Choosing a Whole-House Ventilation Strategy

An update on current standards and how to meet them

BY ALLISON BAILES

As we make homes more and more airtight, ventilation becomes increasingly important. We need to keep replenishing the oxygen that keeps us alive and removing the carbon dioxide that makes us drowsy. We also need to flush out the odors and other disagreeables in the air to keep us healthy and happy. Standards provide some guidance on how to do that. They also help protect you from lawsuits.

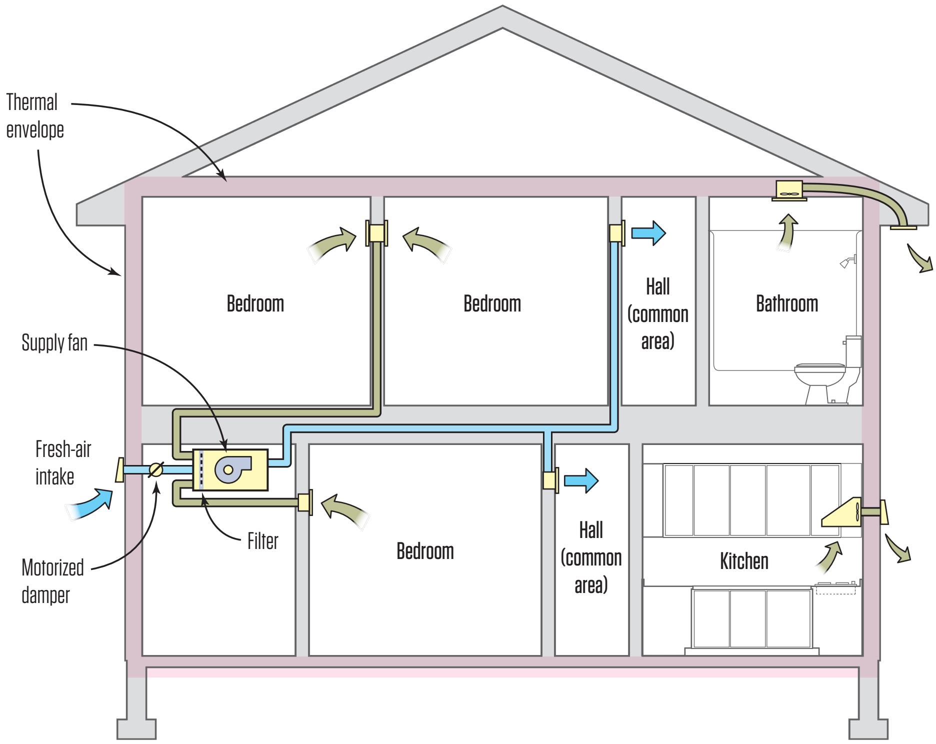
Photos: Ted Cushman

STANDARDS, CODES, & PROGRAMS

Let's start by sorting out the morass of information on ventilation standards so it makes some sense. It all starts with knowledge, and Donald Rumsfeld gave us a great way to think of it when he talked about the known knowns, the known unknowns, and the unknown unknowns.

We certainly know a lot more about indoor air quality and ventilation than we did three centuries ago when John Mayow, an English chemist, physician, and physiologist, conducted early research into respiration and the nature of air. (See "Why We Need Ventilation Standards. A Short History," on page 65.) Back then it was mostly unknown unknowns—they didn't know much, and they didn't even know enough to know how much they didn't know. Today, there are far more known knowns, and far more known unknowns, too. I'd

Stand-Alone Supply



A standalone supply ventilation system uses its own fan to bring outdoor air into the house. To do it without comfort complaints, you'll need to temper the outdoor air before introducing it into the house, which you can do by mixing it with indoor air.

In the minimal configuration, you'll need a box with a fan in it and three ducts. One duct will bring in the outdoor air. A second (and, in the case shown at left, a third) duct will pull indoor air to the box to mix with the outdoor air. A 2:1 ratio of indoor air to outdoor air is a good mix, so if you need to deliver 100 cfm of outdoor air in the living space, you'll need a fan that moves 300 cfm.

like to say that the unknown unknowns are fewer, but that might be a bit delusional.

So our knowledge base grows, and we use it to provide guidance for what we do. That's where standards come in. Standards are focused bits of guidance for specific, scope-limited areas, such as how to design a duct system, test an automatic ice maker, or ventilate a low-rise residential building for acceptable indoor air quality. The main standard in the U.S. that covers that last topic is ASHRAE Standard 62.2. (Standard 62.1 covers ventilation in everything that's not low-rise residential, although there's a scope change happening now. High-rise residential buildings are moving to 62.2.)

A standard is just a set of recommendations, though, and has no real power on its own. It becomes useful only to the extent that it gets adopted for use in codes and programs. ASHRAE has a lot of standards, some widely used, others not so much.

Codes come in two flavors: Model codes are like standards. They're a compendium of guidelines without any real power until they get adopted. The International Code Council (ICC) publishes model codes, such as the International Residential Code (IRC) and the International Energy Conservation Code (IECC). State and local codes are based on model codes. For example, Georgia, the state I'm from, has an energy code based on the 2009 IECC, but we also have supplements and amendments that go along with it.

Programs are generally voluntary and also refer to standards as well as codes. The Energy Star new-homes program has a requirement that insulation levels in qualifying homes meet or exceed the 2009 IECC requirements. (If your state is already on a stricter code, this doesn't allow you to do less.) The program also requires that the ventilation systems in the home meet the requirements of ASHRAE 62.2-2010. If a home you're building is getting certified in that program, you're subject to both of those requirements whether or not they're part of your local code.

WHAT'S THE RIGHT NUMBER?

The science behind how much we should ventilate goes back at least to 1836, when Thomas Tredgold calculated that each person in a building needs 4 cubic feet per minute (cfm) of fresh air just to stay alive. Since then, the recommended ventilation rates have gone as high as 60 cfm per person.

The 2013 version of ASHRAE 62.2 has a whole host of provisions, but let's take a simplified look at the ventilation rates in the standard. It requires 7.5 cfm per person plus 3 cfm per 100 square feet of conditioned floor area. That first part is not based on the actual number of people living in the home. You may not know that num-

System Coefficient Based on System Type

System Type	Distributed	Not Distributed
Balanced	1	1.25
Not Balanced	1.25	1.5

Note: Where there is whole-building air mixing of at least 70% recirculation turnover each hour, the system coefficient may be reduced by 0.25.

The BSC-01 base ventilation rates are the same as the 2010 version of ASHRAE Standard 62.2, so that a 2,500-square-foot, 3-bedroom house would have a base rate of 55 cfm. With a balanced ventilation system that distributes the air throughout the house, that's how much Lstiburek says you need (1 x 55). If you also mix that air, you can cut that by 25%, so with a system that balances, distributes, and mixes, you'd need only 41 cfm (0.25 x 55, per table footnote). If the system had none of those qualities, this house would need 83 cfm (1.5 x 55).

ber for a new home anyway, so the number of people is defined as the number of bedrooms plus one. There's also a provision for reducing that number a bit if a blower door test is carried out on the house. At a measured infiltration rate of about 5 ACH50 or higher, the second part of the formula drops to about 1 cfm per 100 square feet, which is what the 2010 version of Standard 62.2 called for. (This is a rough estimate because the calculation for the infiltration credit isn't easy. There are spreadsheets that help you do that if you want the credit.)

Let's say you build a really tight house, though, and aren't going to be able to get any credit for infiltration. How much would you need to ventilate if the house has three bedrooms and 2,500 square feet? Three bedrooms would mean 4 people, so the first part of the calculation would be 4 x 7.5 = 30 cfm. Using the 2013 standard, the second part would be 3 x 25 = 75 cfm, yielding a total required ventilation rate of 105 cfm.

If you need to meet the 2010 standard, the first part would be the same (30 cfm), but the second part would be based on 1 cfm per 100 square feet: 1 x 25 = 25 cfm. The total required ventilation under this scenario would be 55 cfm.

Therein lies the rub. One of the main issues that's brought so much attention to ASHRAE 62.2 over the past year is that difference between the 2010 and 2013 versions of the standard. The reason ventilation rates went up so dramatically is that versions through 2010 said that you needed 3 cfm per 100 square feet, but automatically gave everyone an infiltration credit of 2 cfm per 100 square feet. There's some interesting history behind that, but all you really need to know is that the committee took away the default infiltration credit and, consequently, required ventilation rates have about doubled—unless you qualify for a reduction with your blower door results.

Enter Dr. Joseph Lstiburek, who was on the ASHRAE Standard 62.2 committee until a few years ago. His company, Building Science Corp., based in Westford, Mass., has designed and studied the ventilation systems for tens of thousands of houses over the past couple of decades, and he has a beef with the higher rates. Lstiburek's main complaints are:

- **Comfort.** In humid climates and in cold weather, the higher ventilation rates can lead to air that's too humid or too dry.
- **Energy.** More ventilation means more outdoor air that needs to be conditioned. Also, to solve the comfort problems in humid and cold climates, you have to use even more energy.
- **Science.** The higher rates aren't based on solid science showing that more ventilation is necessary. (I've covered this in some detail in the Energy Vanguard Blog at energyvanguard.com.)
- **System type.** Exhaust-only, supply-only, and balanced ventilation each have their pros and cons, but they don't ventilate a house equally.

So, Lstiburek introduced his own standard, which he calls BSC-01. It's not a standard in the same sense as the ASHRAE Standard because it hasn't gone through any kind of consensus process and isn't ANSI certified. BSC-01 is more like a set of guidelines or recommendations informed by Building Science Corp.'s vast experience with those tens of thousands of new homes it consulted on.

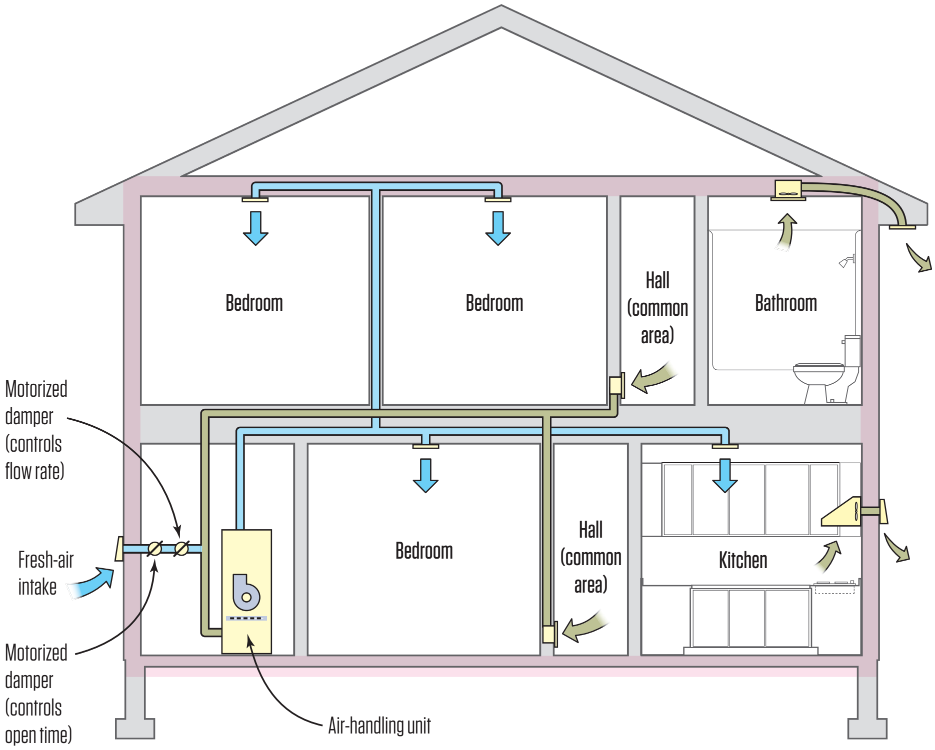
The BSC-01 base ventilation rates are the same as the 2010 version of ASHRAE Standard 62.2, so that 2,500-square-foot, three-bedroom house would have a base rate of 55 cfm. But—and this is the crucial part—that base rate is modified by how much the ventilation air is distributed throughout the house, balanced between exhaust and supply, and mixed with the other air in the house. The table (above, left) shows how it works.

HOW WILL IT ALL SHAKE OUT?

Lstiburek pushed hard on the issue over the past year. He didn't succeed in getting any programs or codes to adopt BSC-01, but he did put pressure on the ASHRAE 62.2 committee. At the ACI National Home Performance Conference & Trade Show in Detroit, in late April, he and several committee members held a panel discussion about the issue, and most in the room believed that Lstiburek had the more persuasive arguments.

Near the end of that discussion, Lstiburek announced that he'd like to be back on the 62.2 committee and has since been reinstated as a member. This is good news for home builders, weatherization crews, and energy auditors because they share many of the complaints on Lstiburek's list.

Central Fan Integrated Supply (CFIS)



The central fan integrated supply ventilation system is the most common supply-only system, especially in the humid Southeast.

In a house with a ducted, forced-air HVAC system, the CFIS system uses the air handler or furnace fan. An important feature of the system is a control like the AirCycler and a damper, which close the duct when you don't want ventilation air. The control can be configured to run the ventilation a certain amount of time (say 30 minutes each hour) so you get the right amount of ventilation without over-ventilating.

DECIDE ON THE VENTILATION RATE

If you're building a house, you have to figure out what ventilation rate you need for the mechanical ventilation system you install. Of course, I'm assuming that you're reading this article because you are installing a ventilation system. If you're building homes with the level of airtightness that many codes require these days—and especially if you're insulating with spray foam—we don't need to argue about the necessity of mechanical ventilation. Just do it.

When picking a ventilation rate, you first need to find out if your building code or efficiency/green building program requires ventilation. If so, you have to install a system that meets their requirements. Energy Star for new homes (and gut-rehabs) and LEED for Homes, for example, both currently require mechanical ventilation that meets ASHRAE 62.2-2010.

If your local code doesn't require ventilation and the home isn't going for certification in a program that requires it, you can do what you want. Building an airtight house and installing mechanical ventilation is the smart way to go, and when it comes time to decide how much ventilation you need to install, Building Science Corp.'s BSC-01 is what I'd recommend. As described above, it starts with the ASHRAE 62.2-2010 rate and then modifies that number up or down according to how well the ventilation air is balanced, distributed, and mixed. Now, let's look at the types of systems.

EXHAUST-ONLY

Using exhaust fans is great for local ventilation of bathrooms, kitchens, garages, and sub-slab areas (for radon control), but it's not a great strategy for whole-house ventilation. It does, however, have some advantages:

- It's inexpensive.
- You're already installing those fans anyway.
- It can help prevent condensation inside walls in cold climates.

Now let's look at the disadvantages:

- You don't know where the makeup air is coming from.
- Contaminants from an attached garage or moldy crawlspace can be pulled into the house.
- Ventilation air probably won't be mixed or distributed well.
- The only filtration that happens is through the building enclosure.

The goal behind whole-house mechanical ventilation is to provide some measure of good indoor air quality. If you take an objective look at those advantages and disadvantages above, it's hard to conclude that you'll get that result with an exhaust-only system. But hey, if meeting code or program requirements at the minimum cost is your objective and you don't care about indoor air quality, this could be your ventilation strategy.

If you decide to go this route, please don't do it in a humid climate where the house will be air conditioned for a significant amount of time. Exhaust fans work by pulling air from the house and sending it outdoors. This puts the house under a negative pressure, and the makeup air comes into the house through random leaks. If enough humid air gets pulled into a wall cavity, you could get some nasty microbial growth in there when it finds the cool backside of the drywall.

Also, if you're building apartments or condos, you're likely to run into difficulty with makeup air. Compartmentalization is leading to much greater airtightness. You can't pull air from the corridors or from neighboring units; it must come directly from outdoors. So, you put enough holes in the exterior wall to allow the ventilation system to move enough air. And then the occupants seal up those holes to stop the drafts as soon as it gets cold.

Sucking on the house isn't such a great idea.

SUPPLY-ONLY

The next option is blowing. You use a fan in the house to collect outdoor air from a known location and distribute it indoors. This overcomes several objections to the exhaust-only system: you know where the air is coming from; you can filter the air on its way in; and you're not causing the house to suck in contaminants from the garage, crawlspace, basement, or attic. It will cost you more than exhaust-only ventilation, though, because you have to spend money on additional controls, ductwork, or fans.

Next, you must figure out what type of supply-only ventilation system you want to install. You have three options: standalone supply, central-fan integrated supply (CFIS), or a ventilating dehumidifier.

The *standalone supply* ventilation system uses its own fan to bring outdoor air into the house. To do it without comfort complaints, you'll need to temper the outdoor air before introducing it into the house, which you can do by mixing it with indoor air.

The illustration on page 62 shows one version of this. The more you pull indoor air from different locations and deliver the mixture to more locations throughout the house, the less likely it is that occupants will feel the temperature difference of the incoming air. That's a good strategy because the less the occupants notice the system, the more likely it is they won't turn it off.

The *central fan integrated supply* ventilation system is the most common supply-only system, especially here in the humid Southeast (see illustration, opposite page). In a house with a ducted, forced-air HVAC system, the CFIS system uses the air handler or furnace fan.

In the bare-bones CFIS configuration, all you need to do is install a duct from the outdoors to the return side of the air handler. Then whenever the heating or cooling system comes on, the air handler will pull in some outdoor air to mix with the return air. One drawback of this configuration is the hole in your building enclosure that sits there 24/7/365.

Although adding only a duct was all some builders did in the old days, now we know it's critical to use controls such as the AirCycler and a damper to close the duct when you don't want ventilation air. The control can be configured to run the ventilation a certain amount of time, say 30 minutes of each hour, so you get the right amount of ventilation without over-ventilating.

Ideally, a CFIS system will deliver most of the ventilation air when the HVAC system is already running. In winter and summer, that's usually not a problem, but in the swing seasons or on mild summer and winter days, the house will need ventilation air at times when the system isn't normally running. In those cases, the controller will turn on the air handler fan to deliver ventilation air when the house isn't calling for heating or cooling.

This system can work well, but what we've found is that many CFIS systems have been thrown in with the assumption that if there's a duct, there will be air. Just as most bath fans don't move

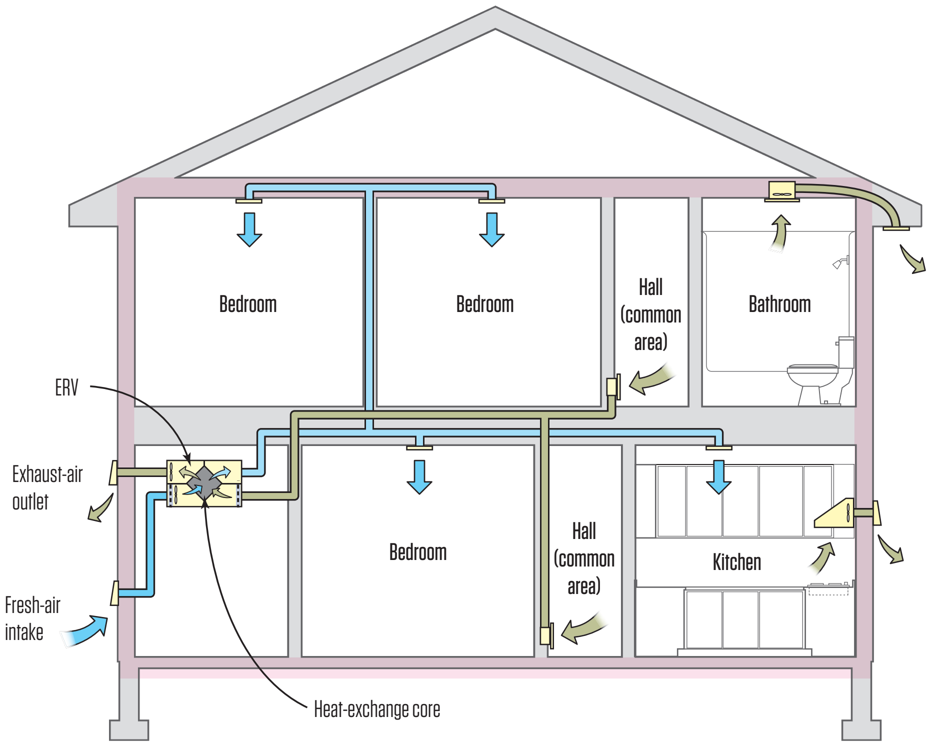
WHY WE NEED VENTILATION STANDARDS. A SHORT HISTORY.

In the 17th century a fellow named John Mayow put small animals in jars with candles and studied how long it took them to die of asphyxiation. By doing so, he proved the existence of a special component of air that keeps us alive. What he termed "nitro-aerial spirit" we know now as oxygen. Combustion and breathing both use it up in an enclosed container, so we need some way of replenishing this "spirit." Knowing what's necessary to keep us alive is a start, but there's far more to ventilation and indoor air quality than that.

In the 20th century, ventilation research had advanced to studying humans in confined boxes. Rather than asphyxiating the subjects, however, this time the researchers ran controlled amounts of ventilation air through the boxes. The objective was to find the minimum ventilation rate at which trained smelling judges would deem the odor of the exiting air acceptable. It was fascinating work really, and they looked at a number of variables: occupant age, social class, and bathing frequency, among others.

But again, there's more to good indoor air quality than preventing asphyxiation in an unsmelly house. The next step is learning about the other hazards in the air we breathe—such as carbon monoxide, volatile organic compounds, formaldehyde, and particulate matter. That's where we are now. There's extensive research going on into how much of this stuff is in the air in our homes and what we can do about it. Not all of the hazards are best solved with ventilation, however. Source control is often the best solution.

Balanced Ventilation With Recovery



A recovery ventilator pulls in fresh outdoor air while exhausting stale air from indoors. The air streams pass through opposite sides of an exchanger core. Ideally, the two air streams do not mix at all but do exchange heat (both ERV and HRV) and moisture (ERV only).

In winter, then, the outgoing warm air gives up some of its heat to the incoming cold air. The warm air also has more moisture and in an ERV, some of that moisture will migrate to the cold, dry air coming into the house. So ERVs and HRVs are balanced ventilation with partial recovery of heat and moisture.

enough air, however, CFIS systems that were never commissioned often don't deliver on the promise of better indoor air quality. It turns out that placement of the outdoor air duct on the return plenum can have a significant effect on the amount of air delivered. Always commission! (This means measure the air flow through the duct and adjust as necessary.)

The *ventilating dehumidifier* is a great system for humid climates, especially in low-load homes. It works just like the standalone supply with one important difference: There's a box with two ducts bringing air in from outdoors and indoors. Then there's a duct sending the tempered ventilation air into the house. The difference is that what's in the box isn't just a fan; it's a fan with direct expansion dehumidifier.

Since ASHRAE Standard 62.2 got rid of the default infiltration credit, new homes trying to meet the 2013 version will probably require more ventilation air. Small, energy-efficient houses have low cooling loads, which means the air conditioner won't run as much. As a result of these two things, many of these low-load homes in humid climates will need some kind of supplemental dehumidification. The ventilating dehumidifier is a great solution, and it's probably even better in mixed-humid than in hot-humid climates because of their already lower cooling needs.

BALANCED

Better than either sucking or blowing ventilation strategies is the sucking *and* blowing strategy. If you do both at the same time with balanced air flow into and out of the house, your ventilation system doesn't affect the house pressure. That's a good thing.

Everyone always thinks balanced ventilation is synonymous with using an energy recovery ventilator (ERV) or heat recovery ventilator (HRV). It's certainly true that ERVs and HRVs are ways of doing balanced ventilation (or can be when they're commissioned properly). But those would both more accurately be described as balanced ventilation with recovery (see illustration, above).

Another type of balanced ventilation system would be a simple combination of exhaust and supply fans, set up to come on and go off together and move the same amount of air. The Lunos fans exploit this concept and even add heat recovery. The fans don't have to be in the same part of the house, and in fact it's better for mixing if they aren't. Then the positive pressure where the supply fans are can push air into the lower pressure areas near the exhaust fans.

So those are your options for balanced ventilation. You can blow equal amounts of air into and out of the house while recovering heat and moisture, or you can just blow equal amounts of air into and out of the house. If you're looking for the Cadillac of ventila-

An HRV is just an insulated box with two fans, four ducts, and a recovery core (the diamond-shaped part in the middle). As the two airstreams go through the core, they exchange heat. They do not add heat to a house, but they will slow-down the loss of heat associated with providing fresh-air ventilation.

tion systems, look no further than an ERV or HRV. There are some very sophisticated models out there with really high efficiency. The two most popular with the Passive House community are those made by Zehnder and Ultimate Air, but the new Air Pohoda has a clever way of recovering heat and moisture. It even lets you dial in the amount of latent recovery you want and can eliminate the need for defrosting the recovery core. If you're in a fairly mild climate without too much latent load, balanced without recovery could be just what you need.

DISTRIBUTING THE VENTILATION AIR

Once you've chosen a ventilation rate and a strategy—exhaust, supply, or balanced—you're almost there. You still have another important decision to make, though: How will you move the ventilation air around the house?

On this topic, I agree with Henry Gifford, who said, "Give me an H. Give me a V. Give me an AC. Don't do HVAC to me." What he meant by that was that he likes to keep those three functions separate. If you're dealing with forced-air systems in homes, separating heating and air conditioning isn't important or practical. But using a separate duct system for ventilation can help.

The argument in favor of using the heating and air conditioning ducts for ventilation is that those ducts are already there, so you might as well use them. It also prevents getting walls, ceilings, and floors cluttered with extra vents and allows you to use the air handler fan to bring in your ventilation air.

The arguments against using the heating and air conditioning ducts are:

- It can be difficult to get the right amount of air flow.
- You can balance an ERV or HRV connected to the return plenum or supply trunkline for when the air handler is running or when it's not running, but you can't balance it for both cases.
- Using the air handler fan to ventilate the house isn't the most efficient way to ventilate because it's usually the biggest fan in the house.

The heating and air conditioning ducts are designed (we hope!) to move a lot more air than the ventilation system, so trying to ventilate through them without the air handler running (as with an ERV/HRV, standalone supply system or a ventilating dehumidifier) may not result in ventilation air getting distributed well.

In the end, to get the best ventilation possible, it's best to use a duct system dedicated to the ventilation system. Obviously, that doesn't work for exhaust-only ventilation, but then why would you want to do that if you care about ventilation effectiveness. It also doesn't work for central-fan integrated supply because it only works when you use the air handler and heating and air conditioning ducts. But any ventilation system—either type of balanced system (with or without recovery), a standalone supply system, or a ventilating dehumidifier—will do better with its own duct system.

WHAT SHOULD YOU DO?

If you care about good indoor air quality and whole-house ventilation that works, the first thing to do is avoid exhaust-only systems. Supply-only systems are a step up, but they have a slight possibility of creating condensation problems in cold climates if the building does not have exterior insulation. This type of system could create a slight positive pressure inside the building, forcing warm, humid, indoor air into wall cavities. If that air finds cold sheathing, it can wet the materials and eventually grow mold or rot the wall. Balanced is best when it comes to ventilation, and balanced with recovery is the best of the best.

Beyond picking a system, though, there are three critical steps to getting a ventilation system that really works: Design properly. Install well. Commission completely. (For more on commissioning a tight house, see my blog post "7 Steps to Commissioning a New Home & HVAC System," at energyvanguard.com.)

Get those three things right, and you'll have a system that should do its job, provide good indoor air quality, and—perhaps most importantly—not be disabled by the home's occupants who don't like the noise or comfort problems that many ventilation systems have.

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