SUSTAINABLE SCHOOLS
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Air Source Heat Pump Application Guide for K-12 Schools

A Sustainable Schools Research Project | January 31st, 2025

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Summary of the Research

This Guide provides information for use by school boards and their design teams when considering application of air source heat pumps (ASHPs) for replacement of end-of-life rooftop units (RTUs), or RTU installations on new schools.

Two school boards took active part in the project, along with 3 leading equipment suppliers. A model was developed using 8,760 hour interval electricity and gas meter data for a school where an ASHP installation had just been completed. The industry partners provided equipment performance data, representative costs and technical advice. The model was first modified to incorporate energy efficiency improvements, and then used to test hourly electricity use and gas displacement due to ASHP operation, along with resulting greenhouse gas emissions reductions and utility cost impacts under alternative rate structures. Life-cycle costing (NPV) was applied to evaluate the economic case for adopting ASHPs.

Results of the work were presented in a recorded open webinar held on January 29th, 2025, attended by 21 school boards and 80 individuals, and with commentaries throughout by the 2 board representatives and the project's technical lead. The meeting included an audience poll, reinforcing the timeliness of this research:

- *9 of the 21 boards had no working experience with ASHP's.*
- *Only 3 had ASHPs in use for more than 5 years.*
- *All but 3 of the boards will be opening new schools in the next 5 years, and all of them have multiple schools with planned RTU replacements.*
- *Only 1 board stated they are not considering ASHPs, with all the others saying "maybe" or "definitely".*

The webinar recording can be found on the Sustainable Schools website.

Primary conclusions and recommendations arising from this work are:

1. *ASHP units should be specified instead of gas-fired RTUs in most circumstances. The cost premium is estimated to be less than 10%, recoverable well within the life cycle of the equipment. ASHPs are among the most cost effective decarbonization technologies, positioning school boards for the low carbon energy transition.*
2. *Energy efficiency comes first, cutting emissions and utility costs and enabling greater operation of the ASHPs.*
3. *Where natural gas is available, hybrid heating systems (ASHPs with supplementary/backup gas) displace most GHG emissions, avoid excessive electricity peaks, and optimize utility costs.*
4. *Heat recovery from exhaust systems can further reduce peak heating demand and energy use.*
5. *Solar PV arrays offset building electricity use and enable greater ASHP operation.*
6. *Smart control algorithms, limiting ASHP operation based on hourly electricity prices, OAT/COP and gas prices, can optimize utility costs and emissions reductions.*

We acknowledge and extend thanks to Toronto District School Board and Ottawa Catholic School Board, and to the project sponsors: Carrier, HTS, Trane, Enbridge Gas and the Independent Electricity System Operator, for their commitment and support of this work.

Questions, comments and suggestions are always welcome: info@sustainableschools.ca

1 Background and Scope

As the urgency to mitigate climate change grows, the need for sustainable and energy-efficient heating and cooling solutions for buildings becomes increasingly imperative. Air source heat pumps (ASHPs) are a promising technology for end-of-life replacement and new installations of rooftop units (RTUs), across all sectors and particularly schools, offering energy savings and substantial greenhouse gas emissions reductions. This Guide aims to assist school boards, facility managers, and HVAC professionals in navigating the process of adopting ASHPs for existing and new schools. With insights into ASHP technology, project economics, installation best practices and performance optimization strategies, the Guide enables stakeholders to make informed decisions and effectively implement ASHP projects.

2 Roadmap to Net Zero

The four steps of a net-zero roadmap are intended to achieve carbon neutrality at the least life-cycle cost. Maximizing energy efficiency always comes first, as the most cost-effective step which also sets the stage for deeper decarbonization by reducing peak demands and building operational capacity. Heat recovery is second, reclaiming heat currently rejected from the building in winter, which in most cases is the least cost source of energy. Electrification and on-site renewables are next, with the final step offsetting remaining emissions with carbon credits.Figure Figure 2-1highlights this GHG emissions progression.

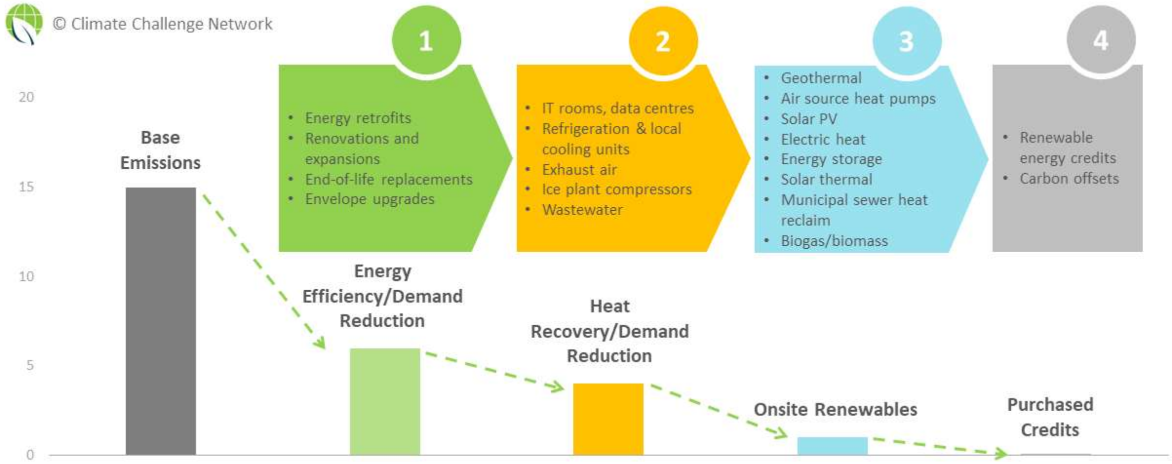

Figure 2-1: Roadmap to Net Zero Emissions

2.1 Energy Efficiency First

Maximizing energy efficiency is almost always the largest and most cost-effective step in decarbonizing buildings. It is considered a prerequisite before capital-intensive measures are implemented. Simple operational practices like scheduling, setbacks and revised sequences of operations, can substantially reduce energy use intensities and set the stage for deeper decarbonization projects.

Importantly, comprehensive energy efficiency also cuts peak heating, cooling and electrical demand, reducing capital investment in heat recovery and electrifications. Energy efficiency should address the following areas:

1. Up-to-date building automation system (BAS) and smart programming.
2. Scheduled HVAC and lighting.
3. Outside air control – optimization and demand control ventilation (DCV).
4. Fan power reduction: variable frequency drives (VFDs), static pressure optimization/reset.
5. Adaptive space heating controls.
6. Domestic hot water (DHW) controls.
7. Lighting retrofits and controls.

2.2 Heat Recovery

Heat recovery plays a crucial role by capturing and reusing waste heat rejected from buildings in winter. For schools, this is mainly from exhaust air fans. Using highly efficient heat recovery systems like enthalpy wheels, a considerable portion of the energy lost in exhaust air can be transferred to preheat/precool and humidify/dehumidify ambient air, enhancing overall energy efficiency.

2.3 Renewable Energy

Renewable energy sources such as solar PV and ASHPs displaces fossil fuel-based energy sources and reduces greenhouse gas emissions.

2.4 Carbon Credits

Purchasing carbon credits from verified emission reduction projects, such as renewable energy, afforestation and reforestation, methane capture, and energy efficiency, can offset residual emissions.

3 ASHP RTU Applications

ASHPs offer a sustainable alternative to conventional RTUs which rely on fossil fuels or grid electricity for heating and cooling. ASHPs utilize outside air as a renewable heat source, applying refrigeration principles to extract heat and upgrade it for building heating. ASHPs achieve positive Coefficients of Performance (COP) values, delivering more heating energy than the electricity they consume.

3.1 Principles

3.1.1 Cooling and Heating Cycles

An ASHP operates in two cycles: cooling and heating, by reversing the refrigerant flow between the building coil and the outdoor condenser. In cooling mode, the ASHP extracts heat from indoor air and transfers it to the outside via the condenser, functioning like a traditional air conditioner. In heating mode (see Figure 3-1), the process reverses—absorbing heat from outdoor air (even in cold temperatures) and transferring it indoors through the building coil. In heating mode, the system may adjust compressor speed, defrost cycles, and fan operation to improve efficiency in colder weather. The (recommended) hybrid ASHP includes a secondary heat source, typically a gas furnace or glycol coil supplied by gas-fired boilers, providing backup and supplementary heating in very cold weather and avoiding excessive demands on the electricity grid. Adaptive dynamic control algorithms are used to optimize energy use and peak demand, accounting for variables including outdoor air temperature, ASHP COP, hourly electricity prices, and peak demand costs, as well as gas rates.

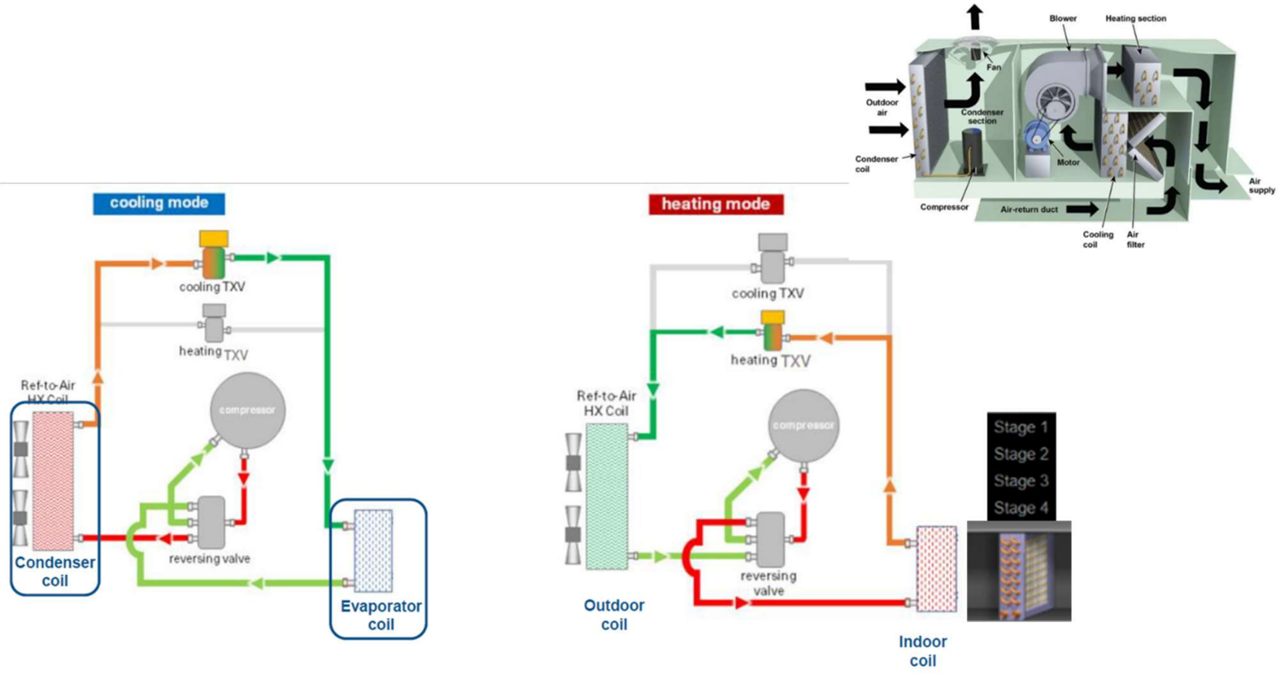

Figure 3-1: ASHP Cycles

3.1.2 Exhaust Air Heat Recovery

Heat recovery from exhaust fans in schools reduces energy consumption, peak heating demand and utility costs and is recommended wherever practicable. Enthalpy wheels (see Figure 3-2) and energy recovery ventilators (ERVs) are the most efficient option, achieving higher heat and humidity transfer efficiencies (around 80%) which improve HVAC system performance. If ducting or other constraints prevent the use of these devices, a runaround glycol coil system serves as an alternative. While less efficient (typical efficiencies around 45 – 60%), glycol loops enable energy recovery by transferring heat between exhaust and outside air streams. These heat recovery solutions optimize ASHP performance, reduce reliance on supplemental heating, and move closer to net-zero energy goals.

- Enthalpy wheel is the most efficient and should be evaluated first (typical efficiencies between 60 – 80%).
- Crossflow plate heat exchangers to be used instead when dealing with harmful or hazardous exhaust (typically efficiencies between 50 - 75%).
- Heat pipes are another alternative to avoid cross-contamination (typically efficiencies between 40 - 60%).
- Glycol runaround heat recovery can be adopted when exhaust and intake airstreams are physically separate and ducting upgrades are excessive (typically efficiencies between 40 - 60%).

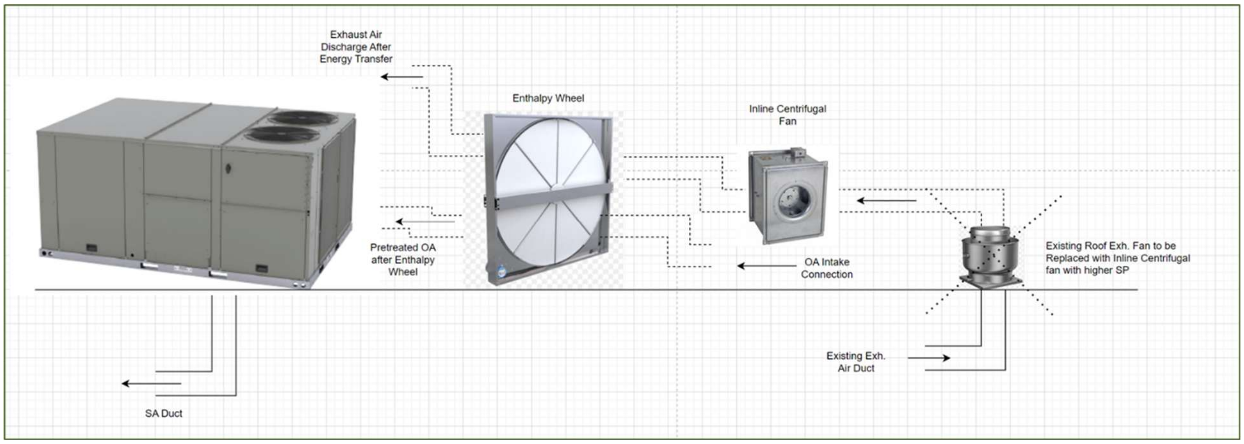

Figure 3-2: Enthalpy Wheel Heat Recovery

3.2 Heating capacities and COPs

As the weather gets colder, heating demand in the school rises at the same time as ASHPs become less efficient – they are unable to extract as much heat from the outside air. Figure 3-3 shows a typical COP range from ~ 3.5 in mild weather (when heating demand is lowest) to 1.5 in the coldest conditions when the cost of electricity to drive the machine is likely to be higher than the savings due to displaced fossil fuel. This correlation varies with internal space temperature. For this Guide, a 75°F indoor design condition has been selected.

- COP equation @ 75°F indoor design temp. = 0.0325 * OAT + 1.4926 (trend line generated from published manufacturer data)
- Capacity equation for 100TR unit @ 75°F indoor design temp. = 11.7076 * OAT + 408.72

Table 3-1shows typical average COPs by month of the year, ranging from lows around 2.4 to highs of 3.5. The table is divided between on-peak, mid-peak and off-peak periods, when hourly electricity costs, which drive ASHP operating economics, are respectively at their highest and lowest. Figure 3-4 presents the linear reduction in ASHP heating capacity with colder outdoor temperatures, with backup heating taking an increasing share of the load. Depending on utility rates, there is a cutoff point where the ASHP should shut down completely. This inverse relationship between heating demand and ASHP capacity makes the ASHP the best incomplete decarbonization solution – efficiently displacing almost all fossil fuel in milder weather (which makes up the majority of annual heating demand), but unable to contribute in the all-important coldest hours and weeks of the year.

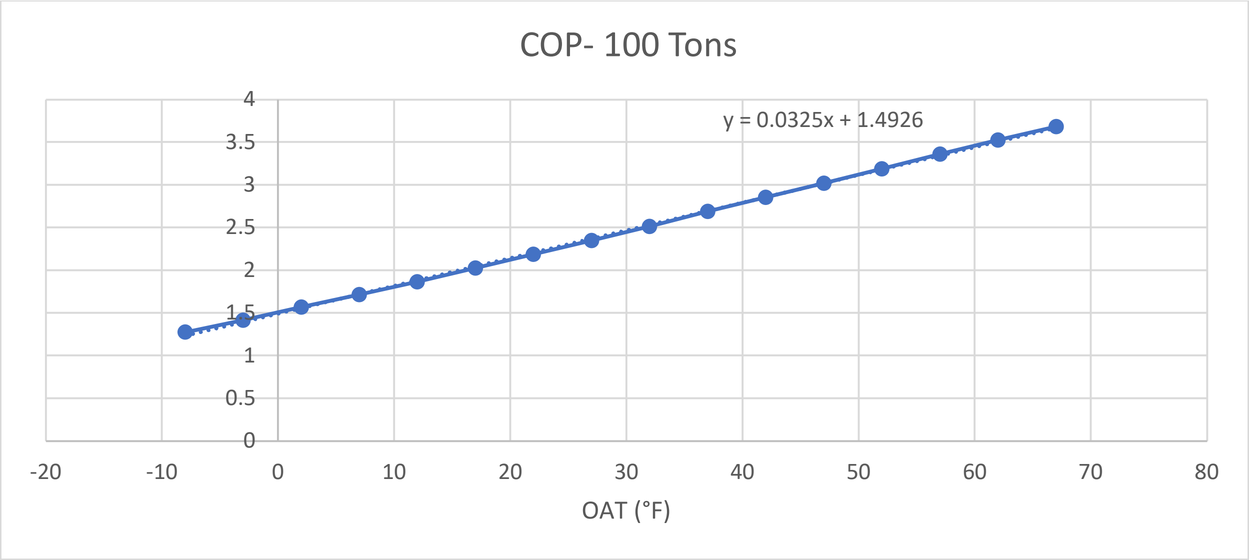

Figure 3-33: Equivalent of 100-Ton ASHP COP Curve

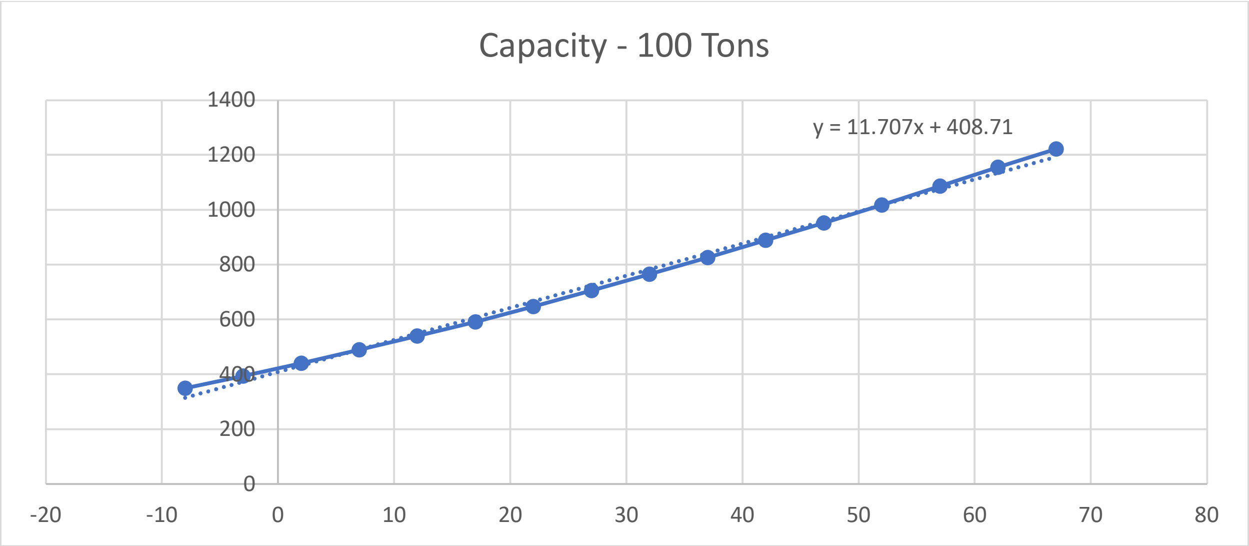

Figure 3-44: Equivalent of 100-Ton ASHP Capacity Curve

Table 3-1: Average COPs

	Time of Day	**Average COPs**											
		Sep.	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Off peak	**11pm-7am**	-	3.2	2.7	2.7	2.4	2.4	2.6	2.9	3.3	-	-	-
Mid peak	**Remaining**	-	3.3	2.8	2.7	2.4	2.6	2.8	3.1	3.5	-	-	-
On peak	**4pm - 9pm**	-	3.3	2.8	2.7	2.4	2.6	2.8	3.1	3.6	-	-	-

4 Utility Rates and Project Economics

4.1 Unconstrained vs Constrained Operation

With unconstrained operation, the ASHP runs during all hours when there is demand for heat in the building. In constrained operation, ASHP operation is limited when the hourly gas savings are less than incremental electricity costs. Constrained operation in Ontario is affected by the follow factors:

- Hourly ASHP COP and capacity equations vs outside air temperature (OAT)
- Actual variable gas price (location and contract dependent)
- Hourly Ontario Electricity Price (HOEP)
- Monthly electricity Global Adjustment (GA)
- Monthly peak kW demand cost

With the incremental gas price at \$0.42/m^3, the economic hourly electricity balance price ranges between \$0.10 (cold weather) and \$0.15/kWh.

For areas where the primary heating energy source is either propane or fuel oil, both of which are more costly than natural gas, ASHP has a wider range of operation. Table 4-1 illustrates relative fossil fuel costs at current rates.

Table 4-1: Fossil Fuel Costs

Period	Propane Cost*	Fuel Oil Cost*	Variable Natural Gas Cost
Rate (\$/L)	0.89	1.21	-
Rate (\$/ekWh)	0.13	0.12	0.04

Given that the ASHP balance point COP is governed by this simple equation, with costs of propane and fuel oil almost 3 times that of natural gas, the ASHPs economic operation would extend to much lower temperatures and COPs.

$$Balance\ ASHP\ COP = \frac{Variable\ Electricity\ Rate}{Variable\ Gas\ Rate}\ x\ \text{Heating System Efficiency (Boiler)}$$

4.2 ASHP Cost Premium

Table 4-2 shows representative ASHP equipment costs, with electric and gas back-up heating source, vs. standard rooftop units equipped with direct expansion (DX) cooling and gas furnace. Prices are out-of-factory and represent current industry averages for equipment only. Installation costs should be similar. We expect controls and commissioning costs to be higher for ASHP systems and total project cost premiums to be around 10% in most cases. Every project is different, and total project costs should be verified in each individual situation.

Table 4-2: ASHP vs RTU Price Comparison

ASHP Capacity (Tons)	Standard RTUs ($)	ASHP with Electric Back-up	Hybrid Back-up Gas Furnace	Hybrid ASHP % Increase Over Standard
5	$15,650	$18,090	$19,290	23.3%
10	$28,150	$29,360	$30,560	8.6%
15	$37,606	$39,450	$41,150	9.4%
20	$51,505	$53,950	$56,650	10.0%
25	$60,432	$63,350	$66,950	10.8%

4.3 Life Cycle Cost Analysis (LCCA)

The life cycle costing analysis shown in Table 4-3 and Figure 4-1 are based on energy modeling for Toronto District School Board's (TDSB) Chester Le Junior Public School (Chester Le JPS) (see the case study in Section 10 of the Guide) and estimated relative capital costs of a hybrid ASHP installation vs gas-fired business-as-usual RTU replacement. The adopted LCCA assumptions are in line with what is adopted by several commercial building owners.

Table 4-3: LCCA Global Assumptions

Global Assumptions	
Escalation Rates	
Electricity	2.00%
Natural Gas	2.00%
Equipment	2.00%
Labour and Maintenance	2.00%
Incentives*	$30,000
Discount Rate	6.00%
Carbon Pricing	$95 in 2025, $15 increment yearly up to $170 in 2030
Study Period (yrs)	15

** Current Ontario incentives*

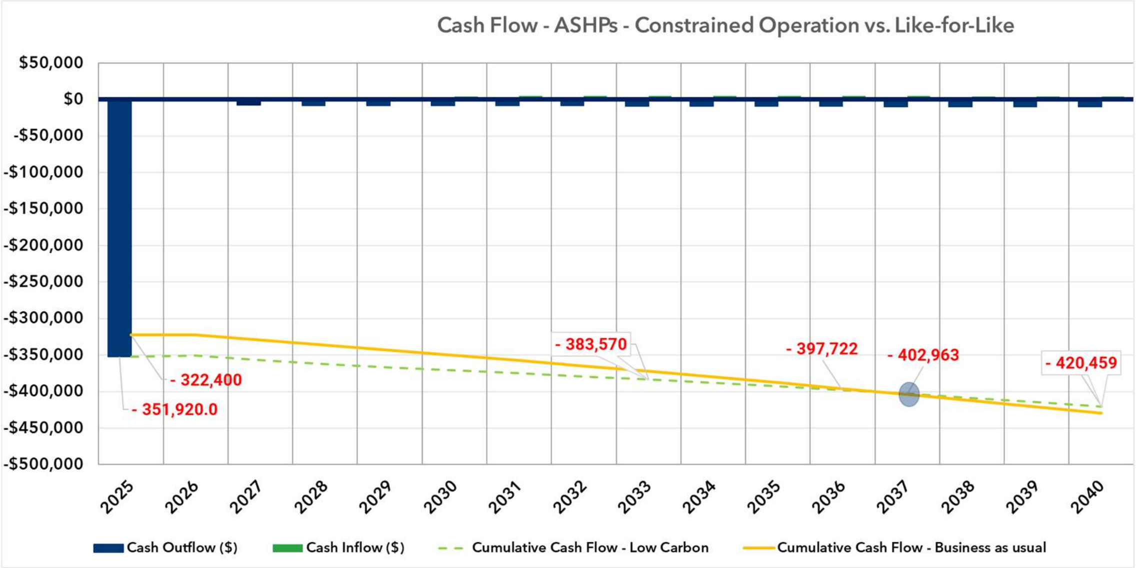

Figure 4-1: 15-year Cash Flow - Constrained Operation vs Like-for-Like

The cashflow shows first cost and ongoing annual costs as blue bars and utility cost savings (constrained operation) for the ASHP option in green. The yellow line is the net cumulative cost of the business-as usual option. The green dotted line shows the higher first cost of the ASHP option which is repaid in this model in 12 years.

4.3.1 Ontario ASHP Incentives

Current incentives for the upgrade to ASHPs provided by Ontario's Save On Energy (SOE) and Enbridge Gas Demand Side Management are summarized below.

- **Save On Energy**
    - Retrofit Program (up to $18,000) per unit depending on capacity (program still in effect).
- **Enbridge**
    - Custom retrofit incentives: $0.25/m3 for natural gas saved, up to 50 percent of project upgrade costs, to a maximum of $100,000 per project.
    - Hybrid ASHP incentives from $1,000 to $10,000 per unit. This program was running up till end of March 2024.

For current and detailed information, visit the SOE and Enbridge websites or contact their customer service departments directly.

5 HVAC System & BAS Integration

5.1 System design

Additional planning and design considerations are as follows:

- **Roof Openings**: Curb adaptors and custom transition curbs can be used to make existing openings work with the new ASHP requirements, avoiding relocation or modifications to existing roof openings.

- **Electrical Capacity**: If the ASHP project entails significant additional peak demand, verify main feeder capacity with the Local Distribution Company (LDC). Upgrades to panels, wiring, and possibly transformers, switchgear and main distribution panels may be required.
- **Demand Management**: Dynamic demand response can extend equipment life and reduce electricity costs.
- **Adaptive Control**: Apply algorithms to optimize ASHP operation based on incremental gas and electricity hourly prices, electricity monthly global adjustment factors and demand charges, ASHP performance equations and efficiencies, and OAT.
- **Training**: Educate staff/operators on ASHP operations, the different variables, and how to setup dynamic controls to optimize operation (utility savings and GHG emissions).
- **Equipment Sizing**: In general, size ASHPs based on peak cooling to avoid internal electrical infrastructure impact. Verify demand increase in winter operation especially if the school has significant electric heat, including portable classrooms. For new builds, ASHP sizing based on peak heating is not economically attractive due to the law of diminishing returns, since around 80-85% of the gas savings can be achieved by sizing the ASHPs based on the cooling load with minimal demand increase over the base case.
- **Dual Fuel (Hybrid)**: Where gas is available, ASHPs with gas-fired secondary heating are recommended to avoid excessive winter peak electrical demand and provide flexibility.
- **Modulating Controls**: ASHP fans and compressors should be equipped with VFDs and gas burners with modulation to allow seamless transition between heat pump and gas-firing operation.
- **Structural Capacity**: Typically, no structural strengthening is required. Weight density of ASHPs is generally close to same size RTUs. Verification by an engineer may be required. Typical load density ranges are as below:

Table 5-1: Equipment Load Density

Equipment	Load Density (lb/ft^2)	Load Density (kg/m^2)
RTU	24 - 32	118 - 157
Hybrid ASHP	26 - 42	114 - 187
Hybrid ASHP + Enthalpy Wheel	29 - 47	125 - 206

5.2 Controls and Integration with BAS

Integration and optimization of controls are fundamental to achieving the desired savings. For the BAS integration, several factors need to be considered for seamless operation, energy efficiency, and proper control, as follows:

Compatibility: Ensure that the ASHP units and their associated control systems are compatible with the existing BAS infrastructure to enable demand limiting and adaptive programming, including communication protocols, interfaces, and integration functionality. Verify compatibility with protocols such as Building Automation and Control Networks (BACnet), Modbus, or LonWorks.

Integration: Work with your consultant, BAS vendor and ASHP manufacturer to develop integration strategies that enable communication and data exchange between ASHP units and the BAS. Implement protocols and interfaces that allow for monitoring, control, and diagnostics of ASHP operation through the BAS interface.

Sensors: Calibrate existing sensors before ASHP installation. Evaluate the placement and installation of sensors, actuators, and other control devices to ensure accurate measurement and control of temperature, humidity, airflow, and other relevant parameters. Position sensors to capture representative conditions and optimize system performance.

Sequence of Operations (SOOP): Develop and program sequence of operations for ASHP operation to optimize energy efficiency, utility costs and occupant comfort. Define setpoints, control algorithms, schedules, and operating modes based on electrical demand, hourly costs, time of day, occupancy and economic balance point temperatures.

Fault Detection and Diagnostics (FDD): Consider FDD algorithms and diagnostics within the BAS to detect, identify, and diagnose potential issues or faults in ASHP operation. Utilize real-time data and analytics to identify performance deviations, inefficiencies, or malfunctions and take corrective action.

Remote Monitoring and Control: Enable remote monitoring and control capabilities through the BAS interface, allowing facility managers to access ASHP performance data, adjust setpoints, and troubleshoot issues remotely. Setup continuous monitoring and data trending.

Energy Management Features: Leverage energy management features and capabilities within the BAS to optimize operation of all building systems including the ASHPs to maximize energy efficiency, demand response and utility cost savings.

Training and Familiarization: Provide training and familiarization for building operators, maintenance staff, and facility managers on the operation, maintenance, and troubleshooting of ASHP systems integrated with the BAS.

Temperature Limits: Typically, ASHPs operation limit is factory preset to switch to auxiliary heat source at a preset temperature (ranging from -5°C to +2°C). This changeover setpoint does not allow harvesting the full potential of ASHPs. The following should be considered for optimum ASHP operation:

- **Dynamic Controls & Energy Awareness:** Adjust setpoints and balance points based on real-time conditions. Optimize based on utility costs, efficiency curves, and weather conditions. Use control algorithms that incorporate real-time electric demand, HOEPs, monthly GAs and demand charges to optimize operational costs.
- **Smart Integration:** Integrate heat pump and furnace controls seamlessly. Improper communication or lack of integration between the ASHP and the gas furnace can lead to simultaneous operation, cycling conflicts, or redundant heating.
- **Monitoring and Maintenance:** Ensure all sensors and components continue to function as intended.

6 Operations & Maintenance

The hybrid ASHP basically includes the same components as an RTU, therefore routine maintenance tasks are similar. However, following are additional issues to manage:

- **Defrost Cycles:** Use adaptive defrost strategies that activate the defrost cycle only when necessary, based on real-time frost buildup detection rather than fixed intervals. This reduces wasted energy and wear on the system.

- **Manage Defrost Water Discharge to Avoid Ice Buildup:**
    - Drain installation – Below ASHP (for new build)
    - Drain pan heater
    - Drain piping insulation and heat tracing

7 Commissioning

Performance-based commissioning is more complex and important with ASHP installations to ensure that the system operates as intended. The following standard **and special** factors should be covered under the commissioning scope of work:

Functional Testing: Conduct functional testing of all ASHP components, including compressors, fans, coils, and controls, to verify proper operation and performance. Ensure that all safety features, alarms, and shutdown sequences are functioning correctly.

System Calibration: Calibrate temperature sensors, pressure transducers, flow meters, and other monitoring devices to ensure accurate readings and control of system parameters.

Control Optimization: Optimize control sequences, setpoints, and operating modes to maximize energy efficiency and occupant comfort, **with particular attention to smooth transitioning between heat pump compressor and gas-fired operation**. Adjust control algorithms to account for changes in operating conditions.

Performance Verification: Verify system performance against design specifications and performance criteria. Measure airflow rates, temperature differentials, and heating/cooling capacities to ensure they meet intended targets.

Safety Checks: Perform safety checks and inspections to identify any potential hazards or safety concerns. Ensure that all electrical connections, refrigerant lines, and mechanical components are secure and in compliance with safety standards.

Trend Logs: Set up key trend logs and record, verify proper operation.

Commissioning Documentation: Update or create commissioning documentation, including test procedures, checklists, and reports, to document the commissioning process and results. Provide detailed records of system settings, configurations, and performance metrics for future reference.

Operator Training: Provide **training for building operators, maintenance staff**, and facility managers on the operation, maintenance, and troubleshooting of the ASHP system. Ensure that personnel are familiar with system controls, alarms, and maintenance procedures to facilitate ongoing operation and optimization.

Post-Commissioning Measurement & Verification (M&V): Implement post-commissioning M&V and ongoing performance tracking to identify any issues or deviations from expected performance. Use data logging and analytical tools to monitor energy consumption, system runtime, and temperature trends over time.

8 Procurement

Project specifications and procurement practices should be reviewed and adapted if necessary to support competitive pricing, and that the overall performance outcomes are achieved. Following are recommended issues to be considered:

- Energy target established up front and communicated to the internal and external project team.
- Commissioning agent retained directly by the board, engaged early and given responsibility for meeting the energy target and documenting achievement of the intended operating performance.
- Holdbacks linked to performance verification.
- (Short-term until experience gained) alternative contractor pricing for ASHP and business-as-usual RTU options.
- Bidder pre-meeting to make clear intended performance outcomes and special requirements.

Individual school boards have procurement departments or officers responsible for managing the procurement process for goods and services required by schools within their jurisdiction. These departments ensure compliance with relevant policies, regulations, and best practices, and should be consulted about additional requirements for ASHP projects.

In Ontario, several entities provide support and resources to assist school boards with procurement processes, ensuring they can efficiently acquire goods and services while meeting regulatory requirements:

Ontario Education Collaborative Marketplace (OECM): OECM is a not-for-profit procurement partner for Ontario's education sector, including public schools, school boards, and universities. They offer a wide range of competitively sourced contracts and procurement solutions tailored to the unique needs of educational institutions.

Cooperative Purchasing Organizations: Some cooperative purchasing organizations, such as the Ontario Education Services Corporation (OESC) and CANOE, facilitate collaborative purchasing agreements and contracts specifically designed for the education sector. These agreements allow schools to access competitively priced goods and services through joint procurement efforts.

9 Further Considerations

Following are additional decision-making factors to be considered whenever a deep decarbonization project including heating system design or replacement is planned:

9.1 ASHP boiler (hydronic heating)

Not within the scope of this Guide, but to be evaluated whenever a boiler plant replacement or installation is being planned.

- Figure 9-1 illustrates a hybrid plant, with the ASHP boiler injecting heat into the hydronic loop.
- Where practicable, an ASHP boiler can offset a substantial portion of fossil fuel combustion in a boiler plant.
- Requires hydronic distribution loop (secondary loop) return temperature of 140°F or below. This limitation is the result of the single compression stage lift limits (typically 95°F) of current machines. Dual compression is available reaching supply temperatures of 180 °F, however, the cost is relatively high with reduced efficiencies.

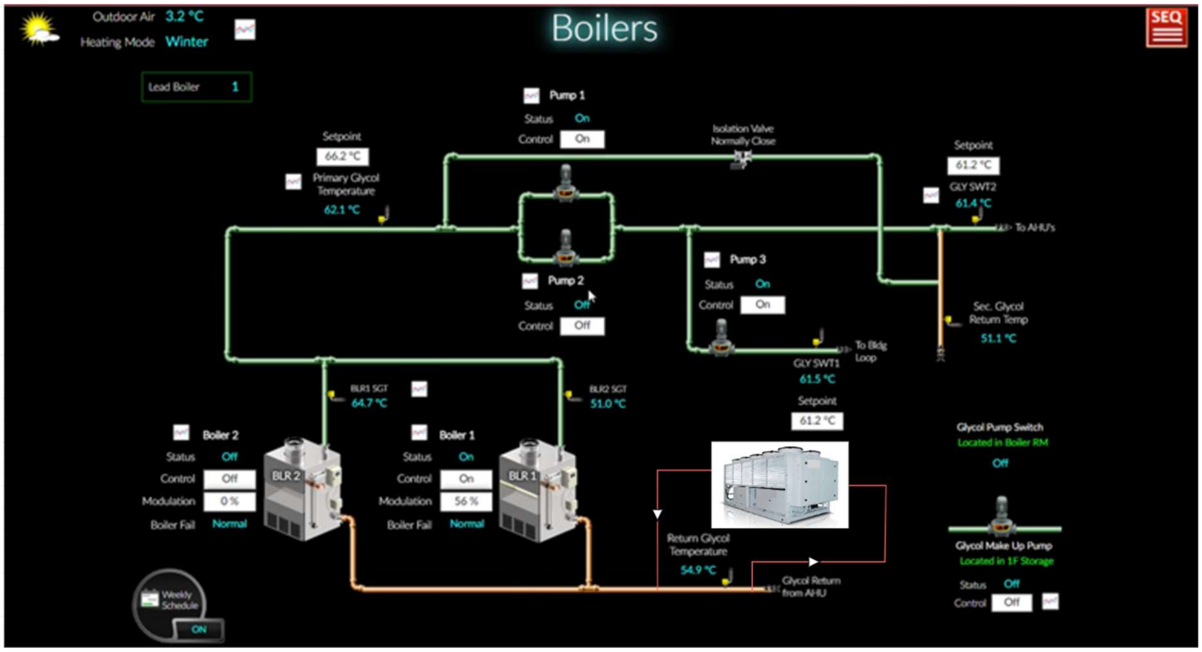

Figure 9-1: Typical ASHP Boiler Connection @ Lowest System Return Temp.

9.2 DHW heating

When DHW is not served by the hydronic loop, an ASHP DHW heater can reduce/eliminate gas use for DHW.

9.3 Solar PV

In most circumstances, solar PV with net metering has a positive life cycle NPV. Schools in particular can benefit as follows:

- **Ease of Installation**: Low-rise buildings with flat roofs.
- **Reduced Grid Dependency**: Solar PV provides renewable electricity to enhance ASHP operation, reducing reliance on the electrical grid.
- **Load Alignment**: Solar PV output aligns with school hours (7 AM–5 PM), meeting heating/cooling needs.
- **Environmental Impact**: A visible sign of commitment to sustainability.

10 Case Study – Toronto District School Board's Chester Le Junior Public School (Chester Le JPS)

10.1 Energy Efficiency First

Table 10-1 summarizes the current energy use intensity (EUI), and the target electricity and gas target savings potentials to reach the top quartile standard for this type of school prior to ASHP or other decarbonization measure installation. Note that the target energy and emissions savings due to energy efficiency are greater than for the addition of the ASHPs, which is the case for many schools. Analysis of interval (hourly) gas and electricity data uncovered excessive peak heating demand during morning startup on the coldest days, and high gas and electricity use in early mornings on schooldays, on PA days and on Saturdays. These are the focus of the Chester Le JPS energy efficiency action as described in Section 2.1.

Table 10-1: Chester Le JPS Target Energy Efficiency Savings

Building	Electricity						Gas						Total $ savings potential
	Consumption		Cost	Target Savings			Consumption		Cost	Target Savings			
	Actual (kWh/ ft²)	Target (kWh/ ft²)	(S)	(%)	($)	(kWh)	Actual (ekWh/ ft²)	Target (ekWh/ ft²)	($)	(%)	($)	(m³)	
Chester Le JPS	8.0	3.9	$62,472	52%	$32,568	198,584	16.5	6.0	$21,250	63%	$13,479	47,799	$46,047

10.2 ASHP Project Description

Chester Le JPS has 2 levels and comprises the original school and an extension containing a new daycare. The daycare is not part of the ASHP project, and this case study is limited to the school as highlighted in Figure 10-1 below and shown schematically in Figure 10-2. The ASHP retrofit was installed in the summer of 2024. The following are a list of the findings and assumptions adopted for the case study:

1. The ASHP installation serves an estimated 90% of total heating demand for the main building and does not serve any of the adjoining childcare. The remaining 10% of the main building heating is provided by hot water convectors and forced-flow heaters supplied by the original boiler plant.
2. Supplementary heating for the ASHPs is by glycol for the boiler plant.
3. The boiler plant comprises non-condensing boilers with SWT ranging between 140°F - 150°F. Modulating burners can handle low load and fluctuating operation.
4. No exhaust air heat reclaim is currently included. Exhaust fan capacity is 5,160 cfm.
5. Electric feeder capacity is sufficient to cater increase in electrical demands.
6. DHW is provided by gas-fired storage tanks with no ASHP connection.

Figure 10-1: Overhead view of Chester Le JPS

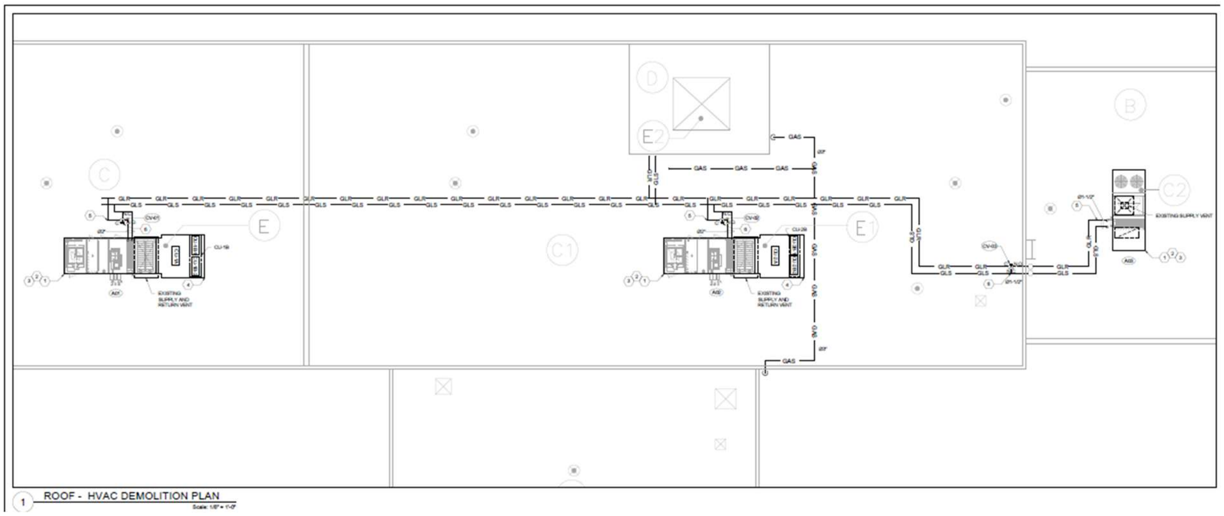

Figure 10-2: HVAC Roof Drawing of ASHPs serving Chester Le JPS

10.3 ASHP Model Calculations

1. Domestic hot water estimated to be 6.3% of total gas use.
2. ASHPs estimated to supply 72% of total space heating demand with the childcare at 28%, not separately metered.
3. Variable gas rate (from bills) = \$0.41/m^3.
4. Variable electricity rate (constrained operation) average \$0.11/kWh.
5. ASHP capacity 100 TR, Power = 88kW @ 27°F, and COP=2.4, design heating capacity = 720 MBH.

10.4 Electricity Rates (Toronto Hydro, Ontario)

Electricity rate structures play a major role in optimizing ASHP operational costs. Electricity bills include energy consumption (kWh) and demand charges (kW/kVA), meaning that peak demand management is important in controlling utility costs.

- Most of the electricity bill comprises components that are either variable with consumption (kWh) or with demand (kW & kVA).
- Limiting monthly peak demand can reduce overall electricity costs and the effective hourly price of electricity. Increasing the monthly limit allows longer ASHP operation but with diminishing returns.
- HOEP vary through the day. The ASHP can run longer when the HOEP is lower.
- The GA varies monthly. The ASHP can run longer in months when the GA is lower. Ontario is considering alternative variable Class B GA rates based on time of day (on-peak, mid-peak and off-peak) which would enable longer ASHP operation during off-peak and mid-peak periods.

10.5 Gas Use Displacement

10.5.1 Unconstrained Operation

Table 10-2 shows the maximum gas offset obtained by running the ASHP up to its full potential to meet the building's heating demand. The low limit cutoff is set for -8°F and was never reached for this period since the lowest ambient was close to 4°F. The ASHPs offset all gas use in unconstrained mode.

Table 10-2: Gas Offset by ASHP under Unconstrained Operation

Time of Day	Gas Offset by ASHP- Unconstrained (m^3)												Totals	
	Sep.	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	m^3	%
Off-peak	-	750	1,690	2,081	2,381	2,138	2,031	1,306	427	-	-	-	12,804	37%
Mid-peak	-	765	2,230	2,317	3,214	2,308	2,086	1,917	321	-	-	-	15,157	44%
On-peak	-	254	941	1,000	1,426	1,002	863	675	72	-	-	-	6,233	18%
													34,194	100%

10.5.2 Constrained Operation

Limiting peak monthly demand increase over the weather-normalized baseline to 15 kW reduces electricity costs. Table 10-3 shows the reduction in gas offset for each time of day, with overall reduction of 84% of unconstrained operation.

Table 10-3: Gas Offset by ASHP under Constrained Operation

Time of Day	Gas Offset by ASHP- Constrained Operation (m^3)												Totals		% of Unconst'd
	Sep.	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	m^3	%	
Off-peak	-	750	1,690	2,078	1,542	1,722	1,900	1,306	427	-	-	-	11,415	40.2%	89%
Mid-peak	-	765	1,933	1,785	1,633	1,645	1,824	1,855	321	-	-	-	11,761	41.4%	78%
On-peak	-	254	877	881	836	823	828	675	72	-	-	-	5,245	18.5%	84%
													28,422	100%	83%

10.5.3 Summary of Gas & GHG Emissions Offsets

Table 10-4 summarizes the cumulative natural gas offset and emissions reductions relative to the baseline moving through energy efficiency and optimization first, and then adopting the ASHPs as a retrofit to existing RTUs. The results highlight the importance of energy efficiency in decarbonization.

Table 10-4: Gas and GHG reduction

Case	Energy Efficiency / Operation Optimization	ASHPs - Constrained	ASHPs - Unconstrained
Gas Reduction %	61.1%	78.0%	81.7%
GHG Reduction (tCO_2)	(50.5) 61.1%	64.5 (78.1%)	67.5 (81.7%)

11 Conclusions and Recommendations

Transitioning from conventional RTUs to ASHPs represents a strategic investment in energy efficiency and sustainability for school boards. While ASHPs come at an estimated 5-10% cost premium, this is recovered well within their lifetime, providing long-term financial and operational benefits. Effective implementation requires a holistic approach—prioritizing energy efficiency measures, leveraging hybrid heating systems, integrating heat recovery, and utilizing onsite renewable energy. Additionally, smart control strategies that optimize ASHP operation based on electricity pricing equipment COP can further reduce utility costs. The following is a summary of key takeaways and prerequisites for successful ASHP adoption in school facilities:

1. Procuring ASHP equipment rather than conventional RTUs is recommended in almost all cases, involving 5-10% additional cost which is recovered well within the equipment lifetime. This electrification strategy positions the board to better manage the uncertainties of the energy transition.
2. Energy Efficiency First → setbacks, scheduling, and OA controls reduce energy and emissions, lower peak heating and electrical demand, and enable greater ASHP operation.
3. Hybrid heating systems (heat pumps with supplementary/backup gas) displace most gas use, avoid excessive electricity peaks, and optimize life-cycle costs.
4. Heat recovery → energy recovery on exhaust systems (enthalpy wheels, crossflow PHEX, runaround loops), further reduces peak heating demand and energy use.
5. Renewable energy → solar PV arrays (roofs or carports) offset building electricity use and enable greater ASHP operation.
6. Smart control algorithms, integrating HOEP with OAT/COP, electricity demand and GA charges, and gas prices can optimize utility costs.

Appendix A – Glossary of Terms

ASHP: Air source heat pumps. In this guide, this include the cold-climate ASHPs or CC-ASHPs

BACnet: Building Automation and Control Networks

BAS: Building Automation System

COP: Coefficient of Performance

Cut-off Control: A control device that restricts the operation of a heat pump or backup heating system to a predetermined range of outdoor temperatures.

DCV: Demand control ventilation

DHW: Domestic Hot Water

DX: Direct Expansion Cooling

e-BPT: Economic Balance Point Temperature - Outdoor temperature at which it is economically desirable to switch from the air source heat pump to a back-up heating source. It is determined based on estimated costs of heat delivery by the air source heat pump versus the back-up system. Calculation of the economic cut-off temperature requires the cost of electricity, cost of backup system fuel, heat pump COP, backup system efficiency and outdoor temperature.

ERV: Energy Recovery Ventilators

EUI: Energy Use Intensity

FDD: Fault Detection and Diagnostics

GA: Global Adjustment

GHG: Greenhouse Gases

GWP: Global Warming Potential

HOEP: Hourly Ontario Electricity Price

HVAC: Heating Ventilation and Air Conditioning

LCCA: Life Cycle Cost Analysis

LDC: Local Distribution Company

LTCO: Low-Temperature Cut-off Limit – the minimum outdoor temperature at which an air source heat pump will no longer be able to operate.

NPV: Net Present Value

NZ: Net Zero

OA: Outdoor Air

OAT: Outdoor Air Temperature

OASBO: Ontario Public School Boards' Association

ODP: Ozone Depletion Potential

OECM: Ontario Education Collaborative Marketplace

OESC: Ontario Education Services Corporation

OPSBA: Ontario Public School Boards' Association

PHEX: Plate Heat Exchanger

RNG: Renewable Natural Gas

RTU: Rooftop Unit

SOE: Save On Energy

Solar PV: Solar Photovoltaic

SOOP: Sequence of Operation

SWT: Supply Water Temperature

t-BPT: Thermal Balance Point Temperature – the temperature at which the heating load line intersects the air source heat pump capacity curve. (i.e., point where heating load of the building matches the heat pump’s output capacity). Above the t-BPT, the heat pump is capable of meeting the building’s heating requirements. Below the t-BPT, the heat pump is not capable of meeting the buildings heating requirements and a backup heating system is required.

TDSB: Toronto District School Board

VFD: Variable Frequency Drive

Appendix B – Industry Sponsors Contact Information

Sponsor	Contact	Position	Contact Information
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