# CHOOSING A Whole-House Ventilation SYSTEM

Increasingly, because of either code changes or customer demand, builders are having to take a closer look at whether the new, tight houses they build have adequate ventilation. Many builders would like to provide something better than just a few bath exhaust fans

**by Judy Roberson**

but aren't sure how to design a simple ventilation system that is reasonably priced and meets the needs of the homeowner.

Most whole-house ventilation systems rely on either exhaust fans or the fans in forced-air heating and air-conditioning systems, because these fans are cheap, ubiquitous, and familiar to builders and homeowners. Yet just because these fans can be adapted for whole-house ventilation doesn't mean they do the job well. In many areas of the country, supply ventilation systems or balanced heat-recovery ventilation systems make more sense than either exhaust ventilation or forced-air systems.

Building codes typically require that bathrooms be ventilated with either an operable window or a spot exhaust fan. The trend in recent years is toward whole-house mechanical ventilation. ASHRAE's upcoming new residential ventilation standard (Standard 62.2) is likely to be incorporated by reference into many building codes within a few years (see *Notebook,* 6/00). Washington State has required mechanical ventilation in all new residential construction since 1991, and Minnesota instituted similar requirements this year.

Most builders, seeing the handwriting on the wall, realize that the trend is toward stricter requirements for mechanical ventilation.

Quiet, automatically controlled, continuous-operation fans are best

**Figure 1.** For homeowners who are away from the house according to a predictable schedule, a programmable timer, like this one from Leviton, works well for controlling ventilation rates.

## The Purpose of a Ventilation System

The purpose of a whole-house ventilation system is to maintain indoor air quality, which means supplying people with fresh air — and, in some cases, lowering the indoor humidity level. Ventilation is accomplished by regularly exchanging indoor air with outdoor air. People perceive indoor air quality differently, but in general, complaints relate to odors, high humidity, and "stuffiness." The key to an effective and efficient ventilation system is to remove indoor air from rooms where the majority of moisture and odors are generated (kitchen, laundry, and bathrooms) and reliably distribute outdoor air to all habitable rooms, particularly bedrooms, where people spend most of their time.

***Sources of indoor air pollution.*** Besides the moisture and odors that people constantly generate as they breathe, bathe, and cook, there are other sources of indoor air pollution to consider. Volatile organic compounds (VOCs) are emitted by some building materials and furnishings, including engineered wood (such as plywood, OSB, and particleboard), carpet, paint, vinyl, and synthetic fabrics. Odors from these materials, which are strongest when they are new, may subside after a few weeks or months, but they can continue to outgas for much longer. By far the best way to control these pollutants, besides keeping them out of the house in the first place, is to ventilate continuously (nonstop) at a low rate.

Other sources of indoor air pollution vary, depending on occupant activities and lifestyle. These include chemicals in cosmetics, clothing, and household cleaning products. When designing a ventilation system, consider whether the occupants smoke, entertain frequently, have indoor pets, or engage in hobbies requiring chemicals. To deal with such pollutants, consider providing a higher level of continuous ventilation, additional spot exhaust fans, or a second, higher ventilation speed.

The most dangerous air pollutants are those that should never be allowed indoors — radon and most combustion gases. Combustion gases from water heaters, furnaces, boilers, fireplaces, and automobiles can all include carbon monoxide. A ventilation system cannot protect occupants from these pollutants. In fact, a poorly designed ventilation system can actually bring these pollutants into the house.

## Qualities of a Good Ventilation System

Homeowners should be informed about their ventilation system but should not be aware of it in their daily lives. If the ventilation system makes noise, creates drafts, or raises the electric bill, people will disable it, in which case indoor air quality may deteriorate and lead to more serious problems. To avoid that, you want to install ventilation systems that are quiet, continuous, and automatic.

***Quietness counts.*** The best way to ensure a quiet system is to select a ventilation fan with a noise rating of less than 1 sone. Remotely located fans don't have to be as quiet, but they should be installed to isolate noise or vibration. Quality ventilation fans are designed for continuous operation for at least ten years. Using a quality fan that is sized correctly is also the best way to minimize operating cost. In the near future, look for the EPA Energy Star label to be appearing on quality home ventilation fans.

***Good controls.*** Ventilation controls should be located in such a way that the system can't be shut off inadvertently. The simplest control is an on/off switch, located in a basement or utility closet and clearly labeled, "This switch controls the ventilation system. It should be ON whenever the home is occupied." A better idea is to install a programmable control that operates the ventilation system continuously on low but allows residents to schedule a higher ventilation rate (cfm) during hours of higher activity (see Figure 1).

***Good distribution.*** It's not enough to introduce outdoor air into a home; that air must be distributed to people where and when they need it. This is one of the challenges of ventilation system design. Remote in-line fans that are

ducted to several rooms provide better air distribution than ceiling-mounted fans. All ventilation systems should be tested at installation to verify that they deliver adequate air to all rooms.

***Filtration.*** The ability to filter incoming air is an important aspect of indoor air quality and ventilation systems. Fans that supply outdoor air to a building make it possible to push the incoming air through a filter, but the fan must be sized to accommodate the additional resistance of the filter, even when clogged. Ventilation fans should be located where they are readily accessible for maintenance and easy replacement of filters.

## Ventilation and Indoor Pressure

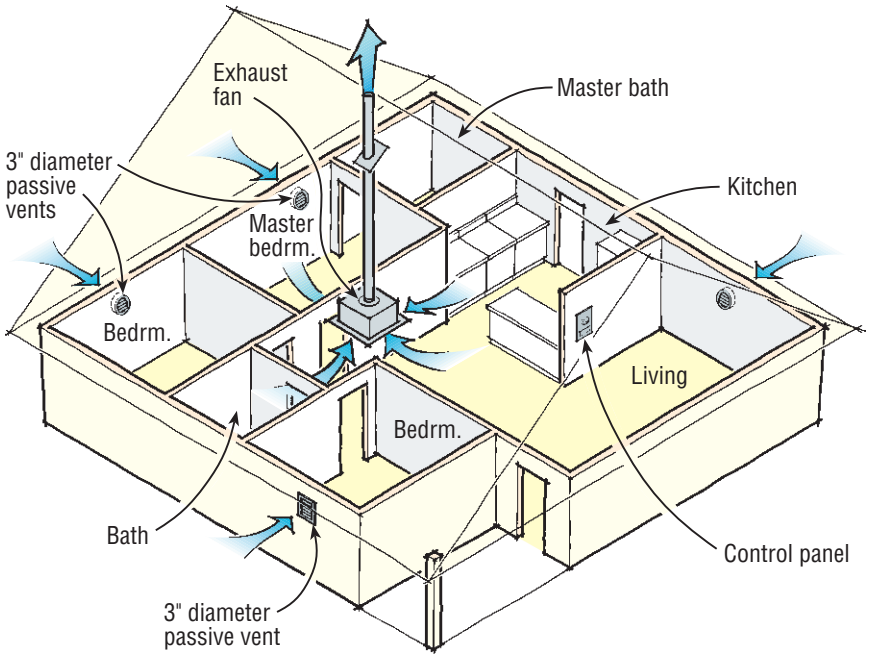
The tighter the house, the more easily it can be pressurized or depressurized (relative to the outdoors) by fans, particularly large fans such as kitchen range hoods (100-1,000 cfm), clothes dryers (100-500 cfm), or forced-air handlers (1,000-1,500 cfm). Although ventilation fans are relatively small (50-200 cfm), they have a disproportionate importance, since they operate continuously rather than intermittently. Builders need to understand indoor pressure because of its implications for safety, health, moisture transport, heating and air-conditioning performance, energy consumption, and ventilation air flow. (Contractor training is available through Advanced Energy Corp. at 919/857-9000.)

From a safety and health standpoint, positive indoor pressure is better than negative indoor pressure (depressurization). Negative indoor pressure as low as 3 Pascals (25 Pascals = 0.10 inches on a water gauge) can cause backdrafting of natural-draft combustion appliances and fireplaces, pull auto exhaust from an attached garage, or pull radon (if present in the soil) through cracks or holes in the foundation. Positive indoor pressure, on the other hand, does not interfere with combustion gas venting and helps prevent these and other outdoor air pollutants from entering a home.

In cold climates, however, positive

# Exhaust Ventilation

### Central Single-Port Exhaust Ventilation




### Multi-Port Exhaust Ventilation

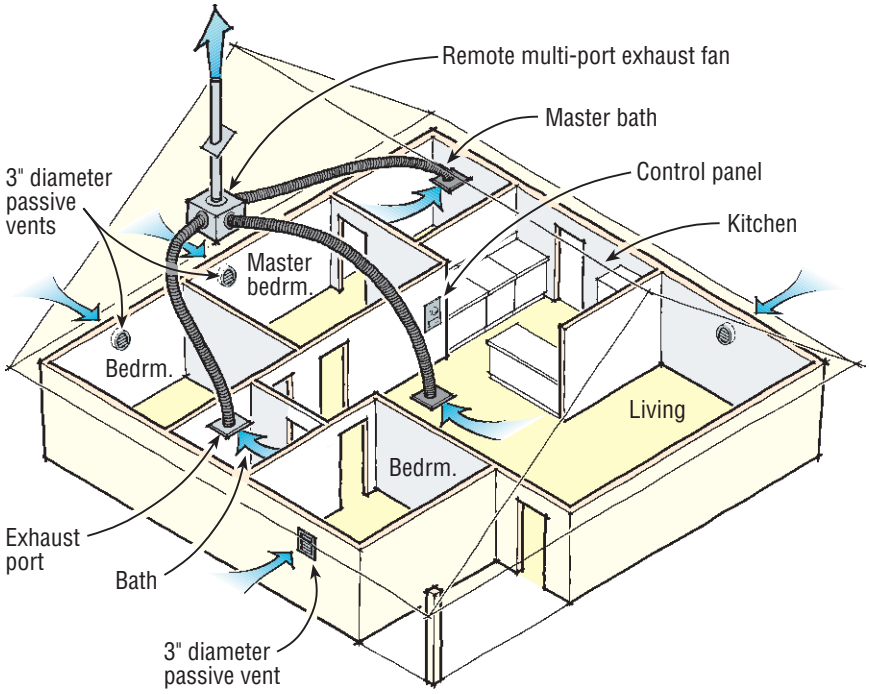



**Figure 2.** Exhaust ventilation systems remove stale air, either from one location (single-port exhaust system, top) or from several locations (multi-port exhaust, bottom). Fresh supply air is drawn into the building passively, either through miscellaneous cracks or through installed passive vents.

**Figure 3.** Bath exhaust fans, like this model from Panasonic, can be used for whole-house ventilation if they are wired for continuous operation.

indoor pressure can cause problems, since indoor air is pushed out through the exterior walls of a home. In very cold weather, moisture in this warm air will condense on cold surfaces inside the wall cavity, where it could cause framing to rot. Similarly, negative indoor pressure pulls outdoor air in through exterior walls, and in hot, humid climates, moisture in this warm air will condense on cold, air-conditioned surfaces within the wall. Savvy wall construction can minimize this potential structural problem but, in general, builders should avoid positive indoor pressure in very cold climates and negative indoor pressure in hot, humid climates.

## Three Types of Ventilation

Mechanical (or active) ventilation uses electric fans to move air into or out of a building, or both. There are three basic types of home mechanical ventilation systems: exhaust, supply, and balanced. Regardless of what a particular system is called, it is always one of these basic types, and you can save yourself a lot of trouble by learning to recognize them.


**Figure 4.** Multi-port ventilators, like these models from Aldes (above) and Broan (right), use a single fan to exhaust air from several locations.

Exhaust ventilation uses a fan to remove indoor air from a building. In a tight house, this creates a negative indoor pressure that pulls outdoor air in through openings in the walls, floor, and roof. Supply ventilation uses a fan to deliver outdoor air to a building. In a tight house, this creates a positive indoor pressure that pushes indoor air out through these openings. Balanced ventilation uses two fans to supply and exhaust similar volumes of air, so it does not affect indoor pressure.

## Exhaust Ventilation

In homes where depressurization does not pose a safety, health, or structural durability risk, exhaust ventilation can be very effective (Figure 2, previous page). Its success depends on the ability of the exhaust ventilation fan to pull air from all parts of the house, a job made difficult by closed interior doors, air leakage sites, and stack effect, which increases with building height and severity of climate. Therefore, exhaust ventilation is most effective in small, very tight homes with open floor plans.

***Single-port versus multi-port.*** Exhaust systems vary according to the location of the fan and the number of exhaust points, or ports. Locating the exhaust ventilation fan in a bathroom saves the cost of one spot fan but makes it harder for the fan to pull air from all the other rooms, especially when the bathroom door is closed. Locating the exhaust fan in a central hall or stairway improves its ability to pull air from all rooms (Figure 3). The multi-port is the most effective exhaust system. It uses a remote fan, located in a garage or attic, connected by small (4- to 6-inch-diameter) ventilation ducts to several rooms, usually each bathroom (Figure 4).

With exhaust ventilation systems, it is not possible to filter incoming air or to control the source of that air, so negative indoor pressure is as likely to pull air from a moldy crawlspace or dusty attic as from outdoors. Exhaust systems sometimes include several passive vents, which are small (4- to 6-square-inch) screened openings installed in exterior walls or windows. These vents are

designed to provide some control over the location of incoming air but require 10 to 20 Pascals of negative indoor pressure to be effective. In other words, the exhaust fan must significantly depressurize the building to ensure that air enters the home through the vents. Otherwise, they are uncontrolled leakage sites, and stack effect determines the direction of air flow (as it does when there is no ventilating fan).

## Supply Ventilation

With supply ventilation, the fan not only draws incoming air from one uncontaminated location, but it can also filter the incoming air, which is important to the growing number of people with asthma, allergies, and chemical sensitivities (Figure 5). Supply systems always include spot exhaust fans in the bathrooms and kitchen for removing excess moisture and odors.

***Forced-air supply systems*** use the fan and ductwork of the forced-air heating or cooling system to distribute ventilation air. Typically, a 6- to 12-inch-diameter supply air duct runs from outdoors to one of the plenums of the forced-air handler. When the forced-air fan runs, outdoor air is drawn into the plenum, mixed with recirculated indoor air, and delivered to the house. But while the need for heating or cooling is intermittent, ventilation is needed all the time, so a control (which costs about $100 installed) must be used to operate the forced-air fan at regular intervals (usually about 20 minutes each hour) for ventilation whenever the fan is not operating for heating or cooling.

Because a standard forced-air fan cannot be operated continuously, it doesn't maintain positive indoor pressure. And since forced-air systems are designed to move ten times as much air as is needed for ventilation (about 1,200 versus 120 cfm), these systems are noisier and more expensive to operate than those designed for ventilation only. Besides the noise, residents may also object to untempered air coming out of the supply registers. These disadvantages can be mitigated by installing an efficient,

# Supply Ventilation

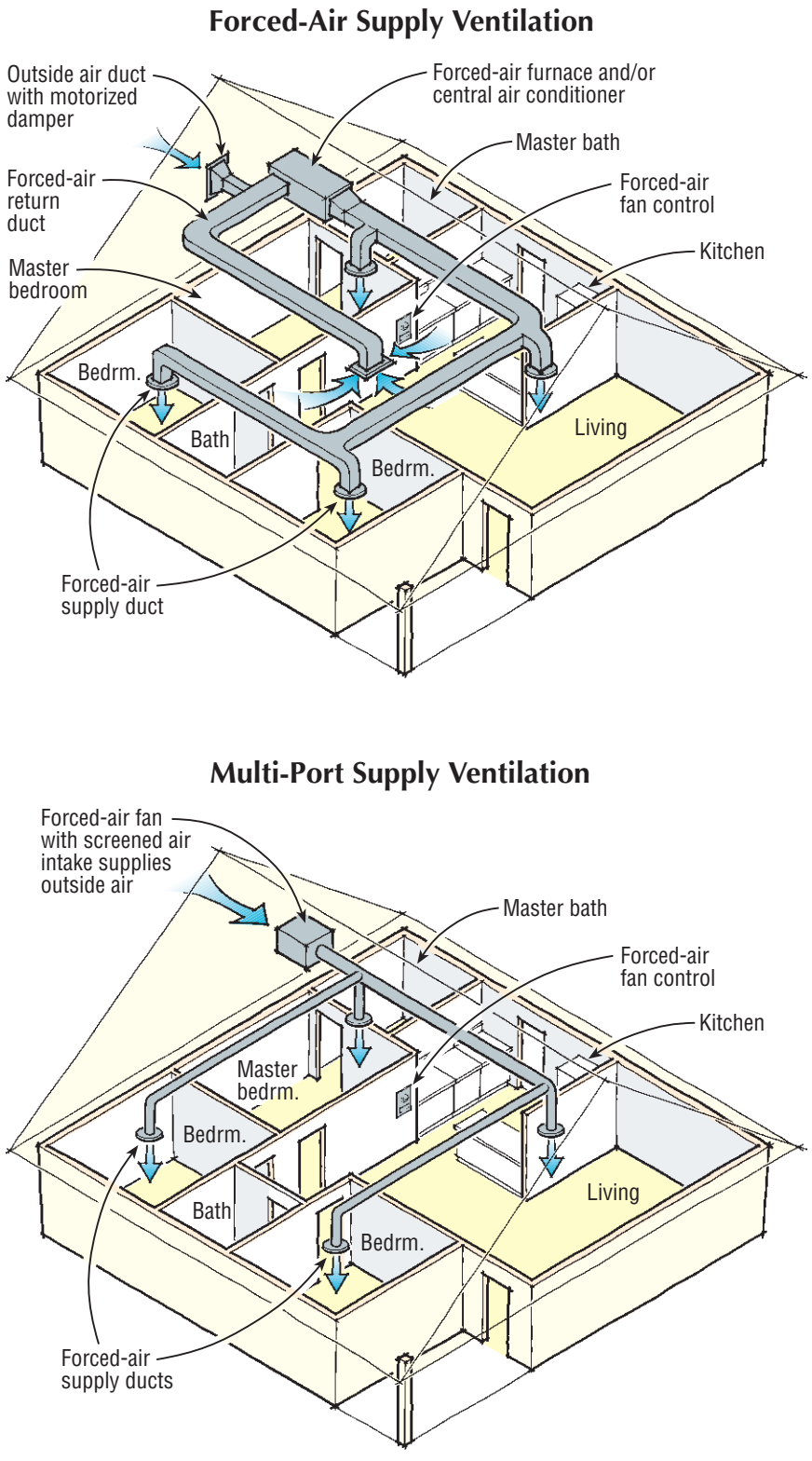



**Figure 5.** Supply ventilation systems introduce fresh outdoor air into a house, slightly pressurizing the building. A forced-air supply system (top) uses the fan on a forced-air furnace or central air conditioner, blending outdoor air with return air in the return plenum. A multi-port supply system (bottom) filters and distributes outdoor air through dedicated 4- to 6-inch-diameter ducts.

# Balanced Ventilation

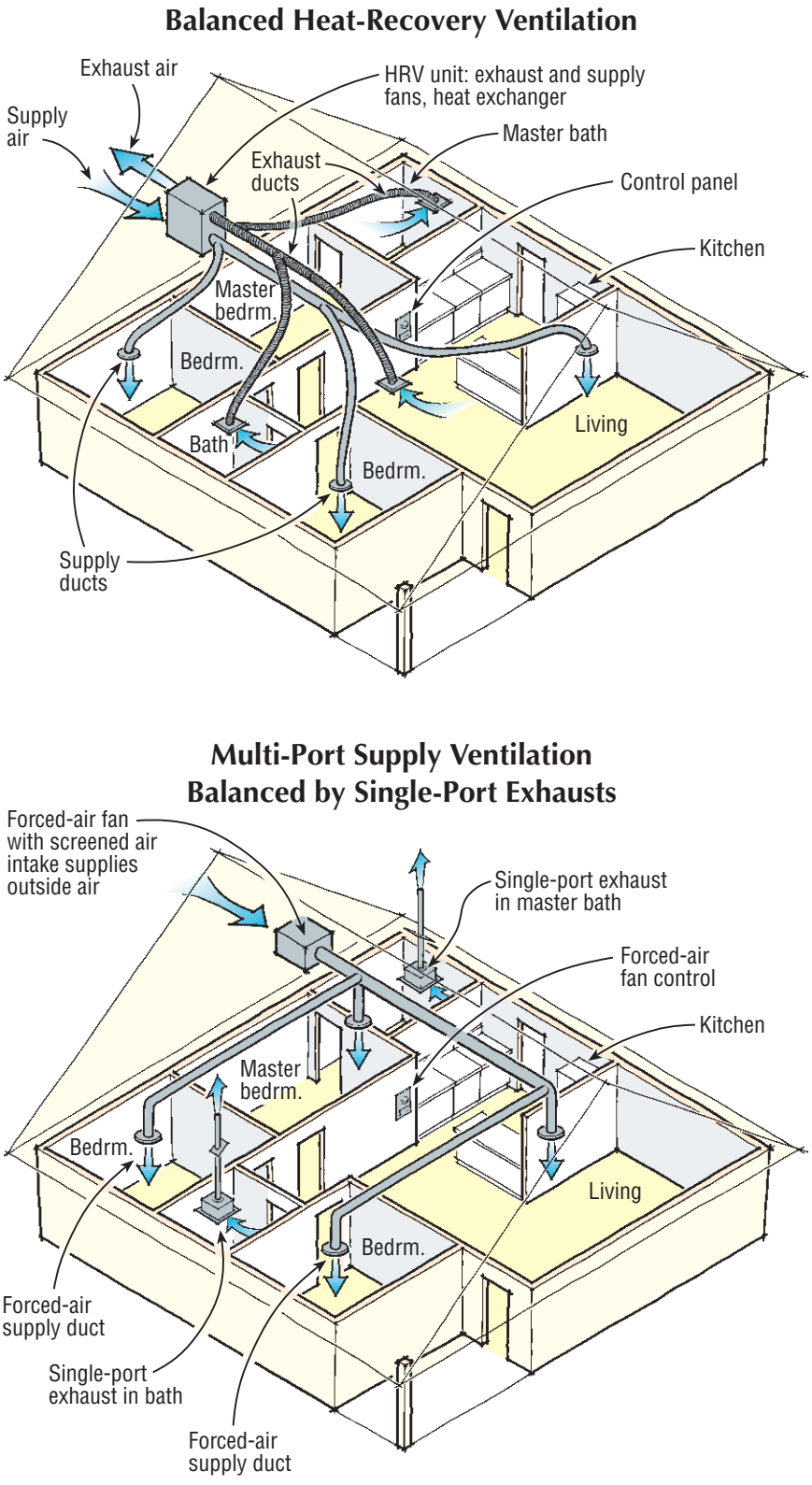



**Figure 6.** A balanced ventilation system uses two fans — one to supply fresh outdoor air, and another to simultaneously exhaust stale air. A heat-recovery ventilator (top) provides balanced ventilation, as does a multi-port exhaust system balanced by a single-port exhaust fan (bottom).

variable-speed (ECM) forced-air fan that can operate continuously. Such a fan increases forced-air supply installation costs by about $1,000.

As an alternative to using the hvac supply system, an independent, multi-port supply ventilation fan can distribute outdoor air to living room and bedrooms through a set of 4- to 6-inch-diameter ventilation ducts. This provides all the benefits of supply ventilation, including quietness, efficiency, air filtration, and positive indoor air pressure, without the drawbacks of using forced-air fans and ducts. Surprisingly, multi-port supply is the least common type of ventilation system currently used, partly because builders and homeowners are more familiar with exhaust fans and forced-air systems.

## Balanced Ventilation

Balanced ventilation systems use two fans that exhaust and supply similar volumes of air, so indoor pressure is not affected (Figure 6). The primary advantage of balanced ventilation, however, is not neutral pressure but the ability to transfer energy from exhaust air to temper incoming supply air. Thus, balanced systems vary according to whether they incorporate heat recovery and how well they do it.

Balanced systems are more expensive than unbalanced systems, because the installation and operation of two fans is required. Balanced ventilation can be used in any climate but is most common in very cold or hot, humid climates, where heat recovery is most cost-effective.

In winter, heat-recovery ventilation systems (HRVs) use heat from the exhaust air to raise the temperature of incoming supply air (Figure 7). Energy-recovery ventilation systems (ERVs) are similar, except they exchange moisture as well as sensible heat energy. ERVs transfer moisture from the more humid to the less humid airstream. In arid climates, moisture is transferred from outgoing to incoming air; in humid climates, moisture is transferred from incoming to outgoing air, until the

ERV's capacity for moisture transfer is reached. ERV moisture transfer is passive, and neither the amount nor the direction of transfer can be controlled.

HRVs and ERVs vary according to the type and efficiency of the heat recovery mechanism and the efficiency of the ventilation fans. When selecting a unit, refer to the Home Ventilation Institute's annual "Certified Home Ventilating Products Directory" (available by calling 847/394-0150, or through their website, www.hvi.org), which reports HRV and ERV efficiencies. HRVs and ERVs provide excellent distribution of air because both fans are usually ducted to several rooms. The main disadvantages of HRVs and ERVs are their high initial cost and the fact that considerable expertise is required to properly install and maintain them.

## Choosing the Right System

Choosing a ventilation system requires balancing cost and performance. For example, forced-air supply ventilation is popular among tract home builders because it's very inexpensive to install; however, it's expensive to operate a standard forced-air fan for ventilation. On the other hand, balanced heat-recovery systems are expensive to install but save on operating costs. The more severe the climate, the greater the operating cost savings with heat-recovery ventilation. Single-port exhaust systems have low installation and operating costs, but often do not distribute air as well as ducted systems. Multi-port supply and multi-port exhaust ventilation have moderate installation and low operating costs.

At Lawrence Berkeley National Laboratory, we devised a ranking system in order to compare the cost and effectiveness of various residential ventilation systems. Our results were intended for production home builders, whose decisions are driven primarily by lowest first cost, but the information provided is useful to any builder or homeowner trying to select a ventilation system.

We evaluated nine ventilation strategies, including three types of exhaust systems, three types of supply systems, and three types of balanced systems. These nine systems were then scored and ranked for four different climates (cold, mixed, hot-humid, and hot-arid, represented by Boston, Washington, D.C., Houston, and Phoenix). Scores were based on three criteria: installation cost, long-term operating costs, and effectiveness of ventilation provided by each system. The lower the costs and the more effective the ventilation, the higher the score. Our criteria for effectiveness included air distribution and indoor air pressure, but they did not include air filtration or source of air.

In all four climates, the ventilation system with the highest score was multi-port supply. However, since positive indoor pressure can cause moisture problems in exterior walls in cold climates, we recommend that in cold climates, a multi-port supply system be balanced by single-port exhaust ventilation, and that


**Figure 7.** Although heat recovery ventilators, like this model from Stirling Technology (left) or these units from Nutech (below), have a high initial cost, they reduce the cost of tempering the ventilation air.

heat recovery ventilation be offered to home buyers as an optional upgrade. Exhaust systems (which usually are not ducted) are as affordable as, but less effective than, supply systems (which usually are ducted). Balanced HRVs and ERVs are most effective, but their high installation cost is difficult to justify, at least in production homes. The report, entitled *Recommended Ventilation Strategies for Energy-Efficient Production Homes*, is available on-line at http://enduse.lbl.gov/Projects/ESVentilation.html.

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## Suppliers of Ventilation Equipment

**American Aldes Ventilation**
800/255-7749
www.americanaldes.com
*Bath exhaust fans, in-line fans, multi-port ventilators, exterior-mount ventilators, HRVs and ERVs*

**Broan-Nutone**
800/558-1711
www.broan.com
*Bath exhaust fans, multi-port ventilators, and Guardian HRVs*

**Carrier/United Technologies**
800/227-7437
www.carrier.utc.com
*HRVs and ERVs*

**Continental Fan**
800/320-0504
800/779-4021
www.continentalfan.com
*Bath exhaust fans*

**Energy Federation**
800/876-0660
www.efi.org
*Distributor of ventilation products*

**Fan America**
800/838-4074
www.fanam.com
*Bath exhaust fans and in-line fans*

**Fantech**
800/747-1762
www.fantech-us.com
*In-line duct fans, multi-port exhaust fans, exterior-mount fans, controls, and timers*

**Grasslin Control**
800/272-1115
www.grasslin.com
*Timers for ventilation control*

**Honeywell**
800/345-6770
www.honeywell.com
*HRVs*

**Kanalflakt**
800/565-3548
www.kanalflakt.com
*Enviro HRVs*

**Lennox International**
972/497-5000
*HRVs*

**Leviton**
800/323-8920
www.leviton.com
*Timers for ventilation control*

**Mitsubishi Electric Air Tech America**
800/627-4499
*ERVs*

**Nutech Energy Systems Inc.**
519/457-1904
www.lifebreath.com
*LifeBreath HRVs*

**NuVent**
513/777-8846
www.nuventproducts.com
*Bath exhaust fans and HRVs*

**Panasonic**
201/271-3287
www.panasonic.com/building
*Bath and whole-house exhaust fans*

**Positive Energy Conservation Products**
800/488-4340
www.positive-energy.com
*Distributor of ventilation products, including in-line exhaust fans and HRVs*

**Raydot**
800/328-3813
www.raydot.com
*HRVs*

**Research Products**
800/334-6011
www.aprilaire.com
*Aprilaire HRVs*

**Snappy Air Distribution Products**
800/328-2044
*Distributor of HRVs manufactured by Nutech*

**Spruce Environmental Technologies**
800/355-0901
www.spruce.com
*Dyna Vent in-line fan*

**Stirling Technology**
800/535-3448
www.lychonia.com
*HRVs*

**Tamarack Technologies**
800/222-5932
www.tamtech.com
*Preventilator exterior-mounted exhaust fans and ventilation controls, and distributor for a variety of ventilation products*

**Therma-Stor Products**
800/533-7533
www.thermastor.com
*Quiet-Vent multi-port exhaust ventilators and distributor of NuTech's LifeBreath HRVs*

**Venmar Ventilation**
800/567-3855
www.venmar-ventilation.com
*HRVs and ERVs*