Mechanical System Design Guidelines for Low Carbon Buildings

Voluntary Design Guidelines for Existing and New Buildings

If you have comments or questions please direct them to:

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Executive Summary

This document provides guidelines and associated capital costs for low carbon mechanical system designs in new and existing multi-unit residential and commercial office buildings. This report focuses on heating, ventilation, and air conditioning (HVAC) systems given their outsized contribution to GHG emissions. Whereas certain designs are inherently low carbon, other designs are presented as “low carbon-ready", meaning they can readily be made low carbon through future retrofits.

The overall priorities are to:

- Plan for integration of a low carbon thermal energy source
  - District energy or building-scale geo-exchange via basement connection
  - Air-source heat pump in mechanical penthouse
- Design for low-temperature heating systems

Capital Costs for Multi-Unit Residential Buildings (MURBs)

New multi-unit residential buildings (MURBs) designed as low carbon-ready have a minimal incremental capital cost range of $0.34 to $1.34 per square foot of gross floor area, which is less than 0.5% of total construction costs in the buildings analyzed. MURBs with distributed (i.e. in-suite) water-sourced heat pumps are inherently low carbon-ready.

Table 1. MURB Capital Costs. This table outlines the associated low carbon-ready costs with different MURB archetypes. Refer to Appendix A for descriptions of each archetype.

MURB	HVAC system	Total capital costs ($)	Incremental cost ($/ft^2)	% of total construction costs
New	4-Pipe Fan Coil Units	$530,000	$1.34	0.49%
	Distributed Heat Pumps	$100,000	$0.34	0.13%
Existing	4-Pipe Fan Coil Units	$1,280,000	$6.36	NA
	Distributed Heat Pumps	$1,640,000	$8.15	NA

Key low carbon-ready design guidelines for new MURBs include:

- Design for low-temperature heating distribution system (~50°C supply water), which works with both in-suite water-source heat pumps and 4-pipe fan coil units.
- Make the building ready for a future district energy or in-building geo-exchange connection by allocating vertical space from parking through to the mechanical penthouse with reverse-return piping connections. If using fan coil units, maintain even riser size throughout the building, if possible.
- Allocate roof space, structural support and power for air-source heat pumps to replace conventional heating and cooling plant if no future district energy connection is expected, and if geo-exchange is not feasible.

The following designs are recommended to prepare existing MURBs for installation of a geo-exchange system, connection to a district energy system, or replacement of the chiller plant with an air-source heat pump:

- Implement an intelligent Building Automation System (BAS) to adjust the supply water temperature based upon building demand.
- Replace existing boilers to accept return water temperatures of ~40°C.
- Install water-to-water heat pumps on higher temperature systems (i.e. building entrances, snow melting) to upgrade those zones of the building.

Capital Costs Commercial Office Buildings

Incremental capital costs for new commercial office buildings range from $1.35 to $3.15 per square foot, which is less than 1.5% of total construction costs in the case studies. Although overhead heating from fan coil units in commercial office building incurs higher equipment costs, it is the preferred low carbon design, compared to perimeter wall-fin.

Table 2. Commercial Office Capital Costs. This table outlines the associated low carbon-ready costs with different Commercial Office archetypes. Refer to Appendix A for descriptions of each archetype.

Office	HVAC system	Total capital costs ($)	Incremental cost ($/ft^2)	% of Total construction costs
New	Wall-fin	$2,540,000	$3.15	1.20%
	Overhead Heat	$2,180,000	$1.35	0.40%
Existing	Wall-fin	$3,380,000	$7.48	NA
	Induction Units	$3,970,000	$3.04	NA

Key low carbon design guidelines for new commercial office buildings include:

- Install a basement chilled water plant that incorporates a heat pump sized for the lighting and a portion of the plug load in the building.
- Maximize heat recovery from internal gains and exhaust streams.
- Design the heating water system for the perimeter loads of a typical floor and ventilation to use ~50°C or lower (Avoid wall-fin distribution).
- Install local heat pumps on higher temperature systems (i.e. building entrances, snow melting) to upgrade those zones of the building.
- Size chilled and heating water risers to be full-size from top to bottom to enable a future basement mechanical plant and district energy connection, or install sleeve openings in a common space so that risers can be installed in the future.
- Incorporate an air source heat pump sized to the smaller of 400 tons, or the difference in the building heating demand and the heat recovery chiller, if no future district energy connection is expected, and if geo-exchange is not feasible.

The following designs are recommended to prepare existing commercial office buildings for installation of a geo-exchange system, or replacement of the chiller plant with an air-source heat pump:

- For buildings without exhaust heat recovery, add chilled water coils to the exhaust air stream to recover heat from the exhaust air as it leaves the building.
- For buildings with steam infrastructure, new condenser water risers are recommended, incorporating distributed heat-pumps in mechanical rooms where steam has been converted to water.
- Replace existing boilers to accept return water temperatures of 40° C.

Contents

Executive Summary **2**
Capital Costs for Multi-Unit Residential Buildings (MURBs) 2
Capital Costs Commercial Office Buildings 3
Introduction **5**
Purpose of the Guidelines 5
Application of the Guidelines 6
Design Guidelines for MURBs **7**
Future-Proof for District Energy or Ground-Source Heating 7
Future-Proof for Lower Heating Water Temperatures 8
Retrofits 9
Design Guidelines for Commercial Office Buildings **11**
Future-Proof for District Energy or Ground-Source Heating 11
Future-Proof for Lower Heating Water Temperatures 12
Retrofits 13
Appendix A: Description of Archetypes **15**
Multi-Unit Residential Archetypes 15
Commercial Office Archetypes 16

Introduction

The City of Toronto has committed to an ambitious set of City-wide energy and greenhouse gas (GHG) reduction targets, including net zero GHG emissions by 2050 or sooner. Over 50% of Toronto's GHG emissions come from buildings, primarily from natural gas combusted for space and water heating (i.e. mechanical systems). Therefore, in order to meet TransformTO GHG emissions targets it is imperative that we consider mechanical system design.

This guideline outlines how developers of MURB's and commercial office buildings can design their mechanical systems to be low carbon, or at least low carbon-ready to minimize the cost of future retrofits. Furthermore, it also recommends key retrofits for building owners. Generally, the higher cost of retrofits means that mechanical system redesigns are best implemented as part of larger retrofits in order to maximize value.

There are a number of financial and non-financial benefits associated with low-carbon mechanical system design, including:

- Fuel flexibility, which will mitigate future increases in energy costs and supply.
- Less and/or smaller mechanical equipment, reducing the need for a conventional mechanical penthouse, which can free up space for amenity or residential area.
- Compliance with the building energy and emissions performance standards.
- Partnerships with **Energy Developers**, which can support cost effective implementation of renewable thermal energy.

Low Carbon Thermal Energy Sources and Energy Developers

Reducing GHG emissions in buildings depends on fuel switching from natural gas boilers to electric heat pumps, which can be coupled with various low carbon energy sources. The focus in this guideline is on air-source and ground-source heat pumps, and connection to district energy systems, which are assumed to be low carbon.

Ground-source heating and cooling is discussed here primarily as a retrofit option for meeting just the peak heating and cooling demands because this would provide the best business case. However, this assumes the project is financed entirely by the building owner, as opposed to Energy Developers (third-party energy providers).

Long-term energy service agreements with energy developers can avoid many of the upfront capital costs for the building owner, and would enable larger ground-source heating and cooling systems for deeper GHG emissions reductions. Likewise, some of the costs associated with district energy connections can be amortized over time through agreements with district energy developers.

Purpose of the Guidelines

This guideline discusses a number of opportunities to help building developers and owners of high rise commercial and multi-unit residential properties future proof buildings for integration with a low carbon thermal energy source/system. This report provides carbon reduction strategies that can be applied to building archetypes which provide comparable cost estimates which an Owner/Developer may use to extrapolate the costs of implementing these strategies on actual projects. The guideline is based on a study completed by the Environment & Energy Division (EED) in collaboration with The Mitchell Partnership Inc., a Toronto-based mechanical building services consulting engineering firm.

The main objectives of this guideline are to:

- Identify the requirements and associated differential cost for "future-proofing" new buildings for later integration with low carbon thermal energy sources/systems.
- Identify the requirements and associated differential cost for retrofitting existing buildings for later integration with low carbon thermal energy sources/systems.

Considering Future Weather

Energy modelling using 2016 and 2040 weather files suggests that cooling demand in MURBs will nearly double by 2040. Furthermore, envelopes designed to minimize heat loss will make these buildings cooling dominant. Designing cooling systems to meet expected demand would not only future-proof the building for occupant comfort, but it would also facilitate later integration of heat pumps as part of a retrofit.

Application of the Guidelines

These guidelines are voluntary and would ideally be considered as part of design development for any new and existing MURB's and commercial office buildings. However, buildings targeting higher levels of energy performance or integration of renewable thermal energy sources will likely use many of the designs and technologies outlined in this guideline. Therefore, as the TGS design requirements become more stringent over the next 10 years, many of the recommended design solutions will likely become industry standard approaches.

This guideline is based on a study of low carbon thermal energy ready buildings, which includes business cases for several types of existing and new buildings. For a copy of the full report please contact EnergyReview@toronto.ca

Design Guidelines for MURBs

New MURBs have the lowest incremental cost for low carbon-ready design, especially when utilizing in-suite heat pumps. Future-proofing MURBs is especially important given how infrequently major retrofits take place in these buildings.

Future-Proof for District Energy or Ground-Source Heating

Connection to a district energy system can be a cost-effective approach to reducing GHG emissions. In situations where a district energy system is being planned, but will not be constructed in time to connect a building, the building can be future-proofed for connection (i.e. district energy-ready). This approach has the added benefit of also making the building ready for ground-source heating.

For MURBs with either 4-pipe fan coil units or in-suite heat pumps:

1. **Install connections on reverse return piping**
   $5,000 per connection (two for heat pumps; four for fan coil units)

   Arrange the reverse return piping from residential suites so that they have accessible points for future connections (ideally be a pair of riser isolation valves or a pair of Tee connections in common areas). These connections would also prepare the building for a central heat pump.

2. **Provide space for future vertical piping**
   $13,000 per floor (filled and covered)

   Allocate vertical space from the parking through to the building level to the reverse-return piping connections, in the form of sleeves over which flooring may be installed to avoid future costs. Service vestibules (elevator, garbage, corners of stair landings) may minimize the impact on space planning.

3. **Provide space for the energy transfer station or central heat pump**
   $25,000-50,000 per space (300 square feet per space at ~$85-165 per ft^2)

   Allocate parking spaces adjacent to the building core to create physical space for a future energy transfer station (ETS) or central heat pump. An ETS requires two (2) spaces, while a central heat pump would requires approximately ten (10).

   MURBs using 4-pipe fan coil units in particular require additional power to be allocated for the future low carbon heating equipment. The estimated cost is $105/kVa.

4. **Allocate power for the low-carbon heating source.**
   $105 per kVa for additional power

   A reasonable estimate is to double the power allocated to the cooling plant to account for the lower efficiency. When a similar technology is producing beneficial heat.

District Energy Systems

District energy systems also called low carbon thermal energy networks, distribute thermal energy to multiple buildings in an area or neighbourhood. These systems typically consist of a heating and cooling centre, and a thermal network of pipes connected to a group of buildings.

The economies of scale of district energy systems mean that low carbon energy sources can be integrated more cost-effectively over time compared to the building-scale.

Please contact the Environment & Energy Division regarding the development of new district energy systems, as well opportunities for connections to existing or planned systems. For further information please follow the link to District Energy Systems on the City of Toronto website.

Future-Proof for Lower Heating Water Temperatures

Where a district energy connection is not likely, there are commercially available heat pumps with the capacities and temperature ranges to provide low carbon heating and cooling on-site. Mechanical systems must be designed for lower heating water supply temperatures to increase the efficiency and cost effectiveness of heat pumps.

1. **Allocate roof space, structural support and power for an air-source heat pump to replace conventional cooling plant.**
   $105 per kVa for additional power

   Allocate 25% additional peak electrical demand beyond conventional cooling plant for the heat pump/chillers.

2. **In a heat-pump building, plan for water-to-water heat pumps in series with the air-source heat pump.**

3. **In a fan-coil building, select building heating water distribution with ~50°C supply water temperature.**

   Commercially available heat pumps will reliably produce 50°C heating water on the coldest days of the year. This will improve efficiency in the near-term and future-proof replacement options.

Air-Source Heat Pumps

Heat pumps are a high efficiency heating technology. Air-source heat pumps exchange heat with the surrounding air of a building using electricity, which also makes them a low-carbon option in Ontario.

The operating cost of heat pumps is related to their efficiency, which is directly related to the difference between the temperature of the heat source (air) and the heat sink (conditioned area of a building). The smaller the temperature difference, the greater the efficiency, and the lesser the operating costs. To reduce the difference between the heat source and sink, the equipment is either installed within an enclosure (this is the most common solution for Variable Refrigerant Flow systems) or required heating water temperature in the building must be reduced.

Heat pump efficiency must be greater than 0.65kW/ton to have a low carbon building which is economically competitive, meaning that a building must be designed with reduced heating water temperatures in order to accommodate an air-source heat pump.

Retrofits

Heating and cooling plants of existing MURBs can be retrofitted to accommodate air- or ground-source heat pumps, or for connection to a district energy system. The key is to time the retrofit with a boiler replacement such that the new boilers are able to accept lower return temperatures.

1. **Replace the existing cooling plant with air-source heat pumps to supplement the conventional heating plant capacity.**
   $1,850 per ton

   This could extend the life of the existing boilers by reducing operating hours, and would enable smaller boilers when they are eventually replaced. Commercially available heat pumps are expected to operate all heating hours above -10°C (95% of hours), which would reduce GHG emissions by 60-80%.

2. **Replace existing boilers to accept return water temperatures of 40°C**
   $40 per MBH (1,000 BTU per hour)

   Replacement options include condensing boilers or cast-iron boilers designed for low return water in order to preserve the existing boiler flues.

3. **Provide ground-source heat pump at the basement level of the building for 5 to 10% of the peak demand capacity.**
   $8,000 per ton (including borehole drilling)

   Ground-source heat pumps have higher capital costs, but are more efficient than air-source heat pumps. In situations where building mechanical systems are planned to be retrofitted, and where the site has space to accommodate borefield drilling, ground-source heating and cooling can be a cost-effective low carbon retrofit.

For MURBs with 4-pipe fan coil units, additional recommendations include:

4. **Implement a Building Automation System (BAS) to provide supply water temperature based upon building demand.**
   $10,000 for each of the pumps on the primary (heat generation) and secondary (load) distribution circuits

   The cost includes a variable frequency drive for each pumps, as well as a flow meter and temperature sensor for each pump pair.

5. **Install water-to-water heat pumps on higher temperature systems (i.e. building entrances, snow melting)**
   $81,000 per heat pump

   Targeting these particular building zones will allow further GHG emissions reductions without affecting the supply water temperature to the rest of the building.

District Energy Retrofit

The unique requirements for retrofitting a building for connection to a district energy system mean that the costs can vary significantly depending on building design. In certain cases, this may be the most-effective low carbon option.

If you are considering replacement of heating and cooling equipment, and you are nearby an existing or planned district energy system, discuss connection opportunities with the system owner/developer.

Design Guidelines for Commercial Office Buildings

Commercial office buildings can take advantage of simultaneous heating and cooling loads to maximize heat recovery, which offers is very cost-effective approach to low carbon mechanical system design. Keys to low carbon designs in new buildings are chiller plants located in basements and space for full-size heating and cooling risers.

Future-Proof for District Energy or Ground-Source Heating

The basement is the ideal location for the chiller plant in new commercial office buildings because it provides the most flexibility for later integration of low-carbon energy sources (e.g. district energy connection, ground-source heat pump).

The trade-off with this design is the cost premium associated with oversized risers and pressure break heat exchangers (for buildings over 20 stories), which is estimated at $250,000 for a new office building.

Where a basement chiller plant is not feasible, key future-proof designs for new commercial office buildings include:

1. **Incorporate sleeve openings for future risers to be installed within a common area, or size chilled water and heating water risers to be full-size from top to bottom**
   $15,000 – 33,000 per floor (~5 floors from ETS to reverse return connection)

2. **Provide space for the future mechanical room.**
   $25,000-50,000 per space (300 square feet per space at $85-167 per ft²)

   Allocate parking spaces adjacent to the building core to create physical space for a future energy transfer station (ETS) or central heat pump. An ETS require two (2) spaces, while a central heat pump would require twelve (12).

The connection point between a district energy system and the building mechanical system occurs at the ETS.

3. **Plan to install an Energy Transfer Station.**
   $560,000 per ETS (at least two parking spaces required)

Plant Location

The location of chilled water and heating plants plays an important role in future proofing buildings for integration of low carbon thermal energy sources.
In making design decisions, there are trade-offs with respect to plant location.

Basement chilled water plants are less common because the equipment has a higher cost in a building greater than 20 storeys, as the equipment needs a greater pressure rating or to be separated from the building pressure through a heat exchanger. There are also two additional risers which need to be added to the core of the building, or at least sleeves through which piping can be installed at a later date. Additional parking spaces may be necessary for a basement energy transfer station and chiller plant.

Buildings which do not have or are unable to incorporate a basement chiller plant or provide a basement connection to DES also have low carbon options, but the first cost and operating cost are both higher as an air-source heat pump would become the next best option.

Future-Proof for Lower Heating Water Temperatures

Similar to MURB retrofits, the objective is to design the heating system so that boilers play a minimal role in providing heating.

1. **Plan to incorporate a heat pump, with the central chilled water plant that is sized for the lighting and a portion of the plug load in the building.**
   $400 per ton

   Using a water-to-water heat pump to upgrade the condenser heat to approximately 50°C allows it be used in the heating water system, reducing boiler use. Sizing for these loads should enable year-round operation in order to maximize efficiency. Modular chillers may be most effective in this case.

2. **Plan to incorporate an air-source heat pump in the mechanical penthouse (maximum capacity of 400 tons).**
   $2,800 per ton (including crane lift and installation)

   Heat pump should be designed to provide ~50°C water.

3. **Install water-to-water heat pumps on higher temperature systems (i.e. building entrances, snow melting)**
   $81,000 per heat pump

   Targeting these particular building zones will allow further GHG emissions reductions without affecting the supply water temperature to the rest of the building.

Lowering the heating water temperatures will necessitate additional heating distribution to each floor. Forced air systems, such as variable air volume overhead heating, induction units, and chilled beams, will have a much lower cost compared to radiant systems such as wall-fin or radiant ceiling panels. Wall-fin heating distribution is therefore not recommended in new commercial office construction. In the new commercial office archetypes studied for this report:

- **Increase capacity of overhead heating coils ($250 per heating zone, per floor)**
- **Additional rows of wall-fin heaters ($35 per linear foot, per floor)**

Retrofits

Retrofits to commercial office buildings depend heavily on the particular mechanical system design. The two examples presented here are wall-fin and perimeter induction units, which are common Toronto archetypes.

Where a district energy connection is possible, the cost to establish a basement connection is similar to that for MURBs:

- **Connection to reverse return risers ($33,000 per floor; ~5 floors)**
- **Two parking spaces ($25,500 per space)**
- **Two Energy Transfer Stations ($560,000 per ETS)**

If this is not possible, the priorities are to maximize heat recovery and reduce heating water temperatures in order to limit use of the boilers.

1. **Incorporate a water-to-water heat pump (50°C) with the central chilled water plant that is sized for the lighting and a portion of the plug load.**
   $400 per ton

2. **Replace existing boilers to accept return water temperatures of 40°C**
   $40 per MBH (1000 BTU per hour)

3. **Provide ground-source heat pump at the basement level of the building for 5 to 10% of the peak demand capacity.**
   $8,000 per ton (including borehole drilling)

4. **Implement a Building Automation System (BAS) to provide supply water temperature based upon building demand.**
   $10,000 for each of the pumps on the primary (heat generation) and secondary (load) distribution circuits

5. **Install water-to-water heat pumps on higher temperature systems (i.e. building entrances, snow melting)**
   $81,000 per heat pump

6. **Add chilled water coils to the exhaust air streams to recover heat.**
   $6 per CFM

Adding coils to exhaust fans and replacing ventilation heating coils, while a minimal per unit cost, would involve retrofits at many discrete locations throughout the building, therefore absolute costs can be significant ($500,000 to over $1 million).

Heat Recovery Opportunities

There are two significant heat sources in buildings from which heat may be recovered; the exhaust air stream and the interior loads (lighting, equipment and occupants). A third which may be considered is the sanitary waste stream.

New construction routinely incorporates exhaust energy recovery and most high-rise building HVAC systems (Central Fan & Heat Pump) incorporate heat recovery from interior loads.

It is common practise that both the boilers and cooling towers are located in the penthouse. It is therefore feasible that the chilled water systems have the potential to supply a portion of the heating load through a heat recovery system, provided that the heat rejection is near the heating plant. Using this rejected heat at the building is the lowest carbon source of heat.

Retrofits to buildings with induction units, which could include buildings connected to district steam for example, incur a significant cost premium:

- **Replace the entire length of the building risers to enable the use of a central heat pump ($17,000 per floor)**
- **Upgrade perimeter controls ($22,000 per floor).**
- **Replace each of the secondary steam-to-water units with water-to-water heat pumps ($400 per ton)**

Appendix A: Description of Archetypes

The archetypes studied in this review were done through a process of technology review and drawing review of existing building designs, including recent building designs, and the synthesis of fictional building Architypes which is representative of the target high-rise building stock.

Multi-Unit Residential Archetypes

New MURB with 4-pipe Fan Coil Units

A pair of 40 storey towers with a common 9 storey podium. The development includes 700 condo units and 100 hotel suites. The below grade parking is heated. The parking ramps, entrance and pathway on the podium roof incorporate snow melting. Each condo unit has a fan coil unit which includes an energy recovery core to pre-treat the outdoor air using the exhaust from the washrooms. The penthouse heating plant consists of condensing boilers with a supply water temperature of 60°C. The building has a penthouse chilled water plant consisting of chiller, cooling towers and heat exchangers to provide waterside economizer. Corridor pressurization is from central air handling units serving all floors above grade. The air is distributed through the common corridor on each floor. The retail areas have a dedicated ventilation air handlings unit and fan coil units for each Commercial Retail Unit (CRU). The pool is served be a dedicated air handling unit. Perimeter heating is provided through pressure break heat exchangers from the penthouse heating plant.

New MURB with heat pumps

35 storey tower with a 5-storey podium. The GFA is 271,000 m² and includes 360 units and ground floor amenities areas. The below grade parking is heated. The parking ramps, entrance and pathway on the podium roof incorporate snow melting. Each unit has a heat-pump unit which serves an overhead duct distribution. The unit includes an energy recovery core to pre-treat the outdoor air using the exhaust from the washrooms. The condenser system is a propylene glycol solution to protect the dry-cooler from freezing in the winter. The dry-coolers are at the tower roof. The heating plant consists of condensing boilers dedicated to the heat pump system and separate set of condensing boilers serving the amenities space. The HVAC equipment serving the amenities space are selected for 82.2°C with a return temperature of 60°C the supply water temperature is reset in accordance with the outdoor air temperature and so will provide condensing efficiencies during most of the operating hours. Corridor pressurization is from central air handling units serving all floors above grade. The air is distributed through the common corridor on each floor. The retail areas have a dedicated ventilation air handlings unit and heat pump units for each CRU. Perimeter heating is provided dedicated system for the amenities area.

Existing MURB with 4-pipe Fan Coil Units

Constructed in 2005, a 20-storey tower with a 2-storey podium. The development includes 200 units. The below grade parking is heated. Each condo unit has a fan coil unit which serves an overhead duct distribution. The fan coil is most often selected for the cooling demand and the same coil is used for heating. The building has a penthouse chilled water plant consisting of chiller, cooling towers and heat exchangers to provide waterside economizer. The penthouse heating plant consists of atmospheric (natural draft) boilers. The heating distribution is then designed to prevent the water being returned colder than 60°C through the use of three-way valves at the fan coil units, as an added precaution the boilers are equipped with 3-way valves to recirculate hot water upon system start-up. Corridor pressurization is from central air handling units serving all floors above grade. The air is for both ventilation in the suites, to pressurize the building and mitigate the risk of odours migrating between units. The retail areas have a dedicated ventilation air handlings unit and fan coil units for each CRU. Perimeter heating is electric baseboard within the retail units. The pool is served be a dedicated air handling unit.

Existing MURB with heat pumps

Constructed in 2010, a 20-storey tower with a 2-storey podium. The development includes 200 units and ground floor amenities areas. The below grade parking is heated. Each unit has a heat-pump unit which serves an overhead duct distribution. The condenser water system is separated by a heat exchanger from the fluid cooler circuit as it contains glycol for freeze protection. The dry-coolers are at the roof. The heating plant consists of atmospheric (natural draft) boilers which have a primary pumping circuit. The condenser water draws the water required to meet the system heating demand through a three-way valve. A secondary heating water pump circulates water for the mechanical room heating, stairs, amenities spaces and ground floor entrance. The HVAC equipment serving the amenities space are selected for 82.2°C with a return temperature of 71°C. Corridor pressurization is from central air handling units serving all floors above grade. The air is distributed through the common corridor on each floor. The retail areas have a dedicated ventilation air handlings unit and heat pump units for each CRU.

Commercial Office Archetypes

Existing commercial office high-rise with wall-fin perimeter heating

20-storey building constructed in the late 60s, 80s or 90s. These buildings are generally around 40,000 m² of office space with a floor plate of 2,100m². Each floor would have one or more fan coil units (compartment units) to serve each floor. Ventilation would be from a central air handling unit. Heating system consists of a penthouse boiler plant with approximately 3,000 kW of heat output capacity and return water temperature kept above 58°C. The tenants which have 24/7 cooling requirements use water-cooled units which are connected to a dedicated condenser water piping circuit. The building would have a penthouse chiller plant which includes a cooling tower designed for winter operation and a plate and frame heat exchanger to allow chilled water to be produced without the chiller. The most common means of perimeter heating is a wall-fin convector. The wall-fin were conventionally selected to save space and initial cost while protecting the boilers by using a supply water temperature of 82°C with a return temperature of 160°F (71°C) this would avoid the risk of acidic condensation forming in the boilers.

Existing commercial office high-rise with perimeter induction units

Constructed in the 1970s, 45 storeys tall with a typical floor plate of 2,700 m² with retail amenities in the concourse level. The below grade parking is heated. The parking ramps incorporate electric snow melting. The building is connected to district steam. The steam distribution through the building is then connected to the secondary water system serving the typical floor perimeter heating loads through heat exchangers. Ventilation and cooling are provided from central air handling units serving all floors above grade. The penthouse chilled water plant includes chillers and cooling tower. The plant incorporates water side economizer which meets the building cooling demand during the winter evenings. The building envelope incorporates insulated glazing units which are 2.7m in height. The perimeter induction units provide either heated or cooled air based on outdoor air temperature and coincident building load. These units are provided with a constant supply of primary air from central fans located in the 14th floor and penthouse. The retail areas have central air handlings units for different occupancies (fitness centre, restaurant, and retail). Fan coil units for each CRU. Perimeter heating in the lobby is supplied through in floor fan coil units. The perimeter heating for the entrance lobby and the retail spaces are from a dedicated heating water circuit.

New commercial office high-rise with VAV overhead heating

50 storey tall with a typical floor plate of 3,000 m² with retail amenities in the podium along with a transit hub. The buildings target LEED Platinum. The below grade parking is unheated. The parking ramps and sidewalks incorporate snow melting. Ventilation is from a central air handling unit serving all floors above grade. The air handling units incorporate enthalpy wheels for heat recovery. The penthouse heating plant consists of condensing boilers with a supply water temperature of 60°C from the boilers. The building has a basement chiller plant and a penthouse cooling tower. Waterside economizer is integrated into the plant and allows the cooling tower to pre-cool or satisfy the building cooling demands during the heating season. Each floor has a fan coil unit which serves an overhead duct distribution to VAV boxes in the interior and fan powered VAV boxes at the perimeter. Only the 4.5m (15') band around the building perimeter requires heating and the perimeter fan powered VAV boxes include hot water heating coils. The retail areas have dedicated ventilation air handlings units for different occupancies (fitness centre, restaurant, conference centre, and retail. Fan coil units for each Commercial Retail Unit (CRU). Perimeter heating is provided as the retail spaces are at ground. The perimeter heating for the entrance lobby and the retail spaces are from the same heating water circuit as the perimeter heating system.

New Commercial High-Rise with Wall-Fin Perimeter Heating

30 storeys with a typical floor plate of 2,500 m² with retail amenities in the podium. The buildings target LEED Platinum. The below grade parking is unheated. The parking ramps and sidewalks incorporate snow melting. The penthouse heating plant consists of condensing boilers with return water from the perimeter heating system used to provide heating to the ventilation. The building has no chiller plant and uses district cooling. Ventilation is from a central air handling unit serving 15 storeys. The ventilation has pressure independent VAV controls at each floor as does the exhaust systems. The air handling units incorporate enthalpy wheels for heat recovery. Each floor has a fan coil unit and most often supplies an underfloor air distribution system for cooling and ventilation. Only the 4.5m (15') band around the building perimeter requires heating. The heated floor area makes up 35% of the floor plate area. A single row of continuous wall fin is provided selected for 71°C supply water. The ventilation is supplied through a manual floor diffuser which allows the VAV controls for the perimeter to close when the zone is heating. The retail areas have dedicated ventilation and fan coil units for each CRU. Perimeter heating is provided as the retail spaces are at ground. The perimeter heating for the entrance lobby and the retail spaces are from the same heating water circuit as the perimeter heating system.