Cold Climate Housing Research Center
CCHRC

Energy Recovery Ventilators in Cold Climates

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Abstract

An energy recovery ventilator (ERV) is used to create a balanced ventilation system in residential and commercial buildings. ERVs bring in outside fresh air which is tempered with outgoing stale air. An ERV recovers both heat and moisture from outgoing air in contrast to a heat recovery ventilator (HRV) which recovers heat only. Historically, HRVs have been used in cold climates as ERVs have performed poorly in cold climates with frosting failures. This study monitored eight ERVs installed in Fairbanks, Alaska to determine if flat plate energy exchangers could perform in cold climates without frosting failure. All eight units performed adequately over the course of the 2013-2014 winter. There were no observed instances of mechanical failure due to excessive frost in the systems, which may indicate that all of the units have adequate defrost strategies for use in cold climates. Further research into the efficacy of ERVs at improving air indoor quality and their overall installed efficiency in cold climates is suggested.

Energy Recovery Ventilators in Cold Climates

Maintaining healthy indoor air quality in cold climates can be challenging due to the need for sufficient fresh air intake. Residential buildings in cold climates have historically relied on air leakage through the building envelope to provide adequate ventilation. However, due to improved building techniques, mechanical ventilation may be necessary as building envelopes become tighter and as new construction seeks compliance with ventilation standards like ASHRAE 62.2.

The widely adopted best practice for providing mechanical ventilation in Alaska is through a Heat Recovery Ventilator (HRV) which brings in outside air by way of a heat exchanger that heats the supply air with the exiting air from the building. An HRV tends to remove moisture from the inside of the house which is an important moisture control strategy in cold climates. However, this moisture removal is often excessive, creating a very dry indoor climate that may cause occupant discomfort. This creates a conflict between providing adequate air exchange and a reasonable interior relative humidity (RH).

Another ventilation option, common in more moderate and cooling-dominated climates, is an Energy Recovery Ventilator (ERV) which is similar to an HRV but also allows for the recovery of moisture from the exiting air. Due to a limited number of ERVs installed in cold climates, the technology in this environment is unproven. Typically people assume that they cannot be used because the energy exchanger will develop frost at cold exterior temperatures. CCHRC conducted this study to gain a better understanding of how ERVs perform in cold climates, particularly if they frost and fail to deliver tempered fresh air. The study found that the systems did not suffer mechanical failure from frost accumulation due to their adequate defrost strategies.

Residential Ventilation

Ventilation systems bring in fresh air and some systems even distribute it throughout a building. Mechanical ventilation exhausts indoor pollutants such as volatile organic compounds (VOCs), cigarette smoke, cooking fumes, carbon dioxide, radon, and more. Some ventilation systems also have filters for incoming air, which can reduce concentrations of particulate matter such as pollen, dust, and combustion byproducts. All in all, ventilation systems help buildings maintain a healthy indoor air quality.

The amount of ventilation needed by a home is specified by ASHRAE standard 62.2 (2010). The standard sets a minimum whole house ventilation rate based on floor area and number of bedrooms. For example, a 3 bedroom, 1500 square foot house should have 45cubic feet per minute (CFM) of fresh air delivered continuously. In Alaska a modified version of the ASHRAE 62.2 standard, 55 CFM is required for a new building to meet the Building Energy Efficiency Standard (BEES) (Alaska Housing Finance Corporation, 2014). Dedicated ventilation systems are especially important in homes with low levels of air leakage due to tighter envelopes, since natural drafts through openings around windows and doors, or through wall materials, are not sufficient to meet indoor air quality requirements.

There are four basic ventilation approaches: none, exhaust-only, supply, and balanced. The first is to not have a dedicated ventilation system at all. This was common when homes were not built as tightly as today, ventilation occurred through the leaky building envelope and windows. Unlike the other approaches, this approach has no control system. This strategy is still used today, supplemented by modern appliances that act as exhaust-only ventilation, such as clothes dryers and wood stoves.

An exhaust-only system uses dedicated appliances, usually a range hood above the stove and exhaust fans in the bathroom, to exhaust air. These appliances are controlled by on/off switches or timers but fresh air must enter a home through holes in the building envelope. An exhaust-only system that does not have make-up air holes in the building envelope can create negative pressure in the house and cause back drafting of combustion appliances.

A supply system is the opposite of an exhaust-only system. In a supply system, a central fan is integrated with a forced air distribution system to provide fresh air to a home. During the heating season in Alaska, a supply-only system will pressurize a home, forcing warm air through leaks to the outside. As this warm air cools, water vapor may condense within the building envelope causing moisture problems; for this reason supply-only systems are not an acceptable ventilation method for meeting BEES.

Balanced ventilation systems use an HRV or ERV to deliver tempered outside air through a ducted system in the house.

HRVs and ERVs

A balanced ventilation system both supplies and exhausts air at approximately equal flow rates. Generally, balanced systems consist of HRV or ERV appliances with control systems that provide both supply and exhaust air (Figure 1). A duct system is used to distribute the fresh supply air to the living room and bedrooms, and exhaust air is pulled from the bathrooms, laundry room, and kitchen.

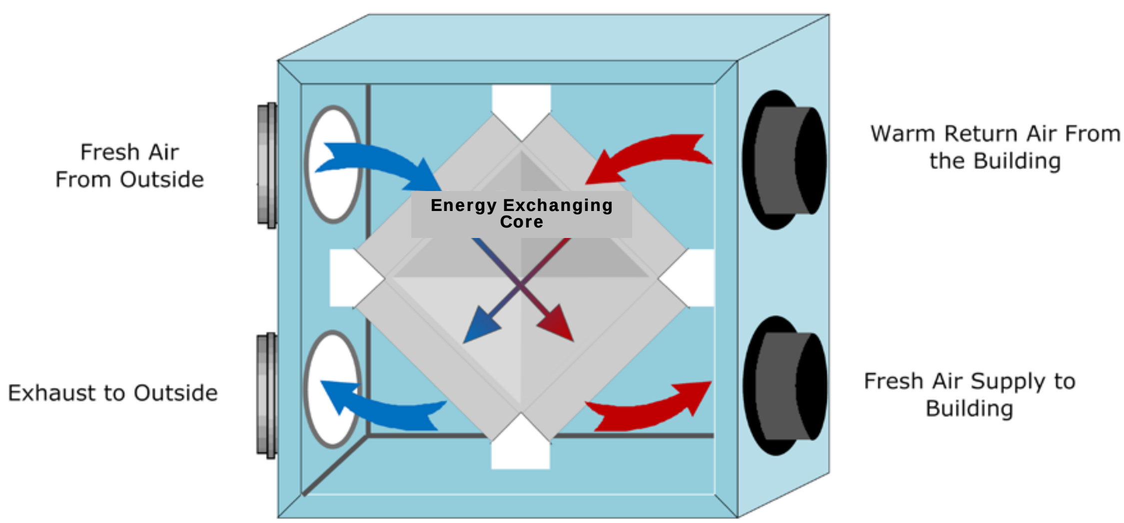

Figure 1. Balanced ventilation system with energy recovery. During the winter, an ERV core transfers heat and moisture from the exhaust airstream to the fresh, incoming air.

Ventilation does come at an energy cost, because exhausted air has been conditioned by a space heating appliance and fresh air is unconditioned unless the ventilation system includes an HRV or ERV. These appliances recover some energy costs by transferring energy from outgoing exhaust air to incoming supply air. During the cold winter months HRVs transfer heat energy from outgoing air to incoming air and ERVs go one step further, recovering and transferring both heat and moisture. HRV and ERVs have electric fans which should run most of the time; these fans add to the electric bill, but the electricity cost is typically less than the cost for space heating to condition the supply air.

ERV Basics

ERVs can transfer thermal energy and moisture between incoming and outgoing airstreams. In cold winter months with low absolute humidity, ERVs transfer some of the heat and water vapor from the warm, moist exhaust air to incoming cold, dry air. In the summer, or year-round in a hot, humid climate, ERVs do the opposite, transferring heat and moisture from warm outdoor air to the cooler outgoing exhaust air.

There are two main types of ERVs, rotary energy wheel and membrane-based ERVs. They differ in the construction of the heat and moisture exchanger or core of the unit. The first type is a rotary energy wheel (Figure 2). Commercial ERVs typically use this type of core which uses a rotating cylinder to transfer heat and moisture. The cylinder rotates slowly through the two air streams, and the amount of heat and moisture transferred will depend on the speed of rotation, the air flow rate, and the wheel properties. The wheel can be made of metal, plastic, paper, or ceramic molded into a matrix pattern to increase the surface area (Dieckmann, Roth, & Brodrick, 2003).

Figure 2. Rotary wheel core. The core of this HRV is a heat exchange only wheel. In an ERV, an energy wheel would transfer moisture in addition to heat.

The second type of ERV core is a membrane-based ERV, also referred to as a MERV or flat plate exchanger, these are used in most residential ERVs (Figure 3). A MERV core is vapor permeable with channels that have shared surfaces for supply and exhaust air to pass through while keeping the air streams separated. As a MERV core contains no moving parts, it is typically easier to maintain than an energy wheel. The MERV transports moisture in three steps. First, moisture is absorbed from the humid air stream onto the membrane surface. It then diffuses through the membrane to the side with lower humidity, where, finally, it is absorbed by the drier air (Zhang, L., Liang, C., et al., 2008). Good membranes are tight to air but fully permeable to water vapor as well as having resistance to microbiological growth and freezing (Alonso, Mathisen, & Simonson, 2012).

Figure 3. Membrane ERV core. A MERV contains channels for air passage, and the membrane surface transfers heat and moisture from one air stream to the other.

Frost Management Strategies

ERVs have sophisticated control systems to balance incoming and outgoing air and to monitor heat and moisture transfer based on indoor and outdoor conditions. In cold climates, ERV controls also operate defrost strategies. Early models of ERVs developed frost at below-freezing outdoor temperatures, causing problems such as decreased heat transfer, blockage of air flow, and fans having to work harder to circulate air (Eakes, 2013). There are a few strategies that ERVs can employ to mitigate these problems: frost prevention or defrost.

Frost prevention works by keeping the air in the core from getting too cold to produce frost. Prevention can involve pre-heating the incoming air with an electric resistance heater or mixing the incoming air with inside air prior to reaching the ERV core. Some frost prevention schemes close the incoming air damper entirely at certain temperatures and create an exhaust-only system until the temperature increases enough to open the damper. Each strategy has certain drawbacks; the heater uses more electricity and makes the ERV less efficient, while mixing the air or closing the damper reduces the amount of fresh air that is introduced to the space leading to an unbalanced ventilation system.

Defrosting involves allowing frost build up and creating a control scheme to melt the frost. A common defrost strategy closes the incoming supply damper and exhausting inside air through the core. This transforms the ventilation system temporarily into an exhaust-only ventilation strategy. Another common defrost strategy closes off incoming supply air and recirculates the interior air for a set period of time to melt any frost that has built up in the core. Recirculating interior air reduces the amount of fresh air into the space, but avoids depressurizing the house. For both defrost approaches, allowing frost to develop in the core and then melting it requires a way to drain the liquid water and a special orientation of the core to allow draining.

Rating Systems

ERVs are tested for efficiency in a number of ways and when manufacturers report their efficiency they may report it in one of several ways. The Home Ventilating Institute (HVI) certifies ERVs for efficiency using a variety of different efficiency metrics. The Sensible Recovery Efficiency (SRE) quantifies the amount of heat recovered from the exhaust air by the incoming fresh air. It is reported as a percentage of the total heat that is available for recovery. For instance, if an ERV has an SRE of 55% for a given flow rate and temperature difference, this means that the ERV core transfers 55% of the heat available in the out-going air to the incoming airstream. The measurement and calculations for the SRE correct for a number of events that add heat to the incoming air in a realistic situation, such as heat that might enter the airstream through the ERV case, airflow imbalances between the supply and exhaust airstreams, heat gains from circulating fans, and energy that might be used to defrost the ERV core. The SRE does not consider the energy recovered in transferring moisture between the airstreams.

The Apparent Sensible Effectiveness (ASEF) is another efficiency often listed by manufacturers. Unlike the SRE, the ASEF is calculated by including the heat transfer from fans to the airflow, heat leaking in or out of the ERV case, and any leaks between the airstreams as they cross through the core. It is also expressed as a percentage and is equal to the temperature rise of the incoming outdoor air divided by the temperature difference between indoor and outdoor air. Typically, it will be higher than the SRE for a given unit, air flow, and temperature difference because it includes heat gained by the incoming air from sources other than the exhaust air.

A third efficiency relates only to ERVs, the Total Recovery Efficiency (TRE). This efficiency gives the net energy that is recovered by the ERV, which includes the sensible (temperature) heat and latent (moisture) heat that is recovered. It is similar to the SRE, except that it also includes the energy associated with the moisture recovered from the exhaust air. The Latent Recover/Moisture Transfer (LRMT) is used to calculate the TRE. LRMT is a number from 0 to 1, with 0 meaning no moisture was transferred from the exhaust air to the supply air and 1 meaning all the moisture was transferred. TRE is expressed as a percentage of the total energy that could be recovered from the exhaust air plus the energy of the exhaust fan. TRE is not tested for heating climates; however it is used in this document as a way to make an equal comparison.

Literature Review

ERVs are used for ventilation throughout the world; however, they are a relatively new technology in cold climates as early ERV models experienced frosting in below-freezing temperatures (Eakes, 2013). New models with defrost technologies are now being used in cold climates, especially as building envelopes improve and ventilation becomes necessary for healthy indoor air quality.

There are several studies that model ERVs in cold climates to determine their energy savings. In general, these studies found that ERVs could provide energy savings of up to 5% over an HRV (Rasouli, Simonson, & Besant, 2010) in commercial installations in cold climates (Fauchoux, Simonson, & Torvi, 2007) (Zhong & Kang, 2009). Several studies also found that the energy transfer effectiveness of ERVs increases with decreasing outdoor temperature (Min & Su, 2011) (Niu & Zhang, 2001). Frosting is a performance concern in cold climates and several studies have looked at ERV wheel cores and their frosting potential (Mahmood & Simonson, 2012); at present time there are no published studies that look at frosting in MERV exchangers.

CCHRC Preliminary ERV Tests (Winter 2013-2014)

Past experiences with ERVs in cold climates indicate that the ERV core may frost closed in the winter and cease to provide ventilation air (Eakes, 2013). However, newer ERV cores that have frost protection and use MERVs rather than energy wheels may function better in cold climates than previous models. Overall there is little research on ERVs in cold climates; CCHRC conducted this study to attempt to fill a gap in knowledge on the installed performance of flat plate core ERVs. Eight membrane core ERVs were studied in order to demonstrate their viability in Interior Alaska. This initial test was designed primarily to determine if ERV cores develop frost over the course of a winter which renders them inoperable.

Study Methods

During the 2013-2014 winter 8 ERV installations in several different locations in Fairbanks, Alaska were monitored for frosting conditions. Each ERV was tested in-situ and interior conditions were not always controlled. The ERV models and their installation details are presented in Table 1. The final column presents manufacturers' reported efficiencies; the last 3 systems do not have efficiencies listed as those units were tested in a different configuration than they are commercially packaged. In these last three systems the HRV cores of the installed Venmar HRVs were removed and replaced with ERV cores. This was done for a few reasons: Venmar HRVs are common in Fairbanks homes and it was suggested that the defrost settings of the Venmar HRV may be better suited than the defrost settings of a Venmar ERV for the cold Fairbanks climate (Kotol, M., personal communication, spring 2013).

These ERV options were chosen because they are available locally and most of them are HVI certified at -13°F. There are very few ERVs certified for cold climates, HVI lists only 64 models. Many ERV models do not have a frost mitigation strategy and would not perform well in a cold climate.

Table 1. ERV systems studied.

ERV	Location	Controls	Defrost Cycle	Specifications
Panasonic FV-04VE1 spot ERV	CCHRC Mobile Test Lab (MTL) Humidified to keep RH above 30%	Constant maximum speed (40 CFM)	At 32°F 60 min on, 30 min exhaust only Below 20°F fan speed low, exhaust only	Apparent sensible effectiveness 66% Total recovery efficiency 36%
RenewAire EV130	CCHRC classroom Humidified to keep RH above 30% sporadically	Always on 130 CFM when the room was occupied	Thermostatic controlled mixing damper in supply duct at 0°F open for 5 min closed for 17.5 min	Apparent sensible effectiveness 77%, Total recovery efficiency 48%
Lifebreath 120ERV	CCHRC Mobile Test Lab (MTL)	Always on at 65 CFM	Supply fan shuts down - 3°C 3 min defrost / 25 vent time -24 °C 4 min defrost / 17 vent time -39 °C 7 min defrost / 15 vent time	Sensible effectiveness 74%, Total recovery efficiency 35% Moisture transfer 0.47
Lifebreath 150ERVD	CCHRC Classroom Humidified to keep RH above 30% sporadically	Always on at 45 CFM	Defrost port opens below - 13°F and closes to incoming air	Sensible effectiveness 80%, Total recovery efficiency 57%
Venmar EKO 1.5 ERV	NE house of the University of Alaska Fairbanks (UAF) sustainable village	Variable manual control (80 to 140 CFM)	Extended recirculation mode Below 14°F 10 min recirc/20 min normal below -17°F 10 min recirc/15 min normal	Apparent sensible effectiveness 75% Total recovery efficiency 52%
Venmar EKO 1.5 HRV with ERV core	SE house of the UAF sustainable village	Variable manual control (80 to 140 CFM)	Extended recirculation mode Below 23°F 10 min recirc/20 min normal below -17°F 10 min recirc/15 min normal	This configuration is not standard and has not been tested for efficiency
Venmar EKO 1.5 HRV with ERV core	Cranberry Ridge Dr.	Variable manual control (80 to 140 CFM)	Extended recirculation mode Below 23°F 10 min recirc/20 min normal below -17°F 10 min recirc/15 min normal	This configuration is not standard and has not been tested for efficiency
Venmar EKO 1.5 HRV with ERV core	Keystone Rd.	Variable manual control (80 to 140 CFM)	Extended recirculation mode Below 23°F 10 min recirc/20 min normal below -17°F 10 min recirc/15 min normal	This configuration is not standard and has not been tested for efficiency

Each ERV system was monitored for temperature and RH on three sides of the ERV core: supply to the building, return from the building, and the exhaust to outside. The temperature of the incoming air was also monitored. Additionally, the temperature and RH of the living space was monitored. Each data point was collected every 15 minutes.

The dew point of the air returning to the ERV from the building was calculated using the RH and temperature. The temperatures on each side of the core were averaged and then evaluated to determine if they fell below the dew point. When they were below the dew point and the averaged temperatures were also below 33°F the system was judged to have conditions suitable for frost accumulation. In addition, periodic visual inspections were performed to look for frost accumulation.

Results and Analysis

Panasonic FV-04VE1-MTL

The Panasonic FV-04VE1 was installed in CCHRC's Mobile Test Lab (MTL) because the test lab has a small interior space (approximately 188 ft^2) and the Panasonic is designed to ventilate one room (Figure 4). The study ran from October 16, 2013 to February 10, 2014. Over the course of the study the MTL was humidified to an average 38% RH on an irregular schedule. When the humidifier was not running the RH was much lower, these sensors do not record any data below 15% so the exact average RH is difficult to estimate.

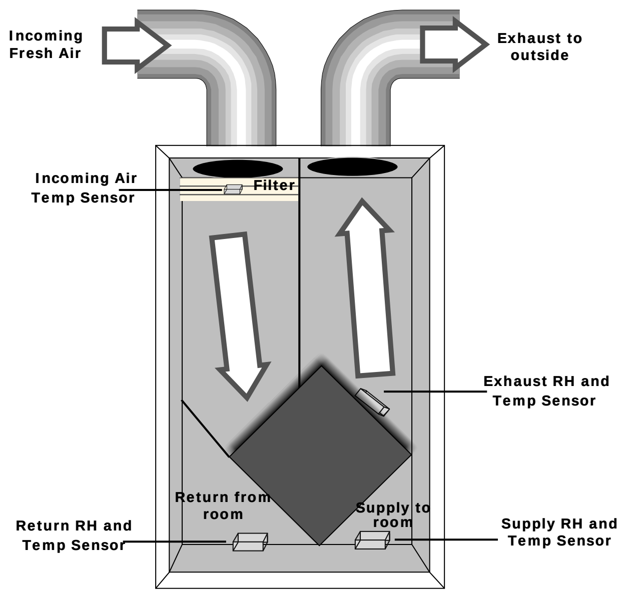

Figure 4. The Panasonic FV-04VE1 in the MTL. This unit only has 2 air ducts; the supply and return from the room are through grills on the face of the unit.

There were 35 incidents when the averaged core temperature fell below the dew point and was below freezing; however each incident lasted less than 15 minutes, too short a time for the core to fill with frost. None of these events had corresponding loss in temperature changes across the core that would indicate frost blocking the core.

This ERV had very few frost potential events due mostly to the frost control system. When the air entering from the outside dropped below 20°F the incoming air damper closed and the ERV became an exhaust only fan. Warm moist air was drawn out of the space and exhausted to the outside, providing no supply air via the ERV. Few core temperatures fell below 20°F as a result of this defrost strategy. This defrost strategy also made it difficult to maintain a constant interior RH over the course of the study. This unit was in defrosting mode 90% of the study.

RenewAire EV130-Classroom

The RenewAire EV130 was installed in the small classroom at CCHRC. The system ran from November 22, 2013 until February 24, 2014. The system was tied to the building control system so that the ERV only ran at 130 CFM when the room was occupied. A majority of the time the system ran with no extra humidification beyond room occupancy. The RH over the entire study averaged 19.5%. During the period of humidification from Feb. 14 to Feb 24 the RH averaged 40%.

This system had a unique set up, in that it had a mixing damper with a thermostatic control, a DF6 defrost accessory, that was designed to open if the incoming air temperature got too cold (below 0°F). Figure 5 provides a schematic for the RenewAire system with sensor locations.

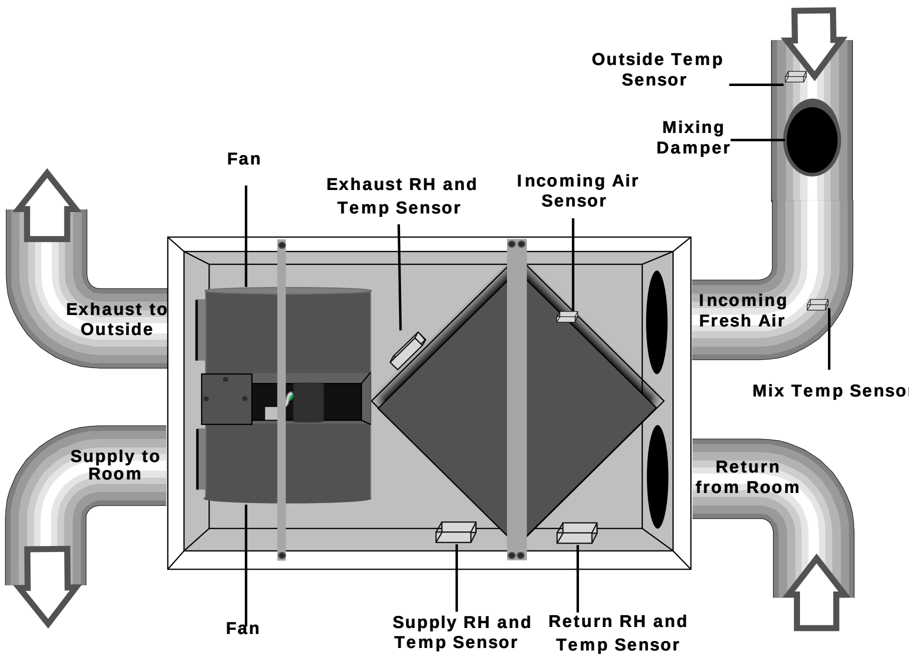

Figure 5. The RenewAire ERV in the classroom. The mixing damper is controlled with a thermostat that is designed to open the damper at 0°F.

The building control system kept this system off whenever the room was unoccupied which led to much less runtime than expected. The unit was off 80% of the monitoring period. Figure 6 shows a sample of temperatures on the incoming fresh air side of the core. The off cycles are apparent as flat lines at room temperatures. The second graph shows a two week period where the mixing damper was engaged. The incoming air temperature was cold enough to warrant opening the damper on Feb. 10, this is visible by the jump in the incoming air temperature circled in green in Figure 6. The port was open for seven hours and then the building control system shut the ERV down. Unfortunately the building control system interfered with the defrost cycle so that it is difficult to determine if the cycle was adequate to prevent frosting.

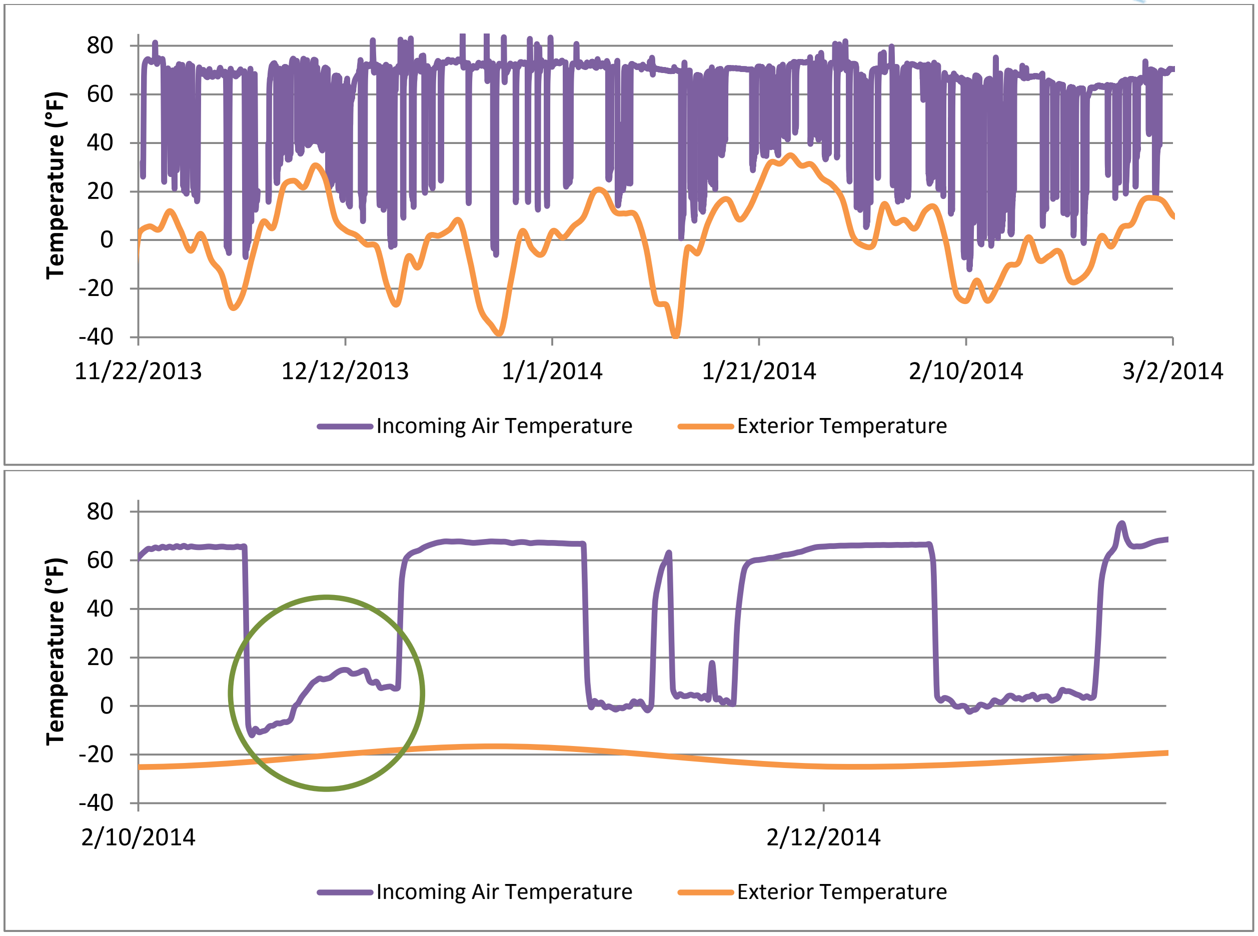

Figure 6. Incoming air temperature in the RenewAire ERV. The second graph shows a close-up view of a two week period of temperature data.

The RenewAire had occasional spots of liquid condensation form in areas inside the unit but it did not freeze. Figure 7 shows a condensation event. It is suspected that the on/off cycles of the building control system may have created conditions for condensation that may not have occurred if the system had run constantly. The warm moist air in the room was stagnant until the system turned on bringing in a sudden rush of cold air that dropped the temperature of the metal components quickly, leading to the condensation on the incoming air side of the exchanger which would not have had warm moist air in it had the system be running. This system had only one 15 minute interval of potential frost conditions.

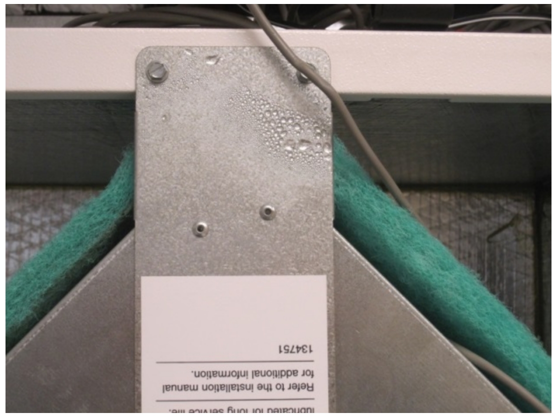

Figure 7. Liquid condensation inside ther RenewAire ERV. There was liquid condensation within the the unit but it did not form ice.

Lifebreath 120ERV-MTL

The Lifebreath 120ERV was installed in the MTL and ran from April 2, 2014 to April 29, 2014 (Figure 8). The unit was set to supply a continual 65 CFM. The interior of the MTL was not humidified during the course of this study. During most of the study the interior RH was low, below 15%. The Lifebreath 120 had no potential frost conditions. The ERV had no frost condition potential in part because the humidity was so low; the study also ran in April when the exterior temperatures were warmer.

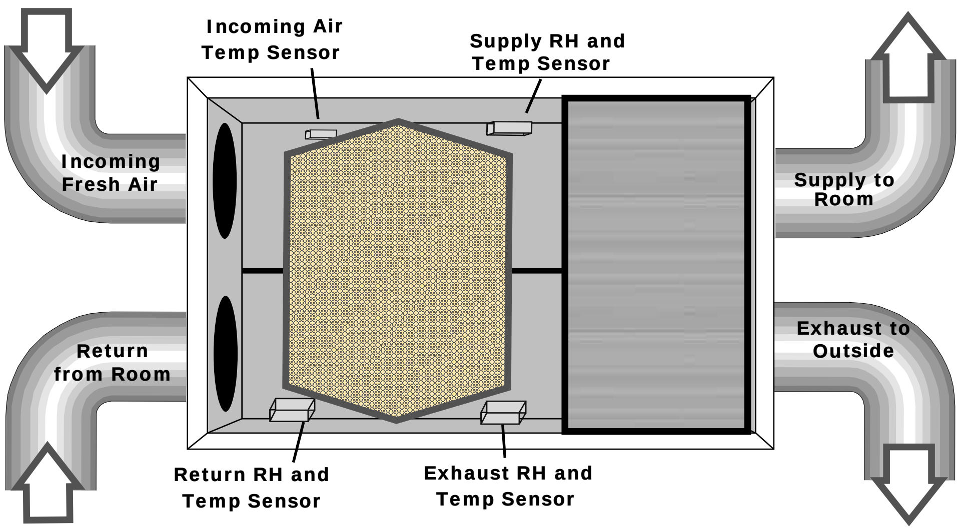

Figure 8. The Lifebreath 120ERV in the MTL. This system was ventilating the 133 ft^2 MTL which had no humidification.

The Lifebreath 120ERV has temperature sensors in the incoming air stream that shuts down the supply motor when the temperature drops below the defrost set point of 26.6°F.This makes the ERV an exhaust only system for 3 minutes and then it vents normally for 25 minutes. As the temperatures became colder the exhaust-only defrost system lasted longer, up to 7 minutes with 15 minutes of incoming air time. There were a few times when the outside temperature dropped below the defrost set point of 26.6°F; the system was in defrost mode for 15% of the study.

Lifebreath 150ERVD-Classroom

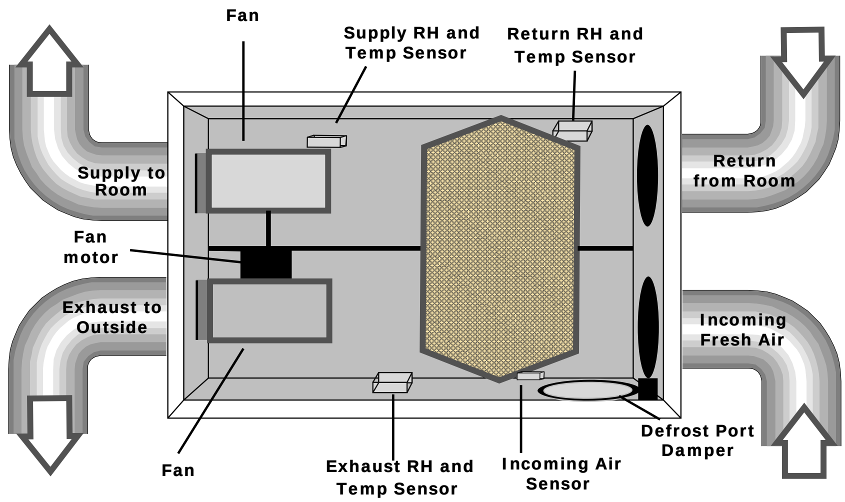

Figure 9. The Lifebreath 150ERVD in the Classroom. This unit has a defrost port which opens at cold temperatures and makes the system exhaust only.

The Lifebreath 150ERVD was installed in the classroom and ran from March 28, 2014 to April 29, 2014 (Figure 9). The unit was set to supply a continual 45 CFM of fresh air. The interior of the classroom was humidified to 40% for the first few weeks of the study. This unit has a defrost port that opens to the room at -13°F and closes the incoming air duct to defrost the core. The defrost cycle was effective at keeping the core from frosting; it ran for 13% of the study. This ERV did not have any potential frost conditions during the study, in part because it ran in April when the exterior temperatures were warmer.

Venmar EKO 1.5 ERV-NE House UAF

The Venmar EKO 1.5 ERV was installed in the Northeast (Tamarack) house of the Sustainable Village at UAF in 2012 when the building was constructed (Figure 10). The house is 1,600 square feet and has room for four students with a common living area and bathroom. For this study the ERV was monitored from November 20, 2013 to December 4, 2013 and January 22, 2014 to March 17, 2014. The settings of the ERV (fan speed and on/off schedule) were variable and controlled by the occupants. During the first part of the study the unit was set to constantly run on low speed and then changed to 20 minutes on low speed and 40 minutes recirculation. For the second part of the study the control was set to run constantly on low speed. Over the course of the study the occupants changed the settings and may or may not have documented the setting changes. The RH in the house was not controlled; however it was monitored and averaged 20%. The ERV did not shut off and stop working at any point during the study (as it did in the study by Kotol (2013)). In fact the unit did not experience any potential frost conditions during this study. The unit was in defrost/recirculation mode 32% of the time.

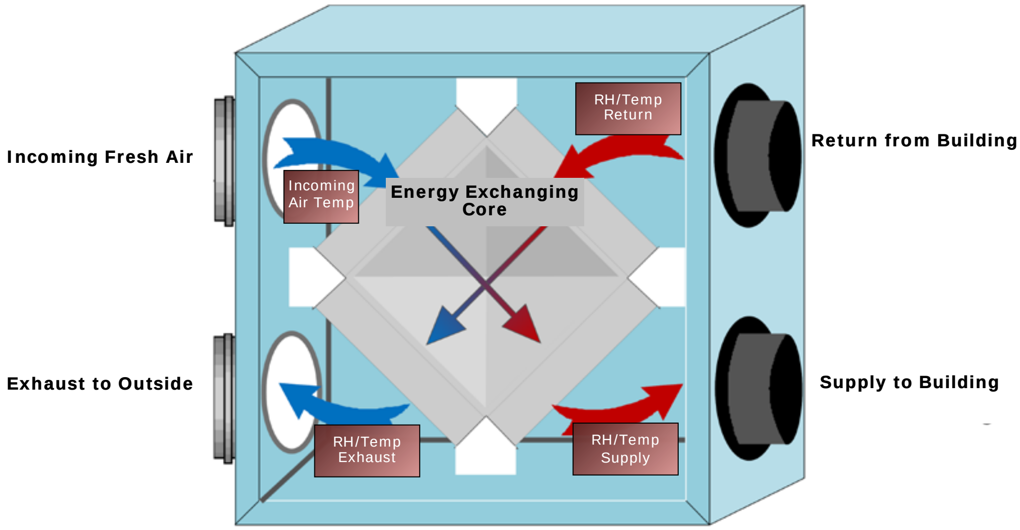

Figure 10. The Venmar ERV and HRV systems. This schematic is the same for all the Venmar units.

Venmar EKO 1.5 HRV with ERV core-SE house UAF

The Venmar EKO 1.5 HRV was installed in the Southeast (Willow) house of the Sustainable Village at UAF in 2012 when the building was constructed. The house is 1,600 square feet and has room for four students with a common living area and bathroom. For this study the HRV core was replaced with an ERV core and the altered system was monitored from November 20, 2013 to December 4, 2013 and January 22, 2014 to March 17, 2014. The settings of the HRV/ERV (fan speed and on/off schedule) were variable and controlled by the occupants. During the first part of the study the unit was set to constantly run on 20 minutes low speed and 40 minutes in recirculation mode on high speed and then changed to constantly low speed. For the second part of the study the control was set to run constantly on low speed. Over the course of the study the occupants changed the settings and may or may not have documented the setting changes. The RH in the house was not controlled; however it was monitored and averaged 21%.

This system had 278 potential frost conditions over the course of the study. Most lasted 15 minutes or less, only seven lasted for an hour. Figure 11 shows the incidents of potential frosting in relationship to the exterior temperature and the RH of the air returning to the ERV. The RH does not really change during these events but the exterior temperature is much lower during the frost potential events. It is possible that the occupants changed the control settings for the ERV, which when combined with colder exterior conditions may account for the potential frosting events.

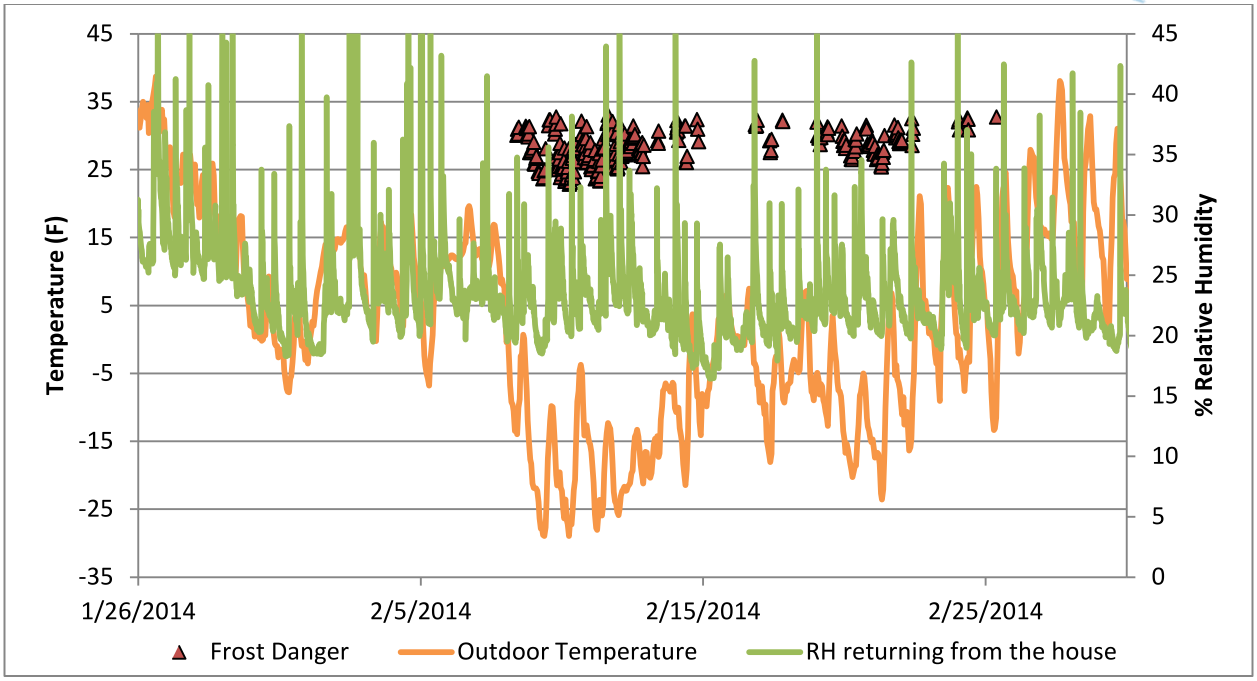

Figure 11. Frost conditions chart for the Southeast House. Each red triangle represents 15 minutes when the ERV core temperature was below the dewpoint and the freezing point.

Venmar EKO 1.5 HRV with ERV core–Cranberry Ridge Dr.

This house has a Venmar EKO 1.5 HRV which is ducted to serve the entire house. The house is 1,450 square feet and has two bedrooms. For this study the HRV core was replaced with an ERV core and the altered system was monitored from November 20, 2013 to March 3, 2014. The settings of the HRV/ERV (fan speed and on/off schedule) were variable and controlled by the occupants. Initially, the unit was set to vent on low 100% of the time; the controls changed over the course of the study. The interior humidity was not tightly controlled during the study; however, it was monitored and averaged 30%. The Cranberry Ridge HRV/ERV had no potential frost conditions. The system was in defrosting mode 8% of the study time.

Venmar EKO 1.5 HRV with ERV core-Keystone Rd.

This house has a Venmar EKO 1.5 HRV which is ducted to serve the entire house. The house is 1,500 square feet and has three bedrooms. For this study the HRV core was replaced with an ERV core and the altered system was monitored from November 22, 2013 to March 12, 2014. The settings of the HRV/ERV (fan speed and on/off schedule) were variable and controlled by the occupants. Initially, the unit was set to vent 30 minutes and remain off 30 minutes out of every hour; the controls changed over the course of the study. The interior humidity was not controlled during the study; however it was monitored and averaged 41%.

This system experienced 345 potential frost conditions. Most of these incidents were less than 15 minutes, only seven lasted an hour and none lasted longer than an hour. The system was in defrosting mode 11% of the study time. Figure 12 shows the frost potential compared to the outdoor temperature and the interior RH. There is no spike in interior RH or unique dip in exterior temperature that coincides with the sudden frost danger incidents. The system had one freezing event due to ice build-up on the data collection sensor freezing the damper open, the event on Feb. 12, 2014 was the result of the data collection and not a failure in the ERV. The potential frost events happened around this time so it is possible the stuck damper due to the sensor location may have contributed to the potential frost events. It is also possible the home occupant changed the control settings of the ERV for some reason during this time. It is interesting to note that the frost danger incidents continued even after the ERV core was switched out for the HRV core, which should theoretically lower the interior RH (the RH dropped around Feb 20, 2014 but the occupants were gone for a week at that time).

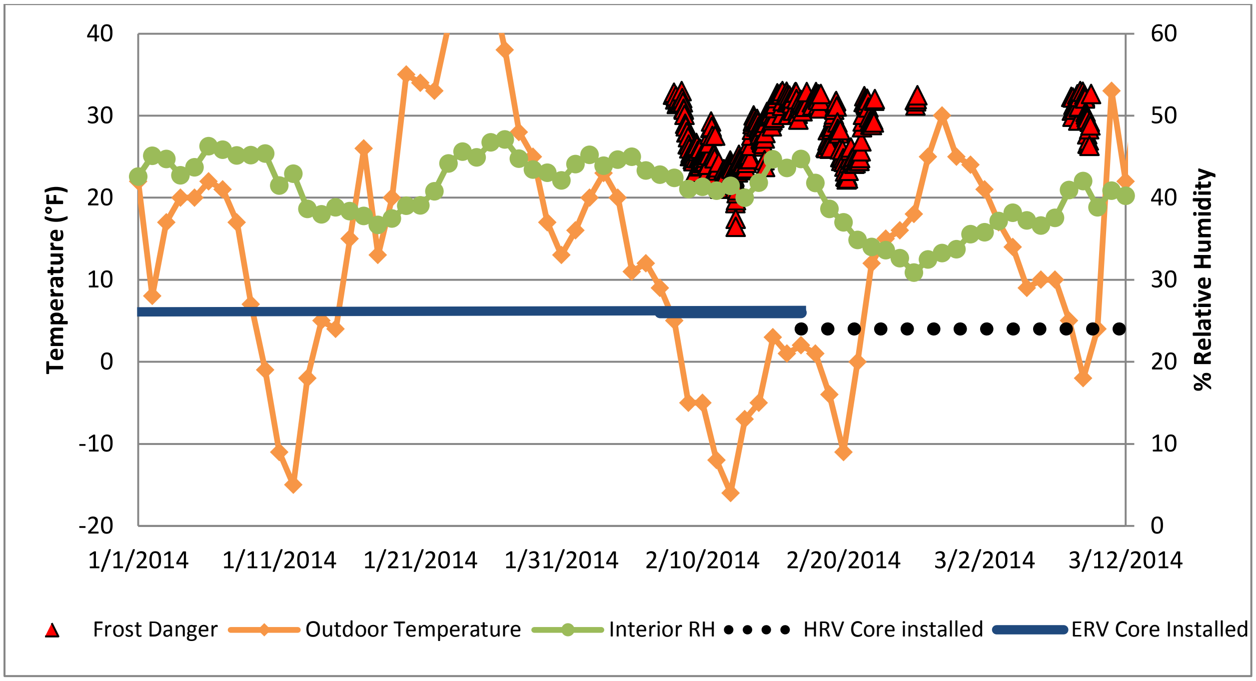

Figure 12. Frost danger incidents in the Keystone Rd. ERV. Neither the outdoor temperature nor the interior RH are dramatically different from previous data.

Discussion

This study shows that ERVs with flat plate heat exchangers can function without becoming inoperable due to frosting in the cold Fairbanks environment provided they have an adequate defrost strategy. However, all of the ERVs studied have a defrost strategy that limits incoming fresh air via the ERV, sometimes to the point where it does not meet ASHRAE 62.2 (findings similar to Kotol's study on HRVs and ERVs (2013)).

There is very little correlation across the 8 systems with the time in frost conditions and the three other variables in the study: interior RH, time in defrost mode, and exterior temperature. Table 2 has a summary of the three variables and the time in frost conditions. Only two of the systems showed any frost potential periods greater than 15 minutes: the Keystone Rd. ERV with the highest interior RH and the ERV in the SE UAF house which saw some of the coldest temperatures. The Cranberry Ridge ERV was the closest in average RH to the Keystone Rd. ERV and did not experience any potential frost conditions. The RenewAire and the Lifebreath 150ERVD both experienced periods of 40% interior RH but did not have potential frost conditions, potentially due to higher outside temperatures or more off time. The ERVs in the Sustainable Village are more confusing because they experienced very similar RH and temperatures, but had different outcomes. These differences could be due to different user controlled settings or to different defrost settings. There are too many variables to draw any clear conclusions in any of these cases.

Table 2. Summary of Results.

ERV	Time with Frost Potential	Average Interior RH	Time in Defrost mode	Average Exterior Temperature (°F)
Panasonic FV-04VE1-MTL	0.2%	19.1%	91%	8.6
RenewAire EV130-Classroom	0	18.8%	80% off	1.9
Lifebreath 120ERV-MTL	0	16.9%	15%	34.3
Lifebreath 150ERVD-Classroom	0	28.5%	13%	34.3
Venmar EKO 1.5 ERV-NE house UAF	0	20.2%	32%	5.5
Venmar EKO 1.5 HRV with ERV core-SE house UAF	4.8%	21.0%	32%	5.5
Venmar EKO 1.5 HRV with ERV core-Cranberry Ridge	0	29.7%	8%	15.5
Venmar EKO 1.5 HRV with ERV core-Keystone Rd.	2.8%	40.6%	11%	12.4

A further question for the use of ERVs in a cold climate is how effective they would be at helping to maintain interior humidity levels. Interior Alaska has a very dry and arid climate in the winter. Often the indoor relative humidity is below the minimum recommended level for health, 40% (Sterling, Arundel, & Sterling, 1985). This is evidenced in this study where only one of the locations achieved 40% humidity constantly. Even locations that were humidified could not maintain a constant 40% humidity. Continuous ventilation with an HRV further dries out the interior air. An ERV may mitigate this extreme drying by reclaiming moisture as well as heat in the core. The two systems that were studied in the hopes of verifying this theory did not have adequate humidity control to resolve the question completely, however, the one building occupant did observe, “with the ERV core humidification was intermittent, with the HRV it needed to be almost continuous” (C. Craven, personal communication, August 21, 2014). Further research could better quantify the extent that an ERV improves the indoor air quality over an HRV in a cold climate.

ERV cores can be made from a number of materials and some handle defrosting moisture better than others. Further study of available ERVs will need to analyze how the core material itself reacts to the liquid water that defrosts out of the core.

This study lacked control of some of the variables which are important for future study. The four Venmar units studied had varied control settings and the occupants changed them over the course of the study. Consistent control settings would go a long way toward eliminating some variables in future studies. Additionally, closer control of interior ambient conditions is necessary to gain a better understanding of how ERVs affect interior air quality in comparison to HRVs. Further study of ERVs should also include information on the air flow through the unit as well as pressures across the core to investigate the affect any frosting has on the air flow through the core.

Conclusions

This study was designed to determine the feasibility of ERVs in cold climates in light of past problems the systems have had in Interior Alaska. The eight models that were studied here did not frost closed, although some of them had the conditions conducive to frost accumulation. The defrost cycles in each ERV worked well to keep the systems from failing over the course of the winter.

More research is required to assess the installed performance of ERVs and necessary improvements for cold climate use. A more controlled study that addresses the changes in RH with an HRV core versus an ERV core is necessary. In addition to improved indoor air quality, ERVs may be more efficient in recovering energy from exiting air as they recover both heat and moisture. The energy performance of ERVs in cold climates has not been studied in installed systems; however, if the models are verified, ERVs might be a good option to improve indoor air quality in cold climates efficiently.

References

Alaska Housing Finance Corporation. (2014, June 18). Alaska-specific amendments to IECC 2012. Retrieved from http://www.ahfc.us/efficiency/research-information-center/bees/

Alonso, M., Mathisen, H., & Simonson, C. (2012). Heat and mass transfer in membrane-based total heat exchanger, membrane study. *Seventh International Cold Climate HVAC Conference* (pp. 248-255). Calgary, Canada: ASHRAE.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). (2010). Ventilation and acceptable indoor air quality in low-rise residential buildings. Retrieved from www.ashrae.org

Dieckmann, J., Roth, K., & Brodrick, J. (2003). Air-to-Air energy recovery heat exchangers. *ASHRAE Journal*, 57-58.

Eakes, J. (2013). ERV understading. *Home Builder Magazine*. Retrieved from http://www.homebuildercanada.com/2603_ERV.htm

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, v. 113(2)*, 436-448.

Holladay, M. (2009, June 15). *Musings of an energy nerd: designing a good ventilation system*. Retrieved November 24, 2013, from Green Building Advisor: http://www.greenbuildingadvisor.com/blogs/dept/musings/designing-good-ventilation-system

Kotol, M. (2013). *Survey of indoor air quality, University of Alaska Fairbanks sustainable village.* Retrieved from http://www.cchrc.org/sites/default/files/docs/UAF_SV_IAQ_final.pdf

Mahmood, G., & Simonson, C. (2012). Frosting conditions for an energy wheel in laboratory simulated extreme cold weather. *Seventh International Cold Climate HVAC Conference* (pp. 223-232). Calgary: ASHRAE.

Min, J., & Su, M. (2011). Performance analysis of a membrane-based energy recovery ventilator: effects of outdoor air state. *Applied Thermal Engineering, 31(17-18)*, 4036-4043.

Niu, J., & Zhang, L. (2001). Membrane-based enthalpy exchanger: material considerations and classification of moisture resistance. *Journal of Membrane Science 189*, 179-191.

Rasouli, M., Simonson, C., & Besant, R. (2010). Applicability and optimum control strategy of energy recovery ventilators in different climatic conditions. *Energy and Buildings 42(9)*, 1376-1385.

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

Zhang, L., Liang, C., et al. (2008). Heat and moisture transfer in application scale parallel-plates enthalpy exchangers with novel membrane materials. *Journal of Membrane Science 325(2)*, 672-682.

Zhong, K., & Kang, Y. (2009). Applicability of air-to-air heat recovery ventilators in China. *Applied Thermal Engineering 29(5-6)*, 830-840.