WHOLE-HOUSE VENTILATION SYSTEMS

Improved control of air quality

Buildings for the 21st Century

Buildings that are more energy efficient, comfortable, and affordable...that's the goal of DOE's Building Technologies Program. To accelerate the development and wide application of energy efficiency measures, the Building Technologies Program:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use

PURPOSE OF VENTILATION

All homes need ventilation—the exchange of indoor air with outdoor air—to reduce indoor moisture, odors, and other pollutants. Contaminants such as formaldehyde, volatile organic compounds (VOCs), and radon that may cause health problems can accumulate in poorly ventilated homes. Inadequate ventilation allows unpleasant odors to linger. Excess moisture generated within the home needs to be removed before high humidity levels lead to physical damage to the home or mold growth.

VENTILATION STRATEGIES

To ensure adequate ventilation, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) says that the living area of a home should be ventilated at a rate of 0.35 air changes per hour or 15 cubic feet per minute (cfm) per person, whichever is greater.

Natural ventilation—uncontrolled air movement into a building through cracks and small holes (infiltration) and through vents such as windows and doors—is the traditional method of allowing fresh outdoor air to replace indoor air. Nowadays, because of central heating and cooling, as well as the desire for privacy, people tend to make little use of windows for ventilation, so infiltration has become the principal mode of natural ventilation in homes. Unfortunately, a home's natural infiltration rate is unpredictable and uncontrollable because it depends on the home's airtightness, outdoor temperatures, wind, and other factors. During mild weather, some homes may lack sufficient ventilation for pollutant removal. Tightly built homes may have insufficient ventilation at most times. Homes with high infiltration rates may experience high energy costs. Also, infiltration may allow contaminated air to enter from a polluted area such as a garage or crawlspace, or may not ventilate the house uniformly.

Whole-house ventilation—use of one or more fans and duct systems to exhaust stale air and/or supply fresh air to the house—can better control the exchange of indoor air with outdoor air. Energy experts often quote the axiom, "seal tight, ventilate right" as their recommended approach to house ventilation. This axiom implies that houses should be tightly sealed to reduce infiltration, and a whole-house ventilation system installed to provide fresh air and remove pollutants when and where needed, in a controlled manner (i.e., in amounts needed) that does not negatively impact indoor air quality, building components, or heating and cooling bills.

Spot ventilation—the use of localized exhaust fans (e.g., kitchen range and bath fans) to quickly remove pollutants at their source—is an important tool to improve air quality whether natural or whole-house ventilation strategies are used. Spot ventilation improves the effectiveness of ventilation systems by removing pollutants at their source as they are generated and should be an integral part of any whole-house ventilation design. In addition to its whole-house ventilation requirement, ASHRAE recommends intermittent or continuous ventilation rates for bathrooms and kitchens as alternatives to operable windows: 50 or 20 cfm for bathrooms and 100 or 25 cfm for kitchens, respectively.

WHOLE-HOUSE VENTILATION SYSTEM DESIGNS

The decision to use whole-house ventilation is typically motivated by concern that natural ventilation is not providing adequate air quality, even with source control by spot ventilation. Whole-house ventilation systems are usually classified as *exhaust ventilation* if the mechanical system forces inside air out of the home, *supply ventilation* if the mechanical system forces outside air into the home, or *balanced ventilation* if the mechanical system forces equal quantities of air into and out of the home.

✓ Exhaust Ventilation Systems

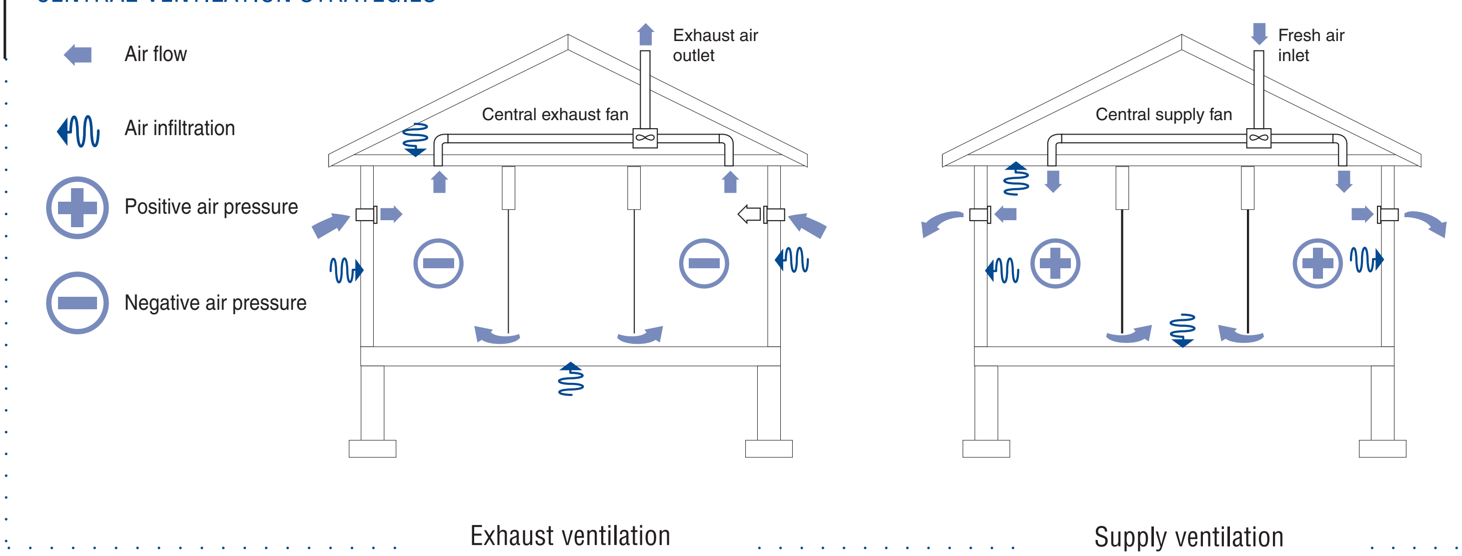
Exhaust ventilation systems work by depressurizing the building. By reducing the inside air pressure below the outdoor air pressure, they extract indoor air from a house while make-up air infiltrates through leaks in the building shell and through intentional, passive vents.

Exhaust ventilation systems are relatively simple and inexpensive to install. Typically, an exhaust ventilation system is composed of a single fan connected to a centrally located, single exhaust point in the house. A preferable design option is to connect the fan to ducts from several rooms (preferably rooms where pollutants tend to be generated, such as bathrooms). Adjustable, passive vents through windows or walls can be installed in other rooms to introduce fresh air rather than rely on leaks in the building envelope. However, their use may be ineffective because larger pressure differences than those induced by the ventilation fan may be needed for them to work properly. Spot ventilation exhaust fans installed in the bathroom but operated continuously can represent an exhaust ventilation system in its simplest form.

Exhaust ventilation systems are most applicable in cold climates. In climates with warm humid summers, depressurization can draw moist air into building wall cavities, where it may condense and cause moisture damage.

One concern with exhaust ventilation systems is that they may draw pollutants, along with fresh air, into the house. For example, in addition to drawing in fresh outdoor air, they may draw in radon and molds from a crawlspace, dust from an attic, fumes from an attached garage, or flue gases from a fireplace or fossil-fuel-fired water heater and furnace. This can especially be of concern when bath fans, range fans, and clothes dryers (which also depressurize the home while they operate) are run when an exhaust ventilation system is also operating. Also, exhaust ventilation systems can contribute to higher heating and cooling costs compared with heat-recovery systems because exhaust systems do not temper or remove moisture from the make-up air before it enters the house.

CENTRAL VENTILATION STRATEGIES



✓ Supply Ventilation Systems

Supply ventilation systems work by pressurizing the building. They use a fan to force outside air into the building while air leaks out of the building through holes in the shell, bath and range fan ducts, and intentional vents (if any exist).

As with exhaust ventilation systems, supply ventilation systems are relatively simple and inexpensive to install. A typical supply ventilation system has a fan and duct system that introduces fresh air into usually one, but preferably several rooms of the home that residents occupy most often (e.g., bedrooms, living room), perhaps with adjustable window or wall vents in other rooms. Supply ventilation systems allow better control of the air that enters the house than do exhaust ventilation systems. By pressurizing the house, supply ventilation systems discourage the entry of pollutants from outside the living space and avoid backdrafting of combustion gases from fireplaces and appliances. Supply ventilation also allows outdoor air introduced into the house to be filtered to remove pollen and dust or dehumidified to provide humidity control.

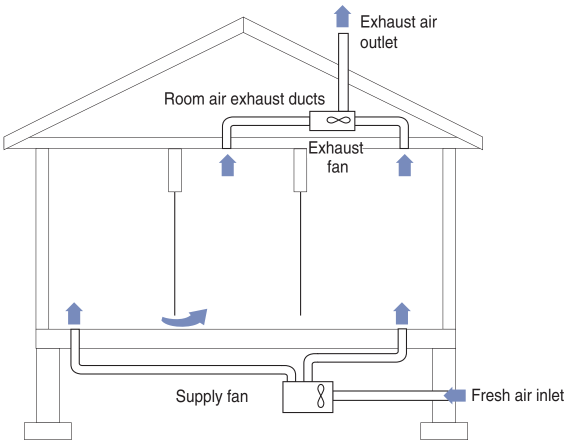
Supply ventilation systems are most applicable in hot or mixed climates. Because they pressurize the house, supply ventilation systems have the potential to cause moisture problems in cold climates. In winter, the supply ventilation system causes warm interior air to leak through random openings in the exterior wall and ceiling. If the interior air is humid enough, some moisture may condense in the attic or cold outer parts of the exterior wall where it can promote mold, mildew, and decay.

Like exhaust ventilation systems, supply ventilation systems do not temper or remove moisture from the make-up air before it enters the house. Thus, they may contribute to higher heating and cooling costs compared with heat-recovery systems. Because air is introduced in the house at discrete locations, outdoor air may need to be mixed with indoor air before delivery to avoid cold air drafts in the winter. An in-line duct heater is another option, but it will increase operating costs.

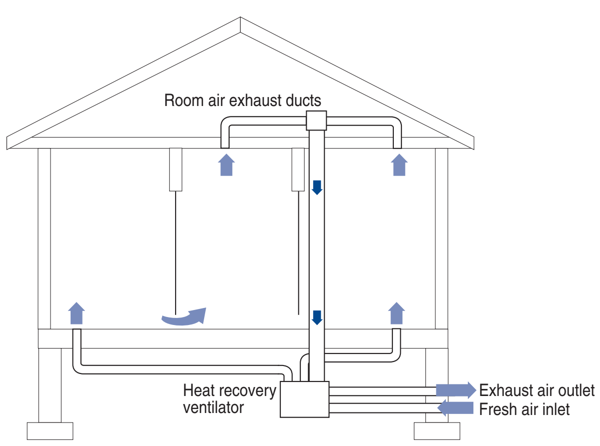
✓ Balanced Ventilation Systems

Balanced ventilation systems neither pressurize nor depressurize a house if properly designed and installed. Rather, they introduce and exhaust approximately equal quantities of fresh outside air and polluted inside air, respectively. Balanced ventilation systems are appropriate for all climates.

A balanced ventilation system usually has two fans and two duct systems and facilitates good distribution of fresh air by placing supply and exhaust vents in appropriate places. Fresh air supply and exhaust vents can be installed in every room, but a typical balanced ventilation system is designed to supply fresh air to bedrooms and living rooms where people spend



Balanced ventilation



Balanced heat-recovery ventilation

the most time, and exhaust air from rooms where moisture and pollutants are most often generated (kitchen, bathrooms, and perhaps the laundry room). Some designs may use a single-point exhaust. Because they directly supply outside air, balanced systems allow the use of filters to remove dust and pollen from outside air before introducing it into the house.

Balanced systems are usually more expensive to install and operate than supply or exhaust systems because they require two duct and fan systems. Like these other systems, balanced ventilation systems do not temper or remove moisture from the make-up air before it enters the house and thus may contribute to higher heating and cooling costs compared with heat-recovery systems. Like supply ventilation systems, outdoor air may need to be mixed with indoor air before delivery to avoid cold air drafts in the winter.

✓ Balanced, Heat-Recovery Ventilation Systems

A special type of balanced ventilation system adds a heat-recovery unit to the basic design. A heat-recovery unit reduces the heating and cooling costs of ventilation by transferring heat from the warm inside air being exhausted to the fresh but cold outside air in the winter, and vice-versa in the summer. Comfort is also improved because the supply air is tempered before delivery, reducing drafts. Some heat-recovery systems also transfer moisture—an advantage in warm, humid climates in the summer and cold climates in the winter.

Balanced ventilation systems with heat recovery are more costly to install than balanced systems without heat recovery because heat-recovery systems require more powerful fans that use more energy to overcome the air resistance of the heat exchanger.

Balanced, heat-recovery units are most cost effective in climates with extreme winters or summers, and where fuel costs are high. In mild climates, the cost of the additional electricity consumed by the fans may exceed the energy savings from not having to heat and cool the air introduced by the ventilation system.

Heat-recovery systems require more maintenance than other whole-house ventilation systems. They need to be cleaned regularly to prevent deterioration of ventilation rates and heat recovery, and to prevent growth of mold and bacteria on heat exchange surfaces. When warm, moist air is cooled, condensate forms on cool surfaces and must be drained from the heat-recovery system. In cold climates, very cold air brought into a heat-recovery system can cause frost formation in the heat exchanger. Because frost buildup reduces ventilation effectiveness and can damage the heat exchanger, heat-recovery systems must have devices to deal with frost.

INTEGRATION WITH FORCED-AIR HEATING AND AIR CONDITIONING SYSTEMS

Integrating whole-house ventilation systems into heating and air conditioning systems can reduce the installation cost of the ventilation system by making use of existing fans and ducts to distribute fresh outdoor air throughout the house. Another advantage of some integrated designs is that fresh air can be effectively mixed with indoor air to alleviate drafts.

Most approaches are supply ventilation designs that introduce ventilation air into the return side of the forced-air duct system, although some introduce air into the supply side. To be most effective, heating and cooling ductwork must be airtight or located within the conditioned space of the house.

Several design issues must be addressed, the solutions to which often come at the cost of increased system complexity.

- Ventilation systems that use the air-handler fan tend to provide the most mechanical ventilation in the winter, when the cost of tempering outside air is highest and it is least needed because natural ventilation is usually greatest.
- Ventilation systems that use the air handler fan also tend to provide the least mechanical ventilation when it is most needed. On mild days, the heating and cooling system may not operate when the amount of natural infiltration is minimal. To compensate for this, a controller can be used to turn the air-handler fan on for a short period of time during each hour that the air-handler fan does not operate for heating or cooling.
- Running a large air-handler fan can be noisy and expensive. One solution is to use a more expensive variable-speed air-handler fan that operates at a low speed when heating or cooling is not needed. This approach may require a motorized damper to keep the ventilation rate nearly constant when the fan operates at different speeds. Another solution is to use a smaller, separate fan to pull outdoor air into the ductwork and distribute it throughout the house.
- Duct systems that distribute heated and cooled air effectively when the air flow rate is 800 cfm or more may distribute it poorly when the flow rate is dropped to 100 cfm or less.

CONTROLS

Ventilation experts usually recommend that whole-house ventilation systems be designed to operate automatically so that fresh air is supplied to the house without occupant intervention. An on-off control may also be required by codes.

✓ Continuous Control

Some experts recommend continuous ventilation to simplify controls and to avoid unhealthy indoor air for the several hours it may take a system to flush out pollutants after having been off for an extended time. If pollutants continuously released from furnishings or building materials are the principal concern, continuous ventilation is most effective.

✓ Programmable Timer

Rather than operate a whole-house ventilation system continuously, a programmable timer can be employed to operate the system intermittently for a selected period of time each day. To provide equivalent ventilation, such a system must have a higher capacity than one that operates continuously.

✓ Occupancy Control

Some experts recommend that whole-house ventilation systems be controlled to provide fresh air only when occupants are home to minimize costs. If the occupants and their activities are the principal cause of indoor air pollution, occupancy-based ventilation controls can be most effective.

Detecting occupancy is difficult. Motion detectors are effective unless the occupants are sitting or sleeping quietly or are out of the view of the sensor. Good coverage may require one or more motion detectors in each room. Carbon dioxide sensors can be effective but are expensive. Setting the detection level may be difficult because a sleeping person gives off little carbon dioxide. Thus, it is difficult to distinguish between a house with sleeping people and one that is unoccupied.

✓ Low-High Switch

A two-speed fan installed in a whole-house ventilation system might be controlled by a low-high switch. This allows the ventilation fan to provide a low level of ventilation continuously, but provides the occupant with the capability to boost the ventilation rate if needed.

✓ Labeling

If a ventilation control switch is used, it should be labeled to provide clear guidance for its proper operation. For example, it might be labeled to say "This switch controls the ventilation system. It should be ON whenever the home is occupied."

DESIGN AND INSTALLATION CRITERIA

✓ Fans

Noise is a major reason people avoid using ventilation systems. Fans used in whole-house ventilation systems and installed inside the house should be quiet (less than 2 sones, but preferably less than 1 sone) or installed remotely outside the living space so that the noise caused by their operation is not perceived.

A significant part of the operating cost associated with a ventilation system is the electricity used to operate the fan. Energy-efficient fans should be used to reduce these costs.

Fans should be sized and selected to provide necessary air flows based on the type, length, and design of the duct system. Fans selected for whole-house ventilation systems should be manufactured for continuous operation and long life (greater than 10 years), and installed in a location that is easily accessible for regular maintenance.

✓ Ducts

The most efficient ventilation ducts are smooth, short, straight, and properly sized. Smooth sheet metal ducts offer low airflow resistance. Because corrugated ducts have greater flow resistance, it is important to keep them as short as possible—stretch the corrugated material to its full length and cut off the excess. Minimize the number of elbows. Provide adequate support. Use mechanical fasteners and sealants (preferably duct mastic) at all joints. Ducts located outside the conditioned space should be insulated.

✓ Duct Terminations

Ducts expelling water vapor or other pollutants must exhaust directly to the exterior—never into attics or crawlspaces prone to moisture problems. Use wall caps or roof jacks with flap dampers, screens, or both to deter access and to reduce air infiltration. Unless they are already integrated into the system (e.g., wall cap with flapper), equip ventilation ducts with backdraft dampers at or near the insulated building boundary.

✓ Indoor Air Circulation

Indoor air must be free to flow between supply and return ports of whole-house ventilation systems. If a supply and return port is not installed in every room, then through-the-wall transfer grills should be installed above doors in rooms with doors that are often closed, or the doors should be undercut to facilitate air flow.

WHOLE-HOUSE VENTILATION SYSTEMS

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Energy Efficiency and Renewable Energy Clearinghouse (EREC)
1-800-DOE-3732
www.eren.doe.gov

Or visit the Building Technologies Program Web site at www.buildings.gov

Or refer to the Builder's Guide
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STEPS FOR DESIGNING A WHOLE-HOUSE VENTILATION SYSTEM

1. Air seal the house as much as reasonably possible, especially the foundation, garage, or other spaces from which polluted air could be drawn.
2. Choose building materials, paints, furnishings, etc., to minimize emissions of VOCs and other pollutants.
3. Select a general ventilation design strategy appropriate for the climate. Consider the type of heating and cooling system to be installed, operating costs of the ventilation system, impact of the ventilation system on heating and cooling operating costs, installation costs, and the desire or need for filtered air (an important consideration for people with asthma, allergies, and other environmental sensitivities). Ensure that depressurization will not lead to moisture damage in wall cavities in humid climates or introduction of pollutants from outside the house, and that pressurization will not lead to moisture problems in cold climates.
4. Determine the house's ventilation requirements by consulting ASHRAE and local codes. A continuous ventilation rate of 50 to 100 cfm is typical.
5. Design the whole-house ventilation system and select appropriate equipment and controls to meet the determined ventilation requirement. In developing the design, keep operating costs (especially fan costs) as low as possible. Keep in mind the contribution of natural ventilation to a house's ventilation requirement. Avoid providing excess ventilation because it can increase heating and cooling costs without significantly improving air quality.
6. Incorporate spot ventilation (i.e., exhausts in kitchens, bathrooms, and other rooms where pollutants are produced) and/or separate spot ventilation systems in the design, following ASHRAE recommendations and local building codes to control moisture and pollution generation at their source.
7. Include both sensible and latent loads induced by the ventilation system in calculations for sizing heating and cooling equipment.
8. After installation, balance and test the system. Make sure ventilation ducts are airtight, design air flows are achieved, control systems work as intended, and controls are clearly and permanently labeled with operating instructions. Provide a homeowner's manual that covers operation and maintenance details, especially for heat-recovery ventilation systems and systems with filters.
9. Consider hiring a specialist to select and design the whole-house ventilation system. Ideally, one engineer should design both the ventilation system and the heating and cooling system, especially if the ventilation system is to be integrated with the heating and cooling system.

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