

Heat & Energy

RECOVERY VENTILATORS

The heat recovery ventilator (HRV) and its close cousin, the energy recovery ventilator (ERV), can often make a home more efficient. Find out here what these boxes do and if your house needs one.

by Neil Smith



A heat recovery ventilator (HRV) or energy recovery ventilator (ERV) is an important component for keeping the air fresh in a tightly sealed energy-efficient home.

Homes Need to Breathe

A house built to modern standards of tight construction will allow only a very small amount of outside air to leak in. But fresh air is needed to dilute the products of human habitation (cooking, cleaning, breathing, combustion, etc.), as well as the chemicals that offgas from building materials, such as particle board and paint. According to the U.S. Environmental Protection Agency, indoor air pollution levels are as much as five times higher than outdoors. And good ventilation is an important part of maintaining good indoor air quality.

Dilution and at-source (spot) exhausting are the main methods for ensuring good indoor air quality. It is possible to remove particles (by filtration), volatile organics (by adsorption), and other harmful products from indoor air, but these technologies are energy-intensive and very expensive (think spacecraft and submarines).

Although houses can be designed to “self-ventilate,” this process depends upon local climate conditions and wind shading—protection by tall walls and trees—which are not controllable. So the practical choice for many of our homes is mechanical ventilation.

Why not just open the windows? In some very mild climates, this might be a fine strategy. But in most of the United States, trying to ensure adequate air exchange defeats the energy-saving intent of a well-sealed building envelope.

The energy cost of exhaust-only or natural ventilation versus energy recovery ventilation can be easily demonstrated. Take a 2,500-square-foot house with indoor conditions of 70°F and 40% relative humidity, and outside air conditions of 30°F and 50% relative humidity. If we ventilate the house with 120 cubic feet per minute (prevailing wisdom of 0.35 air changes per hour) of outside air (as compared to no fresh air at all), here is how much the ventilation will cost us per month. This is due to the additional heating energy required because of the ventilation.

$$120 \text{ ft.}^3/\text{min.} \times 60 \text{ min./hr.} \times (25.3 \text{ Btu/lb.} - 9.06 \text{ Btu/lb.})^* \times 0.074 \text{ lbs./ft.}^3 \times 1.25 \text{ efficiency} \times 24 \text{ hrs./day} \times 30 \text{ days/mo.} \times (1 \times 10^5 \text{ therms/Btu}) \times \$1.50/\text{therm} = \$116/\text{mo.}$$

*Enthalpy of indoor vs. outdoor air (see psychrometric chart)

If we provide the same amount of ventilation, but instead of using exhaust fans only, we recover the airflows through an HRV/ERV with a recovery rate of 70%, the monthly heating cost drops to \$35. An HRV/ERV's only energy input is electricity to run the fans. For this situation, using average residential electricity costs, the monthly cost to run the HRV/ERV would be approximately \$12.

The average power draw of an HRV/ERV is 150 watts. If it runs 24 hours a day for 30 days each month, then the monthly energy consumption would be

$$150 \text{ W} \times 24 \text{ hrs/day} \times 30 \text{ days/mo.} \times 1 \text{ kW/1,000 W} = 108 \text{ kWh/month}$$

HRVs and ERVs use a fan to bring in outside air and another to exhaust air, balancing the amount of air in versus out. This air balance minimizes airflow through the building envelope—by reducing the pressure differential between inside and outside. While doing this, they recover energy from the outgoing airstream via a heat exchanger, which allows heat to move between the two airstreams without mixing or cross-contaminating them.

During the heating season, warm inside air is exhausted and pulled through the heat exchanger, while a separate fan brings in cold outside air. The outside air is warmed by the heat of the exhaust air. During the cooling season, the opposite occurs. ERVs take this energy recovery a step further by allowing moisture transfer between the two airstreams.

If heat recovery is such a good idea, why not recover the heat from every exhaust source, like clothes dryers and

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HRVs and ERVs are sized based on a home's square footage and the desired air exchange rate.

Airflow through HRVs and ERVs transfers heat, while replacing stale air with fresh, functioning in both heating and cooling seasons. (Heating season function shown by flow arrows.)



cook stove hoods? This is definitely not recommended or permitted. Both sources have contaminants in the airstream that will foul the heat exchanger and decrease its efficiency. Furthermore, there are fire risks associated with cooktops and their combustion products. The heat recovery potential from an intermittent exhaust source is negligible, since residential appliances do not continuously run.

HRV/ERVs should be used in any new, tightly sealed home. Most older houses are so leaky that they self-ventilate. Although an HRV/ERV can improve ventilation within a leaky structure, it cannot be expected to save a significant amount of energy, since the unplanned ventilation will still occur.

Assessing Airflow

The purpose of ventilating a building with outside air is to dilute the odors, chemicals, particles, and humidity that are introduced by human activities and offgassed by building materials. If we can also exhaust fouled air at the source, the ventilation system can be more efficient. When the outdoor conditions are right, we can even reduce unwanted humidity by introducing more outside air—typically during the winter.

There are various recommendations for sizing mechanical ventilation systems. An older one called for 0.35 air changes per hour (ACH). Alternate recommendations are based upon a recommended airflow per room. Recommendations vary by manufacturer, but the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), which sets standards for good residential indoor air quality, recommends continuous ventilation of 0.01 cfm per square foot of living space, plus 7.5 cfm per person. So a 1,500-square-foot home with four residents would require 45 cfm.

It's difficult to measure indoor air quality without expensive tests. Rigorous testing would consist of air sampling and analysis by a laboratory. However, a "smell test" can provide at least the first level of measurement. Since our olfactory system readily acclimates itself to new odors, it's important to "test" the air after being out of the house. However, with lower occupant density (bigger houses), bioeffluent (contaminants generated by the human body)

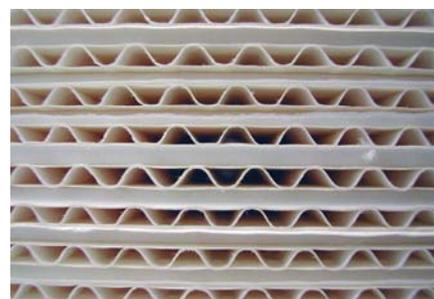
effects are diluted, and we must ventilate to reduce common pollutants (such as formaldehyde found in some building materials) that may not be detectable by the human nose.

Many ventilation codes are minimums, based upon ASHRAE standards. Each code or standard will yield different airflows, but none take into account building materials that may offgas more than others, nor outside air quality, which can vary depending on your locale (local outdoor pollution). To help ensure the best indoor air quality, it is prudent to size airflow liberally—using the standard that results in the most air exchanges. Most HRV/ERVs have multiple speed settings, so airflow can be easily changed as needed.

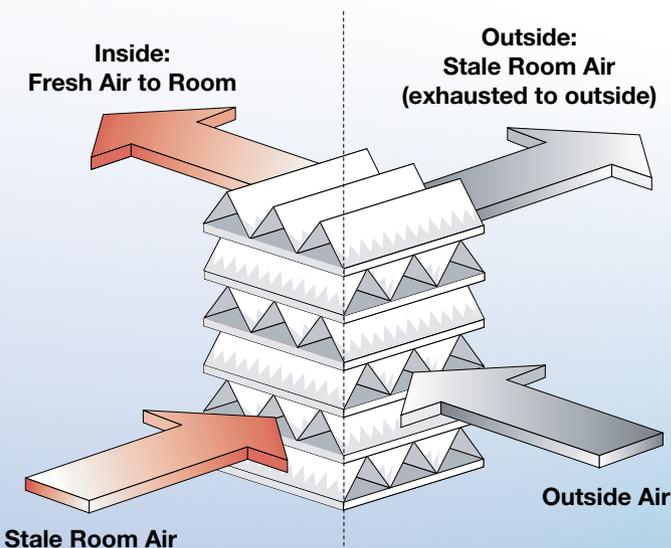
Unknowns include what the inhabitants do. Since airflow recommendation minimums are largely based on occupant loads, a sparsely populated house will likely require more ventilation for building material toxins. A house full of people who cook, bake, and take lots of showers will have its ventilation requirements set by the need to reduce humidity and carbon dioxide. The standards are minimums, so size your system generously.

Before designing whole-house ventilation, remove contaminants at the source (spot exhaust ventilation) with

A closeup of the air-to-air heat exchanger core.



Courtesy Solar & Palau USA (2)



Dealing with Wintertime Dryness

The air inside most houses is drier in the winter because homes are leaky. Cold air has very little capacity to absorb moisture. Take a situation where the outside air is at 40°F with a relative humidity of 50%. As that air moves into your house and is warmed to 70°F, its relative humidity changes to just 16%. How did that happen? The actual amount of moisture in the air did not change. This is reflected on the Y-axis of the graph labeled "Humidity Ratio: Grains of Moisture per Pound of Dry Air."

The term *relative humidity (RH)* is a percentage of how much moisture the air could hold at saturation (for example, right before it rains). Dew point is the temperature to which the air must be cooled for condensation to happen, or in other words, 100% relative humidity. This is best illustrated by a psychrometric chart.

The type of heating system does not affect a home's RH levels. Hydronic (hot water) or hot air systems will not "dry the air out."

With few exceptions, these are closed systems and do not add or subtract humidity from the building air.

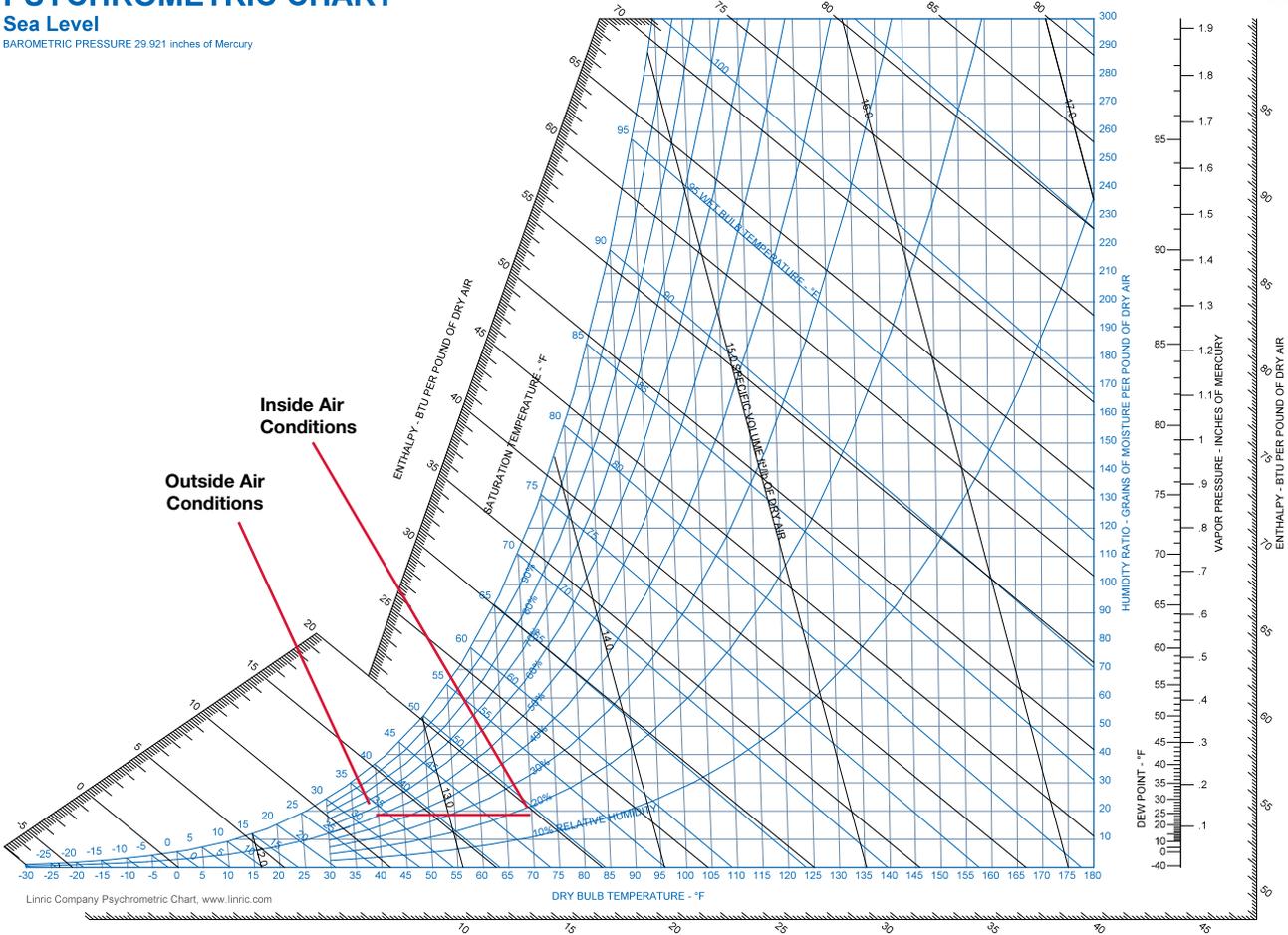
On the other hand, a very tight house without outside air ventilation may end up with moisture issues, such as condensate on windows and doors. This is because in the absence of any significant outside air entry into the building, moisture levels increase in what is effectively a closed system. Condensation occurs when the temperature of a surface is below the dew point of the air. Typically, this happens on windows, since they have the lowest thermal resistance and therefore are the coldest surfaces.

Room condition No. 2 shows the air temperature at 70°F and 50% RH. To illustrate the dew point of this air, a horizontal line is drawn to the left until it intersects the 100% RH curve. This shows that the dew point is about 50°F. So a surface at or below 50°F will have condensation on it from moisture in the air.

Psychrometric charts show the properties of air and water mixtures for the conditions that we encounter in our environment. This chart shows two conditions: cold outside air entering a house and the effects of heating that air.

PSYCHROMETRIC CHART

Sea Level
BAROMETRIC PRESSURE 29.921 inches of Mercury



fans over kitchen ranges and in bathrooms. Allow enough ventilation for peak loads. Bathroom ventilation should be sufficient to avoid condensation on surfaces at any time. Kitchen ventilation must have enough draw to capture the majority of smoke and odors at the source. Continuous low-level ventilation that is “good on average” won’t be suitable.

Make sure the ventilation systems are quiet—otherwise occupants will only use it under the most extreme conditions. HRV/ERVs cannot be expected to handle the peak odor, smoke, and humidity loads from bathrooms and kitchens. Direct-mounted fans or in-line fans, which are acoustically preferable, should be used.

HRV or ERV?

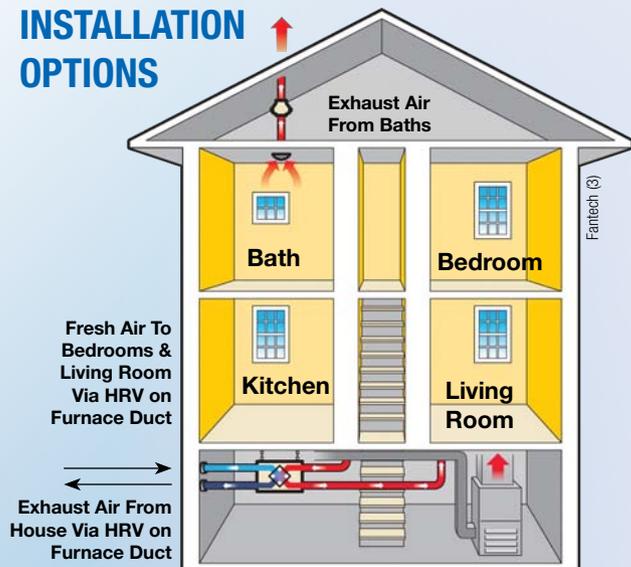
The decision of whether to use an HRV or ERV can be confusing. Traditional wisdom suggests ERVs in climates where there is a significant mechanical cooling needed and dehumidification is required, such as in the Midwest, in the eastern United States, and the Southeast. During summer, it’s desirable to retain the coolness and the aridity of the inside air. Moisture and heat from incoming outside air is transferred to the exhaust airstream, and the ERV becomes a *cool* recovery ventilator.

Well-sealed houses in heating-dominated climates can experience high indoor humidity levels. Therefore, HRVs are recommended, since additional moisture isn’t usually desired.

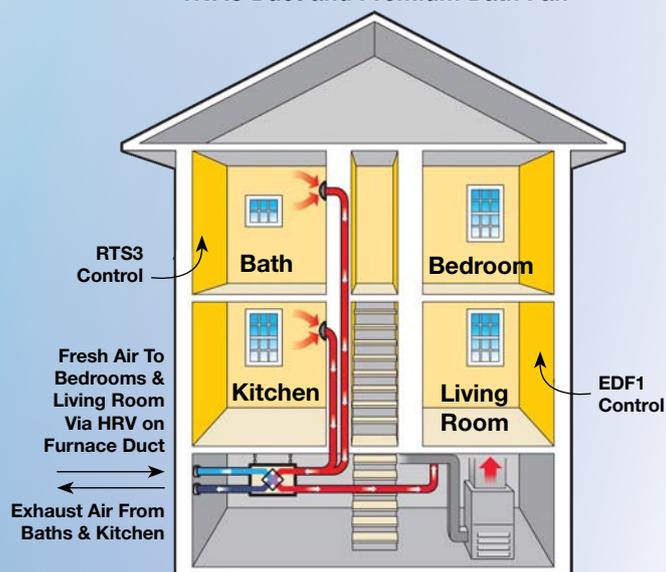
ERVs take the process of recovering energy in the exhaust air one step further. Besides capturing the sensible heat (energy used to raise or lower the temperature) of the air, an ERV transfers latent heat—the energy that is used to add or subtract moisture from air. Typical examples of this are dehumidification and humidification. The ERV recovers the latent heat by allowing moisture to travel across its core. Similar to heat flow, the path is from high humidity to low humidity.

A situation in which an ERV is more useful than an HRV would be energy recovery during the summer months. Your

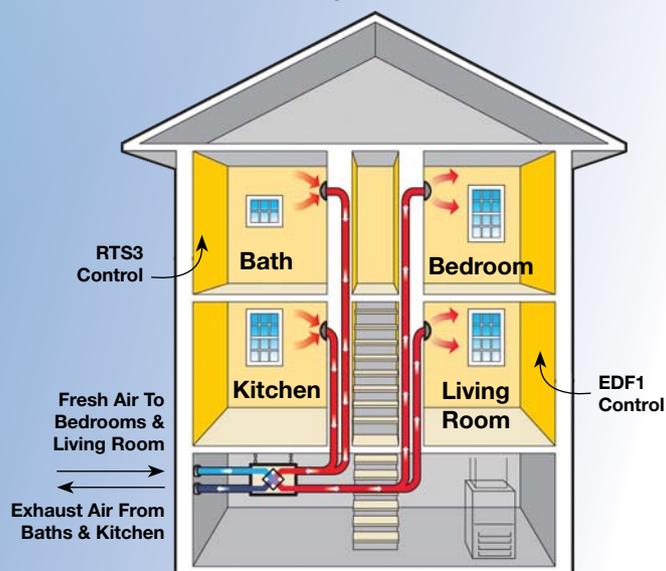
INSTALLATION OPTIONS



GOOD: Simplified Installation Using Existing HVAC Duct and Premium Bath Fan



BETTER: Partially Dedicated Installation

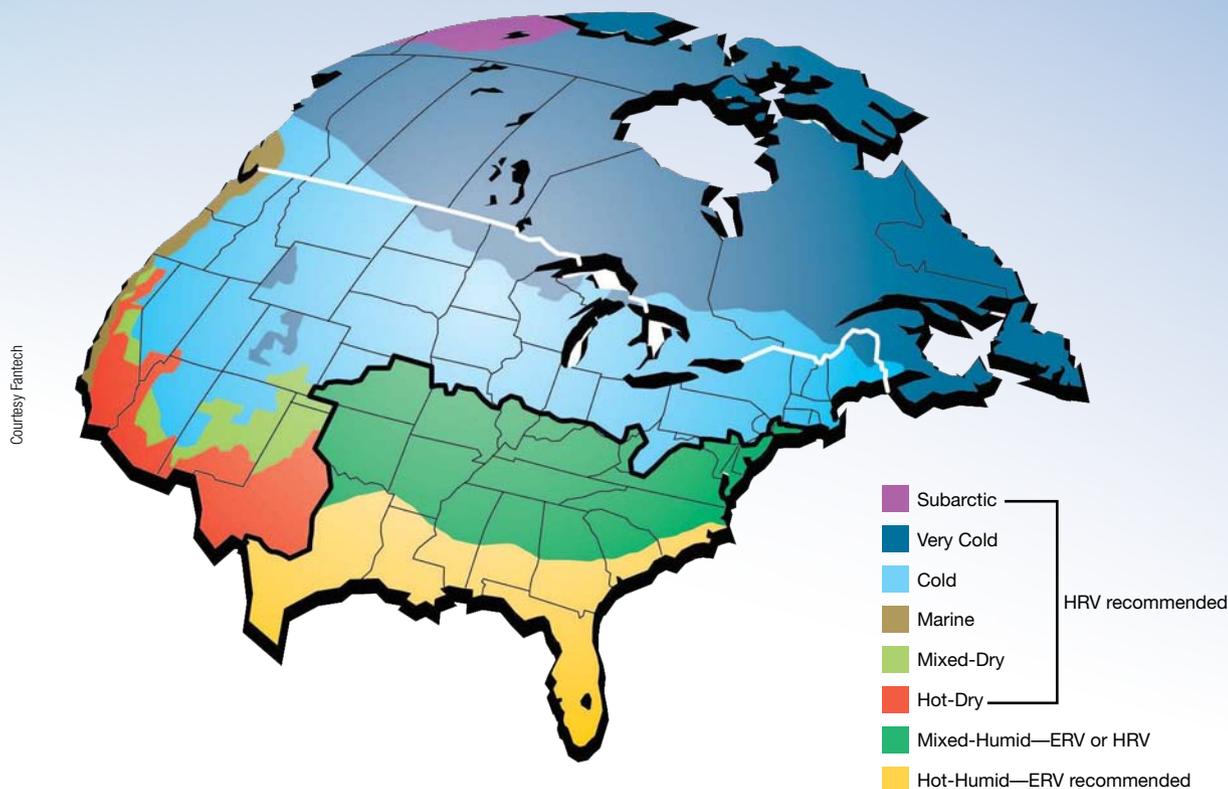


BEST: Fully Dedicated Installation

Ways to Improve IAQ

- Reduce the release of pollutants
- Use nontoxic, natural cleaning products (vinegar and baking soda, for example)
- Use and store paints, stains, and glues outside of the home
- Do not smoke
- Make sure your gas and wood-burning appliances are properly vented
- Make sure you have proper spot-ventilation for cooktops and stoves, and in bathrooms

Climate Zones for HRVs & ERVs



air conditioner has worked hard to dehumidify the inside air. The outside air is hotter and more humid than the inside air. As the ERV exhausts inside air and brings in outside air, two processes are at work. The outside air transfers some of its sensible (temperature) heat to the exhaust air, since the exhaust air is colder. At the same time, the outside airstream transfers some of its moisture to the exhaust airstream. In this way, the air exiting the ERV is cooler and less humid than the outside air. You could call this a “cold recovery” and “arid recovery” unit.

If ERVs do all that HRVs can, then why not always use ERVs? The heat and/or moisture exchanger is typically referred to as the “core.” It’s more difficult (thus more expensive) to fabricate an ERV core, which exchanges moisture as well as heat. Also, since these cores are moisture-permeable, they do not have the longevity of the plastic or aluminum HRV (heat-only) cores.

Configuring the System

Combining the HRV/ERV system with the existing air distribution system may be the only alternative for existing homes. Depending upon the design, the furnace or air-handling unit may have to run in conjunction with the HRV/ERV, which could add considerably to energy usage. For homes that rely on a central air heating/cooling system, the method I prefer is to run every piece of ducting to the HRV/ERV. This means that the duct arrangement looks like an octopus—although it’s not elegant on the surface, the advantage is that the flow to/from intake or supply

grilles can be controlled from a central location, with more precision. Oversize the legs and add a balancing damper (a manually operated butterfly damper) to each. Choose oversized insulated flex duct to minimize pressure drop and keep the system quiet. The grilles should be generous to reduce air noise.

The outside air ducts (exhaust and intake) should be separated by several feet to prevent cross-contaminating the airflows. Place the outside air intake high enough above grade, so that the HRV/ERV isn’t bringing in excess humidity or dirt and dust or be blocked by snowfall, and locate it away from exhaust vents.

Another option is to run a dedicated duct system for the HRV/ERV. This arrangement may be the only choice for houses without other air distribution. A technique that I favor is to pull exhaust air from one or more bathrooms. The HRV/ERV is sized so that it runs continuously, but at a low speed, and can be speeded up from a bathroom-mounted override switch. Each bathroom should have at least 75 cfm (preferably 100 cfm) of airflow to allow for peak exhaust requirements. Using an HRV/ERV with bathroom air input will eliminate the need for bathroom fans and provides balanced ventilation. Otherwise, ventilation will not be controlled.

Some advanced technologies offer further efficiency improvements, such as a defrost function. Although more expensive, they may be appropriate, depending upon the building requirements and the efficiency goal. In conditions of severe cold, HRV/ERVs may require defrosting. This situation occurs when very cold outside air brings the temperature

of the exhaust air down so far that the moisture in the air condenses and freezes. The frost level will eventually build up and block airflow. Manufacturers address this in one of two ways. The simple method is to turn off the fresh air fan for a few minutes. In this way, warm inside air remains warm, flows through the HRV/ERV, warms the core, and thereby defrosts the unit. A more sophisticated method uses a fifth port and a series of operable flaps. This method forces inside air through the core and back to the house. This method is recommended in climates with severe cold, since less heat is wasted. One manufacturer claims that its ERV does not require a defrost cycle due to the efficiency of its moisture transfer.

Units with electronically commutated motors decrease the full load power by about 30%, and can reduce part load power consumption by about 75%. Such units are appropriate where the HRV/ERV is the sole source of ventilation and must run continuously.

Typically, most existing houses are so leaky that an HRV or ERV is pointless. For new construction, the installation cost of an HRV/ERV is not much more than the cost of the equipment (\$550 and up), so long as the duct runs and installation are planned from the beginning.

Properly applied, HRV/ERVs are a great way to improve indoor air quality by introducing outside air, while recovering much of the energy in exhaust air. Although there is a higher capital cost compared to simple exhaust fans, the HRV/ERV system will save energy (and money) over the long term, while providing a quieter, healthier indoor environment.

Access

Neil Smith (neil@hvacquick.com) is a professional mechanical engineer. Neil's interests include HVAC and energy efficiency, and he currently runs the AirScape whole-house fan company.

HRV/ERV Sizing Calculator • www.hvacquick.com/sysbuilder/hrvbuild.php

Residential HRV/ERV Manufacturers:

Carrier • www.residential.carrier.com

Fantech • www.fantech.net

Lennox • www.lennox.com

Nu-Air • www.nu-airventilation.com

Soler & Palau USA • www.solerpalau-usa.com/res_rv.html

UltimateAir • www.ultimateair.com

