infiltration Improvement	Glazing U-Value (Effective)	Glazing SHGC	Corridor Pressurization (cfm/door)	ERV Sensible Eff	ERV Latent Eff	DHW Improvement	Boiler Eff	Chiller Eff kW/ton	Lighting Improvement	Plug Loads Improvement
Tier-3-04	30%	R-20	R-50	15%	U-0.21	0.25	15	75%	70%	30%	95%	0.57	50%	25%
Tier-3-05	30%	R-20	R-50	15%	U-0.21	0.30	15	75%	70%	30%	95%	0.57	50%	25%
Tier-3-06	30%	R-20	R-50	15%	U-0.21	0.35	15	75%	70%	30%	95%	0.57	50%	25%
Tier-3-07	30%	R-20	R-50	50%	U-0.21	0.25	15	85%	80%	50%	95%	0.57	50%	25%
Tier-3-08	30%	R-20	R-50	50%	U-0.21	0.30	15	85%	80%	50%	95%	0.57	50%	25%
Tier-3-09	30%	R-20	R-50	50%	U-0.21	0.35	15	85%	80%	50%	95%	0.57	50%	25%

Appendix C: Results Summary

Model	TEUI (ekWh/m²)	TEDI (kWh/m²)	GHGI (kg eCO2/m²)	Energy Savings	Cost Savings	GHG Savings
ECM-A-01	152.6	54.0	18.6	-23.0%	-12.4%	-32.0%
ECM-A-02	148.9	52.4	18.2	-20.0%	-9.5%	-29.0%
ECM-A-03	145.5	50.9	17.8	-17.3%	-6.9%	-26.1%
ECM-A-04	145.8	49.0	17.5	-17.5%	-9.6%	-24.3%
ECM-A-05	141.5	45.7	16.8	-14.1%	-8.0%	-19.3%
ECM-A-06	139.2	43.9	16.4	-12.1%	-7.1%	-16.4%
ECM-A-07	151.9	53.4	18.5	-22.4%	-12.2%	-31.2%
ECM-A-08	150.4	52.4	18.3	-21.2%	-11.5%	-29.5%
ECM-A-09	145.3	48.6	17.4	-17.1%	-9.4%	-23.7%
ECM-A-10	152.2	52.1	18.3	-22.7%	-14.3%	-29.9%
ECM-A-11	152.3	50.2	18.0	-22.8%	-16.7%	-28.0%
ECM-A-12	144.4	47.5	17.2	-16.3%	-9.5%	-22.2%
ECM-A-13	144.6	45.6	17.0	-16.5%	-12.1%	-20.3%
ECM-A-14	145.1	43.8	16.7	-17.0%	-15.0%	-18.7%
ECM-A-15	134.9	39.1	15.5	-8.7%	-7.3%	-9.9%
ECM-A-16	135.8	37.4	15.3	-9.5%	-10.6%	-8.5%
ECM-A-17	137.1	35.9	15.1	-10.5%	-14.2%	-7.4%
ECM-M-01	151.3	54.5	18.6	-22.0%	-10.1%	-32.1%
ECM-M-02	148.3	56.0	18.7	-19.5%	-4.2%	-32.6%
ECM-M-03	151.8	54.6	18.7	-22.4%	-10.7%	-32.4%
ECM-M-04	150.8	55.5	18.7	-21.5%	-8.1%	-33.0%
ECM-M-05	148.7	51.2	18.0	-19.8%	-10.7%	-27.7%
ECM-M-06	142.8	47.0	17.1	-15.1%	-8.1%	-21.0%
ECM-M-07	149.8	50.9	18.0	-20.7%	-12.6%	-27.7%
ECM-M-08	147.0	47.8	17.4	-18.4%	-12.6%	-23.5%
ECM-M-09	146.4	54.0	17.5	-18.0%	-11.0%	-23.9%
ECM-M-10	142.2	54.0	16.7	-14.6%	-10.1%	-18.5%
ECM-E-01	151.2	54.0	18.4	-21.9%	-12.1%	-30.2%
ECM-E-02	150.0	54.0	18.1	-20.9%	-11.9%	-28.6%
ECM-E-03	151.4	54.0	18.5	-22.0%	-10.9%	-31.5%
ECM-E-04	150.4	54.0	18.5	-21.2%	-9.5%	-31.2%
Tier-1-01	123.9	35.6	14.3	0.2%	2.0%	-1.4%
Tier-1-02	**124.1**	**34.1**	**14.1**	**0.0%**	**0.0%**	**0.0%**
Tier-1-03	124.6	32.8	13.9	-0.4%	-2.3%	1.2%
Tier-1-04	119.1	31.8	13.5	4.0%	3.7%	4.3%
Tier-1-05	119.5	30.3	13.3	3.7%	1.5%	5.6%
Tier-1-06	120.2	29.0	13.2	3.1%	-1.0%	6.7%
Tier-2-01	86.8	29.8	8.7	30.1%	3.8%	38.0%
Tier-2-02	87.2	28.8	8.6	29.7%	2.0%	38.9%

Model	TEUI (ekWh/m²)	TEDI (kWh/m²)	GHGI (kg eCO2/m²)	Energy Savings	Cost Savings	GHG Savings
Tier-2-03	87.8	27.8	8.5	29.2%	0.1%	39.6%
Tier-2-04	86.9	30.4	8.8	30.0%	4.3%	37.4%
Tier-2-05	87.1	29.3	8.7	29.8%	2.7%	38.4%
Tier-2-06	87.6	28.2	8.6	29.4%	0.9%	39.3%
Tier-2-07	**81.8**	**25.4**	**7.9**	**34.1%**	**5.2%**	**44.2%**
Tier-2-08	82.4	24.4	7.8	33.6%	3.3%	45.0%
Tier-2-09	83.2	23.5	7.7	33.0%	1.3%	45.6%
Tier-3-01	48.2	23.7	2.4	54.5%	7.7%	80.0%
Tier-3-02	49.3	22.8	2.5	53.4%	5.9%	79.5%
Tier-3-03	50.5	22.0	2.5	52.3%	4.1%	79.0%
Tier-3-04	46.1	18.1	2.3	56.4%	10.9%	80.8%
Tier-3-05	47.3	17.2	2.4	55.3%	9.1%	80.3%
Tier-3-06	**48.6**	**16.5**	**2.4**	**54.1%**	**7.1%**	**79.8%**
Tier-3-07	45.0	13.1	2.3	57.5%	17.5%	81.3%
Tier-3-08	46.3	12.5	2.3	56.2%	15.5%	80.8%
Tier-3-09	47.7	11.9	2.4	55.0%	13.4%	80.2%