HIGH PERFORMANCE ROOFTOP SYSTEMS
FOR MEDIUM COMMERCIAL BUILDINGS

The design of the HVAC system at Santé Centre began with a conversation about saving energy in commercial buildings. The goal was to optimize building performance and minimize the energy intensity of the building.

In order to take advantage of the economies of scale associated with a mature and experienced rooftop industry we explored and then implemented a combination of emerging technologies including; high performance rooftop heat pumps, energy recovery ventilators, variable air volume distribution systems, and advanced building automation systems (BAS) strategies and sequences.

The actual results have surpassed expectations. Based on the first year of measured data, the actual energy intensity of the building is 12.684 kWh/ft^2, which is almost 50% less than the average Atlantic Canada medium commercial building. The first year's annual operating costs are at an impressive $1.982 per square foot. The revised economic analysis updated to account for the vacant space (approx. 13%) within the building shows an annual savings of $29,597 a payback of just over 5 years for the investment in the High Performance system adopted.

The adoption and advancement of these emerging technologies presents a real economic opportunity for all stakeholders and especially for building owners and businesses. PMC and Nova Scotia Commercial Solutions have the knowledge and expertise to help you explore advanced rooftop solutions for your next project.

May 2017

Prepared by:

Scott Hue, B.Eng
PMC – Performance Management Company Ltd

Sponsored by:

Steve McDougall
Nova Scotia Power Commercial Solutions

TABLE OF CONTENTS

EXECUTIVE SUMMARY

In 2016, the average rent for an office in Halifax was a little over $25 per square foot. Annual energy costs make-up a significant portion of this figure and can range from $2.00 to as high as $4.00 per square foot depending on the building performance and mix of energy sources. To put this in perspective, the annual energy costs of an average 50,000 square foot office building in HRM totals $150,000 (using $3.00 per square foot).

Natural Resources Canada reports that 55% of the annual energy consumption in commercial buildings is used for space heating with additional 4% associated with space cooling. Commercial buildings less than 50,000 square feet account for over 90% of all existing commercial buildings in Canada. Rooftop units (RTUs) are the predominant method of providing heating, cooling and ventilation requirements to these buildings; mainly due to their ease of installation, comparably low upfront installation cost, and minimal engineering requirements.

Advances in rooftop unit technology, however, have been incremental in nature and the bulk of rooftop units installed today utilize old technology. Industry estimates suggest that more than 70% of rooftop units are single speed systems, 40-50% of these systems are oversized, and that 60-85% of them suffer from major inefficiencies such as economizer malfunctions or improper charge and airflow. As a result, many RTU systems provide improper ventilation rates which results in poor occupant comfort and also contribute to significant energy waste.

So how do we take advantage of the economies of scale associated with a mature and experienced rooftop industry but also improve system efficiencies to ultimately reduce the total energy costs and operating expenses of commercial buildings? In 2011, US Department of Energy (DOE) released the “High Performance Rooftop Unit” specification as part of the High Performance Rooftop Unit Challenge that encourages manufacturers to introduce systems with best-in-class efficiency. ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) also released its new 90.1-2013 standards, which includes mandatory increased efficiency standards on packaged rooftops units for both air-conditioning-only and heat pump models.

Although heat pump technology is well established and known to provide significant energy savings compared to standard electrical heaters or fossil fuel equipment; rooftop heat pumps have often been overlooked in the past due to the cold nature of the Canadian winters. Advances in refrigeration technology and new supplementary heat options including modulating natural gas and modulating electric resistance sections have created new opportunities for the implementation of these new High Performance Rooftop Heat Pumps.

Taking advantage of High Performance Rooftop Heat Pumps is also made easier with an advanced Building Automation Systems (BAS). It has been shown that uncontrolled building operations lead to unnecessary energy waste of 10% to 25%. BAS systems help drive savings and they allow building owners to get the most out of the new technology available in high performance rooftop units.

Energy recovery ventilation (ERV) units can also have a significant impact on overall building energy performance reducing the energy associated with heating and cooling the ventilation air by more than 50%. This technology has allowed for the scaling down of the rooftop equipment, which without the application of ERV’s needs to be of sufficient capacity to meet both the building heating and cooling loads, but also the loads imposed by the conditioning of the ventilation air introduced to the building.

This whitepaper’s purpose is to share PMC’s and Nova Scotia Power Commercial Solutions’ experience with interested stakeholders; detailing our approach to HVAC system optimization and to the application of the aforementioned systems and technologies at Santé Centre in Bedford, Nova Scotia. The real-world measured results have been very positive and has resulted in a building energy performance almost 50% less than the average commercial building in Atlantic Canada.

BACKGROUND AND ACKNOWLEDGEMENTS

The impetus behind this project is attributed to the vision and determination of Drs. Jason Plotsky and Cindy Toner. They have been chiropractors and health advocates for over 13 years and their dream was to assemble and hand pick businesses that would assist people on their journey towards optimal health.

The Santé Centre (pictured above) became home to this like-minded team of professionals. During its design and development an important consideration was comfort and annual operating costs. As new building owners Drs. Jason Plotsky and Cindy Toner made a conscious decision to invest in the competiveness of their businesses by targeting energy efficiency. So the project began there - with a conversation about saving energy in commercial buildings.

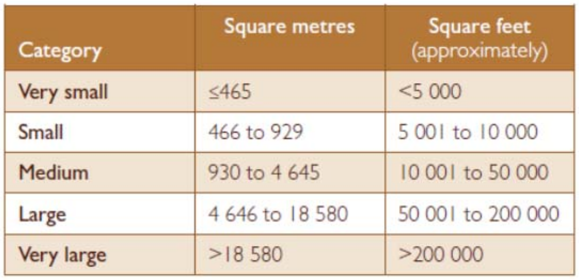
The formal building design process started in the spring of 2014, construction began in late 2015 and various tenants began moving in by the spring of 2016. The building is two storeys, tilt-up construction and has a total floor space of 20,265 square feet.

A number of other organizations contributed critically to the execution and success of the project including: DOC Consultants Inc., Electec Engineering, PMC - Performance Management Company, Nova Scotia's Power Commercial Solutions Group, Efficiency Nova Scotia, Lindsay Construction, Martin Developments, Distech Controls, Global Mechanical, Daikin, and others. Their input and support is appreciated.

BUILDING PERFORMANCE AND ENERGY INTENSITY

Annual energy costs in commercial buildings represent a significant portion of the total costs to operate a building. In Halifax, these costs range between $2.00 and $4.00 per square foot annually. Energy costs account for between 15% and 35% of the total annual operating budgets of commercial buildings (which also includes property taxes, insurance, cleaning, landscaping, security, and telecommunications). There is a vested interest for all stakeholders of commercial buildings to optimize building performance and minimize annual energy costs.

One way to gauge the energy performance of a building is to measure its energy intensity. Energy intensity of a building is defined as the ratio of the total annual energy consumption to the total floor space. Energy intensity for different building types is benchmarked and reported by various organizations in Canada including: NRCAN, BOMA, NB Power Energy Smart, and EnergyStar. Various units of measurement are commonly used including: ekWh/ft^2, GJ/m^2, and kBtu/ft^2. Buildings are also commonly classified into size categories from Small to Very Large.



Category	Square metres	Square feet (approximately)
Very small	≤465	<5 000
Small	466 to 929	5 001 to 10 000
Medium	930 to 4 645	10 001 to 50 000
Large	4 646 to 18 580	50 001 to 200 000
Very large	>18 580	>200 000

Figure 1 - Table from Natural Resources Canada - C & I Energy Use 2009

In Canada the average energy intensity of all Medium commercial buildings is 1.03 GJ/m^2 (or 26.58 kWh/ft^2). **In Atlantic Canada the energy intensity of the average office building (non-medical) was 0.97 GJ/m^2 (or 25.03 kWh/ft^2).** Medical office buildings in Atlantic Canada had a slightly lower intensity of 0.80 GJ/m^2 (or 20.645 kWh/ft^2). Food and beverage had the highest energy intensity at 2.22 GJ/m^2 (or 57.29 kWh/ft^2) and non-food retail had a respectable energy intensity of 0.76 GJ/m^2 (or 19.62 kWh/ft^2).

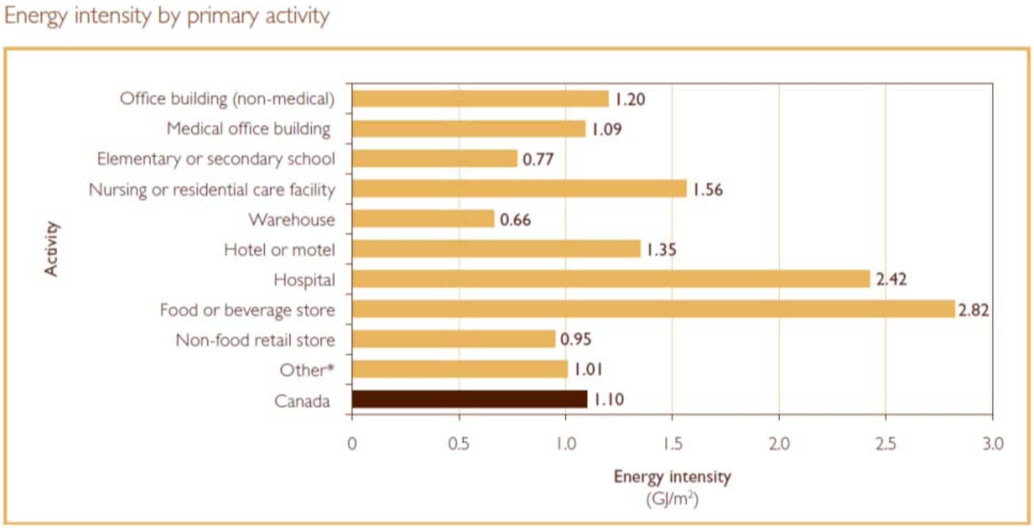


Figure 2 - Figure from Natural Resources Canada - C & I Energy Use 2009

There are several solutions available on the market to reduce the energy intensity and energy costs of medium commercial buildings; however during this initiative we focused on high performance rooftop heat pumps, energy recovery ventilators, and modern building automation systems and control sequences.

HVAC OPPORTUNITIES FOR MEDIUM COMMERCIAL BUILDINGS

TECHNOLOGY REVIEW: MEDIUM BUILDINGS AND ROOFTOP UNITS

Commercial buildings less than 50,000 square feet account for over 90% of all existing commercial buildings in Canada and just over 37% of all commercial floor space (NRCAN - Commercial and Institutional Building Energy Use Survey 2000).

Heating, cooling and ventilation in commercial buildings is served predominately (over 40%) by rooftop packaged air conditioners (RTUs). RTUs are used widely throughout Canada for their ease of installation, comparably low-upfront installation cost, minimal engineering requirements, and ease of replacement at end of lifecycle.

Over the last decade advances in rooftop units have been incremental in nature and the bulk of the rooftop units installed today still utilize old technology. Industry estimates suggest that more than 70% of existing installed rooftop units are single speed systems, that 40-50% of these systems are oversized, and that 60-85% of them suffer from major inefficiencies such as economizer malfunctions or improper charge and airflow (Jacobs 2003, Woolley 2011).

Change, however, is happening. ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) released its new 90.1-2013 standards, which amongst other items includes mandatory increased efficiency standards on packaged air-cooled rooftops for both air-conditioning-only and heat pump models.

In 2011, the US Department of Energy's (DOE) office of Energy Efficiency and Renewable Energy (EERE) also released the "High Performance Rooftop Unit" specification (DOE 2015) as part of the High Performance Rooftop Unit Challenge that encourages manufacturers to introduce systems with best-in-class efficiency. Several manufacturers have exceeded targets set-out by DOE's challenge including; Daikin, Trane, Carrier, and Lennox - and there continues to be advances.

There are four key efficiency advantages provided by High Performance rooftop air conditioners and heat pumps:

1. Variable speed fans reduce fan energy used for continuous ventilation and for part capacity cooling and heating.
2. Staged or variable speed compressors can adjust capacity dynamically and avoid losses associated with cycling.
3. Advanced economizer controls minimize the need for mechanical cooling during favorable conditions.
4. Modern controls and automated fault detection avoid excessive operation and help to keep efficiency on point

Beyond these key improvements, High Performance rooftop units can incorporate a number of other efficiency features including demand controlled ventilation, electronic control for expansion valves, demand response capabilities and variable speed condenser fan controls.

The combination of these technologies provides an opportunity for a 40% to 60% decrease in energy consumption compared to a standard rooftop.

TECHNOLOGY REVIEW: ROOFTOP HEAT PUMPS

Heat pump technology is well established and known to provide significant energy savings compared to standard electrical heaters or fossil fuel equipment. As heat pumps only move heat and do not actually generate it, they have a very high ratio of heat output to energy input. This heating energy efficiency is expressed as a coefficient of performance (COP), while cooling energy efficiency is expressed as an energy efficiency ratio (EER).

Typical heat pumps have a COP of 2 to 4.5, which means the heat pump produces about 2 to 4.5 times as much heat as the electricity it uses. The efficiency of an air-to-air heat pump decreases as the temperature difference between source and supply increases. As outside temperatures drop, the heat pump's energy efficiency reduces.

In practice, a COP of 1.0 will typically be reached at an outdoor temperature around −18°C (0°F) for air source heat pumps. Also, as the heat pump takes heat out of the air, some moisture in the outdoor air may condense and possibly freeze on the outdoor heat exchanger. The system must periodically melt this ice; this defrosting translates into additional energy expenditure. When it is extremely cold outside, it is wise to heat using an alternative heat source rather than to run an air-source heat pump. Also, avoiding the use of the heat pump during extremely cold weather translates into less wear on the machine's compressor.

Rooftop heat pumps have been overlooked in the past due to the cold nature of the Canadian winters. Advances in refrigerant technology and low-ambient controls have improved heat pump performance and efficiencies at low temperatures. In addition, rooftop heat pumps were previously only available with limited choices for supplementary heat. New advanced rooftop heat pumps such as the Daikin Rebel are now available with supplementary heat options including modulating natural gas and modulating electric resistance sections. These units can be set-up to switch from heat pump mode to their supplementary heat source when outdoor air conditions become overly cold. For example, the Daikin Rebel provides a COP of 2.35 at -8.3°C (17°F) and below that the unit can be set-up to switch to its auxiliary heating source. It is interesting to note that in Halifax the average daily temperature in January is -5.9°C which indicates that the supplementary heating source would not be required as often as one might expect. Halifax does experience more severe extremes (as low as -28.5°C), however, the data over almost 30-years shows that during the worst month of January there are only 16-days below -10°C and 1.8-days below -20°C.

HALIFAX Climate Normals 1981-2010 Station Data

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daily Average (°C)	-5.9	-5.2	-1.3	4.4	10	15.1	18.8	18.7	14.6	8.7	3.5	-2.4
Daily Maximum (°C)	-1.3	-0.6	3.1	9.1	15.3	20.4	23.8	23.6	19.4	13.1	7.3	1.7
Daily Minimum (°C)	-10.4	-9.7	-5.7	-0.3	4.6	9.7	13.7	13.7	9.7	4.2	-0.4	-6.4
Extreme Maximum (°C)	14.8	17.5	25.6	29.5	32.8	33.4	33.9	35	34.2	25.8	19.4	16.3
Extreme Minimum (°C)	-28.5	-27.3	-22.4	-12.8	-4.4	0.6	6.1	4.4	-0.8	-6.7	-13.1	-23.3

Days with Minimum Temperature

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
> 0 °C	1.3	1.3	3	12.8	29	30	31	31	30	26.4	12.9	3.8
<= 2 °C	30.5	27.8	30	24.1	6.8	0.04	0	0	0.24	10.5	21.8	28.9
<= 0 °C	29.7	26.9	28	17.2	2	0	0	0	0.03	4.6	17.2	27.2
< -2 °C	27.2	24.7	23.2	7.6	0.21	0	0	0	0	0.79	11.7	23.2
< -10 °C	16	13.7	5.9	0.03	0	0	0	0	0	0	0.52	8.6
< -20 °C	1.8	0.76	0.18	0	0	0	0	0	0	0	0	0.21
< - 30 °C	0	0	0	0	0	0	0	0	0	0	0	0

Another past limitation of rooftop heat pumps was capacity control. For example, a vintage 10-ton rooftop heat pump would have typically included two fixed capacity compressors and a constant speed fan. During milder winter conditions, when only a portion of the heating capacity was required, the first step in providing heat would be to initiate both compressors simultaneously representing 100% of the unit's total heating capacity. This limitation often causes short run-times and repeated cycling of the compressor. This, in-turn, results in hot-cold-hot temperatures distributed to the space creating discomfort for the occupants. The advances of variable speed compressors and fans allow a much greater flexibility in delivering just enough heat as required by space demands. This advancement presents opportunities to more seriously consider rooftop heat pumps in commercial building applications.

TECHNOLOGY REVIEW: DAIKIN REBEL

Although we investigated several rooftop options during the design phase of our project, the Daikin Rebel offered the best performance and available options in the required heat pump capacity. We felt it worthwhile to note within this report some of the features available for these units.

The Rebel is offered in three standard cabinet sizes; 3 to 6-tons, 7.5 to 15-tons, and 16 to 28-tons.

Variable Speed Inverter Scroll Compressor
- Optimum comfort via modulating capacity control
- Exceptional part-load efficiency
- Enclosed for quiet operation
- Improves comfort with outstanding discharge air temperature control

Variable Speed Heat Pump
- More economical than gas heat during winter
- Back-up heat options for extreme cold weather and defrost operation
- Greater comfort control via modulating capacity

Direct-Drive Variable Speed ECM or VFD Fan Motors
- Increase system reliability and efficiency by eliminating belts and bearing setscrews
- Increase energy savings at light-load conditions
- High fan efficiency with backward-inclined design

Supplemental Heat Options
- Gas furnace with 10:1 turn-down, Electric heat with SCR, or Hot water heat

Electronic Expansion Valves
- Deliver optimum control of superheat and prevent liquid refrigerant compressor slugging
- Increase efficiency by lowering head pressure

Energy Recovery Wheel
- Recovers exhausted heat and moisture energy providing energy savings up to 40%

100% Outdoor Air Option
- Low-leak dampers, double-wall blades, edge, and jam seals improve energy savings

Economizer and Outdoor Air Damper Control
- Free cooling when outdoor conditions prevail and integrated operation with mechanical cooling
- Increases efficiency with demand control ventilation
- Building pressure over-ride automatically opens dampers

Double-Wall Foam Cabinet
- Energy efficient R7 and R13 foam-injected panels providing fiber-free air stream

Low Audible Condenser Fans
- Fully modulating head pressure control and low ambient energy savings with variable speed ECM motor(s)

MicroTech® III Unit Controller
- Simplified BAS integration using BACnet® or LONMARK® communications
- Improved serviceability with intuitive unit diagnostics

TECHNOLOGY REVIEW: BUILDING AUTOMATION SYSTEMS (BAS)

Building automation is the automatic centralized control of a building's heating, ventilation and air conditioning, lighting and other systems through a building management system or building automation system (BAS).

Commercial buildings less than 50,000 square feet account for over 90% of all existing commercial buildings in Canada and it is estimated that less than 10% of these buildings have Building Automation Systems (BAS). The consequence is that uncontrolled building operations lead to unnecessary energy waste of 10% to 25%. Using the energy performance (26.58 kWh/ ft^2) of an average Canadian building under 50,000sq.ft as an example, and an average cost of $0.10 per kWh, this energy waste can represents between $13,290 and $33,225 annually.

Even as building automation systems (BAS) become increasingly utilized in larger commercial buildings, they are often overlooked as an option for small and medium sized commercial facilities. In some cases, it is because they are perceived as too expensive or complicated for this application.

Building automation provides an ongoing connection and visibility to how the building and its systems are performing. Modern BAS systems are web-enabled allowing remote access to these control capabilities. BAS systems offer a range of functionality and control, including: customizable alarm notifications, 365-day scheduling, area control, and optimal start and stop features. BAS technology also enables the utilization of energy management solutions making it easier to monitor building data and gain insights into building performance.

BAS solutions also provide greater insight and enable access to a wealth of data regarding what’s happening in a building. For contractors, this additional connection to the building and its systems provides an opportunity to act as a proactive partner in maintaining and servicing the building — for faster troubleshooting and efficient resolution of issues. Issues or problems can be identified prior to a service visit, so they can prioritize service work for the most critical issues and come prepared with any necessary parts for maintenance. A BAS also enables contractors to receive email alarms and alerts, so they can notify customers of issues before they impact occupant comfort.

HVAC rooftop equipment is also becoming more advanced with new technologies, which helps optimize building performance and significantly improve the bottom line. Taking advantage of these high-efficiency, variable-speed technologies in rooftop units is made easier with advanced building controls. This helps drive savings and allows building owners to get the most out of the new technology in rooftop units.

TECHNOLOGY REVIEW: RTU’S AND VARIABLE AIR VOLUME (VAV) SYSTEMS

Variable Air Volume (VAV) is a type of heating, ventilating, and/or air-conditioning (HVAC) system. Unlike constant air volume (CAV) systems, which supply a constant airflow at a variable temperature, advanced VAV systems vary both airflow and temperature. A basic VAV system consists of a fan, cooling and heating coils, filters, supply and return ducting and VAV terminals (often called a VAV box) each with a room thermostat.

For VAV systems using large rooftops or built-up air handling systems the fan speed (and therefore airflow) is typically varied by the application of variable frequency drive (VFD’s). In smaller VAV systems (when rooftops under 15-tons are used), variable airflow from the unit has historically not been possible as rooftop units in this category have only been available with constant speed fans. So, to achieve the variable system airflow required for VAV systems, bypass dampers were incorporated into the system duct design. The rooftop continued to deliver a constant volume of air, but a portion of the total airflow delivered was ‘dumped’ back to the return air stream as demands from the local zones varied. In this way, variable air flow to the zones was achieved, but little energy savings occurred due to the constant nature of the rooftop fan.

New High Performance Rooftops under 15-tons now include variable speed fan technology (i.e., VFD's and ECM fan motors). This variable fan speed technology is also paired with other technologies such as variable capacity (and variable speed) compressor technology, and modulating electric heating elements or high turn-down modulating gas heating technology. The combination of these technologies means less fan energy, less air flow through the coils, and therefore reduced cooling and heating demand and energy. It also means that in VAV applications using smaller rooftops, bypass dampers can be eliminated from the design.

TECHNOLOGY REVIEW: BAS CONTROL STARETGIES AND VAV SYSTEMS

Aside from advances in rooftop technology, another key ingredient to make a VAV system truly "high-performance" is the use of optimized BAS control strategies. Some key strategies include:

Optimal Start/Stop - Optimal start is a control strategy that uses a building automation system (BAS) to determine the length of time required to bring each zone from current temperature to the occupied setpoint temperature. Then, the system waits as long as possible before starting in order for the temperature in each zone reaches occupied setpoint just in time for occupancy. This strategy reduces the number of system operating hours and saves energy by avoiding the need to maintain the indoor temperature at occupied setpoint even though the building is unoccupied. Optimal stop is a control strategy that uses the BAS to determine how early heating and cooling can be shut off for each zone so that the indoor temperature drifts only a few degrees from occupied setpoint before the end of scheduled occupancy. In this case, only cooling and heating are shut off; the supply fan continues to operate and the outdoor-air damper remains open to continue ventilating the building. This strategy also reduces the number of system operating hours, saving energy by allowing indoor temperatures to drift early.

Fan Pressure Optimization - As cooling and heating loads change, the VAV terminals modulate to vary airflow supplied to the zones. This causes the pressure inside the supply ductwork to change. In most standard VAV systems, a pressure sensor is located approximately two-thirds of the distance down the main supply duct. The VAV rooftop unit then varies the speed of the supply fan to maintain a constant static pressure. With this approach, however, the system usually generates more static pressure than necessary. When pressure independent VAV boxes and controllers with flow-sensing devices are used, it is possible to optimize this static pressure control function to minimize duct pressure and save fan energy. Each VAV controller knows the current position of its airflow-modulation damper. The BAS continually polls these individual controllers, looking for the VAV terminal with the furthest-open damper. The speed of the supply fan is then reset to provide just enough pressure so that at least one damper is nearly wide open. This results in the supply fan generating only enough static pressure to push the required quantity of air through this "critical" (furthest-open) VAV terminal. At part-load conditions, the supply fan is able to operate at a lower static pressure, consuming less energy and generating less noise than compared to using a fixed static pressure set-point.

Cooling Supply Air Temperature Reset – During cooling operation, raising the supply-air temperature (SAT) at part-load conditions can save compressor and/or reheat energy. Supply air reset may be either a simple reset to a higher temperature or demand based approach using the warmest temperature that will satisfy all of the zones in cooling (warmest zone). Increasing the SAT reduces compressor energy because it allows the compressors to unload or cycle off. In addition, SAT reset makes an airside economizer more beneficial. When the outdoor air is cooler than the SAT setpoint, the compressors can be shut off sooner and this increases the number of hours when the economizer is able to provide all the necessary cooling. For zones with low cooling loads, when the supply airflow has been reduced to the minimum setting of the VAV terminal, raising the supply-air temperature also decreases the use of reheat at the zone level.

Heating with Primary Air – The conventional way to meet space heating requirements in a VAV system is to use reheat coils (electric or hot water) and/or supplementary baseboard reheat. As the zone cooling load decreases, primary airflow is reduced. When primary air-flow reaches the minimum setting, and the zone transitions to a heating demand, the reheat coil is activated to warm the air to meet space set-point. The controller resets the discharge-air temperature setpoint upward to maintain zone temperature at setpoint until it reaches a defined maximum limit. Typically, the discharge air temperature is limited to minimize temperature stratification when delivering warm air through overhead diffusers.

Primary heating has generally not been provided by the rooftop unit in a VAV system due to difficulties in simultaneously meeting the demands of both interior and exterior zones. Especially in larger buildings, interior zones may require year round cooling as a result of high people and equipment loads. Advanced control strategies can, however, allow primary heat to be delivered from the rooftops in small and medium building applications. While in heating mode, BAS polling of the VAV zones can allow the SAT at the rooftop to be continually adjusted upwards until the warmest interior zone becomes almost too warm. This strategy becomes especially effective on the total building energy consumption when rooftop heat source is provided by heat pump technology.

Ventilation Air in VAV Systems - In a typical rooftop system, fresh outdoor air is delivered to the building through the rooftops outdoor air economizer dampers. In a typical constant volume rooftop application, outdoor air dampers are set to a minimum position (typically 15%) so as to always provide adequate minimum ventilation rates (as set-out by ASHRAE Standard 62). When the rooftop unit includes variable fan speed capability a set minimum position is generally not adequate. As the fan speed reduces, less fresh air will be drawn in through the dampers and there is a risk that inadequate ventilation will be provided. To address this issue, some advanced rooftops use flow measurement devices in the outdoor airstream to vary the position of the outdoor air dampers in order to deliver a target outdoor airflow rate regardless of the fan speed. Yet another method is to pair an Energy Recovery Ventilator (ERV) with a rooftop to deliver a constant volume of fresh air to the return air stream of the rooftop. Since the ERV is independent from the rooftop, variations in the fan speed of the rooftop do not affect the total volume of fresh air delivered. This also means that the rooftop outdoor dampers stay completely shut except for periods of free-cooling.

Demand Controlled Ventilation (DCV) - The most common method to incorporate DCV into the design of an HVAC system is to adjust the amount of outdoor ventilation based on the level of CO_2 in the building air. The CO_2 level can be monitored by a sensor located in the occupied zone or in the return airstream. How DCV is integrated into a building's HVAC system is determined by system type. For example, adding DCV to a packaged rooftop unit may be a simple process of including the CO_2 sensor into a controller that has the DCV control logic built into it. Such a system likely may serve only one, or at most a few, occupied zones and therefore is simpler to control CO_2 levels. A larger building with central air handling may serve many different occupied zones and thus complicates where and how to locate the sensor(s). Determining the proper amount of outdoor air to bring in at the central air-handling unit also is complicated by the variable occupancy patterns within the multiple zones. Properly implemented DCV provides significant energy savings by allowing the amount of the fresh air delivered to be reduced during periods of light occupancy. In Canada these savings can be significant as it is expensive to heat (and humidify) cold outdoor air to comfortable temperatures.

TECHNOLOGY REVIEW: ENERGY RECOVERY VENTILATORS (ERV'S)

Energy recovery ventilation (ERV) is the energy recovery process of exchanging the energy contained in normally exhausted building or space air and using it to treat (precondition) the incoming outdoor ventilation air in commercial HVAC systems. ERV's can have a significant impact on overall building energy performance reducing the energy associated with heating and cooling the ventilation air by more than 50%.

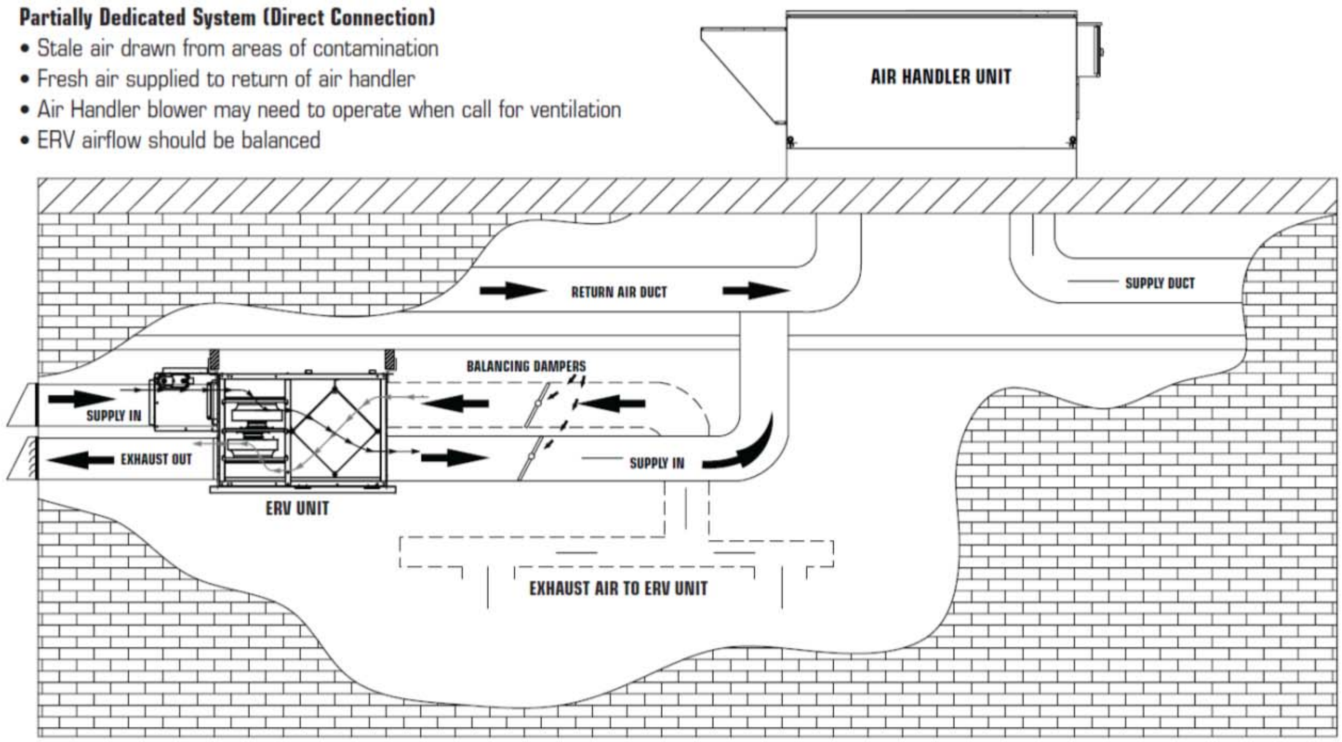
An energy recovery ventilator is a type of air-to-air heat exchanger that not only transfers sensible heat but also latent heat. Throughout the cooling season, the system works to cool and dehumidify the incoming outside air. This is accomplished by the system taking the rejected heat and sending it into the exhaust airstream. During the heating seasons the system works in reverse. Instead of discharging the heat into the exhaust airstream, the system draws heat from the exhaust airstream in order to pre-heat the incoming air.

This technology has not only demonstrated an effective means of reducing energy cost and heating and cooling loads, but has also allowed for the scaling down of equipment such as rooftops which without the application of ERV's need to be of sufficient capacity to meet building heating and cooling loads, but also the loads imposed by the conditioning of the ventilation air introduced to the building.

Canadian climates particularly benefit from ERV technology. The 2013 release of ASHRAE Standard 90.1, "Energy Standard for Buildings (Except Low-Rise Residential)," expanded the requirement for exhaust air energy recovery to systems with as little as 10 percent outdoor air in climate zones 1A, 2A, 3A, 4A, 5A, 6A, 7 and 8. Nova Scotia is located in climate zone 6A. The standard then mandates the application of exhaust air energy recovery for all system operating less than 8000hrs per year and with design supply fan airflow rates greater than 26,000cfm. If a single air handler or rooftop were to serve a building over 26,000sq.ft then an ERV would be mandated under this standard.

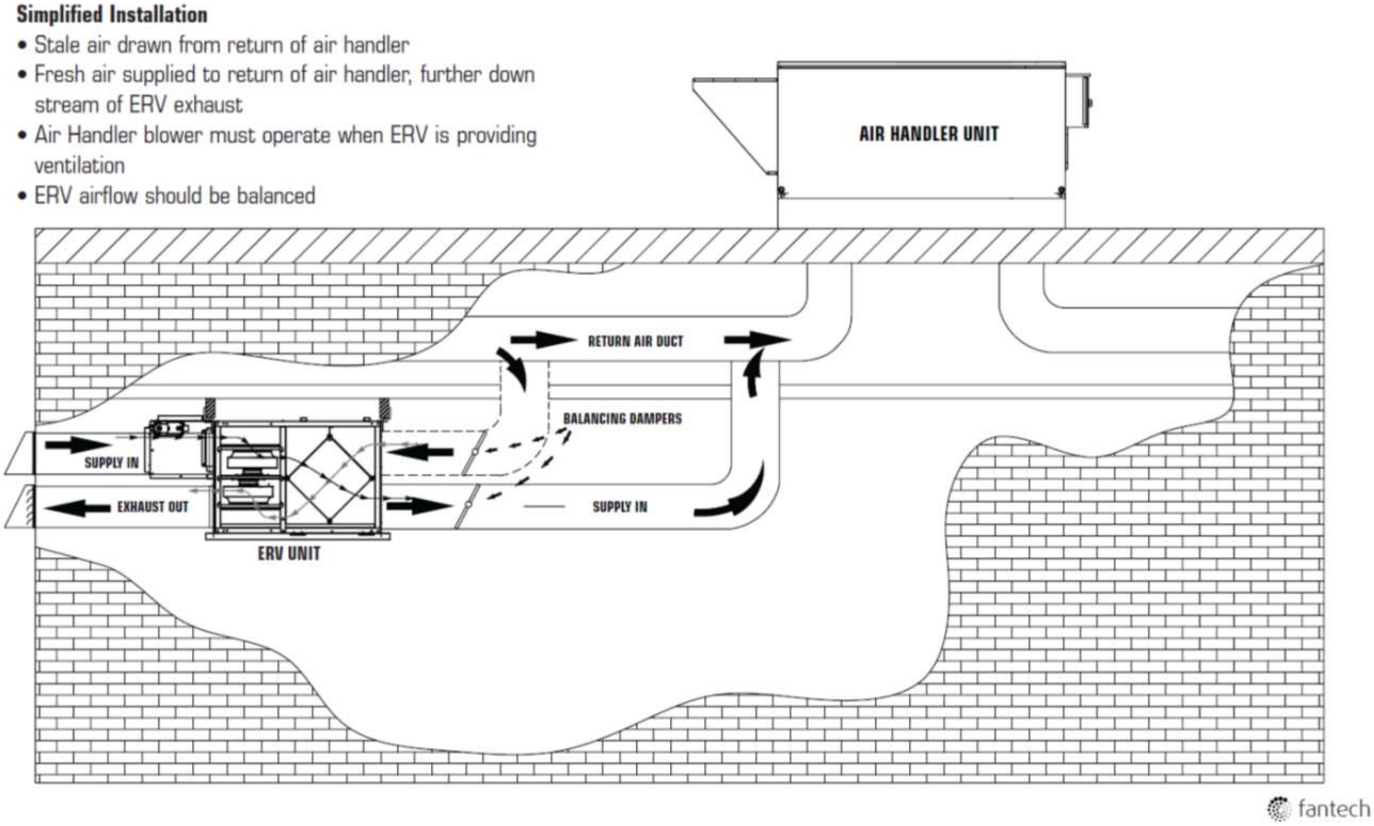
Many High Performance Rooftop units are now available with built-in integrated energy recovery technology. For example, the Daikin Rebel rooftop units are available with an optional Energy Recovery Wheels. This approach has positive energy implications for tempering of ventilation air, however, the air being exhausted through the energy recovery unit can only be drawn the space or as portion of the RTU's return air stream. From a total building design perspective this means that separate exhaust air systems would still be required for areas such as bathrooms and electrical rooms.

Another option is to pair a rooftop with a separate ERV unit. Two example installation arrangements are shown below (Fantech ERV Installation Manual 2015). This approach has the benefit of providing the capability of reducing the requirement of separate exhaust fans for key areas of the building (i.e., common washrooms and small electrical rooms). It also means that as the fan speeds changes in the rooftops it does not affect the volume of outdoor air being drawn into the rooftop unit.



fantech

Figure 3 - Source: Fantech ERV Installation Manual



Simplified Installation

- Stale air drawn from return of air handler
- Fresh air supplied to return of air handler, further down stream of ERV exhaust
- Air Handler blower must operate when ERV is providing ventilation
- ERV airflow should be balanced

Figure 4 - Source: Fantech ERV Installation Manual

PROJECT OBJECTIVES AND FINAL DESIGN APPROACH

The goal of the project was to optimize the energy performance of the Santé Centre minimizing the annual energy costs. The objective was to achieve measured annual energy intensity well below the average office building in Atlantic Canada (25.03 kWh/ ft^2).

The technology and the applications described in the previous sections established the groundwork for our design of a HIGH PERFORMANCE building system. In order to compare the economic benefits of our approach energy models were created for two BASE CASE scenarios and for two HIGH PERFORMANCE scenarios.

BUILDING DESCRIPTION AND DESIGN PARAMTERS

Santé Centre was designed as a two story, slab on grade, multi-tenant building with a total of 20,265 gross square feet to be located in Bedford, NS. The building was divided into nine (9) separate tenant spaces, plus common areas on each floor. Tenant composition was initially assumed to be a mix of office and non-medical offices. It was also assumed that the building would be occupied for 3500 hours annually.

- Wall Assembly: Precast tilt-up wall panel construction, R24 spray foam, 2.5” steel studs, 0.5” Gypsum
- Roof Assembly: Stone ballast, EPDM, R30 EPS insulation, vapor barrier, 1.5” steel deck, OWSJ’s
- Windows: Tinted double glazed low-e windows
- Interior Lights: Unknown during HVAC design – assumption of 1-watt per square foot

BASE CASE SCENARIO(S)

The BASE CASE’s represent a typical approach targeting lowest first cost and simplicity of design. The approach would be to provide (where possible) an individual rooftop unit for each tenant space. Building components included:

- Eight (8) constant volume, 5-ton rooftop AC units with electric (Scenario 1) or single-stage gas heating sections (Scenario 2).
- Ventilation air to be delivered through the rooftop units’ outdoor air dampers.
- Individual exhaust fans for common area bathrooms, electrical rooms and elevator room. Additional exhaust fans as required for tenant area bathrooms, kitchenettes, etc.
- Zoning within each space to be accomplished using by-pass (dump) boxes and stand-alone thermostats. No provision for a building automation system (BAS).
- Back-up perimeter electric baseboard on separate independent thermostats.
- Separate electrical and gas meters for each tenant and for a house panel.

HIGH PERFORMANCE SCENARIO(S)

Several strategies were adopted to improve both the efficiency of rooftop air conditioners and the building performance as a whole. Energy efficient building components included:

- Four (4) 10-ton Daikin Rebel rooftop heat pumps meeting US DOE EERE’s “High Performance Rooftop Unit” specification (DOE 2014). Unit features include: ultra-low leakage outdoor air dampers, variable speed compressors, ECM fan motors and fully modulating SCR style electric back-up coils (Scenario 1) or modulating gas heating sections (Scenario 2).
- Four (4) 800fcm Energy Recovery Ventilators (ERV’s) paired to each rooftop unit providing ventilation air to the return air duct of each rooftop and also providing exhaust to the common area bathrooms as well as one anticipated bathroom in each tenant space. The rooftop economizers to only be used for free-cooling and for 2nd stage or back-up ventilation requirements.

- Variable air volume (VAV) distribution and zoning system with connected and controlled perimeter electric baseboard reheats. Include High Performance features such as Optimal Start/Stop, Fan Pressure Optimization, Supply Air Temperature Reset, Heating with Primary Air, and Advanced Ventilation.
- Web-enabled Building Automation System (BAS) using advanced energy strategies and control sequences.
- Energy monitoring and management for whole building, house and tenant level consumption.

SUMMARY OF ECONOMIC ANALYSIS

Target building performance energy intensity figures were derived for each of the scenarios and an economic analysis was then applied using current energy rates. A table below shows a summary energy model outputs and the resulting economic analysis. Additional detail for both the energy model outputs and the economic analysis can be found in Appendix A and B.

Table 1 - Summary of Economic Analysis

	Scenario 1 (Primary/Backup Electric Heating)	Scenario 2 (Primary/Backup Gas Heating)
BASE CASE Energy Intensity (ekWh/sq.ft/yr.)	28.467	33.618
HIGH PERFORMANCE Energy Intensity (ekWh/sq.ft/yr.)	16.420	23.101
BASE CASE Energy Cost per Sq.Ft	$3.74	$3.40
HIGH PERFORMANCE Energy Cost per Sq.Ft	$2.55	$2.63
Total Project Cost Increase for HIGH PERFORMANCE Option	$155,342.53	$170,216.30
Annual Utility Savings (BASE CASE vs HIGH PERFORMANCE)	$23,938.54	$15,666.95
Simple Payback in Years	6.49	10.86

The results of the economic analysis were presented to the client and it was decided to proceed with Scenario 1, which represented an all-electric solution. Besides being a more attractive economic solution there was a few additional considerations that swayed the final decision.

- Natural gas rates, at the time of the analysis, were at an all-time high in Nova Scotia and there was uncertainty over future commodity pricing.
- The on-going maintenance costs – not included in the analysis – associated with the natural gas HIGH PERFORMANCE option as compared to the electric HIGH PERFORMANCE option are approximately $500 greater annually. In addition, the expected life expectancy of a gas fired heat exchanger is also lower than the electric equivalent.
- It appealed to the client to receive one utility bill as opposed to two separate bills. Since sub-metering was also being implemented, the additional infrastructure required for multiple gas meters on the exterior of the building was also considered a draw-back.

CURRENT STATUS AND MEASURED RESULTS

The energy management portion of the BAS was commissioned in April of 2016. The first full month of collected energy data began in May of 2016 while a full years' worth of data was collected by April of 2017. A summary of actual billing data, as well as measured data (using additional on-site meters) is shown below.

SUMMARY OF ACTUAL ELECTRICAL CONSUMPTION & DEMAND - Sante Centre, 50 Gary Martin Drive, NS

YEAR 1 - Baseline Development Year - May 2016 to April 2017

	2017	2017	2017	2017	2016	2016	2016	2016	2016	2016	2016	2016	
Period	**01/03-01/27**	**01/27-02/28**	**02/28-03/29**	**03/29-04/26**	**04/28 - 06/02**	**06/02 - 07/05**	**07/05 - 07/28**	**07/28 - 08/29**	**08/29-09/03**	**09/03-09/31**	**09/31-11/30**	**11/30-01/03**	
2016-2017	**JAN.**	**FEB.**	**MAR.**	**APR.**	**MAY**	**JUN.**	**JUL.**	**AUG.**	**SEPT.**	**OCT.**	**NOV.**	**DEC.**	**TOTAL**
Days in billing period (NS Power)	24	32	29	28	35	33	23	32	35	28	30	34	**363**
Predicted Consumption (kWh)	-	-	-	-	-	-	-	-	-	-	-	-	**332,756**
Actual Consumption (kWh)	27,000	32,400	27,360	21,240	14,760	12,240	10,800	16,920	21,240	19,080	21,960	32,040	**257,040**
Predicted Demand (kW)	-	-	-	-	-	-	-	-	-	-	-	-	**1,513**
Actual Demand (kW)	138.0	123.0	121.0	114.0	89.0	89.0	55.0	53.0	58.0	68.0	76.0	120.0	**1,104.00**
Total Cost ($-HST)	$4,630.27	$4,853.38	$4,390.63	$3,699.58	$2,656.87	$2,362.76	$1,837.81	$2,323.84	$2,771.66	$2,760.94	$3,139.06	$4,738.60	**$40,165.40**

Building Size (sq.ft): 20,265
PREDICTED kWh / sq.ft / year: 16.420
ACTUAL kWh / sq.ft / year: 12.684

SUMMARY OF MEASURED ELECTRICAL CONSUMPTION & DEMAND - Sante Centre, 50 Gary Martin Drive, NS

YEAR 1 - Baseline Development Year - May 2016 to April 2017

Period	**2017**	**2017**	**2017**	**2017**	**2016**	**2016**	**2016**	**2016**	**2016**	**2016**	**2016**	**2016**	
	JAN.	**FEB.**	**MAR.**	**APR.**	**MAY**	**JUN.**	**JUL.**	**AUG.**	**SEPT.**	**OCT.**	**NOV.**	**DEC.**	**TOTAL**
Total Measured Consumption (kWh)	33,290	27,864	57,086	21,511	17,780	11,730	15,151	16,445	18,113	20,719	21,740	32,040	**293,469.00**
Total Measured Demand (kW)	136.2	122.1	120.5	120.5	not avail.	not avail.	not avail.	not avail.	56.0	66.8	73.1	116.3	**811.50**
House Consumption (kWh)	17,633	14,155	10,062	9,356	11,231	8,591	10,731	11,255	10,238	9,715	9,392	17,505	**139,864.00**
Tenant 1A - Bedford Naturopathic Consumption (kWh)	731	449	711	287	0	0	0	58	89	241	473	872	**3,911.00**
Tenant 1B- Parks Health Shop Consumption (kWh)	1,842	1,594	1,786	1,092	791	642	601	626	649	775	1,289	1,786	**13,473.00**
Tenant 1C- Noggins Consumption (kWh)	2,413	2,302	2,586	2,353	1,085	651	2,127	2,366	2,322	2,490	2,432	2,268	**25,395.00**
Tenant 1D - Cortado Tasting Room Consumption (kWh)	6,222	5,659	6,177	6,027	0	0	0	331	2,847	5,065	5,148	5,676	**43,152.00**
Tenant 1E - VACANT Consumption (kWh)	0	0	0	0	0	0	0	0	0	0	0	0	**0.00**
Tenant 2F - Nova Spinal Care Consumption (kWh)	1,712	1,359	1,687	921	2,160	759	581	600	661	865	1,282	1,617	**14,204.00**
Tenant 2G - NSC Physiotherapy Consumption (kWh)	359	314	360	213	17	26	18	19	56	231	246	312	**2,171.00**
Tenant 2H - Alliance Dental Consumption (kWh)	1,931	1,648	1,869	1,139	2,169	1,025	907	1,016	1,021	1,133	1,241	1,628	**16,727.00**
Tenant 2I - One Up Fitness Consumption (kWh)	446	384	368	124	326	36	186	173	231	203	237	376	**3,090.00**

To date, the Santé Centre is performing very well and the building is consuming less energy than predicted by the HIGH PERFORMACE model outputs. It is, however, important to note that there is still one tenant space currently vacant which represents 2,651sq.ft (a little more than 13% of the total building square footage).

Using reasonable estimates for the vacant space consumption and demand results in an estimated total annual consumption of 319,654 kWh which is less than the 332,756 kWh predicted by the energy model. Given these estimates, the actual annual energy intensity of the building is estimated at 15.774 kWh/ft^2 which is 37% less than the average Atlantic Canada office intensity value of 25.03 kWh/ft^2.

Using the measured results and revisiting the economic analysis yields some positive improvements to the original business case. The updated analysis, as compared to the modelled Scenario 1 BASE CASE, shows an annual savings of $29,597 and a simple payback of just over 5 years.

CONCLUSIONS

The design of the HVAC system at Santé Centre began with a conversation about saving energy in commercial buildings. The goal was to optimize building performance and minimize the energy intensity of the building.

In order to take advantage of the economies of scale associated with a mature and experienced rooftop industry we explored a combination of emerging technologies including: high performance rooftop heat pumps, energy recovery ventilators, variable air volume distribution systems, and advanced building automation systems (BAS) strategies and sequences.

The energy model and economic analysis provided an easy justification and business case for the adoption of these emerging technologies. In the Scenario 1 HIGH PERFORMANCE case, the energy model outputs predicted a 34.40% reduction in annual energy intensity compared to the average Atlantic Canada medium commercial building and a 43.32% savings over the model created for the BASE CASE standard rooftop approach. The predicted annual savings were estimated at approximately \$24,000 and the annual operating costs would be reduced by \$1.18 per square foot (from \$3.74 per square foot to \$2.55 per square foot).

The actual results have surpassed expectations. Based on the first year of measured data, the actual energy intensity of the building is 12.684 kWh/ft^2, which is almost 50% less than the average Atlantic Canada medium commercial building. The revised economic analysis updated to account for the vacant space within the building shows an annual savings of \$29,597 a payback of just over 5 years for the investment in the high performance system adopted. The first year's annual operating costs are at an impressive \$1.982 per square foot. When fully occupied, and at today's utility rates, the anticipated annual operating cost is \$2.391 per square foot.

Given that commercial buildings less than 50,000 square feet account for over 90% of all existing commercial buildings in Canada, we believe our experiences and the measured results to date represent a significant opportunity for all invested stakeholders. The adoption and advancement of these emerging technologies provides a real economic advantage for building owners and businesses.

APPENDIX A – ENERGY MODEL OUTPUTS

ENERGY MODEL OUTPUTS

There are two scenarios or sets of energy comparisons provided below. In each scenario the only parameters that is adjusted is the fuel source for the heating sections of both the BASE CASE and the HIGH PERFORMANCE rooftop units. All of the other parameters (as detailed above) remain constant between the two scenarios.

1. In Scenario 1 eight (8) constant volume, 5-ton rooftop AC units with electric heating sections are compared to four (4) 10-ton Daikin Rebel rooftop heat pumps with fully modulating SCR style electric back-up coils.

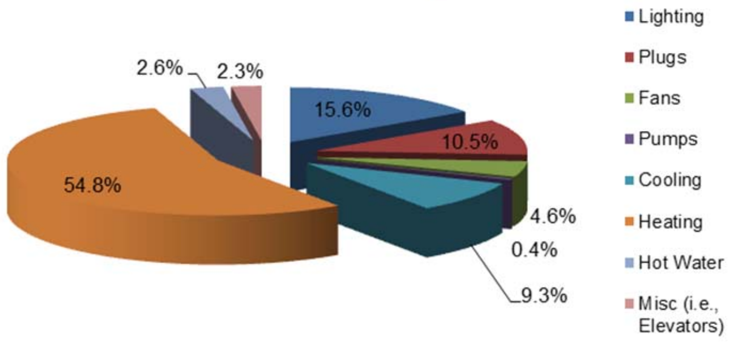
2. In Scenario 2 eight (8) constant volume, 5-ton rooftop AC units with single-stage gas heating sections are compared to four (4) 10-ton Daikin Rebel rooftop heat pumps with fully modulating gas heating sections.

ANNUAL ENERGY CONSUMPTION: SCENARIO 1

The annual energy consumption and annual demand for each system (or piece of equipment) included in the building design were modelled using the design constraints and criteria summarized previously in this report. The resulting energy model outputs were used to establish an Annual Energy Distribution as shown below.

Annual Energy Distribution by Major Component - BASE CASE - AC with Electric Heating Section

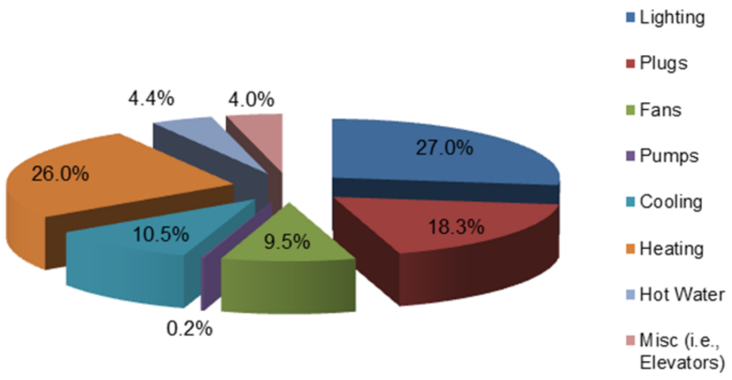
	%	kWh/yr
Lighting	15.59%	89,917.40
Plugs	10.54%	60,795.00
Fans	4.61%	26,604.85
Pumps	0.38%	2,207.76
Cooling	9.26%	53,405.67
Heating	54.77%	315,952.57
Hot Water	2.56%	14,744.12
Misc (i.e., Elevators)	2.30%	13,262.22
	100.0%	**576,889.59**



The resulting BASE CASE annual energy intensity was 28.467 kWh/ft^2 for a standard rooftop AC unit with an electric heating coil. This calculated value exceeds the average Atlantic Canada medium commercial office building energy intensity value of 25.03 kWh/ft^2, but is not unrealistic based on the design parameters included in the BASE CASE.

Annual Energy Distribution by Major Component - HIGH PERFROMANCE - Heat Pump with SCR Electric Back-up

	%	kWh/yr
Lighting	27.02%	89,917.40
Plugs	18.27%	60,795.00
Fans	9.53%	31,704.48
Pumps	0.23%	756.08
Cooling	10.49%	34,895.79
Heating	26.05%	86,680.59
Hot Water	4.43%	14,744.12
Misc (i.e., Elevators)	3.99%	13,262.22
	100.0%	**332,755.68**



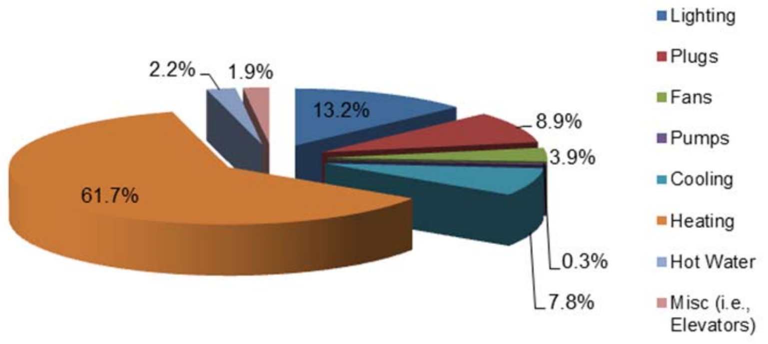
The resulting HIGH PERFORMANCE annual energy intensity was 16.42 ekWh/ ft^2. This calculated value represents a 43.32% savings over the Scenario 1 BASE CASE above and a 34.40% savings over the Atlantic Canada average.

ANNUAL ENERGY CONSUMPTION: SCENARIO 2

The annual energy consumption and annual demand for each system (or piece of equipment) included in the building design were modelled using the design constraints and criteria summarized previously in this report. The resulting energy model outputs were used to establish an Annual Energy Distribution as shown below.

Annual Energy Distribution by Major Component - BASE CASE - Gas-Fired Heating Section

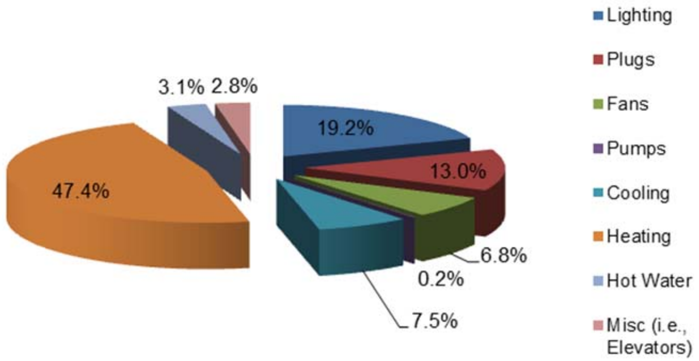
	%	kWh/yr
Lighting	13.20%	89,917.40
Plugs	8.92%	60,795.00
Fans	3.91%	26,604.85
Pumps	0.32%	2,207.76
Cooling	7.84%	53,405.67
Heating	61.70%	420,334.43
Hot Water	2.16%	14,744.12
Misc (i.e., Elevators)	1.95%	13,262.22
	100.0%	**681,271.45**



The resulting BASE CASE annual energy intensity was 33.618 kWh/ft^2 for a standard rooftop AC unit with a single stage gas-fired heating section. The energy consumption figures included in the annual distribution above are reported in equivalent kilowatt-hours (ekWh) for ease of comparison.

Annual Energy Distribution by Major Component - HIGH PERFROMANCE Modulating Gas Fired Heating Section

	%	kWh/yr
Lighting	19.21%	89,917.40
Plugs	12.99%	60,795.00
Fans	6.77%	31,704.48
Pumps	0.16%	756.08
Cooling	7.45%	34,895.79
Heating	47.44%	222,069.90
Hot Water	3.15%	14,744.12
Misc (i.e., Elevators)	2.83%	13,262.22
	100.0%	**468,144.99**



The resulting HIGH PERFORMANCE annual energy intensity was 23.101 ekWh/ ft^2. This calculated value represents a 31.28% savings over the Scenario 2 BASE CASE above and a 7.7% savings over the Atlantic Canada average.

APPENDIX B – ECONOMIC ANALYSIS

The energy model outputs were then used in conjunction with construction costs estimates to determine the economic benefit of the two HIGH PERFORMANCE scenarios as compared to the two BASE CASE scenarios. The tables below provide a summary of that analysis. At the time of the analysis NS Power Commercial Rates were $0.11841 for Tier 1, $0.08562 for Tier 2, and $10.497 for Demand and the rate for Natural Gas was $19.67 per GJ.

SCENARIO 1 ECONOMIC ANALYSIS

BASE CASE Utility Data

Annual ELECTRICAL Consumption (kWh)	576,890
Annual ELECTRICAL Demand (kW)	1,691
Energy Intensity (kWh / ft2 / year)	**28.467**
TOTAL Energy Costs	**$75,714.05**
Energy Cost per Square Foot	**$3.74**

HIGH PERFORMANCE Utility Data

Annual ELECTRICAL Consumption (kWh)	332,756
Annual ELECTRICAL Demand (kW)	1,513
Energy Intensity (kWh / ft2 / year)	**16.420**
TOTAL Energy Costs	**$51,775.50**
Target Energy Cost per Square Foot	**$2.55**

Relative Energy Savings

Annual ELECTRICAL Consumption (kWh) **Savings**	244,134
Annual ELECTRICAL Demand (kW) **Savings**	178

Financial Summary

Construction and Engineering Cost increase over BASE CASE	$178,738.60
plus Energy Management and Monitoring Services for **5 Years**	$5,900.00
minus Incentive Contribution from Efficiency Nova Scotia	$29,296.07
TOTAL Cost Increase of HIGH PERFORMANCE Option	**$155,342.53**
Total Annual Utility Savings	$23,938.54
Simple Payback in Years	6.49

SCENARIO 2 ECONOMIC ANALYSIS

BASE CASE Utility Data

Annual ELECTRICAL Consumption (kWh)	307,962
Annual ELECTRICAL Demand (kW)	1,079
Annual NATURAL GAS Consumption (GJ's)	1,344
TOTAL Equivalent Annual Consumption (ekWh)	681,271
Energy Intensity (kWh / ft2 / year)	**33.618**
TOTAL Energy Costs	**$68,944.30**
Energy Cost per Square Foot	**$3.40**

HIGH PERFORMANCE Utility Data

Annual ELECTRICAL Consumption (kWh)	271,109
Annual ELECTRICAL Demand (kW)	1,077
Annual NATURAL GAS Consumption (Litres)	709
TOTAL Equivalent Annual Consumption (kWh)	468,145
Energy Intensity (kWh / ft2 / year)	**23.101**
TOTAL Energy Costs	**$53,277.35**
Energy Cost per Square Foot	**$2.63**

Relative Energy Savings

Annual ELECTRICAL Consumption (kWh) **Savings**	36,853
Annual ELECTRICAL Demand (kW) **Savings**	2
Annual NATURAL GAS Consumption (GJ's) **Savings**	635

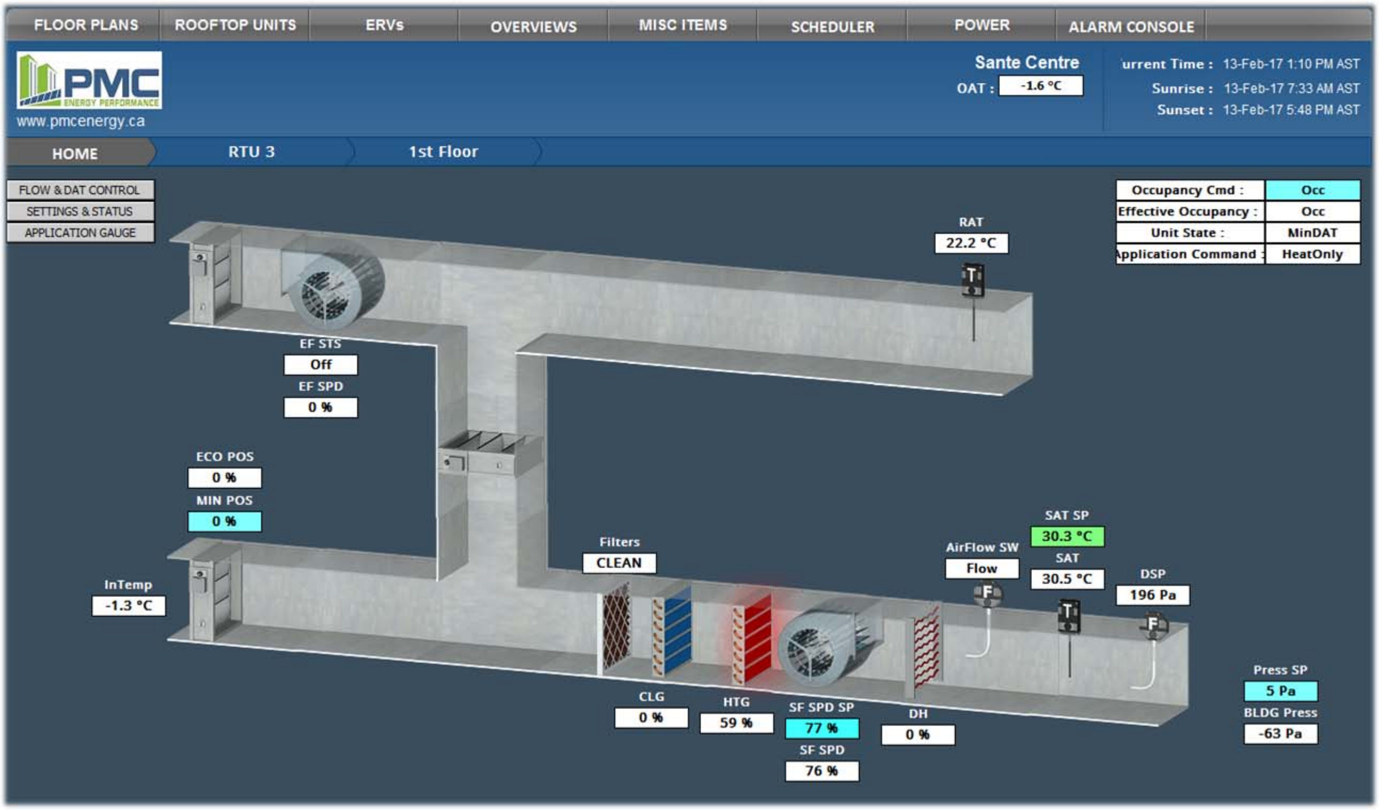
Financial Summary

Construction and Engineering Cost increase over BASE CASE	$168,738.60
plus Energy Management and Monitoring Services for **5 Years**	$5,900.00
minus Incentive Contribution from Efficiency Nova Scotia	$4,422.30
TOTAL Cost Increase of HIGH PERFORMANCE Option	**$170,216.30**
Total Annual Utility Savings	$15,666.95
Simple Payback in Years	10.86

APPENDIX C – BAS SCREEN CAPTURES

The Daikin Rebel Rooftops are working as hoped and responding well to via the BACnet integration to the Building Automation System (BAS). Some example screen capture images of the BAS system are provided below for visualization purposes.

It can be seen in the screen capture below that the rooftop is modulating at part capacity. The compressor is working at 59% to achieve a supply air temperature setpoint of 30.3°C and the ECM fan is operating at 77%.



OAT : -1.6 °C

urrent Time : 13-Feb-17 1:10 PM AST

Sunrise : 13-Feb-17 7:33 AM AST

Sunset : 13-Feb-17 5:48 PM AST

Occupancy Cmd :	Occ
Effective Occupancy :	Occ
Unit State :	MinDAT
pplication Command :	HeatOnly

RAT 22.2 °C

EF STS Off

EF SPD 0 %

ECO POS 0 %

MIN POS 0 %

InTemp -1.3 °C

Filters CLEAN

AirFlow SW Flow

SAT SP 30.3 °C

SAT 30.5 °C

DSP 196 Pa

CLG 0 %

HTG 59 %

SF SPD SP 77 %

SF SPD 76 %

DH 0 %

Press SP 5 Pa

BLDG Press -63 Pa

Figure 5 - BAS Screen Capture - RTU-3

In the screen capture image below, the yellow indictor next the VAV zones means that no occupancy has been detected for at least a one hour period and the zone has reverted to a standby setting (i.e., reduced space temperature set-point). It is interesting to note that this screen capture image was taken during an active snow storm in Nova Scotia resulting in most tenants taking an unplanned day off. The system is responding well, reducing the space temperature during this unoccupied period and thereby minimizing the energy consumption of the building.

Sante Centre

OAT : -1.6 °C

urrent Time : 13-Feb-17 1:14 PM AST

Sunrise : 13-Feb-17 7:33 AM AST

Sunset : 13-Feb-17 5:48 PM AST

Figure 6 - BAS Screen Capture - 2nd Floor