Next Gen Rooftop Units

FRESH AIR, FRESH SAVINGS AT NOVA ACADEMY OF COSMETOLOGY

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V.20260818

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Acknowledgements

Next Gen Rooftop Units (RTUs) would like to thank Nova Academy of Cosmetology for their interest and time in energy recovery ventilator performance monitoring. We would like to extend our appreciation to all the manufacturers and manufacturers' representatives who participated in this research.

Next Gen RTUs initiative and this report are funded through Minnesota's Efficient Technology Accelerator (ETA), a partnership funded by the state's participating investor-owned utilities (IOUs) and consumer-owned utilities (COUs), administered by the Minnesota Department of Commerce, Division of Energy Resources (DER), and implemented by Center for Energy and Environment (CEE).

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We would also thank the following staff for their guidance and assistance in analysis and reporting:

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Executive Summary

Overview

Nova Academy of Cosmetology supports students across Minnesota as they prepare to launch a successful career in the beauty industry. When the academy needed to upgrade their HVAC system at their Mankato location, it also needed to increase their outdoor air intake to provide more fresh air for its students, instructors, and clients. To meet Minnesota energy code requirements associated with outdoor air intake, a dedicated outdoor air system (DOAS) with an energy recovery ventilator (ERV) was installed.

To better understand how much energy they were able to save with an ERV on their DOAS, Nova Academy partnered with the Next Gen Rooftop Units (RTUs) Initiative to monitor the performance of the ERV. Next Gen RTUs strives to advance the performance of RTUs to meet the growing demand for energy efficient and sustainable building solutions. The program strives to deliver energy efficiency and emission reduction goals where the market needs support, driving long-term sustainability in commercial buildings.

While Next Gen RTUs primarily focuses on ERVs bolted on or integrated into RTUs with lower outdoor air (OA) requirements than DOAS, this report describes the operations and impact of an enthalpy wheel ERV integrated in a DOAS.

DOAS systems provide heating, cooling, and a high volume of ventilation to a building. Often a DOAS system uses 100% OA, meaning it brings in all outdoor air to heat and cool the space and does not use any of the air in the space itself. RTUs, on the other hand, heat, cool, and ventilate but with a much lower percent of outdoor air, commonly only 18% OA. Data from the DOAS control system was used to describe ERV operations and estimate cost, energy, and site emissions savings in Minnesota. This data can be used to inform future research and modeling of ERVs on RTUs.

Approach

Researchers collected data from the manufacturer’s existing monitoring system for the 2024 calendar year, during which outdoor temperatures reached as low as -9.9 °F and as high as 98.1°F. Monitored data included temperature, humidity, occupancy, and power sensors. Researchers used standard methods to analyze the performance of the ERV and heating and cooling equipment and to estimate the energy, cost, and emissions savings from this system.

Results

Researchers found that the enthalpy wheel ERV in the RTU performed well, with a recovery energy ratio (RER) as high as 47 in heating and up to 19 in cooling. The presence of an ERV saved 2209.6 therms of heating and cooling energy over the course of the monitoring period, with 1257.98 therms of natural gas avoided by the furnace specifically. The cost analysis was less straightforward as there was only a single reference electricity bill from which researchers could base the rate calculation. Even so, based on the usage the ERV savings potential is significant.

Lessons Learned

- **The ERV spent 75% of occupied time in energy recovery over the course of the year.** In comparison, the economizer was used about 24% of the occupied time. This increased in the winter, when the ERV spent nearly 60% of the heating occupied time recovering energy and less than 1% economizing.

- **It is possible to downsize primary HVAC when utilizing energy recovery.** This would reduce first cost, unit size, and weight on roof structure.

- **The energy recovery system saved 1,729 therms of gas and 2,692 kWh of electricity over the course of the year.**

- **Energy recovery in cooling during the summer resulted in significant demand savings.** The biggest savings happened in July, when the weather was both hot and humid and the ERV saved nearly 37kW.

Energy Recovery Ventilator Overview

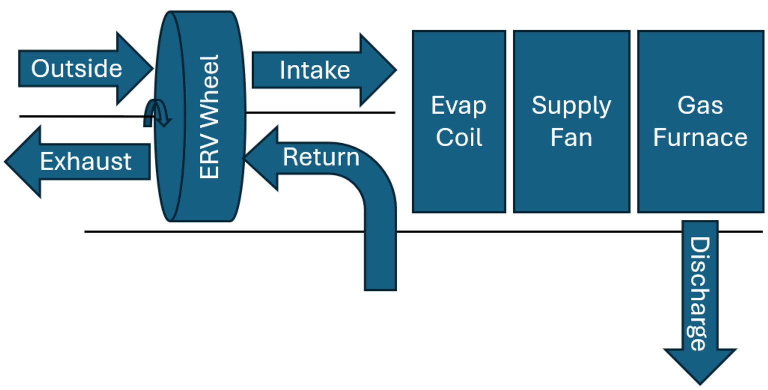
ERVs save energy in buildings by reducing the amount of energy needed to condition incoming ventilation air. They are more commonly found in applications with high outside air fractions, including in applications that use DOASs to provide 100% outside air to the space.

ERVs function by transferring energy between an exhaust airstream and an incoming airstream before the incoming air reaches the primary heating and cooling section of an HVAC system. ERVs commonly include an air-to-air heat exchanger (AAHX), which enables heat and/or moisture transfer between the airstreams. These AAHXs are typically either plate-type or wheel-type. This site used a wheel-type ERV, which rotates a wheel made of heat and/or moisture transfer media through ducts containing each airstream, shown in Figure 1.

Figure 1. Energy Recovery Wheel in DOAS system

ERVs bring the incoming ventilation air conditions closer to the desired supply air conditions, using air from the conditioned space to pre-cool fresh air on hot summer days or pre-heat fresh air in frigid winter conditions. This process is shown in Figure 2. Pre-conditioning ventilation air with an ERV can significantly reduce the demand for heating and cooling from the primary HVAC equipment.

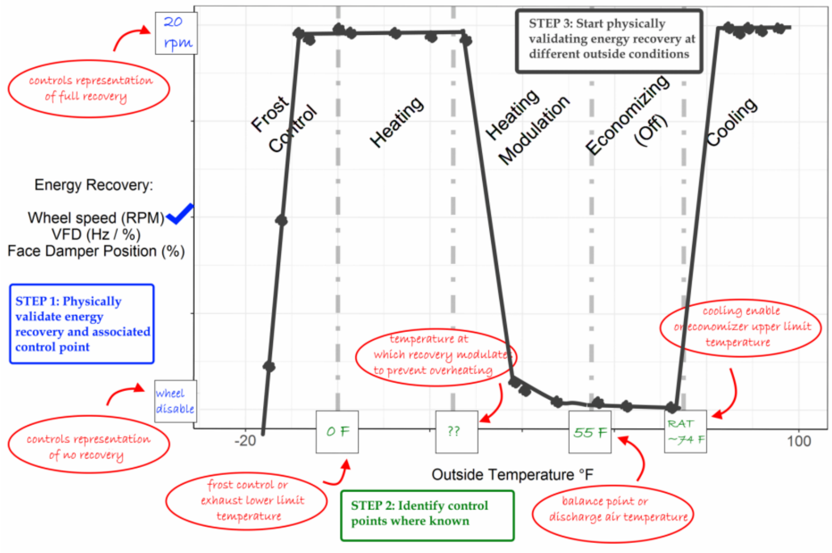
Figure 2. DOAS with ERV schematic



The amount of pre-conditioning needed is a function of outdoor conditions. Therefore, ERV controls should vary the amount of energy recovered as outdoor conditions change. Ventilation systems accomplish this in several ways. Some systems can direct some or all ventilation air around an ERV using bypass dampers. Wheel-type systems equipped with variable speed drives can reduce energy recovery by reducing wheel speed. Other methods include varying the exhaust air-flow rate by cycling or changing the speed of the exhaust fan.

These modulation approaches, shown in Figure 3, are used to operate ERVs in one of five different modes. At the hottest outdoor conditions, ERVs operate in maximum recovery mode to cool and dehumidify incoming air (Cooling Mode). When outside conditions are below the supply air enthalpy setpoint, but the building still requires cooling, the ERV enters an Economizing Mode and recovery is reduced or disabled. Disabling recovery in these conditions is important to avoid pre-heating then mechanically cooling air that would have met supply air requirements without any conditioning. Similarly, recovery is limited in mild heating conditions to avoid pre-heating the incoming air above the supply air temperature setpoint (Heating Modulation Mode). In colder heating conditions, the ERV operates at maximum recovery again (Heating Mode). Finally, in the coldest weather, it may be necessary to limit recovery to avoid pulling so much heat from the exhaust stream that moisture from the exhaust stream condenses and freezes on the heat exchanger, blocking airflow (Frost Control Mode). With extremely dry indoor winter conditions in Minnesota, frost control is typically only a concern below about 0°F ambient conditions.

Figure 3. Example energy recovery control modes (Quinnell, 2017)



METHODOLOGY

Site Details

The 22-ton rooftop HVAC system monitored as part of this project was configured as a DOAS system with an ERV, providing 100% outside air. The unit is shown in Figure 4.

Figure 4. Monitored DOAS system

Primary heating was provided by a modulating high turndown bent tube furnace supplied with natural gas with an output range of 30 kBtu/h to 365 kBtu/h. The design supply airflow of 4,975 CFM was provided at a constant supply air temperature of 70°F whenever the building was occupied. This is high airflow, almost double the typical CFM per ton of heating on a DOAS. The ERV section of the RTU included a variable-speed wheel-type AAHX without bypass dampers. This unit was equipped with a remote monitoring system, allowing researchers to collect data directly from the unit at a four-minute/point resolution. 4

The building had occupied hours from 8:00 a.m.–5:00 p.m., Monday–Saturday, and until 8:30 p.m. on Wednesdays. The monitored system was configured to run whenever the building was occupied and otherwise remained off. Supplemental space heating and cooling for the building was provided by other packaged rooftop equipment.

Data Collection

The manufacturer of the HVAC system equipped it with sensors and a data acquisition system that allowed researchers to regularly download the required performance data. Fields collected for this project included various air temperatures, differential pressures, airflow measurements, actuator statuses, and power readings, and are shown in Table 1. Data was generally available at four-minute intervals and was interpolated to a consistent one-minute basis to align observations with different timestamps.

Table 1. Data collected from unit controller

Sensor Type	Value	Units
Air Temperature	Outside, Intake, Discharge, Return, Exhaust	°F
Air Relative Humidity	Intake, Discharge, Return	%
Air Dew Point	Intake, Discharge	°F
Differential Pressure	Wheel Exhaust, Wheel Supply	in w.c.
Airflow	Supply	CFM
Gas Valve Command	Gas Valve 1, Gas Valve 2	0–10 V
Power	Supply Fan, Cooling System (Virtual Sensor)	kW
Information	Operating Mode, Occupancy	

Unit Operation and Performance

Occupancy

Occupancy schedules were obtained from the site contact and verified by observing the value of the occupancy field in the operating data.

Operating Modes

This ERV was configured to activate in heating mode when the outside air temperature was 3°F below the supply air temperature setpoint and activate in cooling mode when the outside air enthalpy was 3 Btu/lb above the supply air enthalpy setpoint.

Using the difference in outgoing air stream temperatures, i.e., the difference between the air temperatures at the return and exhaust positions, researchers identified the ERV mode of operation as either recovery or economizing. When the system reduced energy recovery, the exhaust airstream temperature difference approached zero. Plotting the exhaust airstream temperature differences versus outside air temperature revealed two distinct linear relationships that were used to classify ERV operations as economizing or recovery.

By combining this ERV mode label with the controller's reported climate control mode, the detailed ERV operating modes were established. These consisted of cooling economizing, cooling recovery, fan-only economizing, heating economizing, and heating recovery.

The assumed classification was validated by plotting hourly average sensible effectiveness versus outside temperature and labeling points with their assumed ERV mode. The sensible effectiveness quantifies how effectively the ERV transfers sensible heat between the incoming and outgoing airstreams, expressed as the ratio of actual to maximum possible heat exchange based on air temperature and heat capacity rates.

Equation 1. ERV sensible effectiveness

$$E_s = \frac{T_i - T_o}{T_r - T_o}$$

The heat capacities of the two airstreams, which are included in the formal definition of sensible effectiveness, were found to be within an average difference of 1.12% and never more than 8.69% different, so for this analysis they are assumed to be equal. This means the sensible effectiveness equation was simplified to a ratio of temperature differences as shown in Equation 1.

In economizing modes, the energy wheel in this system slowed or stopped, which was reflected by undefined sensible effectiveness. Economizing behaviors observed in heating or cooling mode indicated that heat and moisture transfer through the ERV was reduced to prevent the intake temperature and/or humidity from exceeding the discharge setpoints.

Performance Metrics

The primary performance metric for energy recovery systems is the Recovered Energy Ratio (RER). This is the ratio of the thermal energy recovered by the system to the input energy needed to operate the energy recovery system. This metric is useful because as a unitless energy ratio, it allows for direct comparison to the COP of heating and cooling equipment. For wheel-type ERVs, the input energy is the energy required to rotate the wheel through the two airstreams plus the incremental fan power required to move air through the wheel.

For this analysis, the input power required for the ERV was assumed to consist only of the incremental fan power required to overcome the pressure drops across the ERV. The power required to rotate the ERV was assumed to be negligible relative to the increased fan power. Researchers calculated the increased fan power as a function of airflow and pressure drop based on the algorithm in the Minnesota TRM for determining peak kW savings from ERVs. As described in Table 1, the pressure drops across both the supply and return portions of the energy recovery wheel were directly measured by pressure sensors within the unit.

The power required to overcome the pressure drop in each of the supply and exhaust airstreams was calculated using Equation 2.

Equation 2. Power required for energy recovery

$$\mathrm{P_{recovery}} = \mathrm{k_1} \frac{\dot{\mathrm{V}}\,\Delta\,\mathrm{P}}{\eta_\mathrm{m}\,\eta_\mathrm{f}}$$

Where $P_{recovery}$ is power input for energy recovery (kW), $\dot{\mathrm{V}}$ is airflow (ft^3/min), $\Delta \mathrm{P}$ is pressure drop across the ERV (in w.c.), η_m is fan motor efficiency, η_f is fan efficiency, and k_1 is a conversion factor shown in Equation 3.

Equation 3. Conversion factor for energy recovery power input equation

$$k_1 = \frac{5.2\ \mathrm{lb/ft^2}}{1\ \mathrm{in\ w.c.}} \times \frac{1\ \mathrm{hp}}{33013\ \mathrm{ft-lb/min}} \times \frac{0.746\ \mathrm{kW}}{1\ \mathrm{hp}} = 1.175 \times 10^{-4} \frac{\mathrm{kW}}{(\mathrm{in\ w.c.})(\mathrm{ft^3/min})}$$

Analysis

This analysis estimated energy, cost, and emission savings resulting from the use of an ERV. Because cost and emissions savings are proportional to energy and demand savings, the savings analysis began with calculating energy and demand savings.

Energy and Demand

Energy savings were estimated based on the difference in energy consumption between the actual installed equipment and a hypothetical alternative HVAC system providing the same output. This approach required measuring or estimating the energy inputs and outputs of the actual system. Then, the hypothetical energy consumption of an alternative system was estimated by assuming that the alternative system provided the same output as the actual system and using the alternative system's rated efficiency to assume field efficiency. The equipment monitored in this project had both gas and electricity energy inputs, with outputs of heating and cooling capacity.

Gas Consumption

Researchers calculated the actual furnace output capacity based on the airflow and temperatures across the furnace heat exchanger. The hypothetical furnace output capacity without an ERV was estimated by calculating the capacity needed to heat the supply air from the outside air temperature to the discharge setpoint temperature. The gas input for each scenario was estimated by dividing each capacity by the rated efficiency of the furnace. The gas savings from the ERV were estimated as the difference in the hypothetical gas input without an ERV and the actual gas input with an ERV.

Electric Energy

The DOAS system required electricity for mechanical cooling and to operate the energy recovery system. Relative to a system without an ERV, the supply and exhaust fans required additional power to provide the required airflow given the pressure drop introduced by the energy recovery system. The energy required to rotate the energy recovery wheel was assumed to be negligible relative to the increased fan power. The incremental electricity consumption for a system with an ERV shows up as increased electricity consumption relative to a system without an ERV in heating operation, and reduced electricity savings in cooling operation.

Actual electric power input was estimated as the sum of the energy recovery power input and the measured power required for mechanical cooling. Hypothetical energy input of a system in the same application without an ERV was estimated as the total cooling capacity required to cool the outdoor air to the supply air conditions, divided by an average mechanical cooling COP calculated from the operating data for 2024. Electricity savings were calculated as the difference between actual and hypothetical energy inputs.

Electric Demand

Demand savings were estimated during summer months (June–September) and assumed to be zero for all other months of the year, since the ERV has a negligible impact on facility power demand except during the summer. Without facility-level power monitoring, the peak demand was assumed to occur during the hottest hour the building was occupied each summer month. The demand savings were estimated as the power that would be required to provide the cooling capacity the ERV provided, assuming the observed COP in those conditions, minus the power required to operate the ERV.

Operating Cost

The cost savings associated with ERVs come from purchasing less gas and electricity, as well as reduced demand charges for electricity. As gas and electricity rates are subject to change as the market for energy shifts, and this estimate uses the lower bound of costs by volume as laid out in the utility rate books, estimated savings for the 2024 calendar year are not necessarily representative of future savings.

Gas Cost Savings

Without historical gas bills to reference, researchers dove into the rate book for the building's gas utility to build a model of the gas rates throughout the year. Based on the range of monthly gas input to the DOAS system and estimated gas consumption for other end uses, researchers assumed that the facility purchased gas at the small commercial rate. Fixed costs and any surcharges or refunds based on factors that would be the same regardless of the presence of an ERV were ignored.

The main volumetric charges for gas at this site were the fuel charge, delivery charge, and the Weather Recovery Rider, which went into effect in September 2021 and extended through 2024. The minimum possible volumetric charges for each month in 2024 ranged from $0.96786/therm to $1.02685/therm depending on the month (CenterPoint Energy).

Electric Cost Savings

The electric rate structure was determined from the May 2025 bill obtained from the site. Researchers broke down the rate structure into fixed and volumetric costs. This bill showed the occupants were charged for electricity under the general rate and helped provide a reasonable range for the base estimate of the cost per kWh of electricity. The rates gleaned from the May 2025 bill are in Table 2, with fixed costs bolded.

Table 2. Sample electric bill structure

Line Item	Rate
Basic Service Charge	**$25.98**
Energy Charge	$0.04765/kWh
Fuel Cost Charge	$0.021294/kWh
Sales True Up	$0.00176/kWh
Demand Charge Winter	$11.90/kW
Affordability Charge	**$9.20**
Resource Adjustment	**$21.35**
Interim Rate Adj	**$32.85**
City Fees	**$16.50**
City Tax	0.50%
County Tax	0.50%
State Tax	6.88%

The demand cost savings were based on average demand reduction over the hottest one-hour interval during the calendar month, multiplied by the published seasonal demand rate, rather than the highest 15-minute rate of usage over the billing period. Any discrepancies in duration and assumed billing period are assumed to not have a significant impact on the demand cost estimate. Incremental savings from taxes were excluded from this analysis.

The monthly volumetric rates and demand charges compiled from the rate books are summarized in Table 3.

Table 3. 2024 Monthly utility rates

Month	Electricity Cost ($/kWh)	Gas Cost ($/Therm)	Demand Charge ($/kW)
January	0.07341	0.96786	11.9
February	0.07539	0.96786	11.9
March	0.07638	0.96786	11.9
April	0.08272	0.96786	11.9
May	0.08579	1.02685	11.9
June	0.08360	1.02685	16.49

July	0.08491	1.02685	16.49
August	0.08372	1.02685	16.49
September	0.08089	1.02685	16.49
October	0.07921	1.02685	11.9
November	0.06830	0.96786	11.9
December	0.06718	0.96786	11.9

Emissions

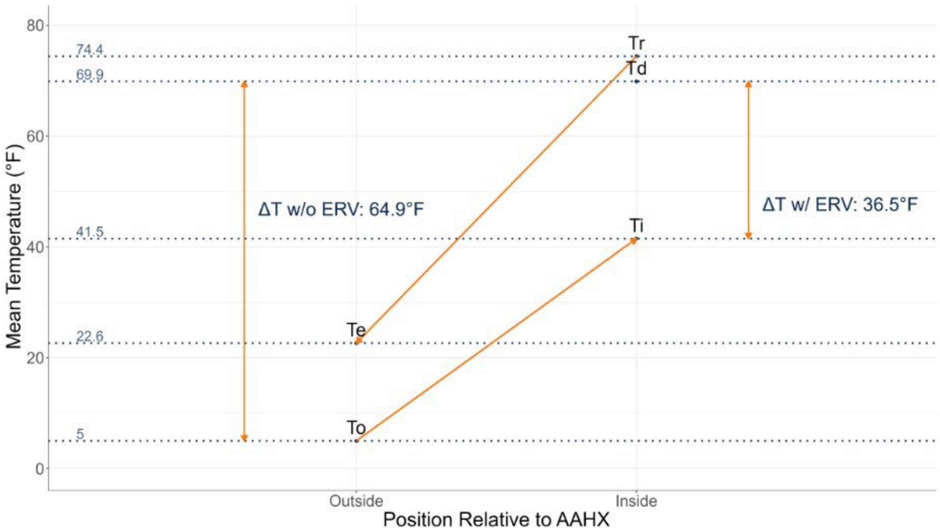
Emissions savings were estimated by summing the emissions savings for each fuel type. The emissions savings from each fuel type were estimated by multiplying the emissions factor for each fuel type by the total estimated units of energy saved by fuel type. This analysis assumed an emissions factor of 5.31145 kg CO_{2e}/therm for natural gas and 0.42068 kg CO_2 /kWh for electricity. The gas emissions rate was derived using the EPA GHG Emissions Factors Hub (U.S. EPA, 2025). The electric emissions factor was derived using the eGRID2023 Subregion Output Emissions Rates table (U.S. EPA, 2025).

Monitoring and Verification Results

Performance Examples

While most of the analysis in this report summarizes the performance of the ERV on a monthly or annual basis, the following example shows average temperature values on a single very cold day to further illustrate the impact of energy recovery on ventilation heating loads. Figure 5 shows the average temperatures throughout the system as horizontal lines: Tr is return air temperature, Td is discharge temperature to the space, Ti is intake temperature to the furnace section, Te is exhaust temperature to the outdoors, and To is the outdoor air temperature. The points are shown at their locations with respect to the AAHX, either outside or inside. The sloped arrows show the actual average temperature changes of the air as it moves through the AAHX. The supply airstream increases in temperature from 5°F to 41.5°F by extracting heat from the exhaust airstream, which decreases in temperature from 74.4°F to 22.6°F. The vertical lines on the plot show how with an ERV, the furnace only needs to increase the air temperature from Ti to Td, a difference of 36.5°F, rather than from To to Td, which is a difference of 64.9°F.

Figure 5. Temperature changes across ERV in very cold weather

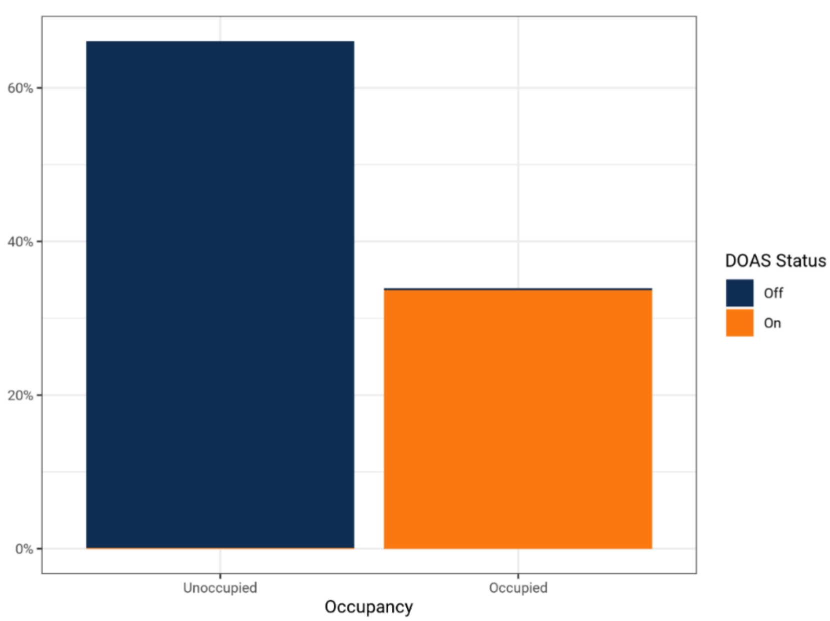


ERV Operations

Occupancy

The building was occupied for 33.9% of the observation period. Using a power threshold of 2.5 kW for the supply blower motor to label the DOAS system as on, the DOAS system was on for 33.2% of the observation period. In general, the occupancy and operation of the DOAS were directly correlated. During the observation period, the building was occupied for 99.4% of the time that the DOAS containing the ERV was on, and the DOAS containing the ERV was on 99.8% of the time when the building was occupied, as shown in Figure 6.

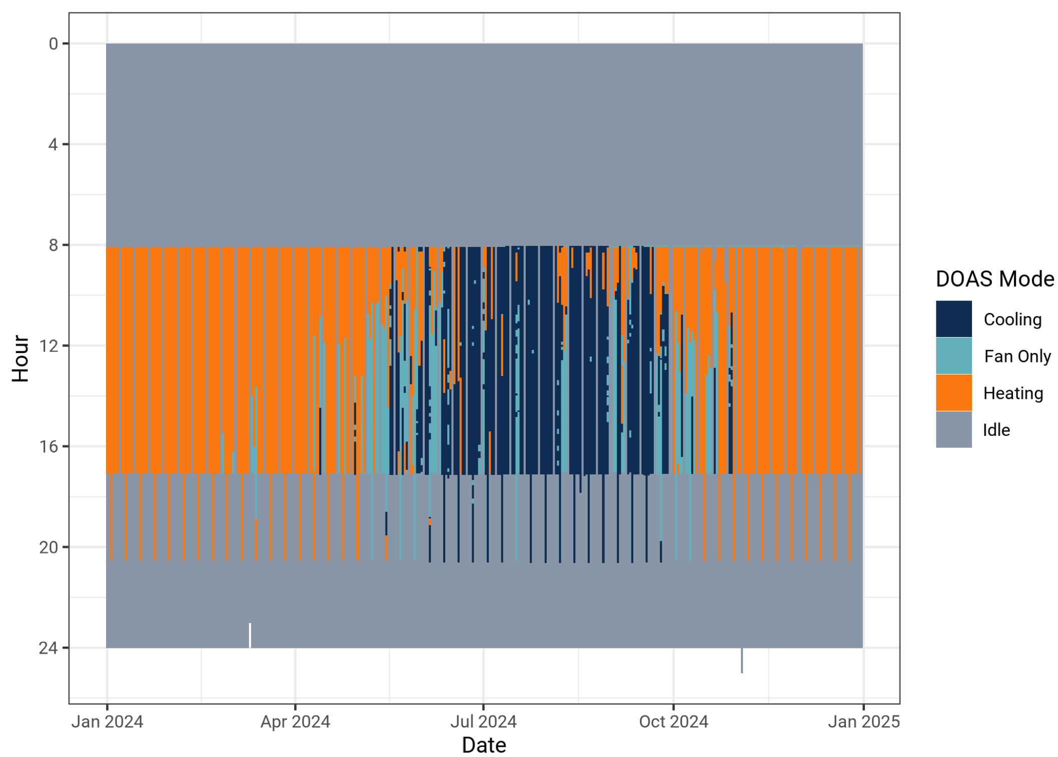
Figure 6. Building occupancy by DOAS status



Operating Modes

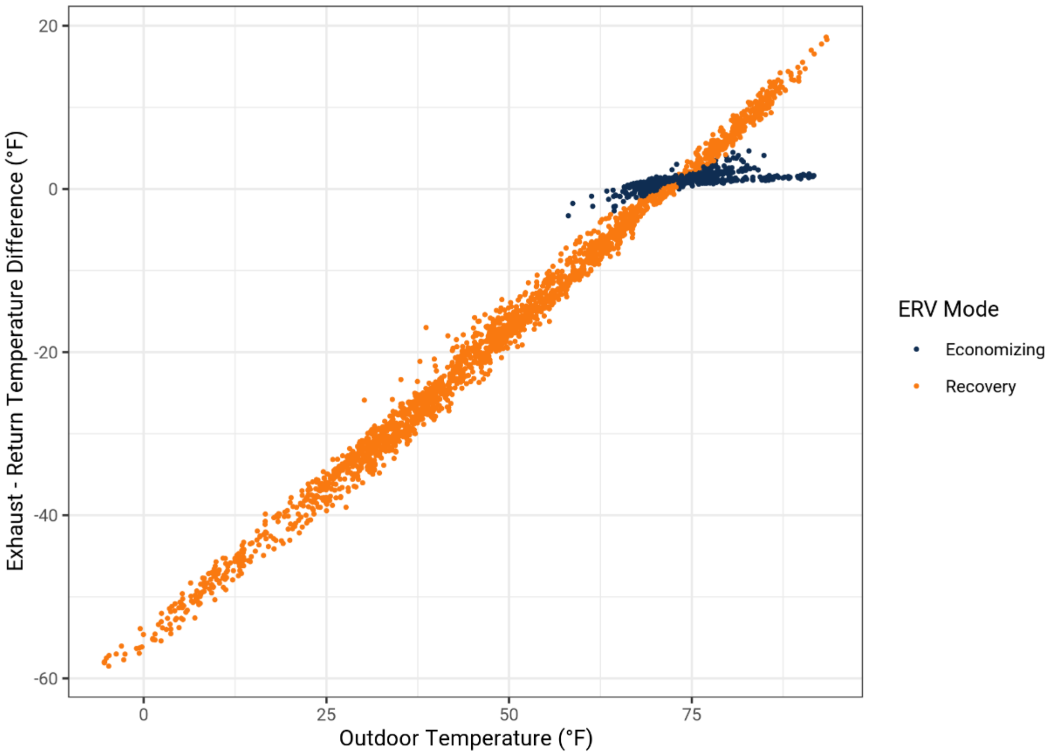
The DOAS system had four operating modes identified in the control system: Idle, Heating, Fan Only, and Cooling. Idle corresponds with the system being off, which generally only occurred when the building was unoccupied. For the winter months, the system operated almost exclusively in Heating mode when it was not idle, as shown in Figure 7. In the shoulder seasons, the system tended to be in Heating in the morning, followed by Fan Only and/or Cooling in the afternoons. In the summer, the system was usually in Cooling when not idle — however, short stretches of Fan Only were common, and short stretches of heating, especially in the mornings, still occurred.

Figure 7. DOAS mode by hour of year



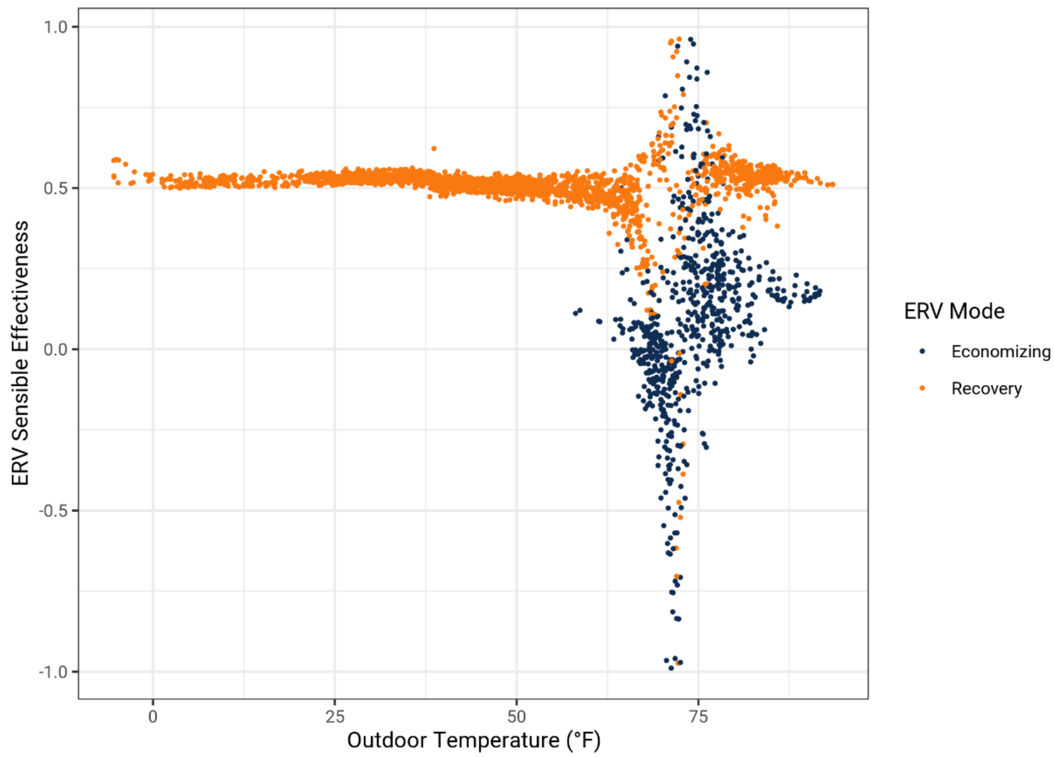
The energy recovery section of the DOAS system had two modes of operation: Economizing and Recovery. These were not explicitly labeled by the control system but rather labeled by researchers according to observed energy recovery performance. The clearest separation of the two modes was obtained by plotting the exhaust vs. return temperature difference against the outdoor temperature, shown in Figure 8. When in recovery mode, the temperature difference between the two airstreams was large in magnitude and grew the further the outdoor temperature was from the return air temperature. In economizing mode, when the energy recovery wheel was slowed to reduce recovery, the exhaust vs. return temperature difference was closer to zero across a wide range of outdoor temperatures. Economizing behavior typically occurred at milder outdoor temperatures, with the lowest temperature economizing behavior occurring at 58°F.

Figure 8. Plotting exhaust stream temperature differences vs. outdoor temperature shows distinct ERV operating modes



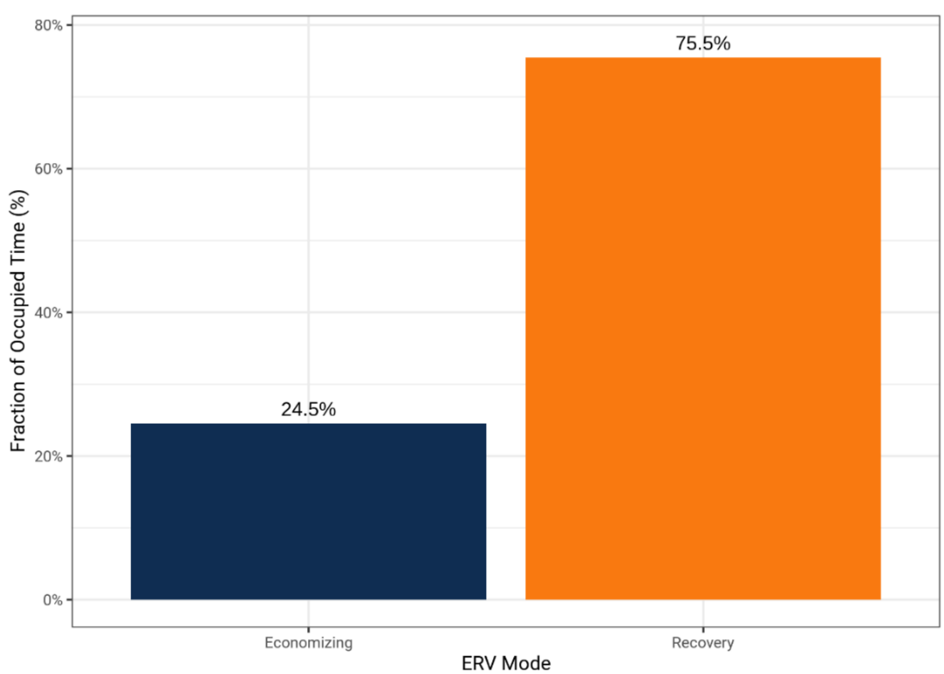
Sensible effectiveness describes how effectively the ERV changes the temperature of the supply airstream. When the outdoor temperature and return temperatures are close together, the calculation yields meaningless results because it involves division by a small difference. The plot of sensible effectiveness vs. outdoor temperature illustrates this effect, shown in Figure 9. The key points in this plot are that where the calculation is valid, the sensible effectiveness is relatively constant above 0.5 in recovery mode and reduced below 0.25 in economizing mode.

Figure 9. ERV effectiveness is reduced during economizing



In Minnesota's cold climate, the ERV spends over 75% of occupied time in recovery mode, shown in Figure 10. There are relatively few hours of the year where the outdoor conditions are appropriate for economizing mode.

Figure 10 ERV operating mode fractions



The detailed breakdown of the operating modes shown in Figure 11 shows that the ERV spends nearly 60% of the time in a heating recovery mode, less than 1% of the time in a heating economizing mode. This shows that when heating is required, the ERV almost always helps meet the heating load. When cooling is required, the ERV helps meet part of the cooling load more often than not (15.8% cooling recovery vs. 12.9% cooling economizing). Only 10.8% of occupied hours required neither heating nor cooling for ventilation air. When this data is weather-normalized, we see even more heating and cooling recovery, as shown in Figure 12. When weather-normalized, we see less than 12% of the occupied time spent in economizing, while over 80% of the occupied time was spent in energy recovery.

Figure 11. Detailed ERV operating mode fractions

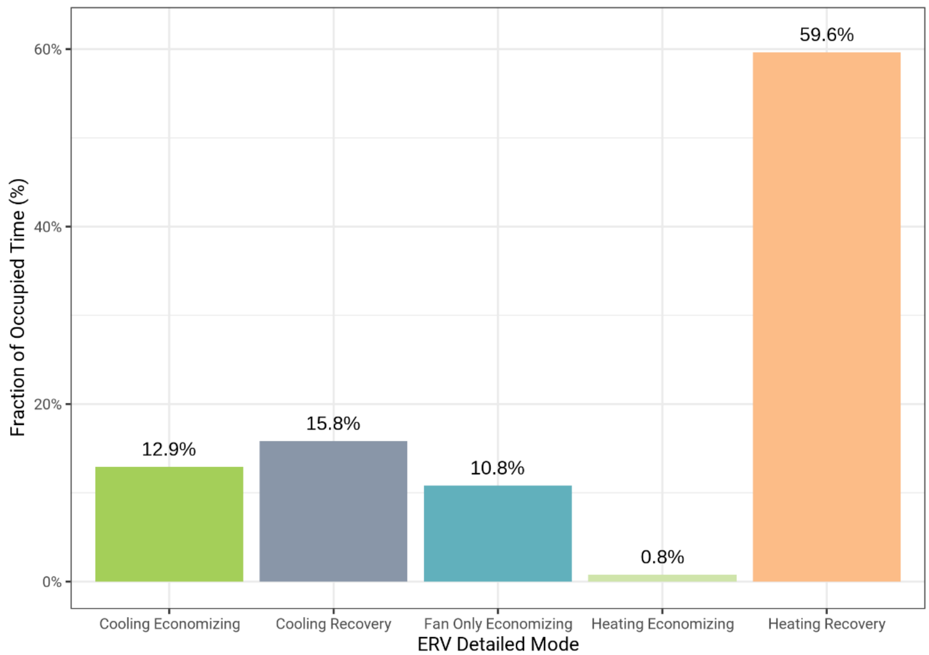
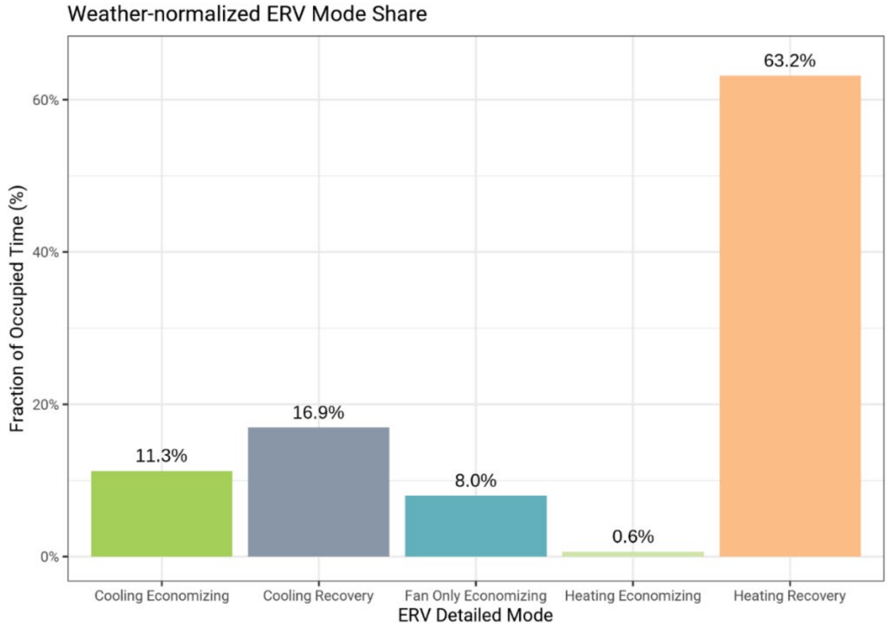


Figure 12. Weather-normalized ERV operating mode fractions

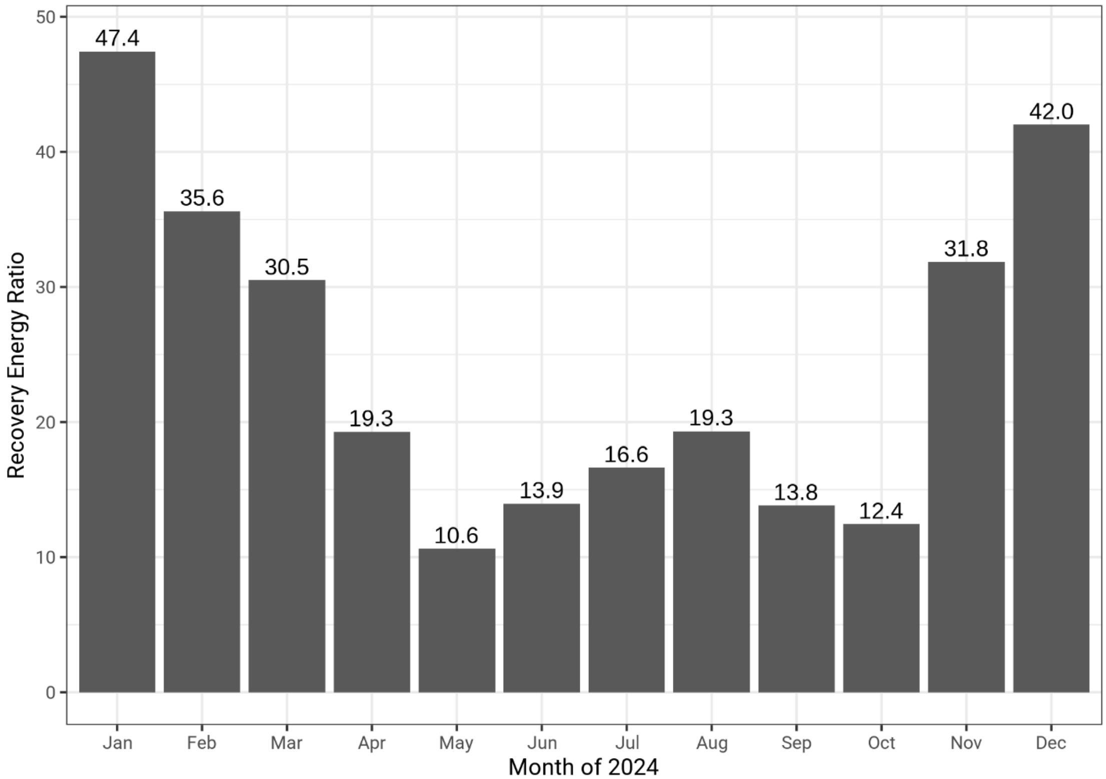


Performance Metrics

Recovery Energy Ratio

The recovery energy ratio, or RER, is the ratio of thermal energy recovered by the ERV to the input energy needed to operate the energy recovery system. This formulation means the RER is unitless, and it allows for direct comparison to the COP of typical mechanical equipment. Figure 13 shows that the monthly average RER is highest in the heating season, with values over 40 in January and December. Since conventional gas-fired heating equipment has a maximum COP of less than one, this means the ERV is more than 40 times as efficient as a conventional gas-fired furnace. In the cooling season, the RER is lower, primarily because the amount of recovery is lower. However, assuming a conventional AC COP of 3, the ERV is still many times more efficient than conventional cooling equipment. The lowest RERs occur in the shoulder seasons, when recovery is minimized and additional fan power is still required to move air through the energy recovery wheel, but the monthly average RERs are still better than anything conventional heating or cooling equipment can achieve.

Figure 13. Average RER by month



Peak Capacity Reduction

A key benefit of energy recovery is that it allows the design capacity of the heating and cooling equipment to be reduced. In 2024, with the help of the energy recovery section, the overall DOAS system provided a higher peak heating capacity of 370 kBtu/h and cooling capacity of 36 tons more than the rated conditions of the furnace or air conditioning, 365 kBtu/h and 22 tons, respectively. In the peak heating conditions, the furnace only had to provide 173 kBtu/h heating. In the peak cooling conditions, the AC only had to provide 12 tons of cooling. Down-sizing primary HVAC equipment when energy recovery is possible is a useful design strategy with multiple benefits, including reduced first cost, reduced physical size, reduced weight, and easier installation.

Savings

Energy

Overall, the energy recovery system saved 1,729 therms of gas and 2,692 kWh of electricity. These savings are due to the significant reduction in heating and cooling load from the energy recovery wheel.

Figure 14 shows the monthly gas and electricity savings in common units. This is broken down in Table 4. The electricity savings indicate negative values during the heating season, representing the energy penalty associated with moving air through the energy recovery section. However, this penalty is quite small compared to the magnitude of gas savings. In the cooling season, there is a net electricity savings after accounting for the increased power required to move air through the ERV.

Figure 14. Energy savings by month

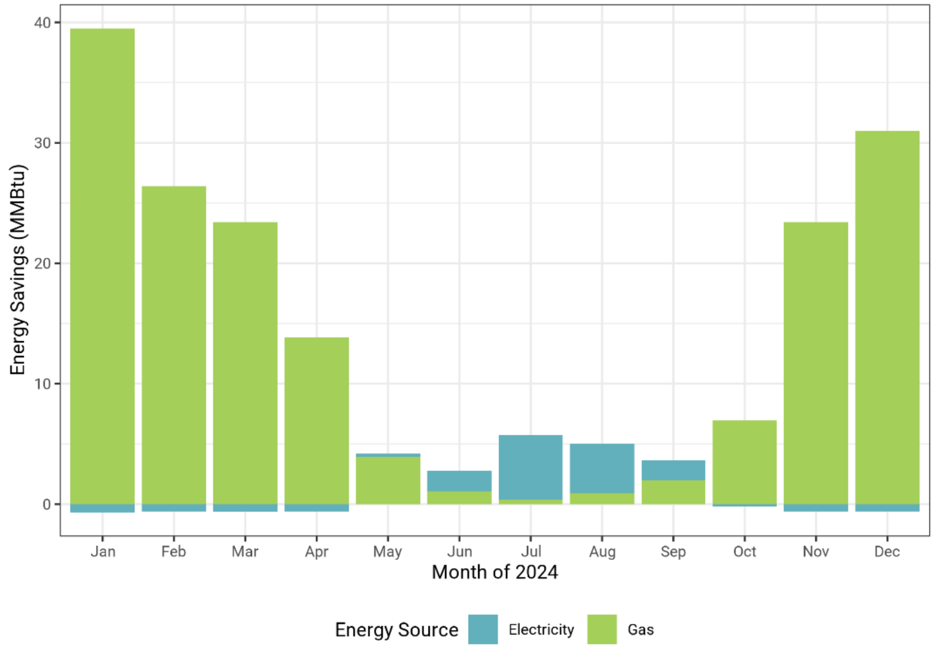


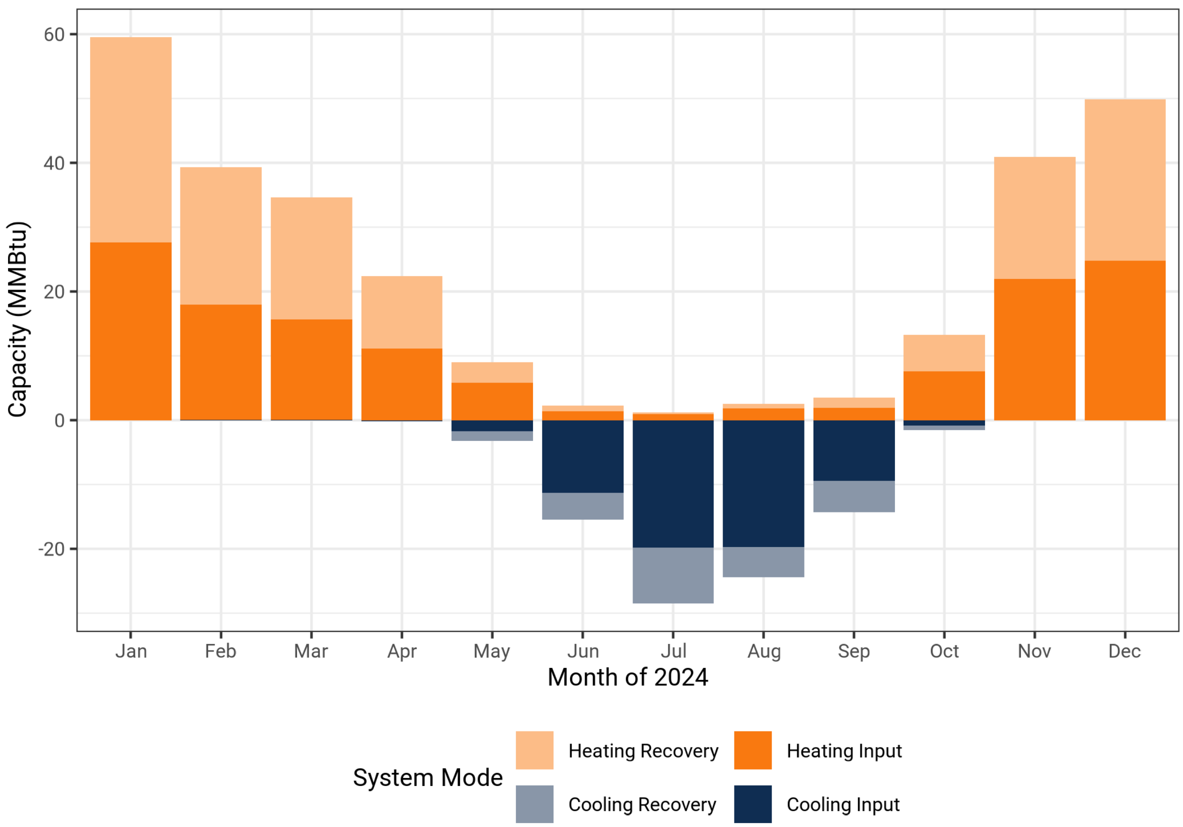
Table 4. Energy savings by month table

Month	Gas Savings (therms)	Electricity Savings (kWh)
Jan	395	-198
Feb	264	-176
Mar	234	-184
Apr	139	-173
May	39	74
Jun	11	509
Jul	4	1576
Aug	9	1196
Sep	20	472
Oct	69	-54
Nov	234	-175
Dec	310	-175
TOTAL	1729	2692

Capacity

Plotting heating and cooling capacity by mode shows the difference between a DOAS with and without an ERV. This is shown in Figure 15. The total height of the bars is the amount of heating and cooling capacity that would be required without an ERV, and the darker shaded bars represent the capacity that is required with an ERV. Note, in this plot, negative values for capacity represent cooling. This plot also shows that in the heating season, the ERV assumes over half the heating load. In cooling season, the share of the cooling load met by the ERV is relatively smaller but still significant. For example, the ERV provides around 30% of the total cooling load in July.

Figure 15. Capacity by month and source



Demand

Demand savings associated with the energy recovery system were significant, especially in July, when the hottest hour of the month was also extremely humid. In these conditions, the ERV drastically reduced the latent load on the mechanical cooling equipment, resulting in demand savings of nearly 37 kW. The demand savings for the other months, which is likely more typical, were in the range of 12.3 kW–16.2 kW, as shown in Table 5.

Table 5. Electric demand savings estimates

Month	Outdoor Temperature (°F)	Outdoor RH (%)	Demand Savings (kW)
June	89.6	54	12.3
July	91.4	83	36.8
August	93.5	61	16.2
September	88.7	39	12.3

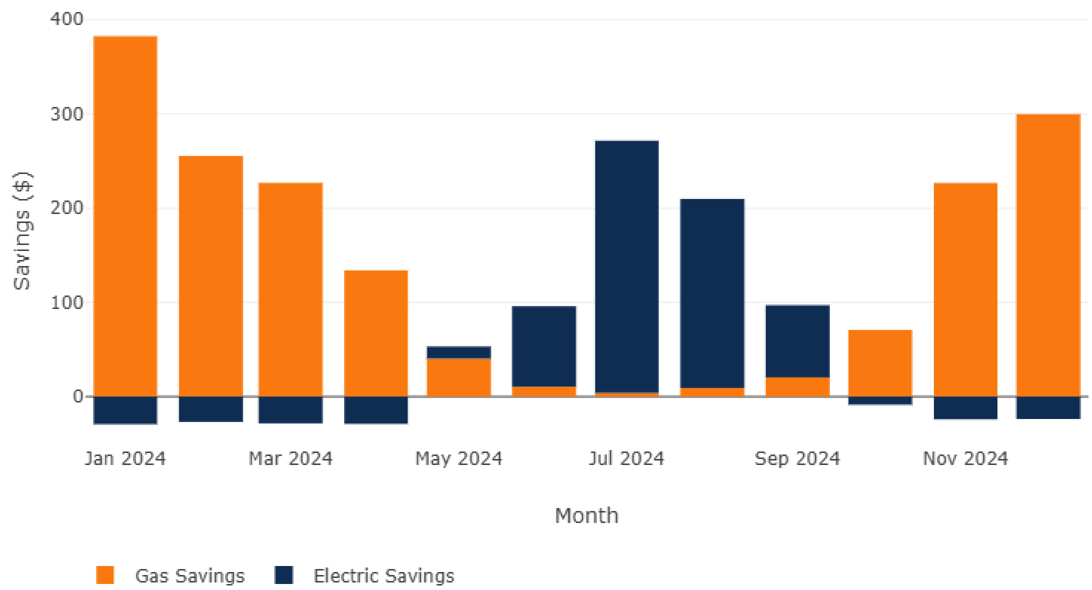
Cost

Cost savings result from purchasing less gas and electricity, and from reduced electric demand charges, shown in Figure 16. The ERV reduced the operating cost of this DOAS by approximately $3,202 in 2024. Of this savings total, the largest share ($1,682) is from gas cost savings. Electric demand reduction resulted in $1,283 in savings, and electric energy consumption resulted in an additional $237 in savings, as shown in Table 6.

Table 6. Cost savings annual summary

Source	Cost Savings
Gas	$1,682
Electric Energy	$237
Electric Demand	$1,283
2024 Total	**$3,202**

Figure 16. Monthly cost savings by utility



For Figure 16, negative savings are indicative of the actual costs being greater than the costs for the hypothetical system. In this case, the electricity used to overcome the pressure differential across the ERV by the blower fan would not be needed by the hypothetical system and so electricity costs are not offset and count as negative savings.

Emissions

Using the emissions factors noted in the Methods section, the ERV helped avoid an estimated 9,181 kg CO_2e (10.1 tons CO_2e) compared to the hypothetical DOAS gas emissions for the year, as shown in Table 7. The ERV is also estimated to have avoided 1,135 kg CO_2 (1.24 tons CO_2) of emissions from electricity compared to the hypothetical system.

Table 7. Emissions summary

	Natural Gas Emissions (kg CO_2e)	Electric Emissions (kg CO_2)	Total Emissions (kg CO_2)
Actual	9077	5101	14178
Hypothetical	18258	6236	24494
Avoided	9181	1135	10316

Conclusion and Lessons Learned

Minnesota's cold winters and hot humid summers provide opportunities for ERVs to generate significant energy savings. While this study monitored a DOAS, lessons can be learned from this study that extend across light commercial RTUs as well. For example, the DOAS studied spent 75% of the time occupied in energy recovery mode, which shows that outdoor air temperatures are appropriate for energy recovery for a large part of the year, regardless of the HVAC system the ERV is serving.

It was also shown that HVAC systems can be downsized when energy recovery is utilized, which could save first cost, weight, and installation time. This could be applied to RTUs, and would be especially useful for heat pump RTUs, where heat pump capacity may be smaller in heating than it is in cooling.

Summer demand charges were reduced due to energy recovery during cooling. This would support existing demand response programs and reduce both customer cost and grid demand during summer peaks.

With these energy and bill savings, ERVs should be considered a strong energy-saving strategy, to be supported by utility programs and energy code, for both DOAS and RTU applications.

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