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ENERGY STRATEGY REPORT

FOR

300 BLOOR WEST

DATE:

2017-12-11

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1. EXECUTIVE SUMMARY

The Energy Strategy for 300 Bloor West studies the potential to achieve net zero. The energy conservation measures explored serve to advise the level of investment required and overall feasibility of achieving net zero for this development. The intent is to inform and to produce a data base for net zero feasibility for the City of Toronto.

The base building design is assumed to meet Ontario Building Code SB-10 2017 requirements and incorporates many energy conservation measures resulting in and energy use intensity of approximately 187 ekWh/m^2. Essential energy conservation measures include window to wall ratio less than 60%, improved envelope performance, LED lighting, in suite energy recovery, high efficiency fans with ECM motors or VFDs, high efficiency pumps with VFDs, high efficiency heating and cooling plant that includes effective performance at part loads due to condensing boilers and chillers with variable speed compressors.

Additional energy conservation measures were analyzed and focused on areas with the greatest opportunity to reduce the development's loads as well as investigating alternate strategies such as ground source heat pumps, combined heat and power and various passive and active solar strategies.

The nature of the development density and site area do not facilitate the area of PV required to achieve net zero. Therefore an 'Approaching Net Zero' design was analyzed which incorporates advanced load reductions including improved glazing performance and a solar wall for corridor ventilation. Additionally, ground source heat pumps provide the heating and cooling as well as domestic hot water. This design results in 106 ekW/m^2 and a simple payback period of approximately 36 years.

It is recommended that lower window to wall ratio and lower flow plumbing fixtures be incorporated in the design. These measures reduce the overall development energy load at reasonable incremental costs and result in an overall energy intensity of approximately 172 ekW/m^2.

Results Summary

Design Case	EUI (ekWh/m^2)	Energy Savings	Emissions Savings	Cost Savings	Simple Payback Years
Base Design	187	-	-	-	-
Recommended Design 2+7	172	8.2%	10.6%	5.6%	immediate
Approaching Net-Zero	106	43.1%	73.8%	10.7%	36

Appendix A contains the detailed baseline energy model input assumptions. Appendix B contains a point form summary of the energy conservation measures which include estimated performance values, incremental costing, impact on the energy performance and other design considerations.

2. PROPOSED DEVELOPMENT SUMMARY

1. Project Description

The proposed development is comprised of:

- Building gross floor area is 378,770 square feet (sf)
- Total Residential dwelling units 259, levels 9 through 38
- Retail café and dining hall space on the ground floor
- Office space on levels 2 through 8
- Above grade parking garage

2. Energy Conservation Design Features

The baseline design assumptions were determined from information available and with the intent of meeting the energy requirements of SB-10-2017. Detailed energy model inputs can be found in Appendix A. The following energy conservation measures are incorporated in the base building design:

- Good opaque envelope performance with R15 walls and R30 roofs & soffits
- Good glazing performance: low-e, argon fill, 19mm thermal break, insulating spacers
- In suite ventilation energy recovery provided for dwelling units
- Low-flow lavatories, showerheads and faucets
- High efficiency condensing boilers
- High efficiency condensing domestic water heaters
- High efficiency chillers, with variable speed compressors
- Variable speed control on all fans and pumps

3. Energy Performance

The energy use intensity of the baseline design is less than 200 ekWh/m^2, aligning with SB-10 2017 energy targets for a mixed use residential building. The following chart summarizes the modelled baseline building performance:

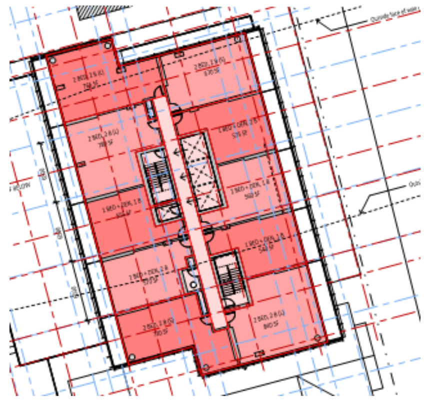
EUI (ekWh/m^2)	Emissions (kgCO_2/m^2)	Annual Cost/m^2
187	20.3	15.5

- Emissions determined from SB-10 2017
- Using current average prices: Electricity $0.13/kWh & Natural gas = $0.25/m^3

3. BASE BUILDING DESIGN DESCRIPTION

1. Massing & Orientation

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



A typical residential floor plane is shown rotated to true North. The exterior wall exposure is predominately East and West.

The window-to-wall ratio (WWR) has been estimated at 60% overall. This estimate allows for 65% WWR for all occupied spaces. Small jut outs, mechanical rooms or walls that have close building adjacencies have been assumed to have no glazing.

2. Daylighting

The proposed building's form and function promote daylighting. However, these are residential buildings in which occupant behavior will drive the savings far more than automated controls. No credit has been taken in the energy models for daylighting, as it is inherent in the ASHRAE default residential lighting schedules.

3. Thermal Performance

Thermal performance values have been estimated based on previous projects with the intent of meeting the 2017 SB-10 requirements.

- Exterior wall performance: R15, slab penetrates insulation plane reduced to R10 overall
- Roof/Soffit/Parking Garage plenum: R30
- Windows Frames: aluminum frames, with 19mm thermal break, insulating spacer
- Windows Glass: double glazed argon fill, soft low-e coating

4. Lighting

The baseline lighting targets have been set equal to or better than the 2017 SB-10 requirements. LEDs will need to be incorporated into the baseline design to achieve these lighting power density targets.

Occupancy sensors will be utilized to control 50% of the corridor and stair lighting and 100% of all storage and mechanical spaces.

5. Appliances

All in suite appliances have been set to Energy Star minimum requirements.

6. Heating & Cooling

One central heating and cooling plant will serve the proposed development. Retail and office spaces have systems that are not served by the central plant. The following list summarizes the baseline mechanical design. Detailed model inputs and performances can be found in Appendix A.

- Hot water is provided by high efficiency natural gas boilers
- Chilled water is provided by water cooled chillers with variable speed compressors
- Fan coils provide space conditioning
- ECMs on all fan coils and indoor VRF units
- VRF serving office and retail spaces

7. Ventilation

Dwelling unit ventilation is provided by in suite energy recovery ventilators. Residential 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 35% of the base design ventilation. Measures to reduce the corridor ventilation load will be explored.

8. Domestic Hot Water

Domestic hot water is provided by high efficiency condensing domestic water heaters. Low flow fixtures have been incorporated into the base design. However there is still opportunity to further reduce the domestic hot water load.

4. ENERGY CONSERVATION MEASURES

Energy conservation measures were determined by first examining where the base building design loads could be reduced. Many load reduction measures have been incorporated into the base 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

1. 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: 1) lower solar heat gain coefficient 2) lower U-value 3) Lower U-value combined with a lower solar heat gain coefficient (SHGC). 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 pains (i.e. triple glazed) or increasing the thermal break of aluminum frames.

The first glazing performance measure assumed a low-e coating equivalent to Solarban 70XL, with a centre of glass SHGC of 0.27. Incremental cost estimate based on $0.10/square foot of window area. This reduced the cooling load substantially; however the reduced solar heat gain increased space heating loads and resulted in an increased total energy use.

The second glazing performance measure assumed triple glazing, with a centre of glass U-value of 0.18. Incremental cost estimate based on $7.00/square foot of window area. This resulted in heating load reductions which generate higher energy and emissions savings than cost savings.

The third glazing performance measure assumed triple glazed windows with solarban 70XL low-e coating, and a centre of glass performance of SHGC=0.25 and U-value=0.18. Incremental cost estimate based on $7.10 square foot of window area. The improved window performance reduced heating and cooling loads substantially; resulting in balanced savings between energy, emissions and cost. However, the incremental capital cost is quite substantial and not recommended as an individual measure. The increased glazing performance is recommended for a net zero design, where decreased loads help reduce equipment sizing.

2. Domestic Hot Water

Lower Flow Fixtures

1.9LPM lavs and 3.8 LPM kitchen sinks should have negligible incremental capital costs and will reduce the domestic hot water load by 20%.

Drain Water Heat Recovery

Utilizing drain heat 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. Preliminary sizing estimate 650 square meters of collectors required and $500/square meter of collector area. 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.

3. 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 35% 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.

Solar Wall

Solar walls are beneficial when there is a large amount of ventilation air required and energy recovery is difficult or impossible to incorporate into the design. Solar walls are composed of dark colour south facing wall with perforations and a small plenum space. This plenum preheats the incoming air and reduces the total heating load; 70% effectiveness can be achieved in heating. A bypass strategy would need to be incorporated when the make-up air units are operating in cooling mode.

Preliminary sizing estimate of 1 ft^2 solar wall required for 4 cfm of ventilation air, results in 3,475ft^2 total solar wall area. Preliminary cost estimate $50/square foot of solar wall area. The area required for the solar wall would need to be determined in detailed design as well as sufficient southern exposure adjacent mechanical spaces where the make-up air units are located; these detailed design considerations would be the driving factor for the feasibility of incorporating this strategy.

The solar wall was analyzed as an alternative to photovoltaics serving the electrical load of the building and is intended to be incorporated into the 'Approaching Net Zero' design.

4. 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 in the summer months. The soil remains at more constant temperatures and essentially serves as a highly efficient heat rejection medium.

Integrating geothermal into the building is typically done in two alternative ways. The heat can be transferred with a water-to-water heat pumps (centralized system) or multiple water-to-air heat pumps (distributed system). Multi-unit residential buildings utilize distributed heat pump systems as the typically the base 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 ~0.13/kWh, whereas the average natural gas costs is \$0.02/ekWh (\$0.25/m^3). Therefore energy cost savings will be far less significant than energy savings.

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.

Ground source heat pumps were analyzed in combination with load reduction measures to create the 'Approaching Net Zero' design. 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 close to 100 ekWh/m^2.

5. 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 sync, the efficiency and feasibility of a CHP is reduced.

The base electrical load was used to size the combined heat and power plant measure. An annually seasonal efficiency of 72% was determined through hourly analysis. However the base electrical and heating loads are not in sync; therefore, the overall impact of the combined heating and power plant resulted in increased energy consumption as well as greenhouse gas emissions.

The disparity between current utility costs resulted in energy cost savings. Although this strategy facilitates some on site power generation and therefore inherent resiliency, it is not recommended for the proposed development due to the increased energy consumption and emissions.

6. Photovoltaics

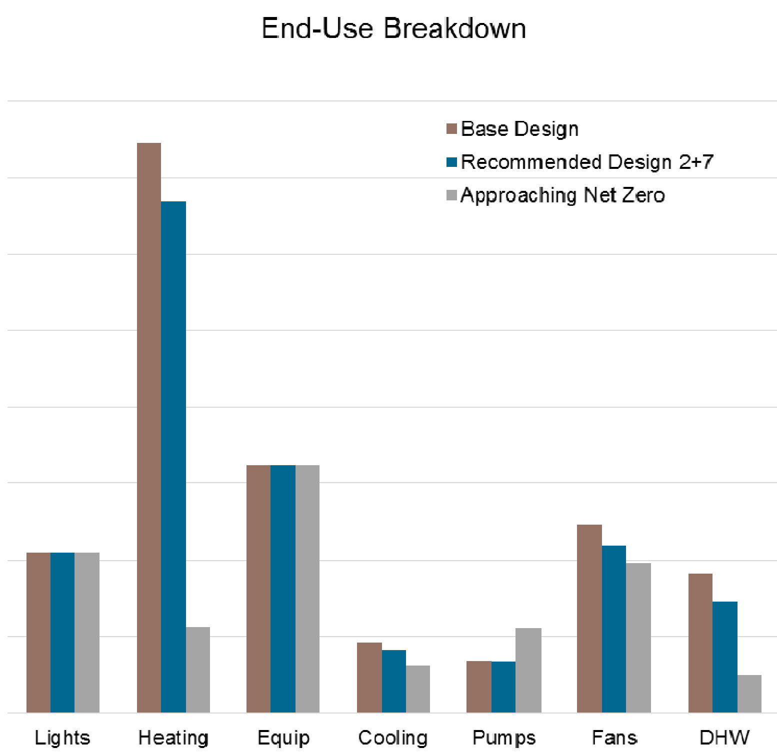
Photovoltaic (PV) cells capture sunlight to generate electricity. PV cells, or solar cells, are arranged together in a module to collect sunlight and convert it into usable electricity. The electricity can be used as a partial or complete supply for a building's electricity needs. Excess electricity 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. A preliminary estimate of approximately 14,100 square meters of PV is required to offset the energy consumption of an adjusted 'Approaching Net Zero' design. However the total site area is less than 4,000 square meters. Considering this project limitation, it is more beneficial to integrate other solar strategies such as solar domestic hot water and solar ventilating air heating.

The estimated incremental cost of a PV system required to offset the energy use of the net zero design is based off of $700/m^2 of PV and results in $9,940,000. Due to the high capital cost and required area, a system that is sized for the available roof area would be more feasible.

5. RESULTS SUMMARY - ENERGY CONSERVATION MEASURES

Design Case		EUI (ekWh/m^2)	Energy Savings	Emissions Savings	Cost Savings	Simple Payback Years
Base Design		187	-	-	-	-
1	Reduce WWR 50%	181	3.1%	3.7%	2.5%	immediate
2	Reduce WWR 40%	175	6.2%	7.3%	5.0%	immediate
3	Solarban 70XL	188	-0.8%	-3.4%	2.1%	1
4	Triple Glazing	174	7.0%	10.3%	3.4%	49
5	Triple, low-e Solarban 70XL	175	6.2%	6.5%	5.8%	29
6	R25 Effective Wall	183	2.1%	2.8%	1.3%	24
7	Lavs 1.9 LPM | Kitchen 3.8 LPM	183	1.9%	3.2%	0.6%	immediate
8	Drain Water Heat Recovery	181	2.9%	4.9%	0.8%	32
9	Solar Domestic Water heater	173	7.4%	12.3%	2.1%	34
10	Energy recovery - Corridor Ventilation	168	10.0%	17.4%	2.2%	28
11	Solar Wall - Corridor Ventilation	172	7.7%	12.8%	2.3%	17
12	Ground Source Heat Pumps	126	32.7%	69.0%	-5.7%	never
13	Combined Heating & Power	211	-13.0%	-44.9%	11.1%	14
14	Recommended Design 2+7	172	8.2%	10.6%	5.6%	immediate
15	Recommended Tier 2 Design 2+5+6+7	157	16.1%	20.7%	11.2%	14
16	Approaching Net-Zero	106	43.1%	73.8%	10.7%	36
17	Net-Zero	-	100.0%	100%	100%	26



6. 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.

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 NOX emissions as well as a constantly available fuel supply that does not have to be manually delivered.

The distribution and sizing of the backup systems will need to consider Ministry of Environment and Climate Change requirements for NOX emissions. Typically the generators must be located at higher levels such as a penthouse to satisfy the emissions requirements.

Preliminary estimate for 650kW diesel generator capacity is estimated at $325,000, whereas two natural gas generators providing the same total capacity is estimated at $650,000.

APPENDIX A: ENERGY MODELLING ASSUMPTIONS

MODEL SUMMARY

Project Title	**300 Bloor West**
Date	**12/11/2017**
Location	**Toronto**
Software	**eQUEST 3.65**

BUILDING MODELED GFA

Gross Building Area (ft^2)	315,700
Above Grade Floors	38
Below Grade Floors	1
Total Number of Floors	39

Parking Garage not included in GFA

OPAQUE ENVELOPE	DESIGN	
	Description	Performance
Typical Wall	TBD	10
Roof/Exposed Floor	TBD	30
Parking Garage Plenum	TBD	30

Reduced overall wall performance for balcony slab penetrations. Opaque wall assumed effective R15

CURTAINWALL	DESIGN	
	Description	Performance
U-value	Frame: 19mm thermal break Glazing: 12mm argon fill, low-e = solarban60, clear Warm edge spacer	0.35
SHGC		0.34
Window to Wall Ratio		60%

INTERIOR LIGHTING	DESIGN	
	Description/Controls	LPD
Amenity & Lobby	Targets per SB-10 2017 or better LEDs throughout Corridor & Stairs 50% OS control Mech/Elec, Storage & lockers 100% OS control	0.65
Corridor		0.60
Dwelling Unit		0.54
Lockers & Storage		0.48
Office		0.79
Mech		0.43
Retail/Café		1.06

ELECTRICAL	DESIGN	
Amenity & Lobby	ASHRAE default per space type	0.23 W/ft^2
Office		0.70 W/ft^2
Dwelling Unit	Energy star appliances	2,700 kWh/year/suite
Misc Fans	Preliminary estimate Total power de rated for varying schedules	2 kW
Misc Pumps		13 kW
Elevator		14 kW
Exterior Lighting	Estimate, per SB10-2017	2.5 kW

AIR-SIDE HVAC	DESIGN Description/Performance
MUAs Corridors, Main lobby & Amenity	DOAS Supplying tempered ventilation air to corridors, lobbies & amenities Sized for 50 cfm per suite + Amenity/Lobby ventilation requirements Supply Fan kW/cfm: 0.0008 Hydronic Heating & Cooling Coils Units on time of day schedule controlled by VSD -High speed operation: 7:00am-9:00 am & 4:00-9:00pm -Low speed operation 30 cfm per suite
4-Pipe Fan Coils + ERVs Condo & Rental	Ventilation Provided in accordance with ASHRAE 62.1-2010 -System Efficiency = 1.0 | Delivery effectiveness = 0.8 1 bedroom 50 cfm | 2 bedroom 75 cfm | 3 bedroom 100 cfm <u>ERV Performance</u> Energy Recovery: 65% Sensible, 40% latent effectiveness Fans: ECM motors, 0.0009 kW/cfm <u>Fan Coil Performance</u> Fans: Multiple speed settings, with ECM motors - High speed kW/cfm: 0.0002 - Low Speed kW/cfm: 0.0001 <u>Exhaust Fans:</u> - Washroom: 50 Watts - Kitchen Hood: 75 Watts - Dryer: 75 Watts
4-Pipe Fan Coils Main lobby & Amenities	Ventilation Provided in accordance with ASHRAE 62.1-2010 -System Efficiency = 1.0 | Delivery effectiveness = 0.8 Heating & Cooling provided by fan coils Fan Power 0.0002 kW/cfm, ECM multiple speed fans
VRF Retail & Office	Ventilation Provided in accordance with ASHRAE 62.1-2010 Indoor Unit: Supply Fan: 0.0002 kW/cfm, ECM multiple speed fans Outdoor Unit: Heating COP 3.5 | Cooling COP 4.0
Exhaust Fans Parking Garage	No heating provided Exhaust fans controlled by CO sensors Exhaust Fan Efficiency: 0.0001 kW/cfm ASHRAE 62.1-2010 Exhaust rates: 0.75 cfm/ ft2

WATER-SIDE	DESIGN Description/Performance
Hot Water	Natural gas condensing boilers, 95% thermal efficiency Setpoints (supply/return): 130/110F Pumps: head = 100' w.g., imp eff = 75%, motor eff. = 92% + VFDs
Chilled Water	Centrifugal Chiller COP 6.2, variable speed compressors Setpoints (supply/return): 42F/55F Pumps: head = 100' w.g., imp eff = 75%, motor eff. = 92% + VFDs
Condenser	Cooling towers, efficiencies per ASHRAE 90.1-2010 + VFDs Setpoints (supply/return): 85/95F Pumps: head = 80' w.g., imp eff = 75%, motor eff. = 92% + VFDs
Domestic Hot Water	Natural gas condensing water heaters, 95% thermal efficiency Lavs 3.8 LPM | Showers 5.7 LPM | Kitchen sink 5.7 LPM Supply Temperature: 140F

All pumps to be variable speed, coupled with 2-way valves

APPENDIX B: ENERGY CONSERVATION MEASURES SUMMARY

1. ARCHITECTURAL

1. Reduce Window to wall ratio 50%

- Window to wall ratio 50%
- No incremental cost
- Recommend reducing the window to wall ratio further; see next measure

2. Reduce Window to wall ratio 40%

- Window to wall ratio 40%
- No incremental cost
- Recommend utilizing this overall window to wall ratio

3. Low-e Performance

- Assumed solarban 70XL performance, centre of glass SHGC = 0.27
- Incremental cost based on $0.10 /square foot of window area
- Same frame performance, substantial thermal breaks with insulating spacers
- Reduced the cooling load substantially; however the reduced solar heat gain increased space heating loads and resulted in an increased total energy use
- Other methods of solar control incorporated into the base design, therefore not recommended in this application.

4. Triple Glazed

- Assumed centre of glass U-value = 0.18
- Same frame performance, substantial thermal breaks with insulating spacers
- Incremental cost based on $7.00/square foot of window area
- Reduced heating load substantially
- Recommend combining improved U-value with improved SHGC for more balances savings.
- Incremental cost are quite substantial, not recommended as an individual measure

5. Low-e Performance + Triple Glazed

- Assumed solarban 70XL performance, centre of glass SHGC 0.25, U-value = 0.18
- Same frame performance, substantial thermal breaks with insulating spacers
- Incremental cost based on $7.10/square foot of window area
- Reduced heating & cooling load substantially
- Incremental cost are quite substantial, not recommended as an individual measure
- Increased performance recommended for net zero design, where decreased loads help reduce equipment sizing. See combined ground source heat pump measure 'Approaching Net-Zero'

6. Increased Wall Performance R25 overall

- Assumed framing through insulation layer making additional insulation requirements nominal R20
- Incremental cost ~ $2.00 / square foot
- Base design wall constructions not established, incremental costs will vary depending on base wall design wall thickness and space restrictions.
- Not recommended as an individual measure
- Increased performance recommended for net zero design, where decreased loads help reduce equipment sizing. See combined ground source heat pump measure 'Approaching Net-Zero'

2. DOMESTIC HOT WATER

7. Lower Flow Fixtures

- 1.9 LPM lavatory & 3.8 LPM sink, reduces domestic hot water loads by 20%
- Negligible incremental cost
- Recommend using lower flow fixtures

8. Domestic Water Drain Recovery

- Savings estimated using a recovery effectiveness of 30%
- $500/dwelling unit
- Low flow fixtures conflict with this strategy, as separating the plumbing makes it more difficult to achieve proper waste flushing
- Not recommended in this application

9. Solar Domestic Water Heater

- Backup system and thermal storage will be required
- Assumed 30% annual load not bet by solar
- This measure was run using the lower flow fixtures to reduce initial system sizing and costs
- Preliminary estimate 650 square meters of collectors required
- Cost estimated at $500/square meter of collector
- System loads and sizing would need to be calculated during detailed design
- Space restraints might not allow for backup and storage equipment or the solar collectors

3. VENTILATION

10. Corridor Ventilation - Energy Recovery

- Assumed typical enthalpy wheel performance: 75% average effectiveness
- Preliminary cost estimate $20/cfm. Typically energy recovery costs are much lower, however the cost/cfm was increased to account for additional ductwork required to exhaust

through the corridor MUAs. Additional costs and space requirements have yet to be quantitated

- Recommend investigating alternate methods to reduce corridor ventilation loads; see next measure

11. Corridor Ventilation - Solar Wall

- Assumed conservative solar wall performance: 50% average effectiveness
- Preliminary estimate: 1 ft2 solar wall required for 4 cfm of ventilation air, 3,475ft2 total.
- Preliminary cost estimate $50/square foot of solar wall area
- Loads and sizing would need to be calculated during detailed design to determine feasibility

4. CENTRAL HEATING & COOLING PLANT

12. Ground Source Heat Pumps

- Whole building served by GSHP; heating COP = 4.0, cooling COP = 5.0
- Domestic hot water to water-water heat pump, seasonal COP = 3.0
- Incremental costs $4000/ton for loop
- Removed chiller costs assuming $2000/ton
- Incremental costs do not account for soft costs such as design, or project specific limitations such as the ground loop being below the parking garage
- Not recommended for this application. Measure was run as an illustrative comparison for what would be required to achieve Net-Zero ready design
- Ground Source Heat pumps systems have better payback when coupled with reduced building demands; see 'Approaching Net-Zero measure'

13. Combined Heat & Power

- Base electrical load, i.e. minimum 24/7 electrical load was used to size the CHP
- 120kW generator, electric efficiency = 37%, 50% thermal efficiency, 72% annual efficiency
- Cost decreases significantly, however energy and emissions increase
- Incremental costs estimated at $705,000
- Not recommended for this application

5. COMBINED MEASURES

14. Recommended Design - 8% energy, 11% emissions 6% cost savings

- Window to wall ratio 40%
- Lower Flow fixtures 1.9 LPM Lavs & 3.8 LPM kitchen sink

15. Recommended Tier 2 Design - 16% energy, 21% emissions 11% cost savings

- Window to wall ratio 40% overall
- Triple glazing with Solarban 70XL low-e
- Improved wall performance, effective R25, overall with slab penetrations effective R15
- Lower Flow fixtures 1.9 LPM Lavs & 3.8 LPM kitchen sink

16. Approaching Net Zero - 43% energy, 74% emissions, 11% Cost savings

- Ground source heat pumps coupled with:
  - Window to wall ratio 39% overall
  - Lower Flow fixtures 1.9 LPM Lavs & 3.8 LPM kitchen sink
  - R25 walls, Triple glazed windows + Solarban 70XL
  - Solar Wall corridor ventilation
- Ground source heat pumps should be considered with building demand reductions. It’s not feasible to incorporate this level of mechanical equipment upgrades without first reducing the building loads.
- Used for illustrative purposes to determine what is required to achieve close to 100ekWh/m2