



## Project Description

### Historical Significance

The Bank of Canada, the nation's central bank, recognizes 234 Wellington Street in Ottawa as a landmark. The 80,000 m<sup>2</sup> Head Office Renewal Project set objectives to transform the workplace, address life-safety compliance, improve security and maintain the intrinsic architectural value of the centre building (1939), and architect Arthur Erickson's additions (1979). **Bouthillette Parizeau (BPA)** focused on providing integrated engineering solutions and recognized the Renewal Project's priorities to minimize energy consumption, maximize energy recovery, improve indoor air quality and reduce the environmental footprint.

The Bank of Canada Head Office occupies a city block in Ottawa's downtown core. In 1979, Arthur Erickson, an internationally acclaimed Canadian architect, designed two elegant glass towers, three lower levels and a connecting atrium space, preserving the original 1939 granite-clad bank building as the centrepiece.

The complex included an exterior plaza and a museum to house the National Currency Collection. As of 2011, the facility was out of alignment with contemporary codes and life safety standards.

### Systems Addressed

In recent decades seismologists have recognized the Ottawa region as a more active seismic zone than previously understood. As a result, the buildings' earthquake resistance was at about 40% of the current code requirement. The building systems, including fans, boilers, generators and IT were at their end of life and their distribution capacity was insufficient.

### Flexible Open Floor Plans

To address the client's programmatic and technical requirements as a modern central bank, the integrated design team developed a modular office design that restores open floorplates to the office towers and accommodates roughly 1,700 people. The planning module, dictated by the exposed repetitive coffered structure, allowed for a diverse range of enclosure options so that each floor plate has a combination of open office configurations, private offices and collaborative areas. Office partitions and open workstations were built with systems furniture to facilitate simple reconfiguration over time.



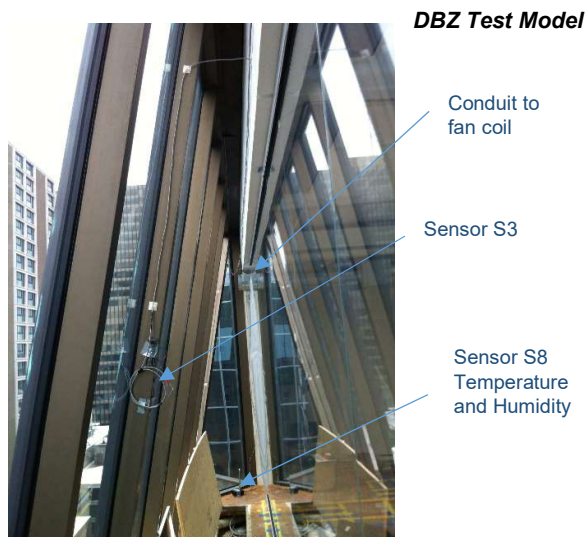
*Bank of Canada Head Office*

## Dynamic Buffer Zones

**P**rior to the renovations, the curtain walls of the office towers accounted for the envelopes' energy loss and the discomfort of occupants working near the perimeter walls.

**A**n active double-skin wall was created to significantly improve the performance of the fully glazed exterior walls. On every floor, 457 mm (18") from the perimeter, glazed partition walls were installed. The walls extend from a raised low-profile access floor to the upper slab, thus forming the inner skin of dynamic buffer zones (DBZs).

**A**ctive double-skin walls are not generally considered in Canada for office buildings, and even less in retrofit applications, particularly when the interstitial space is separated by the floor slabs at each level. To find the most optimal solutions, BPA developed computer models studying the conditions. Models included heating inside the DBZs, heating in the occupied space along the interior partition of the DBZs, and without additional heating along the tower perimeters. This last option was selected.



**H**eat loss across the perimeter walls of the towers had been estimated at 5,255 MBH (1540 kW) in peak conditions. Knowing Ottawa's weather conditions, avoiding perimeter heating to occupied spaces was revolutionary and warranted testing.

## Meticulous Testing

**B**efore the start of construction, with the building occupied, a corner of a floor area was made

available to create a mock-up of the intended double-skin wall design. The conditions of concern were the ones in cold weather, so testing took place in the months of January and February when temperatures dropped below -30°C, providing valuable data on the performance of the wall under harsh conditions. Temperature and humidity sensors were installed on glass surfaces and on mullions at various elevations. The sensors were also installed throughout the occupied areas. Exhaust air temperature was measured. The outdoor environmental conditions were recorded based on Environment Canada data. A data logger facilitated the gathering of the relevant data. The design team carefully analyzed the information. The tests confirmed the design assumptions and demonstrated some weaknesses in the theoretical model. A revised model was reviewed and provided the basis for implementing the design.

Guiding principles included:

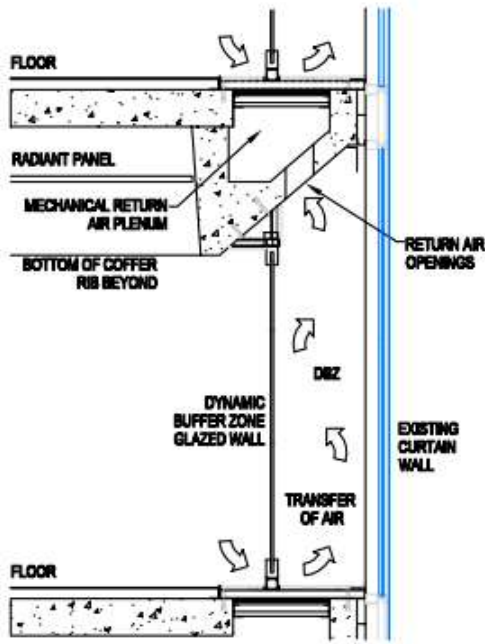
- the air in the occupied space needed to be maintained at a minimum of 22.2°C (72°F) and
- the interior glazed surfaces of the DBZs required a minimum temperature of 12.2°C (54°F) to meet comfort conditions as recommended by ASHRAE Standard 55.

**I**t was determined that, under severe conditions with exterior temperatures reaching -30°C, without any solar gains, and with the air entering the DBZs controlled at 22.2°C (72°F), the surface of the interior glass measured 17.2°C (63°F), well above the minimum for occupant comfort. All surfaces of the DBZs are maintained above the dew point temperature when the relative humidity is maintained at 25%.

**T**he annual energy savings due to the DBZs versus the curtain wall using energy modelling tools was estimated at \$98,839.68 each year.

**N**ot adding heat at the perimeter of the towers improved the energy performance of the building. The lower air temperatures in the DBZs significantly reduced the heat transfer through the exterior curtain wall. Additionally, cold air can be heated by the main air handling systems when energy recovery measures are in place.

*Dynamic Buffer Zone – Air Movement*



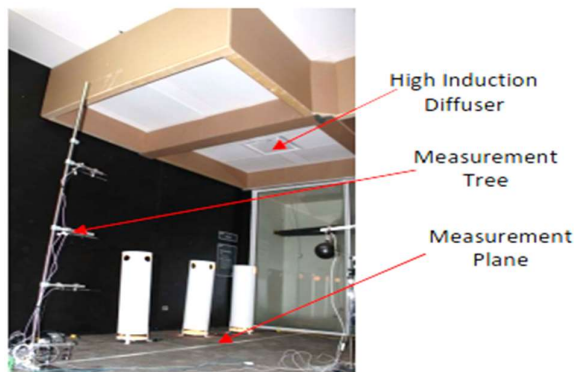
Grilles were installed in the access floor on both sides of the new partition allowing air to move from the occupied space to the DBZs. Air is captured at the upper end of the DBZs and returned to the central air handling systems in the penthouse effectively turning the DBZs and return air paths into a passive perimeter heating system. Automated blinds were integrated in the DBZs preventing the radiant heat gains from reaching the occupied space and reducing the amount of cooling required. The two towers, starting at the second floor, use the DBZ as return plenums, increasing thermal comfort and generating energy savings. The DBZs provided an innovative method to control the workspace environment by improving the thermal performance of the building envelope and using passive principles of air movement. The interior glazed partitions separating the DBZs from the occupied areas allow natural light to reach

occupied areas. The DBZs that are in plain sight provide teachable moments, exposing the tenants to the mechanical systems.

## Radiant Cooling Panels

To renew the office towers as a workplace, offering open, collaborative and transparent environments remained a focus. The modular office design works with the unique exposed concrete coffered structure. To remain visible, the structural beams required careful consideration by the consulting engineering teams. Radiant cooling panels were introduced in the recesses of the coffered structure, reducing airflow requirements by 50%. The air volume distributed to the floors was limited to meet the ASHRAE 62.1 requirements for indoor air quality. The reduction of distribution ductwork standardized air duct openings into the concrete coffers, providing adequate air distribution and precise temperature control in the space. As a result, relative humidity is controlled and building pressures are maintained.

In addition to the radiant panels, the air diffusers, VAV boxes, control valves, sprinklers and lighting were integral to the infrastructure systems and required coordination to fit within the structural concrete coffers. A mock-up of the installation was made at a specialized laboratory in Winnipeg to test the air movement and air temperature on the effects of the concrete beams and hanging lights within the coffers. The tests optimized the diffuser selection, determined the maximum airflow that could be introduced in each coffer without creating downdrafts, and provided an understanding of the air movements relative to all elements in the ceiling.



*DBZ Test Model*



2X4 beam added to represent light fixture

*Mock-up Installation for Air Movement*

## Innovation

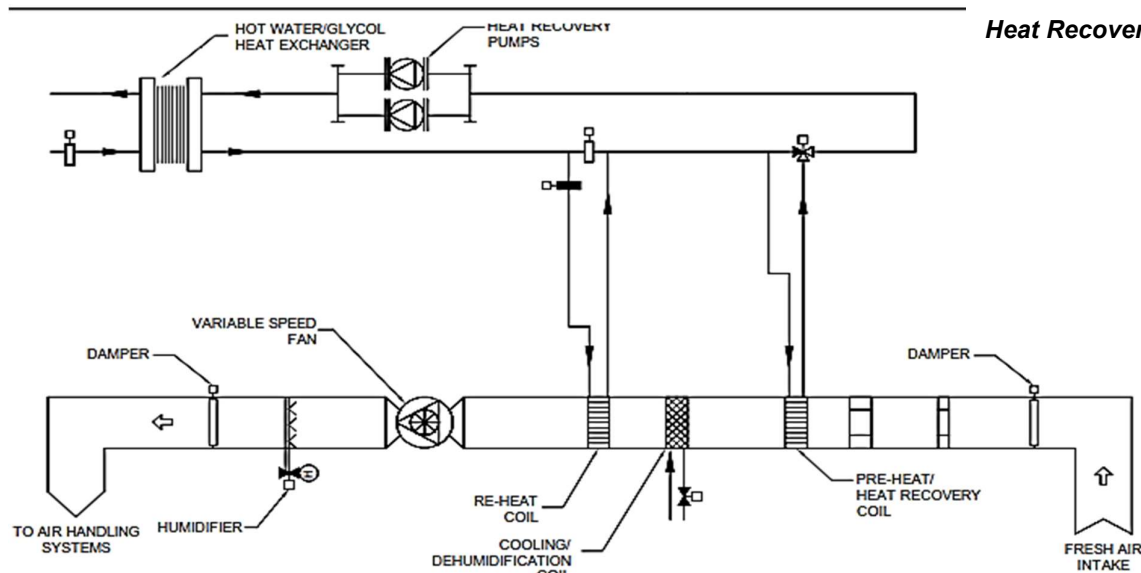
Relative humidity during summer is carefully monitored to avoid a dew point condition on the radiant panels. It was controlled via a dedicated outdoor air system and supplies air to the systems feeding the tower floors. Dehumidification strategies are in place to maintain the relative humidity on each floor to below 50%. A glycol runaround loop was installed to recover the heat from the outside air before being cooled for dehumidification. The heat is reinjected into the supply air stream at the required temperature in the winter. The same system is used to pre-heat the cold outside air.

### Heat Recovery System

Steam and chilled water supply from the district heating and cooling plant provided opportunities for energy efficiencies and cost reductions. The new systems produce low temperature hot water either from the steam supplied by the district

heating plant or by the heat recovery chillers. The heat recovery from the chillers utilize the heat rejected on the condenser side of the chillers, and target internal heat gains to offset the use of the steam. Heat recovered from interior zones is used to create hot water to heat the building perimeters.

The chillers are sized based on the interior heat gains of the building when fully occupied. In order to maximize the energy recovery, cooling coils were installed in the exhaust air to recover the heat to use for heating. Energy modelling predicted an energy savings of 37,811 GJ versus ASHRAE 90.1-2007 for this energy saving alone. Steam to low temperature hot water heat exchangers remain as an alternate heating source. The heat recovery chillers control sequence activates chiller operations when a simultaneous heating and cooling demand prevails.



*Heat Recovery System*

## Complexity

### Air Distribution

Renovating two glass office towers, the stone clad centre building and the connecting atrium space while instilling energy efficiencies was a lofty goal! LEED® Gold Certification is in progress. The need to respect original design elements and the buildings' heritage qualities influenced the owner, the design team and the constructor as the Renewal Project was realized.

During the project, engineers considered two primary air distribution challenges.

Firstly, the exposed structural coffered slabs limited potential air distribution and localized temperature control. Secondly, the original building had incremental air handling units feeding each floor. Mechanical rooms with intake louvres located on the perimeter of each floor of the east and west towers serviced the original systems.





**Collaborative Work Space**  
Photo Credit: Bank of Canada



**Lighting Design**  
Photo Credit: Bank of Canada

## Complexity

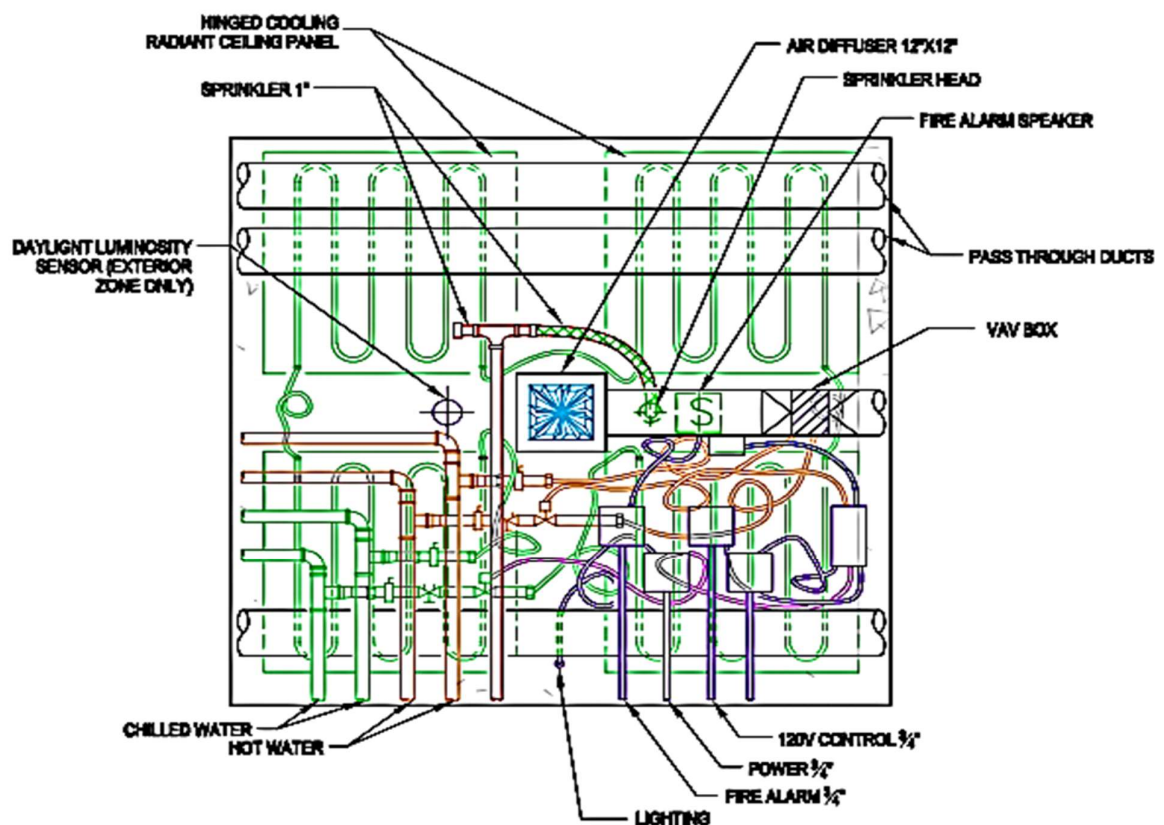
### Radiant Cooling Panels

The new concepts reduced the service area requirement in the building core, and eliminated the perimeter mechanical rooms and exterior louvres. Radiant cooling panels installed in the recesses of the coffered structure reduced airflow requirements by 50%. The air volume distributed to the floors was limited to meet the requirements of ASHRAE 62.1 for indoor air quality and for return air requirements for adequate humidity control on the floors. Reducing the distribution ductwork allowed standardized air duct openings into the

concrete coffers, which provided adequate air distribution and precise temperature control in the space. The relative humidity in the space is then controlled and building pressures are maintained. The obsolete shaft openings in the east and west tower cores were repurposed as exit stairs to meet current code requirements.

The cool air at the ceiling level within the coffers posed a challenge in terms of air distribution, but led to innovative solutions. Mechanical, Electrical and IT components had to be carefully coordinated and integrated.

#### Radiant Cooling Panel



## Complexity

A second on-site mock-up coordinated the elements prior to the mass production of the radiant ceiling panels. A hinged section was introduced to the radiant panels to simplify and efficiently provide access to the control elements such as the control valves, VAV boxes and other electrical components, which are installed in the approximately 356 mm (14") deep void above the radiant panels.

A low-profile raised flooring system was added in combination with the existing in-slab walker duct system to provide flexibility for the design of the office workstations and reduce congestion in the limited ceiling spaces. The accessible floor facilitated the distribution of power, telephone and IT to the open concept office accommodations, which takes advantage of the natural light and outside views from the glazed exterior wall. The interior lighting was integrated into the design and repetitive fixtures hanging in the exposed coffers were equipped with occupancy sensors.

A system of air movement tempers the walls of the centre building, the 1939 neo-classical stone-clad building, and controls moisture travelling through the stone walls. Extending air to the window sills controlled the temperature fluctuations often associated with glazing.

### Atrium Solutions

Arthur Erickson's artful design used a soaring 12-storey Atrium to link the centre building to the two towers. The space represents a volume of 56,633 m<sup>3</sup> of air. The air-handling equipment was installed at the penthouse level.

For summer months, BPA designed the cold air supply to flow through existing vertical shafts into air grilles designed to hang just above occupied zones. Comfort conditions were maintained in occupied zones. Air stratifies up to the 12<sup>th</sup> floor and smoke exhaust fans are used and are turned on at low speed to reject high temperature air to the exterior.

In winter, Atrium heating uses in-slab low temperature stretch convectors located along the exterior curtain wall. In-floor radiant heating system provides the necessary balance. The Atrium HVAC system was validated through a *Computational Fluid Dynamics Analysis* studying the air movement of this massive air volume and validating surface temperatures of the glass at the curtain wall, thereby optimizing the design to prevent condensation on the surface of the curtain wall. The occupants now enjoy the comfortable conditioned Atrium space without mechanical noise, perfect for gatherings and informal workspaces.



View of Atrium

### HVAC Systems

The size of the new mechanical penthouses built on the roof of each tower were strictly limited by the City of Ottawa's bylaws concerning building height. The centralized variable volume HVAC systems benefit from the diversity in the building and optimize the energy recovery on the air side. There was no ground space available outside of the building footprint to install heat rejection equipment such as cooling towers or water coolers. Thus, the design includes heating coils at the discharge of the smoke venting fans. With a series of motorized dampers, these fans draw air from the outside, which is then heated. The fans reject the excess heat from the chiller condensers into the atmosphere if the internal heating load is insufficient. This sequence stabilizes and optimizes the use of the heat recovery chillers.

The HVAC system is designed to respect the diversity of the buildings, space usage and necessary zones.

The Head Office Renewal Project is composed of the centre building, the Atrium, the east and west towers, and the basement levels. Each of the two towers have dedicated outside air systems that feed the supply systems. The systems distribute air through three distinct ventilation fans for each tower, bringing air to levels two to 12, and to the mezzanines. The heritage centre building has a dual-duct system with a cold and hot deck servicing the building. The Atrium heating system is composed of a constant volume fan and heating coil. The fresh air, supplied to the Atrium, is located in the basement. Two other fresh air systems supply the east and west side of the buildings respectively.

# Complexity

## Keen Coordination

The Renewal Project's complexity required keen coordination between design disciplines, constructors and suppliers. The design was a collaborative process that required sharing of data and design concepts both within and outside of BPA. BPA was committed to being an effective and efficient participant in the design and construction processes. The project at the time of Construction Document production represented one of the

largest use of BIM tools in Canada, including Revit and BIM 360. Our technologists used BIM modelling tools to produce integrated and coordinated drawings, and our senior engineers evaluated the output to ensure that submissions met design concepts and requirements. Our approach was consistent from the initial stages of design through to construction and post-construction.

# Social and Economic Benefits

## Social Benefits

The Renewal Project provided an opportunity to reimagine the Bank of Canada Museum and to enhance the public spaces by improving the landscape and public amenities at a meaningful location near Ottawa's parliamentary precinct. The goal of the Renewal Project was to create an efficient workplace, improve occupant wellness, and provide an infrastructure of engineering systems that conserved energy and simplified operations and maintenance. It was also to create a modern public service workplace that could attract, retain and enable resources to work smarter, greener and healthier.

The new landscaped plaza's design nods to our Canadian landscape through a set of abstract elements integrating architecture, building services and landscape at the foreground of the mirrored towers. Three large glass pyramids create an informal seating area for Bank staff and passersby. Structured elements animate the exterior space and provide mechanical and lighting innovations while acknowledging the vertical elements of the neighbouring Confederation and Justice buildings. The plaza frames the Bank of Canada museum entry, providing staging for busloads of school

children and tourists, and functions as an accessible, multi-faceted public realm throughout the year.

Client, stakeholders and consultant representatives were key components of the integrated design team. To meet the requirements of credit IEQ C7.2 LEED NC-2009, a survey on thermal comfort is to be distributed to the building occupants, and corrective measures are to be implemented if more than 20% of the occupants are unsatisfied with the ambient conditions. The strategy was to assess relevant environmental variables in problem areas in compliance with ASHRAE 55 guidelines. These include, but are not limited to, air temperature, radiant air temperature, air speed (velocity) and humidity. A permanent monitoring system verifies that the building performance reaches the intended designed comfort criteria.

Throughout the design process, operations and maintenance of engineering systems remained a consideration. Designs incorporated ease of access to equipment, including the DBZ areas. The Building Automation System was centralized and converged with other systems to facilitate the exchange of information, using open communication protocols to optimize building operations. The operations personnel remained active in the design of the new building systems and provided valuable knowledge. The systems and equipment were selected based on manufacturer representation in Canada and readily available parts. Training sessions were given to the Owner representatives on all the systems to facilitate their understanding of the building's operations and to ensure that the buildings performed to their fullest extent, while providing exemplary comfort for the occupants

*Bank of Canada Plaza*



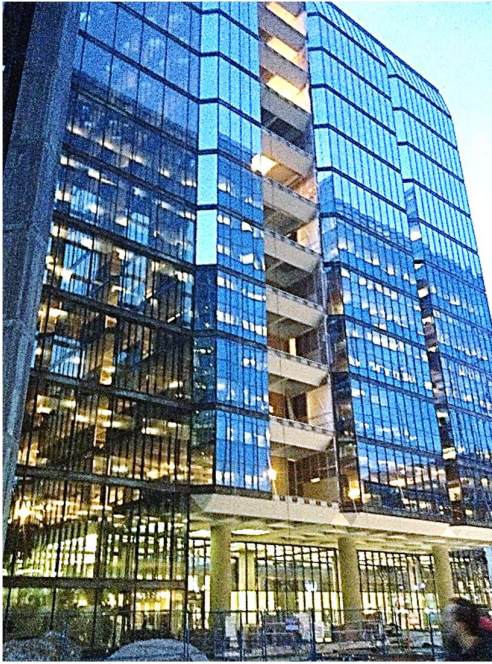


## Social and Economic Benefits

### Economical Benefits

**Sustainable design**, a core principle at **BPA**, considers the environment and the impact of design solutions to the world around us. Attention was paid during the Bank of Canada Renewal Project to the occupants' well-being, energy efficiencies, productivity, and recognition of the connection to nature established by Erickson's 1970's design.

*Exterior West Tower*



The Renewal Project restored the office tower floorplates to their original, largely open concept. Collaborative meeting spaces introduced in the buildings' lower levels allowed for controlled access of external guests. The Atrium, redesigned with landscape material of Canadian greenery, provides a variety of collaborative work scenarios.

The Bank of Canada was committed to delivering a sustainable project based on LEED® principles. The LEED Gold Certification application shows that the energy model performed 43.8% better than ASHRAE 90.1 2007 in terms of energy consumption, and 30.9% better in terms of cost. Based on utility bills, the annual energy consumption before renovations was approximately 125,000 GJ and was reduced to 48,321 GJ after renovations, resulting in savings.

The Bank of Canada Head Office Renewal Project followed a methodical process using a construction

management delivery model. BPA was first involved with the completion of an Infrastructure Renewal Feasibility Study. The project included schematic drawings for alternative schemes for new HVAC, plumbing and electrical power systems, along with a Study Report in several iterations integrating overall architectural and planning options. Detailed energy modelling was provided using E-Quest to predict the energy performance of each option, along with direct payback and lifecycle costing of energy efficiency measures. This phase of the project took place from September 2011 to January 2012.

The Bank selected an integrated design team to proceed with the Head Office Renewal Project. The project was phased to include occupant relocation (including all office accommodations and the museum), base building renovations/retrofit, and Head Office fit-up, including the move back into the refurbished building at 234 Wellington Street. In 2013, the Bank renovations began. The anticipated budget of \$450M was carefully followed throughout the project with a mechanical budget estimated at \$100M. Energy-efficient measures totaled \$20M with a payback of eight years. Overall engineering system site changes amounted to less than 1% of the budget.

A third-party commissioning agent involved throughout the design, construction and post-construction phases of the project. Design, drawings and specifications followed a rigorous path to meet the owner's requirements. The methodology described in Guideline 0 and 14 issued by ASHRAE in terms of commissioning provided direction. The comparison of the energy consumption in the first occupied year, compared to the reference building, stands as a testament to the value of the commissioning process. The optimal energy consumption of the building is the result of a design process considering the latest technology, engineering design initiatives, and the client's acceptance of innovation. The building is a collection of coherent and adapted strategies tailored specifically for the building, the location and the climatic conditions. Automatic controls facilitate the systems' precision at the exact moment it is required in order to derive maximum benefit from the appropriate investments.



# Social and Economic Benefits

## Environmental Benefits

The MEP strategies considered by **BPA** were benchmarked and refined by means of space usage analyses, energy simulations and comprehensive calculations. The tools were fundamental to predict the behaviour of the buildings with multiple energy recovery strategies and effective sustainability goals.

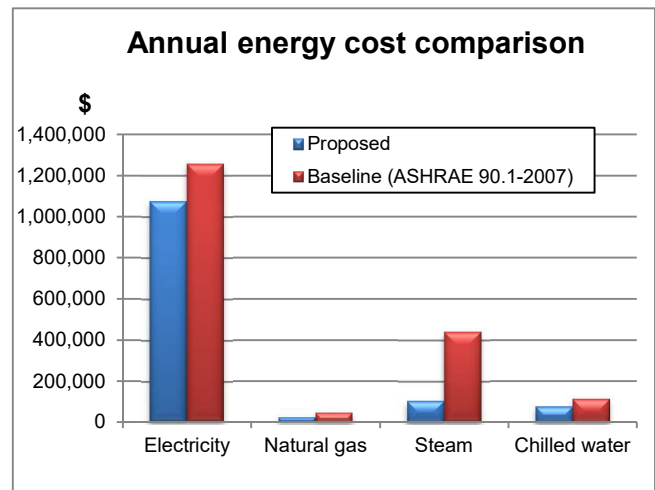
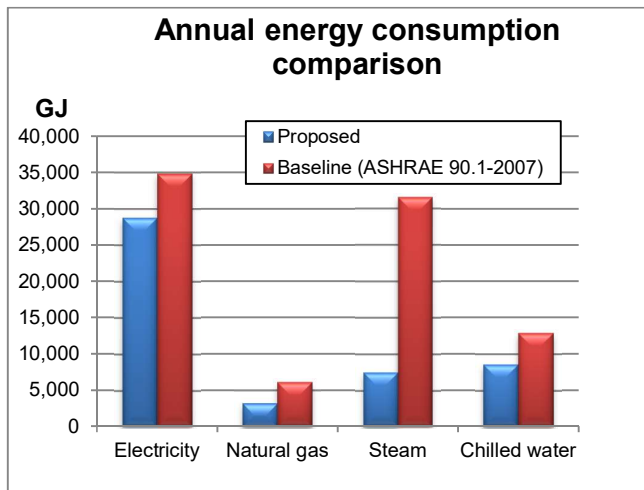
The Bank of Canada Renewal Project aimed to provide a healthy work environment based on sustainable principles. The project is LEED® registered, with LEED® Canada NC 2009 Gold certification in progress. Inherent to the Renewal Project is the location of the complex in the core of Ottawa adjacent to bus routes and bike paths, and an anchor to the pedestrian Sparks Street Mall.

The complex is 43.8% better than ASHRAE 90.1-2007 referencing energy consumption and 30.9% better referencing cost. Energy efficiency measures included efficient lighting with occupancy sensor controls and the use of dynamic buffer zones in the east and west towers to reduce heat loads. Air economizers on equipment, the use of 100% outside air for cooling; recovery of heat contained in exhaust air; chillers installed as heat pumps to recover heat from the interior zones to create hot water used to heat the perimeter of the building; and optimization of building operating sequences all benefit the environment. The HVAC and energy conservation strategies resulted in significant greenhouse gas emission reductions

including 3,700 tons of CO<sub>2</sub>, with a 31% reduction in reference to ASHRAE 90.1-2007.

From the start, the Bank of Canada's objectives were clear: to restore the existing complex and respond to a changing workforce with advancing technologies. The Renewal Project re-used the existing structure and maintained much of the existing building envelopes. Seismic upgrades were accomplished "invisibly" by reinforcing the cores of the towers, installing deep rock anchors below the existing foundations, and reinforcing the distinctive waffle slab structure. New shear walls were constructed from the third basement up to the top floors of the towers. The centre building core was rebuilt. Sustainable materials including wood and steel from regional sources promoted the local economy and limited GHG emissions.

The buildings use finishing products with low VOC content in HVAC adhesives as well as for the insulation. As per SMACNA recommendations, ductwork installation was sealed after each working day and was delivered on site sealed. Flush-out procedures took place nine days prior to occupation and 24 additional days afterwards. Indoor temperatures and humidity were monitored during this process. The duration was calculated for each HVAC system and executed simultaneously with stringent system values.



ANNUAL ENERGY CONSUMPTION STATISTICS		
Total cost	GJ/m <sup>2</sup>	\$/ft <sup>2</sup>
1,291,278 \$	0.67	1.65

## Social and Economic Benefits

The ventilation monitoring system promotes occupant comfort and well-being, most notably with respect to air quality. The densely occupied spaces were provided with automated system controls transmitted to the building operator when the conditions varied from the set point. For non-densely occupied spaces, direct outdoor airflow measurements are provided with an accuracy of plus or minus 15% of the design minimum outdoor air rate. CO<sub>2</sub> sensors with humidity monitors were included strategically on the office floorplates, in meeting rooms and conference rooms.

Ottawa has several outdoor air sampling stations that can be viewed including the website [Ottawa Downtown, Ontario, Canada Air Pollution: Real-time PM2.5 Air Quality Index \(AQI\)](#). Generally, the most elevated contaminants found in Ottawa are PM<sub>2.5</sub>, O<sub>3</sub>, NO<sub>2</sub>, CO and SO<sub>2</sub>. The levels however are below the EPA's established guidelines. Neighbours that might produce contaminants or alter the outdoor air data are absent.

The filtration sections of the air treatment units have pre-filters at MERV 8 minimum efficiency with some cartridge filters of MERV 13 efficiency. The decentralized systems, including the heat pumps,

have filters of MERV 8 efficiency. For the kitchen extractor, the compensated outside air is filtered by MERV 8 filters. The filters' efficiency complies with ASHRAE 52.2-2007, and are part of a regular maintenance program. When comparing ventilation rates considering space usage, the installed airflow exceeds ASHRAE standard 62.1-2007 at normal occupancy densities.

The design of the air conditioning systems in the Bank of Canada buildings respects the criteria established by the ASHRAE Fundamentals for a condition of 0.4% in air conditioning and 99.6% in heating, by using the meteorological data of the nearest station. In the conditioned zones, the HVAC systems are designed to maintain a maximum of 50% humidity at all times. The overall air balancing of the building is maintained at positive pressure to avoid air infiltration.

The Water Efficient prerequisite and requisite credits are addressed with the use of low-flow plumbing fixtures including toilets, urinals, lavatory, cafeteria and kitchenette sinks and infrared controls reducing water consumption by 35.03%.

## Meeting Client's Needs

The Bank of Canada Head Office Renewal Project aimed to address performance and infrastructure deficits, modernize and elevate the Bank as a workplace, address life safety compliance, achieve higher levels of sustainability, and improve security all while preserving the cultural and historical significance of the complex. The public spaces around the Bank of Canada at a significant downtown location anchor the Spark Street outdoor pedestrian mall, and are adjacent to Parliament Hill. The Renewal Project was awarded the 2017 Award of Excellence: Public Places and Civic Spaces from the City of Ottawa.

**Knowledge Centre**  
Photo credit: Bank of Canada



Accomplishing these objectives were essential to remain relevant as a workplace and the home of Canada's foremost financial institution. Within the office towers, the floor plates were restored to their original, largely open concept. Seismic upgrades reinforced the cores of

the towers and the distinctive waffle slab structure. Systems upgrades were achieved using the latest technology to expose the structure of the towers as Erickson had intended. To achieve this, the design team leveraged the skills of all disciplines. To minimize ductwork, a "dynamic buffer zone" and radiant cooling system were added to address principal heating and cooling needs. This allowed ducts sized for the ventilation requirements only. Radiant panels conceal the optimized ductwork and other system devices within the coffers, and introduces new sprinkler piping for fire protection. The extensive power and data cabling needs of the modern office are serviced through a low-profile access floor for long-term flexibility.

Throughout the design process, operations and maintenance of engineering systems remained a consideration. The equipment was designed to be easily accessible. The Building Automation System was centralized and converged with other systems to allow exchange of information, providing a smart-building to the occupants and operators.