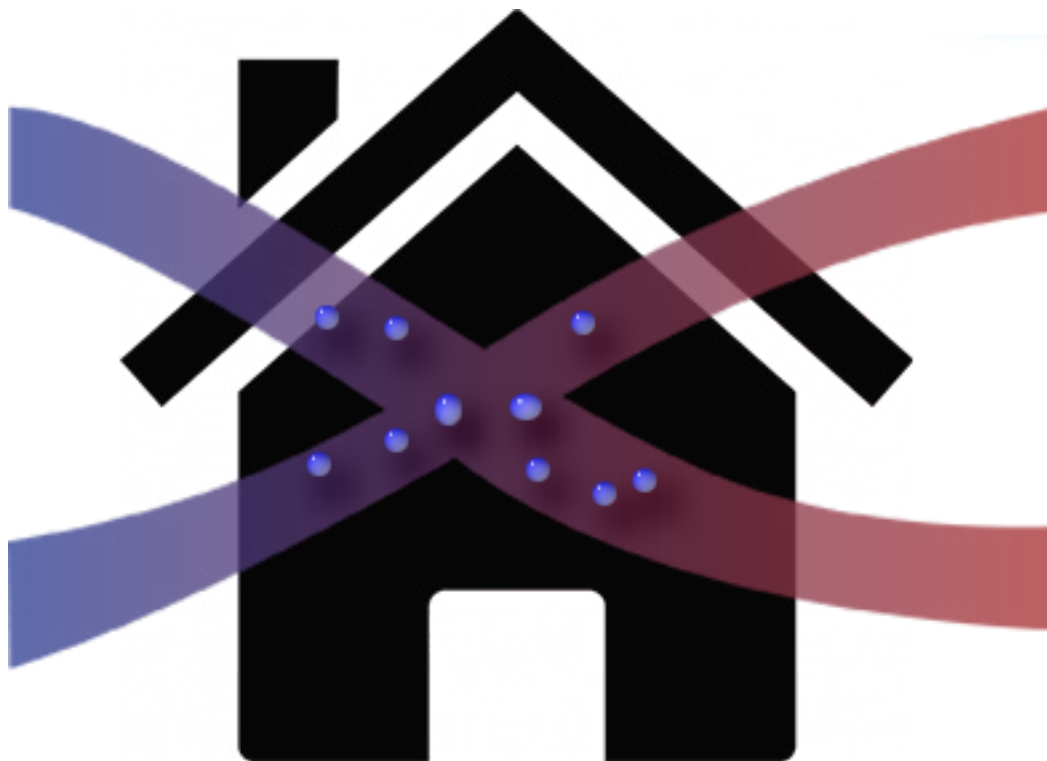COLD CLIMATE HOUSING RESEARCH CENTER
CCHRC

Energy Recovery Ventilators in Cold Climates

Investigating the Potential of ERVs to Improve
Indoor Air and Effectiveness in Cold Climates

by Robbin Garber-Slaght &
Vanessa Stevens

Energy Recovery Ventilators in Cold Climates

Investigating the Potential of ERVs to Improve Indoor Air and Energy Recovery in Cold Climates

Abstract

Mechanical ventilation is a solution to improving indoor air quality in newer, airtight buildings that are designed to minimize energy use. However, ventilation comes with its own costs and can cause problems of its own. Introducing cold, dry outdoor air into a space increases heating costs and can over-dry the indoor air. Heat and Energy Recovery Ventilators (HRV/ERVs) can mitigate the heating costs somewhat by recovering heat from the exiting air. This study was designed to determine if ERVs improve indoor relative humidity over HRVs and to compare the energy recovery effectiveness of an ERV to that of an HRV. The study found that at indoor relative humidity levels above 25% the ERV can significantly improve the relative humidity over an HRV, but at lower RH there is less improvement in indoor humidity. The energy effectiveness data is inconclusive with the ERV and HRV core showing similar sensible effectiveness.

Keywords: Ventilation, Energy Recovery Ventilators (ERVs), Heat Recovery Ventilators (HRVs), Indoor Air Quality

Energy Recovery Ventilators in Cold Climates
Investigating the Potential of ERVs to Improve Indoor Air and Energy Recovery in Cold Climates

Indoor Air Quality (IAQ) is a growing concern in colder regions as buildings become more airtight. Older buildings have passive air leakage in the form of leaky building envelopes, but new construction techniques are designed to minimize air leakage through the envelope, which results in very little fresh air entering the building. This means that indoor pollutants like volatile organic compounds (VOCs) and particulate matter (PM2.5) can buildup and create poor IAQ in the building. To correct poor IAQ, mechanical ventilation systems are installed to exchange stale indoor air with fresh outdoor air. These ventilation systems often remove moisture from the air and do not replace it, causing buildings to become too dry for human comfort and health. Energy Recovery Ventilators (ERVs) are a potential solution for excessive drying of indoor air, as they exchange heat and moisture from the exhausting air into the incoming air stream. ERVs are not often used in cold climates so their performance is relatively unknown in these areas.

In the cold arid climate of Interior Alaska the average winter indoor RH for homes is about 27% (Johnson, Schmid, & Siefert, 2002). This humidity level is considered low for human health and comfort (Sterling, Arundel, & Sterling, 1985). A ventilation system that exhausts air or is balanced and recovers heat from exiting air can further dry the already dry indoor air. ERVs have the potential to recover some humidity and thus maintain or improve the indoor air.

This study is a follow-up to a Cold Climate Housing Research Center (CCHRC) study of ERV frosting in 2014 (Garber-Slaght, Stevens & Madden, 2014) which concluded that ERVs did not frost to the point of inoperability. This study was designed to answer a few questions that came to light in the previous study:

1. Can ERVs improve indoor relative humidity (RH) over Heat (only) Recovery Ventilators (HRVs)?
2. How does the effectiveness of energy recovery in an ERV compare to an HRV?

Literature Review

The optimum indoor RH for human health is 40–60% (Sterling, Arundel, & Sterling, 1985). However, due to Interior Alaska's extreme cold climate, buildings cannot tolerate such high levels. Siefert et al. (2008) suggest an RH zone of 30–50% as a compromise. ERVs can be effective in maintaining more acceptable indoor RH in homes, as shown by both modeling and experimental research. The effectiveness of ERVs is dependent on climate and season, with the highest effectiveness levels achieved when outdoor and indoor temperature and RH have the largest difference; in Alaska this is during the cold season.

There are two types of ERV energy exchangers: rotary and fixed plate. Rotary exchangers, also called energy wheels, are cylinders filled with an air permeable structure that rotates. As the wheel rotates the supply and exhast air pass through the wheel in a counter-flow pattern. Fixed plate exchangers are also called membrane based cores or cross flow energy exchangers. Plate energy exchangers have parallel plates that separate the supply air from the exhaust air, which pass each other in a cross-flow pattern. In an HRV only heat is transferred from the exhaust to the supply; in an ERV plate exchanger heat and water vapor are transferred across the plates.

Relative Humidity

Fauchoux, Simonson, & Torvil (2007) used TRNSYS modeling software to determine if an energy wheel

could improve the RH and perceived air quality in a building while reducing energy consumption. Among four North American cities that were considered in the modeling, the energy wheel was successful in reducing peak RH levels in office buildings in Tampa, Phoenix, and Vancouver, while Saskatoon saw little change (Fauchoux et al., 2007). In the cold dry climate of Saskatoon, the energy wheel had a maximum RH difference of +10% and a minimum of -5% but averaged between 0.5% and -0.5%, indicating little effect of the ERV. Lam, Lee, Dobbs, & Zhai (2005) utilized EnergyPlus software to model five different HVAC systems, including an ERV, an ERV with an economizer, and an ERV with bypass option in a generic building model occupied by 10 people. The building was placed in 62 cities in the United States for comparison simulations. The effectiveness of the ERV on improving indoor RH conditions, as measured by a reduction in the number of hours when indoor RH was not in an acceptable range, was dependent on climate. ERVs were more effective at saving energy when the heat loss or gain resulting from outdoor air was a major contributor to the building heating/cooling load, with the bypass option increasing the energy efficiency of the system (Lam et al., 2005).

In a field study (Aubin et al., 2013) in Quebec City, researchers monitored the indoor air quality of 43 homes that received additional ventilation by installing HRVs and ERVs. They found that the addition of an ERV in a home helped maintain acceptable indoor RH during winter, which are typically dry. On the other hand, HRVs lowered the indoor RH during the winter, caused by the additional ventilation through intake of cold, dry outdoor air. In the summer, both HRVs and ERVs increased RH in the homes (Aubin et al., 2013). In a separate study, Ouazia, Swinton, Julien & Manning (2006) compared an ERV directly to an HRV during the cooling season (heating conditions were not studied) in a side-by-side test using the twin houses at the Canadian Centre for Housing Technology in Ottawa. The house with the ERV was found to have more efficient humidity control, with a consistent lower RH during the humid summer (5% to 10%) for airflows of 65 and 115 cfm. The study has also shown that the ERV helped to reduce the latent ventilation load (reduction of up to 12% of the A/C electricity consumption). Rudd & Henderson (2007) monitored indoor temperature and RH in 43 homes in warm-humid and mixed-humid climates. The homes had a variety of HVAC systems and different levels of designs in regard to energy use. Three of the high performance homes in the study had ERVs. These homes had higher RH levels than the standard-performance houses with centrally integrated fan supply ventilation systems or no mechanical ventilation, but slightly lower RH than other high performance homes with different types of ventilation. The ERVs were found to help reduce the latent ventilation load (during cooling applications) in the high performance homes, but did not improve indoor RH during times of part-cooling load or no-cooling load conditions (Rudd & Henderson, 2007).

Frosting

CCHRC published a report on ERVs in 2014 where researchers studied the in-situ freezing potential of ERVs in Fairbanks, Alaska. The study found that while there were periods of time when some systems had the potential to freeze, the cold climate defrost strategies of the units prevented freezing failures in the systems. The study did not address any improvements in indoor air or the heat recovery effectiveness of the units (Garber-Slaght, Stevens & Madden, 2014).

Rafati Nasr, Fauchoux, Besant & Simonson (2014) found that cross-flow heat exchangers are less prone to frost blockage than other types of cores (i.e. counter flow or enthalpy wheels). Rafati Nasr et al. (2014) additionally reported that energy exchangers have a lower frosting risk than heat exchangers. Energy exchangers usually cost more than HRVs but have larger energy savings (Rafati Nasr et al., 2014).

HRV and ERVs in cold climates have an added requirement of a defrost cycle. Often this defrost cycle lowers the effectiveness of the unit. There are a variety of ways to prevent frost failure in an ERV or HRV;

they are presented in Table 1 along with associated penalties.

Table 1. ERV and HRV frost control strategies.

Frost Control Strategy	Penalty
Electric preheat of incoming air	*Increases electrical demand/use* *Lowers the effectiveness of the unit*
Mixing incoming air with room air to preheat	*Cross contamination of fresh air with stale air* *Less fresh air is supplied to the building*
Closing the incoming air damper totally or in part to create an exhaust-only unit	*Depressurization of building* *Fresh air depends on the leakiness of the building envelope* *Contaminant transfer from adjacent zones*
Recirculating exhaust air temporarily through the core to melt ice	*No ventilation during defrost* *Cross contamination of air* *Water needs to drain from the unit*
Closing the incoming air damper to temporarily create an exhaust fan that allows ice to melt	*Depressurization of building* *Water needs to drain from the unit* *Contaminant transfer from adjacent zones*

Several recent studies have looked at defrost cycles, efficiency, and indoor air quality. In general, the frosting limit (the minimum outdoor temperature that does not lead to frost in the core) for ERVs is 9 to 18F° (5 to 10C°) less than HRVs (Rafati Nasr et al., 2014). This lower frosting limit lowers the energy and IAQ costs of the defrost cycle for ERVs. Rafati Nasr (2016) showed that the required defrosting time for an energy exchanger is much less than a heat exchanger under similar operating conditions. Additionally, the frost accumulation rate in the energy exchanger was three times slower than in the heat exchanger (Rafati Nasr, 2016). Zhang & Fung (2015a) found that the yearly defrost demand for an HRV is 3.5 times greater than that of an ERV in the Toronto area. Rafati Nasr, Kassai, Ge, & Simonson (2015) found that ERVs are less impacted by cold weather and are more effective in colder climates due to their ability to lower the frosting limit.

Effectiveness

The Home Ventilating Institute (HVI) certifies ERVs for efficiency using a variety of different efficiency metrics. Their main efficiency terms are defined in Table 2 (Home Ventilating Institute, 2015).

Table 2. HVI's ERV and HRV efficiency terms.

Efficiency Term	Definition
Sensible Recovery Efficiency (SRE)	The net sensible energy recovered by the supply airstream as adjusted by electric consumption, case heat loss or heat gain, air leakage, airflow mass imbalance between the two airstreams and the energy used for defrost, as a percent of the potential sensible energy that could be recovered plus the exhaust fan energy.
Apparent Sensible Effectiveness (ASEF)	The measured temperature rise of the supply airstream divided by the difference between the outdoor temperature and entering exhaust system air temperature, then multiplied by the ratio of mass flow rate of the supply airflow divided by the mass flow rate of the lower of the supply or exhaust system airflows.
Total Recovery Efficiency (TRE) or Enthalpy Efficiency	The net total energy (sensible plus latent, also called enthalpy) recovered by the supply airstream adjusted by electric consumption, case heat loss or heat gain, air leakage and airflow mass imbalance between the two airstreams, as a percent of the potential total energy that could be recovered plus the exhaust fan energy.

ERV Testing

CCHRC tested three ventilation units from February 2015 through May 2015. Two of the units studied were originally installed as HRVs, but as part of the study the HRV core was swapped with an ERV core on a weekly schedule. The HOUSE system is in a private home and is ducted to serve the entire house. The house is 1,500 ft^2 and has three bedrooms and three occupants. The house has in-floor hydronic heat. The MTL system is in CCHRC's Mobile Test Lab, a 188 ft^2 unoccupied space. The space is ducted with one supply and one return duct from the main room, the main room is heated with electric radiant heaters. A humidifier set to maintain the indoor RH at 40% was employed to create humidity in the absence of occupants. The third unit is a residential size ERV that maintained its original ERV core throughout the study. This unit is installed in a CCHRC classroom. The CLASS ERV unit is ducted to serve two classrooms and one bathroom, which are heated with hydronic baseboard. Since the space is occupied intermittently it was humidified during the study to 40%. Table 3 presents details on the three units.

Table 3. ERVs tested.

Model	Location	Defrost Cycle	Controls
Venmar EKO1.5	CCHRC Mobile Test Lab (MTL)	Extended HRV recirculation mode Below 23°F 10 min recirc/20 min normal Below -17°F 10 min recirc/15 min normal	Constant 157 CFM first 2 weeks Constant 80 CFM for the rest of the study (5 weeks)
Venmar EKO1.5	Private Home Keystone Rd. (HOUSE)	Extended HRV recirculation mode Below 23°F 10 min recirc/20 min normal Below -17°F 1 min recirc/15 min normal	Programmed control 20 min/hr at 132 CFM; constant 66 CFM from 6 to 9 am and 5 to 11 pm
Lifebreath 150ERVD	CCHRC upstairs classroom (CLASS ERV)	Defrost port opens to the conditioned space and closes to incoming air Below 27°F 3 min defrost / 25 min vent time	Always on at 45 CFM

Each unit was monitored in multiple places for temperature and relative humidity. Table 4 shows information on the sensors used while Figures 1 and 2 show the location of the sensors. There were also a temperature and a relative humidity sensor in the space conditioned by the ERV unit. Additionally, each unit had a differential pressure transducer measuring any changes in pressure across the exchanger core in the exhaust stream.

Table 4. Sensors.

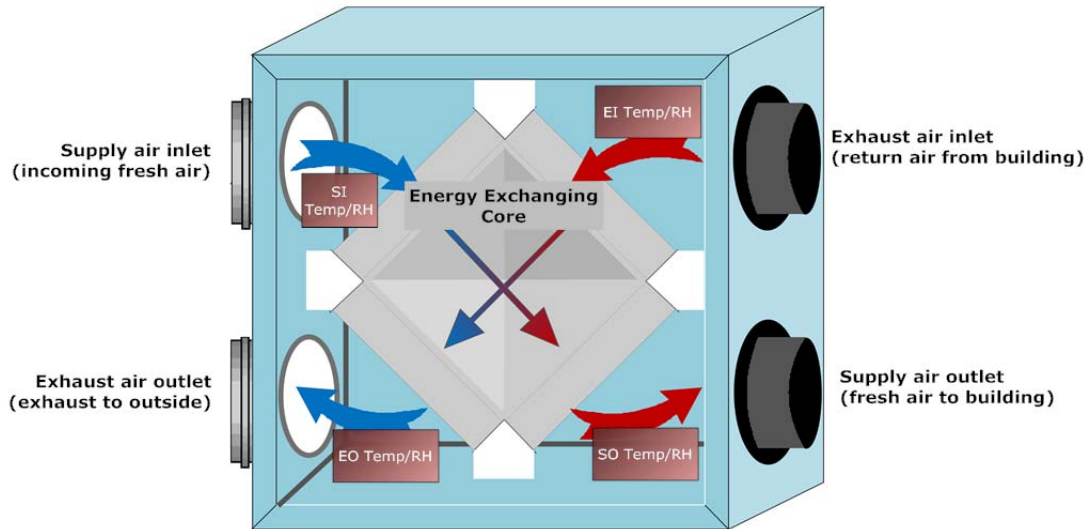| Sensor Type	Range and Accuracy
Temperature – NTC thermistors	-20°C to 80°C ±0.1°C (-4°F to 176°F ±0.18°F)
Relative Humidity – HIH 4000	0 to 100% ±3.5%
Pressure – Setra 265	0 to 1 WC ±1% F.S.

Figure 1. The MTL and HOUSE systems showing sensor locations. The HRV and ERV core for this unit are interchangeable. Each location had one of each sensor strategically placed to record the mixed air average. SI stands for Supply Inlet, EI is Exhaust Inlet, SO is Supply Outlet, and EO is Exhaust Outlet.
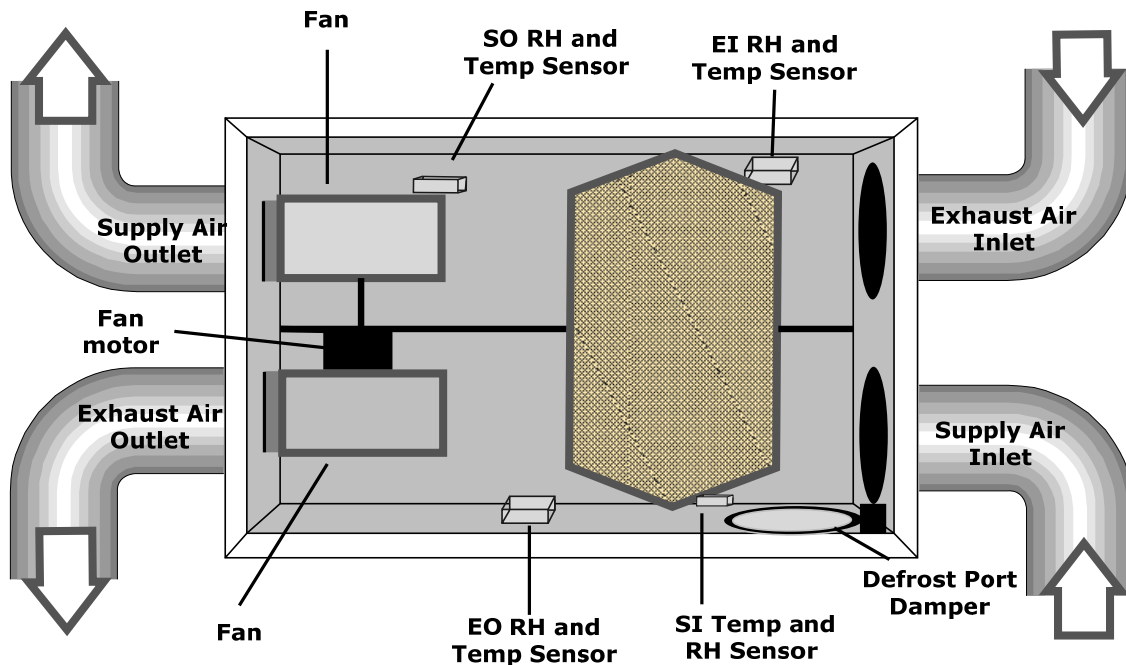

Figure 2. The CLASS ERV showing sensor locations. This unit uses the defrost port damper to defrost the cross-flow core for short periods of time at cold temperatures. Each location had one of each sensor strategically placed to record the mixed air average. SI stands for Supply Inlet, EI is Exhaust Inlet, SO is Supply Outlet, and EO is Exhaust Outlet.

The conditioned space was analyzed for differences in RH based on whether the ERV or HRV core was installed at the time. The temperature and RH across the core was used to estimate the sensible, enthalpy, and moisture transfer effectiveness. The supply and exhaust flows were assumed equal (based on balancing

the flows at the beginning of the study). With equal flows and disregarding any heat transfer beyond the transfer in the exchanger, the sensible effectiveness can be calculated using Equation 1. In terms of HVI standards this equation is most equivalent to the ASEF. Where *T* is temperature (°C), *SI* is supply inlet, *SO* is supply outlet, and *EI* is exhaust inlet. Fan power and air leakage across the core are ignored.

$$\text{sensible effectiveness} = \frac{T_{SO} - T_{SI}}{T_{Ei} - T_{SI}}$$ (1)

The mass transfer effectiveness, also called latent effectiveness, is a function of the humidity ratio, which was calculated using ideal gas law relationships. Equation 2 was used to determine the humidity ratio (*w*) of each air stream and Equation 3 (Zang & Fung, 2015b) was used to calculate mass transfer effectiveness. *P* is air pressure (assumed barometric pressure at sea level, 1013.25 hPa) and *Pw* (hPa) is the partial pressure of water vapor.

$$\text{humidity ratio } (w) = 0.62198 * \left(\frac{P_w}{P - P_w}\right)$$ (2)

$$\text{mass transfer effectiveness} = \frac{w_{SO} - w_{SI}}{w_{EI} - w_{SI}}$$ (3)

The total heat recovery or enthalpy effectiveness (disregarding transfer from the fans or through the cases) was estimated using Equation 4 (ASHRAE, 2013), where *i* equals enthalpy at each location of the ERV (KJ/Kg air). Enthalpy was estimated using Equation 5 (McQuiston, Parker, & Spitler, 2005), which uses a constant 0°C to assume a constant specific heat (again assuming equal flow). *T* is temperature in °C.

$$\text{enthalpy effectiveness} = \frac{i_{SO} - i_{SI}}{i_{Ei} - i_{SI}}$$ (4)

$$\text{enthalpy}(i) = T + w(2501.3 + 1.86T)$$ (5)

These effectiveness estimates are based on measurements of in-service ventilation systems with several simplifying assumptions about system performance, therefore the calculations are of unknown accuracy. HVI provides efficiency numbers for these units at a steady state temperature of -13°F (see Table 7). The calculated effectiveness estimates in this study allow for a comparison between the HRVs and ERVs in widely varying conditions.

Results

Relative Humidity – HOUSE

The data collection system inside the HRV/ERV in the private home failed, however the indoor RH was on a separate system and there is extensive data on the indoor RH over the course of the study. During the first 2 months of the study, the cores were changed every seven days on Monday evenings. During this 2-month period average RH with the ERV core installed was 42.4% while it averaged 37.2% with the HRV core. Table 5 shows the average RH breakdown by date. The large mass of cellulose in this house creates a hygric buffer that tempers sudden changes in indoor RH. The colder period between March 9 and March 17 was caught almost entirely by the HRV core and could be a reason for lower RH with the HRV core (as the outdoor

temperature drops, the absolute humidity in the incoming air drops to close to 0), although the following two weeks had similar outdoor temperatures and the ERV core maintained a higher RH by 5%. Figure 3 shows the changes in RH over time and marks the changes in the core. The RH with the ERV core is generally higher than with the HRV core. As the house was occupied over the course of the study there are more variables at play than just the core type and the outdoor temperature. Occupant behavior most likely accounts for many of the fluctuations in the RH, which was not controlled nor monitored as part of this study. Figure 4 shows the changes in RH inside the house over the course of a few days. The spikes in RH at end of each day show when the occupants were in the home and influenced the indoor RH.

Table 5. HOUSE RH by date and core.

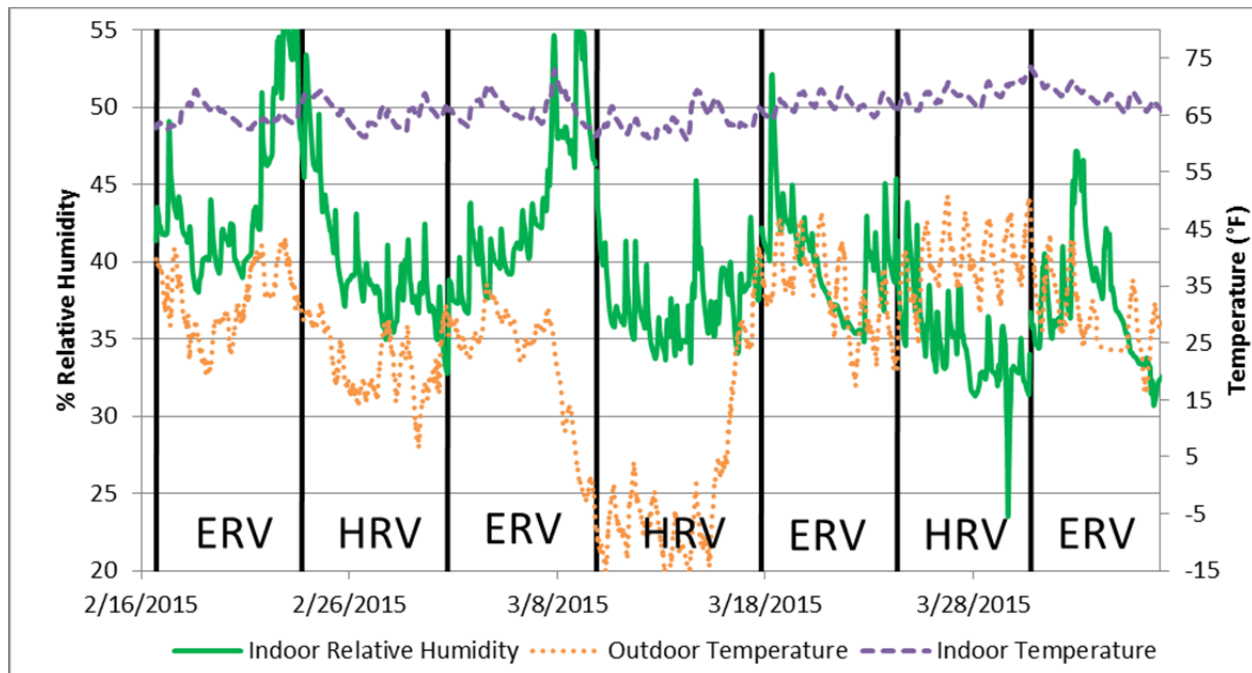| Date	RH with ERV	Date	RH with HRV
2/16 to 2/23	44%	2/23 to 3/2	39%
3/2 to 3/9	42%	3/9 to 3/17	36%
3/17 to 3/24	40%	3/24 to 3/30	35%

Figure 3. HOUSE indoor relative humidity based on core. The indoor RH tracked with the changing of the cores, but was most affected by outdoor temperature.
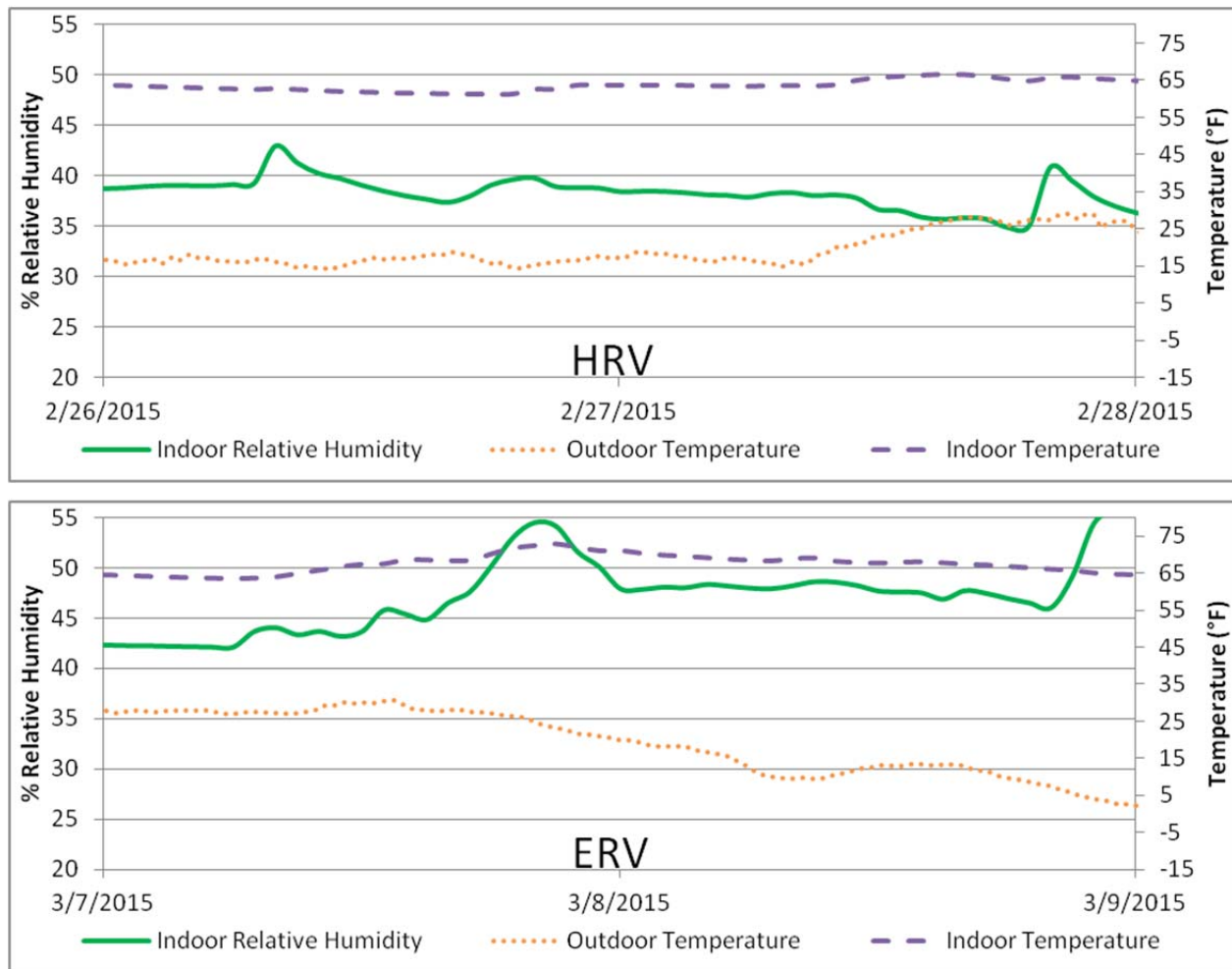
Figure 4. Sample daily conditions in the HOUSE. These charts show the effect the home occupants had on the indoor relative humidity.

Following the 2 months of exchanging cores on a weekly basis, the ERV was put in place and left. As the outdoor temperatures rose the indoor relative humidity also rose, until the homeowners found the house "too stuffy" (personal communication, J. Grunau, April 2015). Figure 5 shows the rise in relative humidity with the rising temperatures. The HRV core brought the indoor humidity down to more comfortable levels (as defined by the home occupants) within a day.
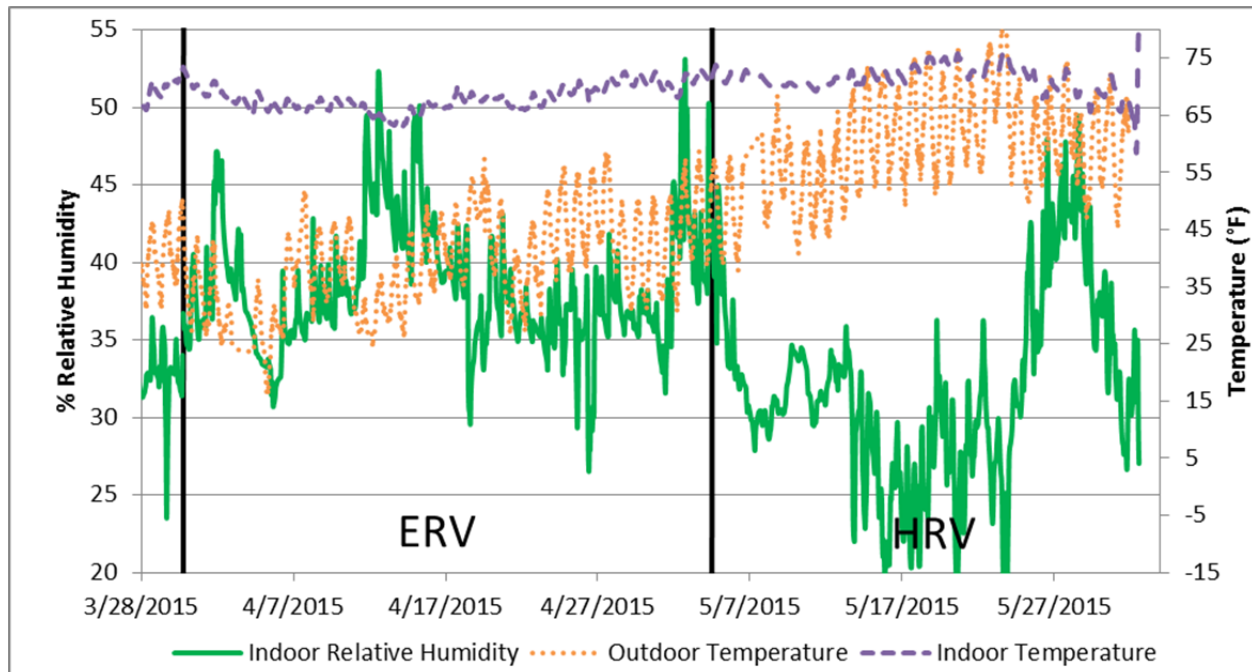
Figure 5. Last month of HOUSE relative humidity with the ERV core. The house occupants found the air in the house "too stuffy" and changed the core back to the HRV in early May.

Relative Humidity – MTL

The MTL was set up to maintain a constant RH of 40% while periodically rotating ERV and HRV cores. The Venmar EKO HRV/ERV hybrid set up in the MTL showed quantifiable moisture recovery with the ERV core. The MTL was humidified over the course of the study and the amount of water used by the humidifier was tallied for each core. The amount of water required to maintain a healthy 40% RH for 7 days with the HRV is higher than that needed for the ERV core: 48 liters for 7 days with the ERV versus 94 liters for 7 days with the HRV core. The first two core swap periods had the HRV/ERV unit set to maximum flow rate (140 CFM) which required too much water leading to the loss of humidity in the MTL during both periods. After the first two swaps the fans were turned to minimum flow rate (80 CFM). The HRV still ran dry for 10 hours during the testing. Figure 6 shows the humidity and water volume over time. The outdoor temperature and moisture content did fluctuate and probably added to some of the changes in water needs.
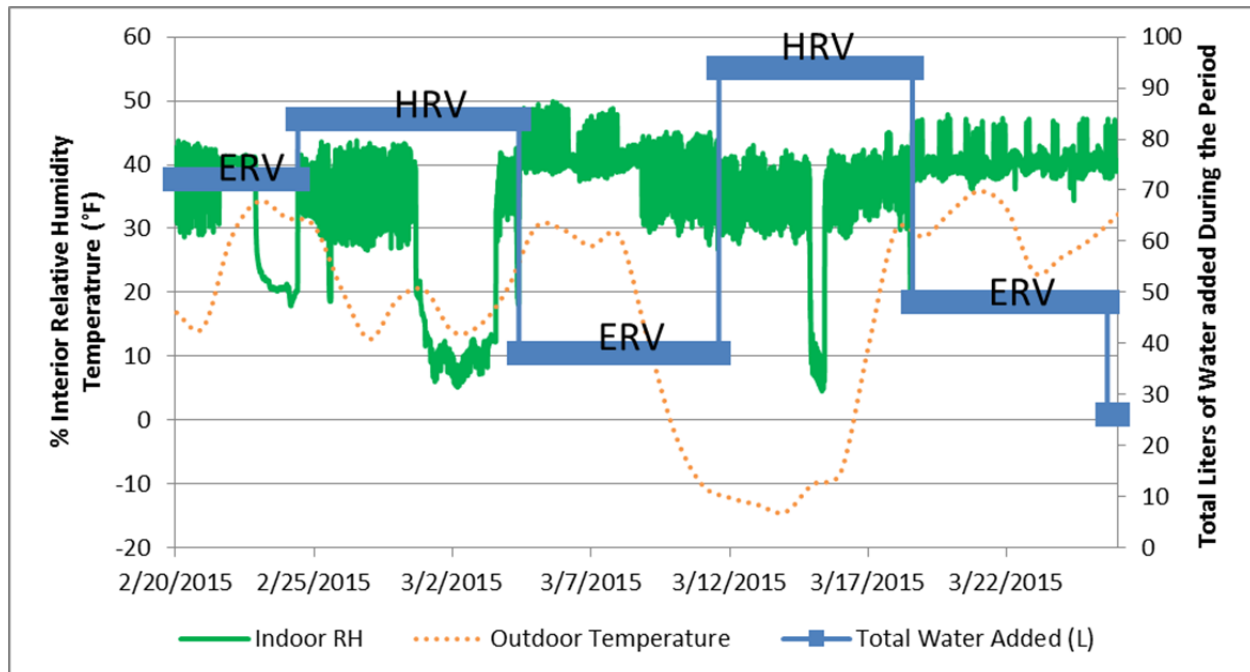
Figure 6. Indoor RH in the MTL based on core. The HRV required more water to maintain higher indoor humidity. The water is the total used during each 7 day period. The 2 drops in RH are when the humidifier ran dry as the HRV core required more water than expected.

Frosting - MTL

A damper in the ERV/HRV system in the MTL apparently froze open during a defrost cycle while the HRV core was installed. The freeze-up occurred around March 15, 2015 when the temperature was the coldest during the study period (-15°F). The freeze-up is apparent in the change in differential pressure across the exhaust airstream through the core and in the internal temperatures of the unit (Figure 7). The system defrosted completely after outdoor temperature rose above 20°F and the ERV core was installed.

The defrost cycle in all of these units creates liquid condensate that needs to run off. In the MTL the amount of condensate produced by the HRV/ERV was tallied for each core swap. The ERV core did not produce any measurable condensate, even though the temperatures were below the frosting limit and the defrost cycle certainly ran. In one seven-day cycle the HRV core produced 18 liters of condensate. Table 6 presents environmental conditions and condensate collected over the course of the study.

Table 6. Defrost Conditions of MTL ERV/HRV.

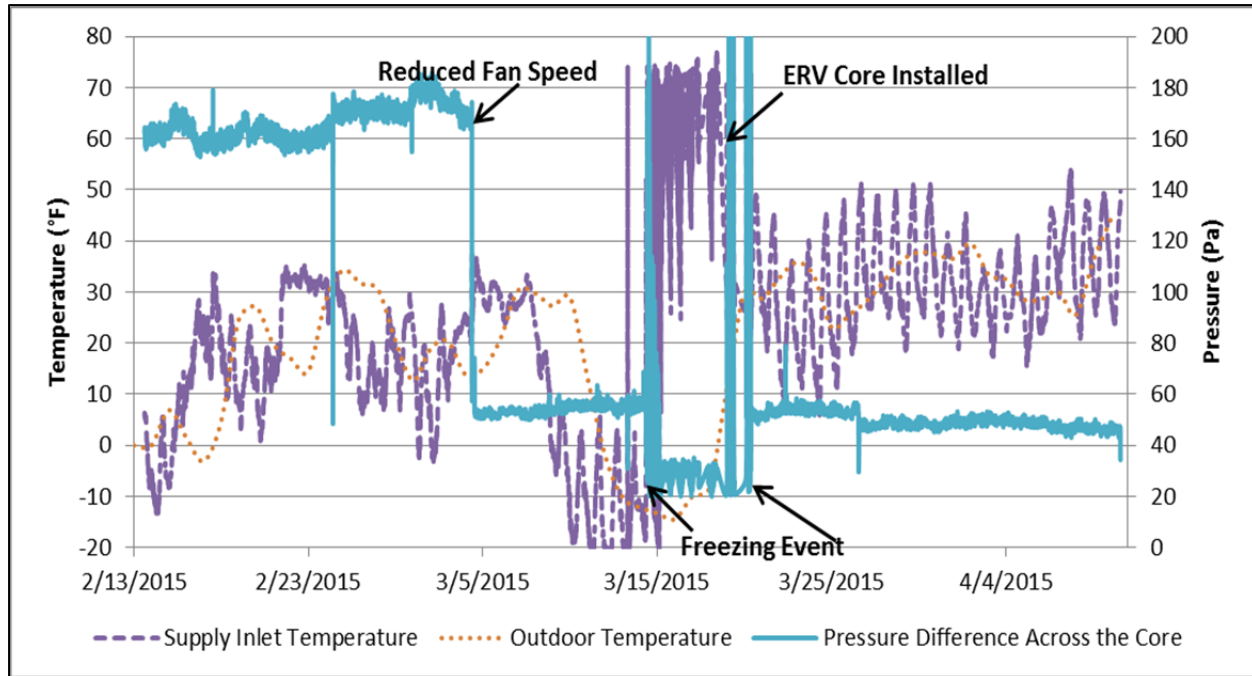| Date and Core	Average Indoor RH	Average Outdoor Temperature	Average Outdoor RH	Condensate
2/13 to 2/24/2015 **ERV**	32.0%	17.3°F	78.6%	Not Recorded
2/24 to 3/4/2015 **HRV**	28.6%	20.4°F	77.7%	Not Recorded
3/4 to 3/11/2015 **ERV**	40.3%	17.3°F	75.6%	0 L
3/11 to 3/18/2015 **HRV**	35.9%	-3.4°F	63.5%	18 L
3/18 to 3/25/2015 **ERV**	40.2%	29.8°F	57.2%	0 L
3/25 to 3/31/2015 **HRV**	25.2%	35.4°F	49.8%	2L

Figure 7. Pressure difference in the MTL HRV/ERV unit. The incoming air temperature was lower than the outdoor air as the outdoor air sensor was on the roof of the building well away from the MTL.

Effectiveness

The ERVs in the MTL and the classroom had adequate data to allow for the calculation of in-situ effectiveness. None of the calculations take into account the energy added by the fans or lost through air leakage across through the ERV case. Table 7 provides a summary of the factory specifications for the ERV units used. Figures 8 through 12 present graphical information on the in-situ effectiveness. The effectiveness data is fluctuating due in part to the defrost cycling but also due to changing outdoor temperatures.

Table 7. HRV and ERV specifications.

ERV	Location	Controls	Defrost Cycle	HVI Ratings
Lifebreath 150ERVD	*CCHRC Classroom*	*Always on at 45 CFM*	*Defrost port opens to bring in room air 27°F 3 mins defrost / 25 vent time*	*Sensible effectiveness 80%, Total recovery efficiency 57%*
Venmar EKO 1.5 ERV	*MTL*	*On 157 CFM then at 80 CFM*	*Extended recirculation mode 23°F 10 min recirc/20 min normal -17°F 10 min recirc/15 min normal*	*Apparent sensible effectiveness 75% (at -13F) Latent/Recovery Moisture Transfer 0.61 (at -13F)*
Venmar EKO 1.5 HRV	*MTL*	*On 157 CFM then at 80 CFM*	*Extended recirculation mode 23°F 10 min recirc/20 min normal -17°F 10 min recirc/15 min normal*	*Apparent sensible effectiveness 89% (at -13F)*

Effectiveness - Classroom ERV

The sensible effectiveness of the ERV in the classroom was relatively steady over the course of the study (see Figure 8). The average sensible effectiveness was 73%. The enthalpy effectiveness is dependent on the moisture content of each stream through of the core. It tracks slightly below the sensible effectiveness as the moisture transfer across the core is not as effective as the heat transfer. The average enthalpy effectiveness was 68%.
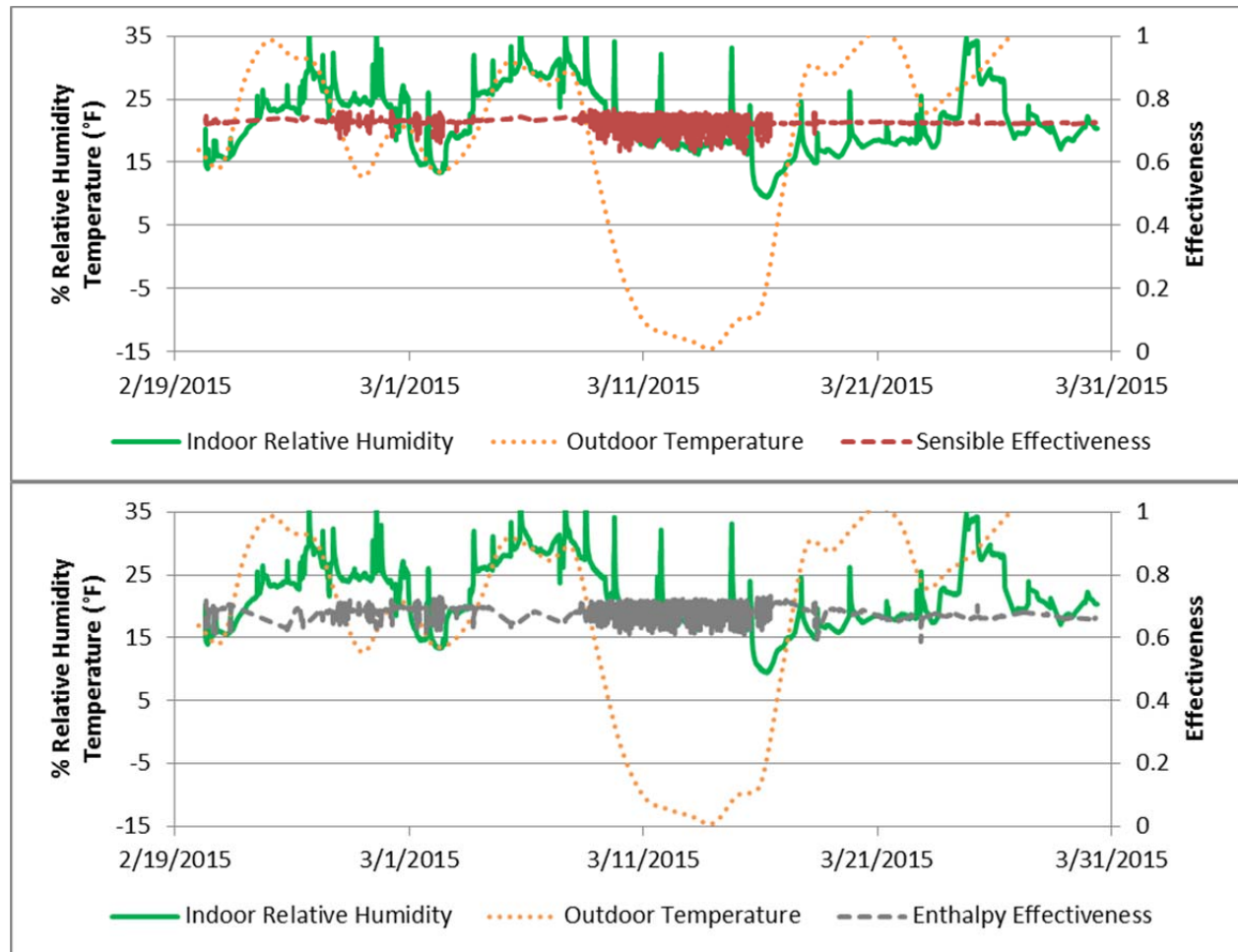

Figure 8. Effectiveness and conditions for the CLASS ERV. The sensible effectiveness is lower than the HVI tested 80% but the enthalpy effectiveness is greater than the HVI 57% at 68%. These differences could be due to different flow rates between the HVI testing and the in-situ testing.

The mass transfer effectiveness was volatile and had the best stability when the incoming air from outside was the coldest (Figure 9). At the coldest temperature the air coming in was the driest, which allowed for the greatest mass transfer from air with large amounts of moisture to air with almost no moisture (this will also have the greatest uncertainty in the data (ASHRAE, 2013)). The average mass transfer effectiveness during this period of higher transfer was about 44%. Over the entire course of the study the mass transfer averaged 29%.
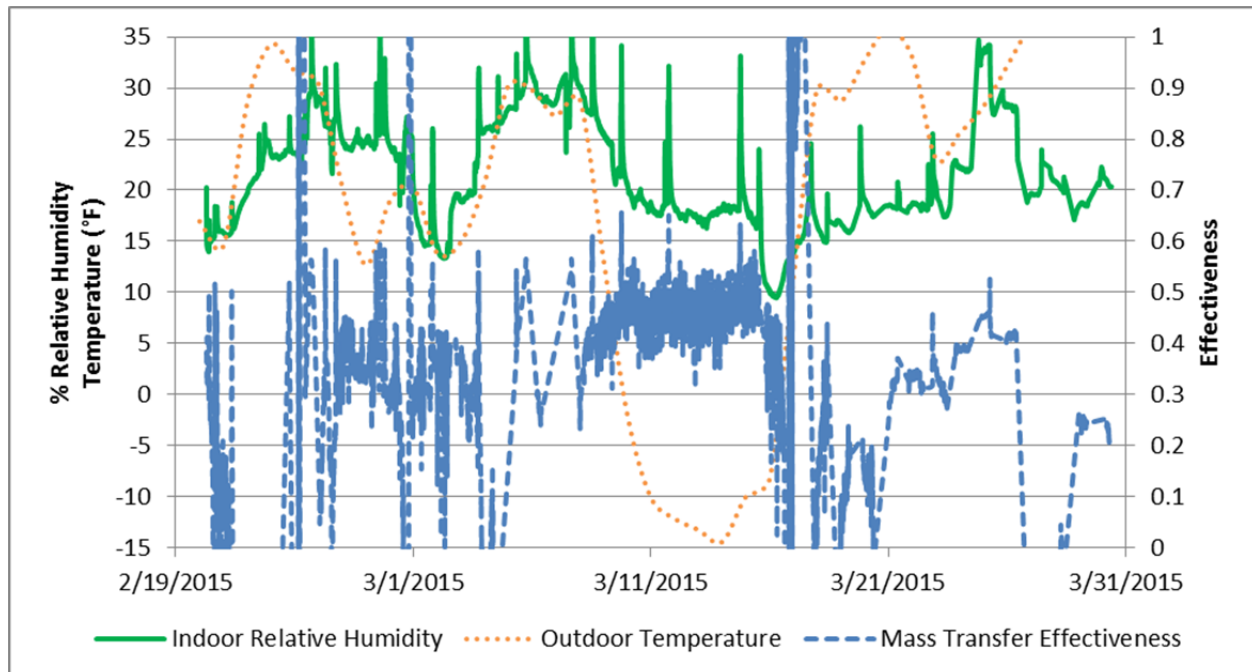
Figure 9. Mass transfer effectiveness for the CLASS ERV. The mass transfer effectiveness was highly variable due to many factors: leakage around the core, errors in data collection, and low RH in the classroom.

Effectiveness - MTL HRV and ERV combination

Figure 10 shows the sensible and enthalpy effectiveness over time for the MTL. The data is filtered to remove the defrost cycles. The sensible effectiveness was relatively stable over time but did climb when the outdoor temperature dropped. The sensible effectiveness with the ERV core averaged 57% over the entire study. The HRV core had a slightly lower sensible effectiveness of 55% over the entire study (a 2% difference that is in the margin of sensor inaccuracy); however it rose to 75% when the outdoor temperature dropped below 0°F. The enthalpy effectiveness tracked with the sensible effectiveness more than the mass transfer effectiveness. However, the ERV core did have higher enthalpy effectiveness than the HRV core. The ERV core averaged an enthalpy effectiveness of 65%. The HRV enthalpy effectiveness averaged 46%.
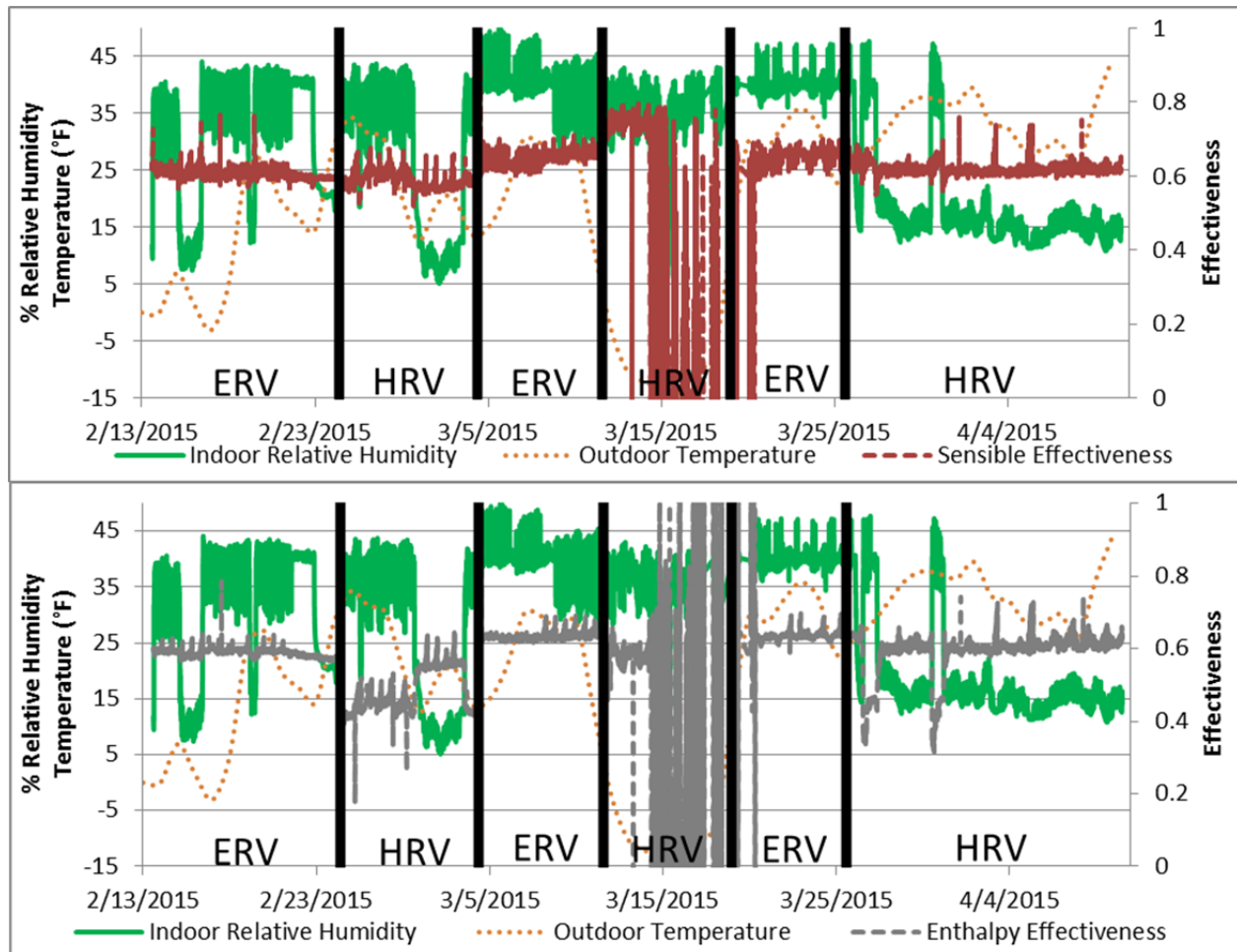
Figure 10. Effectiveness and conditions of the MTL ERV/HRV. The volatile data between March 14 and 18 is because a damper froze partially shut and very little air was being introduced to the space. This frozen damper occurred when the HRV core was in the unit and only thawed out after the ERV core was put in place and the outdoor temperature rose.

The mass transfer effectiveness is shown in Figure 11. Since the HRV core does not allow for mass transfer, any effectiveness numbers above zero for the HRV core are assumed to be the result of air leakage inside the unit, which can mix airstreams or from condensation build up in the core. The mass transfer effectiveness appears to be a function of the indoor RH. When the RH dropped below 15% in mid-February the mass transfer effectiveness dropped to zero. As the RH dropped after the humidification of the space stopped, relative lack of moisture on both sides of the core led to the widely oscillating and erroneous mass transfer effectiveness after March 25. The average mass transfer effectiveness for the ERV core at 40% RH was 45%.
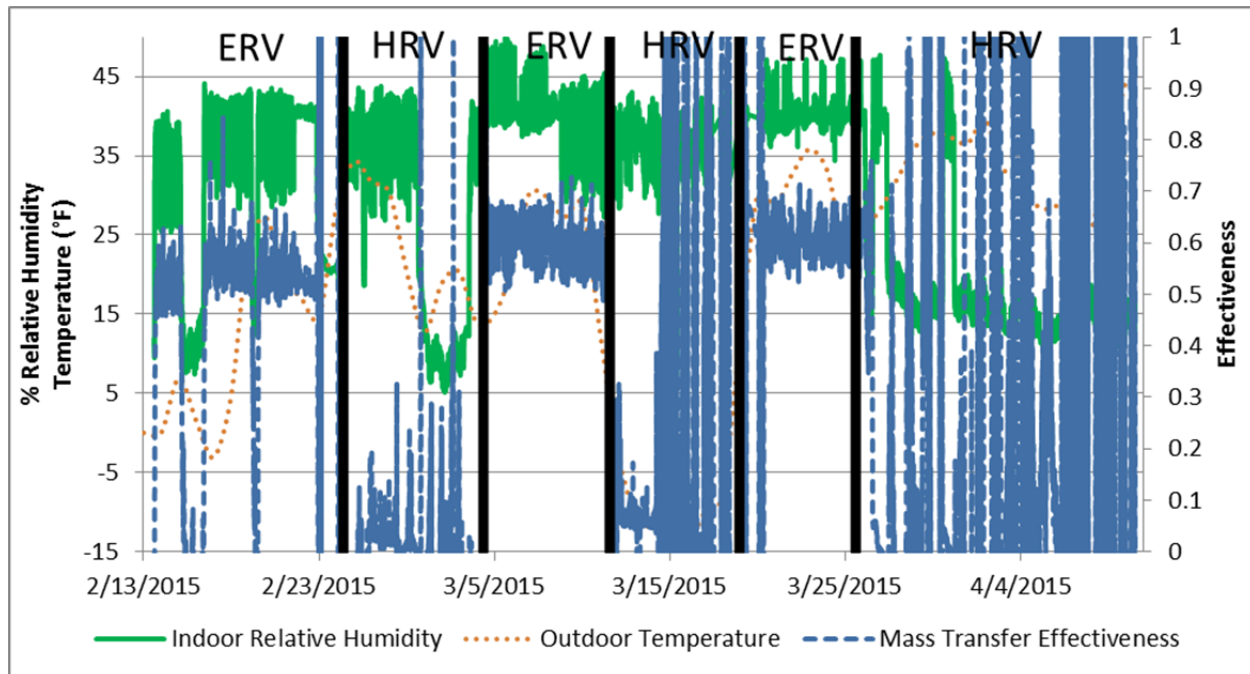
Figure 11. Mass transfer effectiveness and conditions of the MTL ERV/HRV. Theoretically, the HRV core does not have any mass transfer.

Discussion

This study found that houses with higher-than-average indoor RH can use an ERV to maintain those high levels of moisture. Figure 12 shows how the effectiveness of mass transfer tracks with the level of indoor RH. More indoor RH allows for better mass transfer across the core. However, Aubin et al. (2013) found that ERVs improve RH in homes with lower humidity values. It might be worthwhile to look into the humidity improvement in Alaskan homes with average RH (27%), though anecdotal evidence suggests that ERVs improve RH in lower RH homes as well (Garber-Slaght et al., 2014).
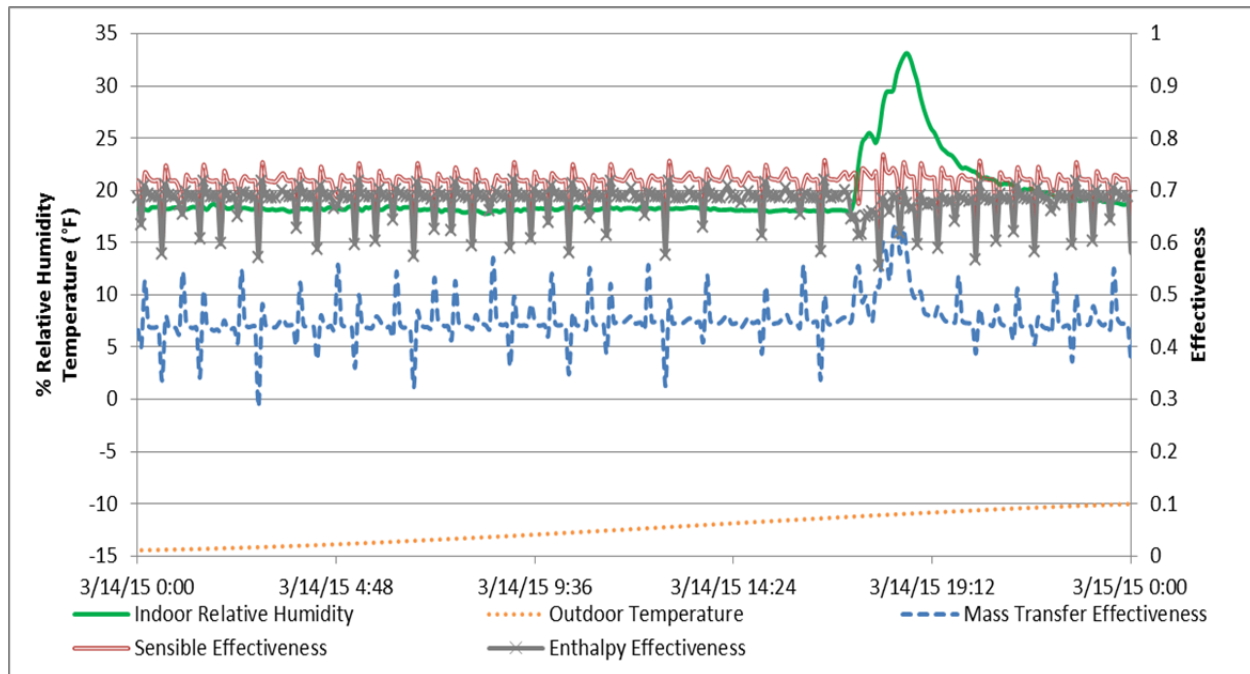
Figure 12. Effectiveness and conditions showing defrost cycles for the CLASS ERV. Increased indoor RH improves the mass transfer effectiveness.

There has been an ERV operating in the CCHRC classroom since 2014. The RH in the 240 sq. ft. classroom has been tracked and compared to the RH in the office area (870 sq. ft.) adjacent to the classroom, which has an HRV. Figure 13 compares the RH in the two locations over the 2015-2016 winter. The office typically had four occupants while the classroom was rarely occupied. As the higher humidity in the fall season gave way to the low winter humidity, the ERV maintained a slightly higher RH. When the indoor RH dropped below the 10% and lower threshold, which is typical of this building in the winter, the ERV did not maintain higher RH when compared to the HRV. Figure 14 shows the average RH per month and the difference between the HRV and ERV. At 25% RH the ERV improved the RH by 5%; at 12% RH the ERV only improved the RH by 1.5% (the RH sensor accuracy is ±3.5%).

ERV cores can have higher enthalpy effectiveness, but does that translate into more cost savings relative to HRV in cold climates? Enthalpy effectiveness deals with both sensible (heat) and latent (moisture) recovery. Sensible heat recovery is what drives heating costs, so the core that is more effective at recovering sensible heat will save the most money in heating. Since ERV cores tend to have a lower sensible effectiveness in their HVI ratings, there are no cost savings in having an ERV over an HRV. However, in this study the Venmar ERV had a slightly higher sensible effectiveness than the HRV core, which could indicate that the differences in effectiveness found in lab tests may not be as large when considering installed performance of ventilation systems in a cold climate. Additionally, the shorter defrosting cycles of the ERV could make the ERVs more energy efficient. This potential was not addressed in this study. If there is cost in humidifying a building then the ERV core with the higher enthalpy effectiveness (65% for the ERV versus 46% for the HRV) would be the logical cost saving choice, but humidifying is rarely required in buildings in Interior Alaska.
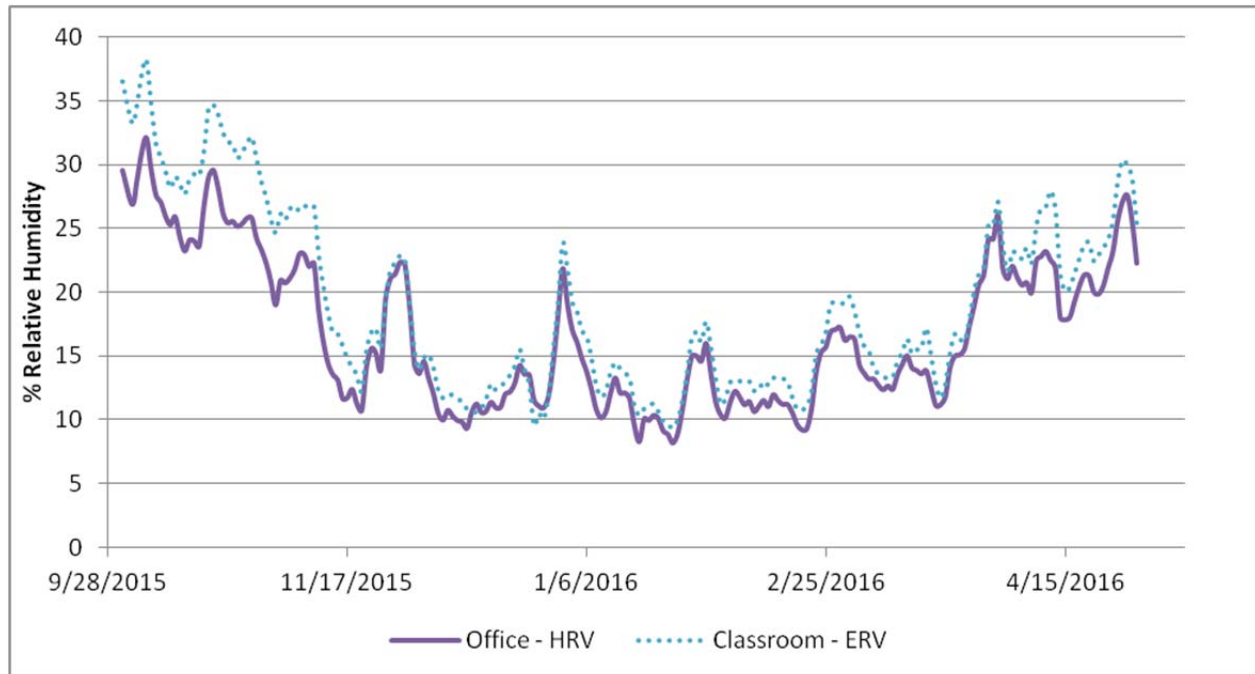
Figure 13. Relative humidity in the CCHRC facility. The office and classroom are open to each other, but are served by different ventilation appliances. No humidity was introduced into either space (except by occupants) during this period.
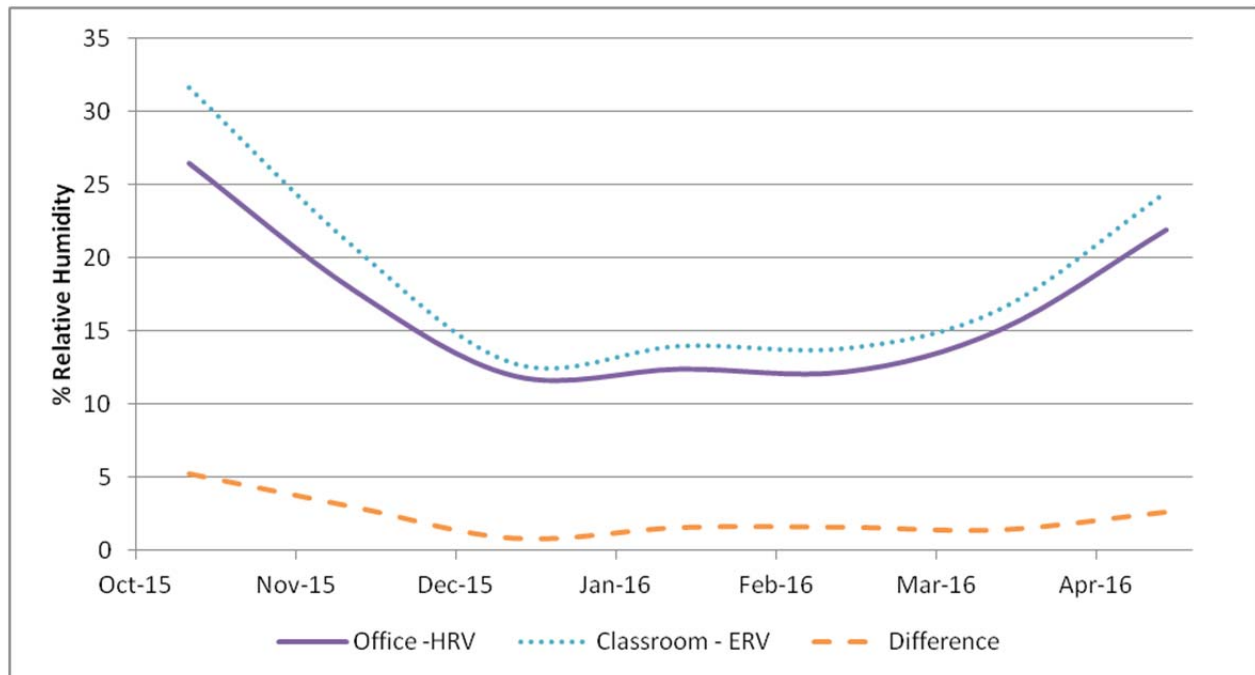

Figure 14. Average relative humidity in the CCHRC facility. The monthly average data shows how the ERV elevates the indoor humidity slightly.

Conclusion

The ERVs studied here improved the indoor RH by more than 5% when indoor RH started above 25%, at lower RH the improvement was down to 1.5%. Further study of ERVs at lower RH could expand the

understanding of the low end of the RH spectrum. Higher indoor RH (above 55%) was not studied with this project, but in higher RH situations ERVs may not be conducive to healthy air in cold climates; this also needs further study.

The comparison between the ERV and HRV cores in terms of energy recovery effectiveness was not evaluated completely with this study. HRV and ERV cores in this study tended to be very similar in sensible effectiveness whereas HVI ratings show a significant difference. To gain a real understanding of the energy effectiveness of the different cores, a larger sample of systems would need to be studied in-situ. With such small differences in effectiveness, a statistically significant sample would probably be necessary to reach meaningful conclusions.

Despite lingering concerns about ERVs not being able to function in cold climate regions such as Alaska, the one freezing event in this study happened while the HRV core was installed. ERVs tend to be less prone to freezing as they remove moisture from the airstream before it reaches the dew point. This fact was exhibited in the MTL ERV that did not have any condensation drain out while the ERV core was installed but drained liters of water with the HRV core. ERVs can be a viable alternative to HRVs in the cold dry climate of Interior Alaska, especially in situations where a more humid indoor environment is desired.

References

ASHRAE. (2013). ANSI/ AHRAE Standard 84-2013 method of testing air-to-air heat/energy exchangers, Atlanta, USA: American Society of Heating Refrigeration and Air Conditioning Experts.

Aubin, D., Won, D., Schleibinger, H., Lajoie, P., Gauvin, D., Gingras, V., & Fulger, D. (2013). Comparative effectiveness of heat and energy recovery ventilators at improving indoor air quality and ventilation rates in Canadian single family homes with asthmatic children. Canada: National Research Council of Canada, Canada Mortgage and Housing Corporation, and the Institute National de Sante Publique du Quebec.

Fauchoux, M., Simonson, C., & Torvi, D. (2007). The effect of energy recovery on perceived air quality, energy consumption, and the economics of an office building. *ASHRAE Transactions, 113(2)*, 436-448.

Garber-Slaght, R., Stevens, V., & Madden, D. (2014). Energy recovery ventilators in cold climates. Cold Climate Housing Research Center. Retrieved from
http://www.cchrc.org/sites/default/files/ERV_ColdClimates.pdf

Home Ventilating Institute. (2015). HVI tested/certified heat recovery ventilators and energy recovery ventilators. Retrieved from http://www.hvi.org/proddirectory/CPD_Reports/section_3/index.cfm

Johnson, R., Schmid, J., & Siefert, R. (2002). Assessment of indoor air quality in Interior Alaskan homes. *Journal of Cold Regions Engineering, 16(4)*, 218-229.

Lam, K., Lee, S., Dobbs, G., & Zhai, C. (2005). Simulation of the effect of an energy recovery ventilator on indoor thermal conditions and system performance. Proceedings of the Ninth International IBPSA Conference. Montreal, Canada: International Building Performance Simulation Association.

McQuiston, F., Parker, J. & Spitler, J. (2005) *Heating, ventilation and air conditioning; Analysis and design*. 6th ed. John Wiley and Sons, Inc.

Ouazia, B., Swinton, M., Julien, M. & Manning, M. (2006). Assessment of the enthalpy performance of houses using energy recovery technology. *ASHRAE Transactions, 112(1)*, 26-33.

Rafati Nasr, M., Fauchoux, M., Besant, R., & Simonson, C. (2014). A review of frosting in air-to-air energy exchangers. *Renewable and Sustainable Energy Reviews, 30*, 538-554.

Rafati Nasr, M., Kassai, M., Ge, G., & Simonson, C. (2015). Evaluation of defrosting methods for air-to-air heat/energy exchangers on energy consumption of ventilation. *Applied Energy, 151*, 32-40.

Rafatinasr, M. (2016). Frosting in membrane energy exchangers. (Doctoral thesis, University of Saskatchewan, Saskatoon, Canada).

Rudd, A., & Henderson, H. (2007). Monitored indoor moisture and temperature conditions in hot-humid US residences. *ASHRAE Transactions, 113(1)*, 435-449.

Siefert, R., Deer, C., George, M., Kaluza, P., Loudon, P., Moore, G.,…Woodward, J. (2008). Alaska residential building manual. Cooperative Extension Service of the University of Alaska Fairbanks. Retrieved from https://www.ahfc.us/files/2813/5716/1325/building_manual.pdf

Sterling, E., Arundel, A., & Sterling, T. (1985). Criteria for human exposure to humidity in occupied buildings. *ASHRAE Transactions, 91(1)*, 611-622.

Zhang, J., & Fung, A. (2015a). Experimental and numerical investigation of the thermal impact of defrost cycle and residential heat and energy recovery ventilators. *Energy and Buildings, 97*, 129-136.

Zhang, J., & Fung, A. (2015b). Experimental study and analysis of an energy recovery ventilator and the impacts of defrost cycle. *Energy and Buildings, 87*, 265-271.