

High-Tech and Heating Cooling

BY PATRICK McCOMBE

A new generation of **variable-capacity heat pumps and air conditioners** promise quieter operation, increased efficiency, and greater comfort



Imagine your car's engine only had one speed. To go somewhere, you'd start the engine, and then it would run at its maximum rpm until you wanted to slow down or stop. Then you'd turn off the engine to coast or brake. I think you'd agree this kind of car would be difficult to control and would make for a pretty rough ride. What's confusing to me is that most central heating and cooling systems in this country work almost exactly that way. When your thermostat calls for heating or cooling, your HVAC equipment goes full tilt until the set point is reached and then it shuts off, waiting for the next call from the thermostat.

On top of this, heating and cooling equipment is sized so it can keep the house warm or cool in the coldest or hottest periods, which is

often only a few days or weeks a year. The result is a noisy HVAC system that in most conditions only runs for a few minutes at a time, making it difficult to maintain an even temperature and control humidity. Adding insult to injury, American HVAC systems are routinely two or three times bigger than load calculations call for, making the inherent comfort problems of on/off operation even worse.

But there is a solution. It's described as *variable capacity*, which means the HVAC appliance's output is matched to the heating or cooling load automatically, contrasting with the on/off operation of single-stage and to a lesser extent two-stage equipment (which has two operating speeds). With variable-capacity heat pumps or air conditioners, the equipment's compressor runs at a slower speed for a



New SEER standards in 2023

P.E. Cameron Prince, a product manager for Allied Air Enterprises, told me that

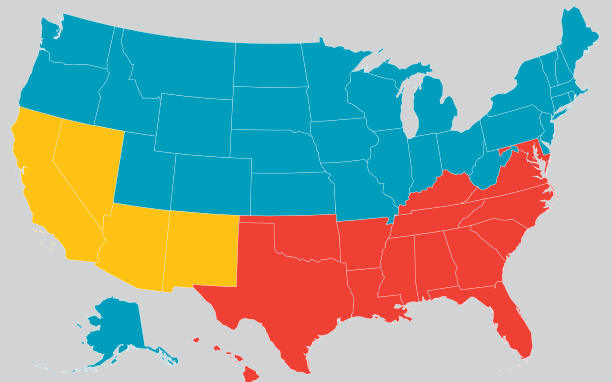


we can expect to see more variable-capacity equipment on the market because of new efficiency standards. The first standards of the National Appliance Energy Conservation Act, which specify the minimum efficiency requirements for central air-conditioning and heat-pump equipment, take effect in 2023.

The new rules require a minimum seasonal energy-efficiency ratio (SEER) of 14 for residential systems in the northern part of the United States and up to 15 for the southern part of the U.S. In addition, the new standards require an increase in the heating seasonal performance factor (HSPF)—8.8 HSPF compared with the current standard 8.2 HSPF.

Variable-capacity equipment has higher SEER ratings and will likely get more common with the new rules, but it's just one of several engineering options equipment manufacturers have at their disposal to increase efficiency.

Region	Central A/C ≤ 3.5 tons	Central A/C > 4 tons	Heat Pumps
North	14 SEER	14 SEER	15 SEER
South	15 SEER	14.5 SEER	—
Southwest	15 SEER 12.2 EER	14.5 SEER 11.7 EER	—
Nationwide	—	—	8.8 HSPF



HVAC terms to know

Understanding heating, cooling, and ventilation strategies involves industry-specific lingo. Specs among variable-capacity heat pumps and air conditioners vary widely. Understanding their differences starts with understanding the terms that describe their performance.

SEER, or seasonal energy-efficiency ratio, describes the cooling efficiency of central air conditioners and heat pumps in cooling mode. Higher numbers mean greater efficiency.

EER, or energy-efficiency ratio, compares the Btu per hour of cooling to the amount of electricity used to produce it. Higher numbers mean greater efficiency.

HSPF, or heating seasonal performance factor, describes a heat pump's overall heating efficiency taking into account defrost cycles and the need for supplemental heat. Higher numbers mean greater efficiency.

Turn-down is defined inconsistently, but refers to the minimum capacity of a variable-capacity heating or cooling appliance. Variable-capacity central equipment turn-down is generally between 30% and 70% of the equipment's maximum output.

Sensible cooling is the load associated with making the building a comfortable temperature. Solar gain, heat generated from appliances, and air leakage are only a few of the factors affecting it.

Latent cooling is the load associated with dehumidification and the energy consumed in removing it from the air and water-absorbing materials in the building and home furnishings.

Manual J is the Air Conditioning Contractors of America (ACCA) heat gain and loss calculation to determine the loads in a building. A building's size, airtightness, insulation, and glazing are a few of the considerations.

Manual D is the ACCA method for calculating register number and sizes, duct layout and design, and airflow per room.

Short-cycling is when heating and cooling equipment runs for short periods of time, which hampers efficiency, reduces comfort, and reduces equipment life.

Commissioning is the setup of a new system, including adjusting blower speed, air delivery, and any other aspects of operation for maximum efficiency and comfort.

longer time, which provides quieter operation, better humidity control, and greater efficiency.

Variable-capacity modulating boilers are well-known by plumbers and HVAC techs in heating climates, and ducted and ductless mini-splits (see "Making Sense of Minisplits," *FHB* #296), which are also variable-capacity systems, have become ubiquitous in both heating and cooling climates. But variable-capacity central equipment, which has been around for a decade now, is lesser known.

If you want one of these systems, you'll have to do your homework, because HVAC contractors and manufacturers sell a lot more entry- and mid-level heating and cooling equipment, which seems to be their focus. According to a 2021 J.D. Power report on HVAC equipment, variable-capacity central equipment represents only about 5% of central HVAC equipment sales, so if you want better HVAC gear for your or your client's house, this article is a good place to start.

The advantages of variable capacity

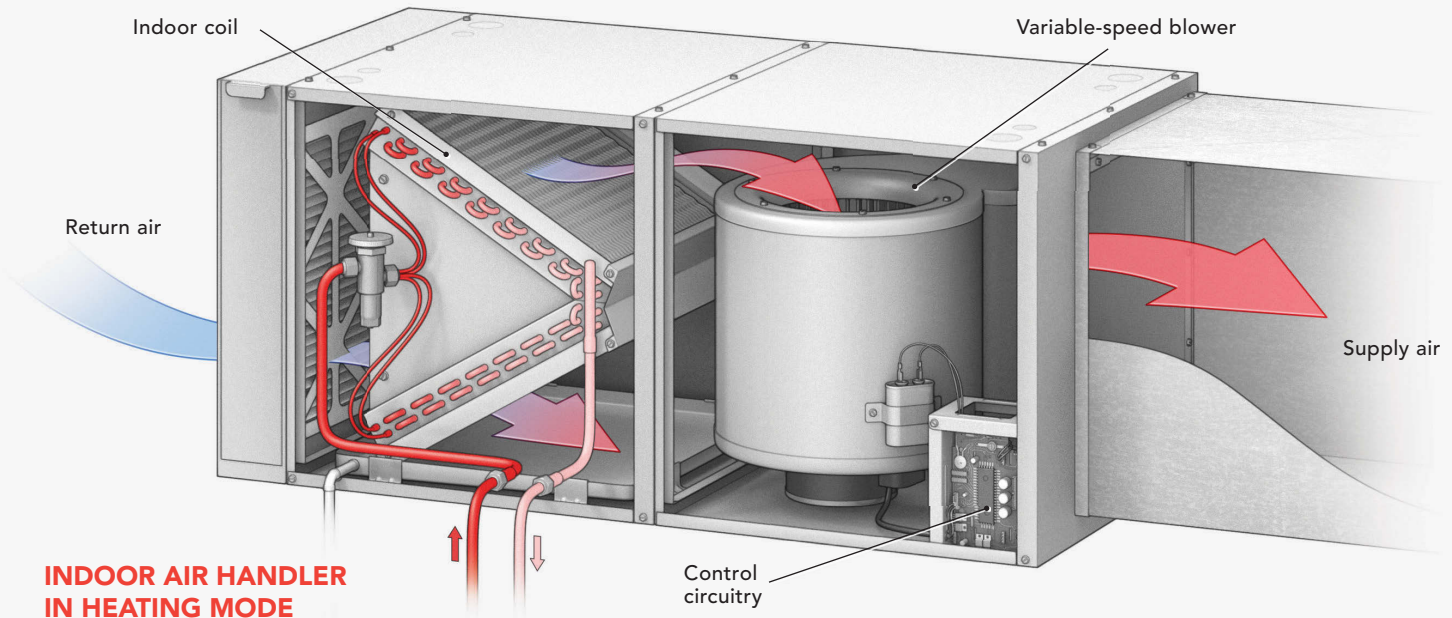
As I mentioned earlier, common HVAC equipment is sized so it can handle the loads on the hottest or coldest days of the year. (When you add in safety factor and conservative load calculations, equipment is often sized at 20% to 30% over the peak load.) The rest of the season, it runs for a few minutes and then shuts off. Variable-capacity equipment has a compressor and control circuitry that can slow down the refrigeration cycle, so it runs for a longer time. (For this reason, these systems are also described as variable-speed.) The big difference among variable-capacity equipment is the "turn-down ratio," which is how much the system can throttle back. The most sophisticated variable-capacity central equipment can turn down to about 20% of its maximum capacity to better match the heating or cooling loads. Less-desirable equipment may turn down to as little as 70%. For comparison, some minisplits operate at less than 9% of their maximum capacity in low-load conditions. Turn-down means variable-capacity systems can offer the following advantages:

Better humidity control—If you've ever been in a building that feels cold and clammy on summer days, you're experiencing overcooling without effective humidity control. This is a result of the conventional equipment running a short time and then shutting off, a condition known as short-cycling. Variable-capacity systems allow the equipment to run longer for better dehumidification.

Quieter operation—Inside, the system is running at a lower speed, so there's no woosh of air rushing through the registers. The outdoor unit is quieter because it's running slower too. Eric DeLuca, director of green building for Massey Berg LLC, a residential builder and remodeler in Minneapolis, has been enjoying his Bryant variable-capacity heat pump for more than a year now. He put it this way: "It's so quiet, I often can't tell it's running until I put my hand above the outdoor unit and feel the hot air blowing out. When my neighbor's single-speed air conditioner roars on, I can hear it from inside my house."

Better filtration—With a conventional system, the air is only filtered when the system is running, which in shoulder seasons may be a few minutes an hour or less. A variable-capacity system runs for much longer periods, so it's filtering a greater percentage of the time.

Lasts longer—The longer lifespan of variable-speed equipment was explained to me by P.E. Mark Jussaume, whose day job is running the Boston office of SmithGroup, a 1200-employee architectural and engineering firm that specializes in the construction and renovation of buildings and outdoor spaces for government, medicine, and edu-

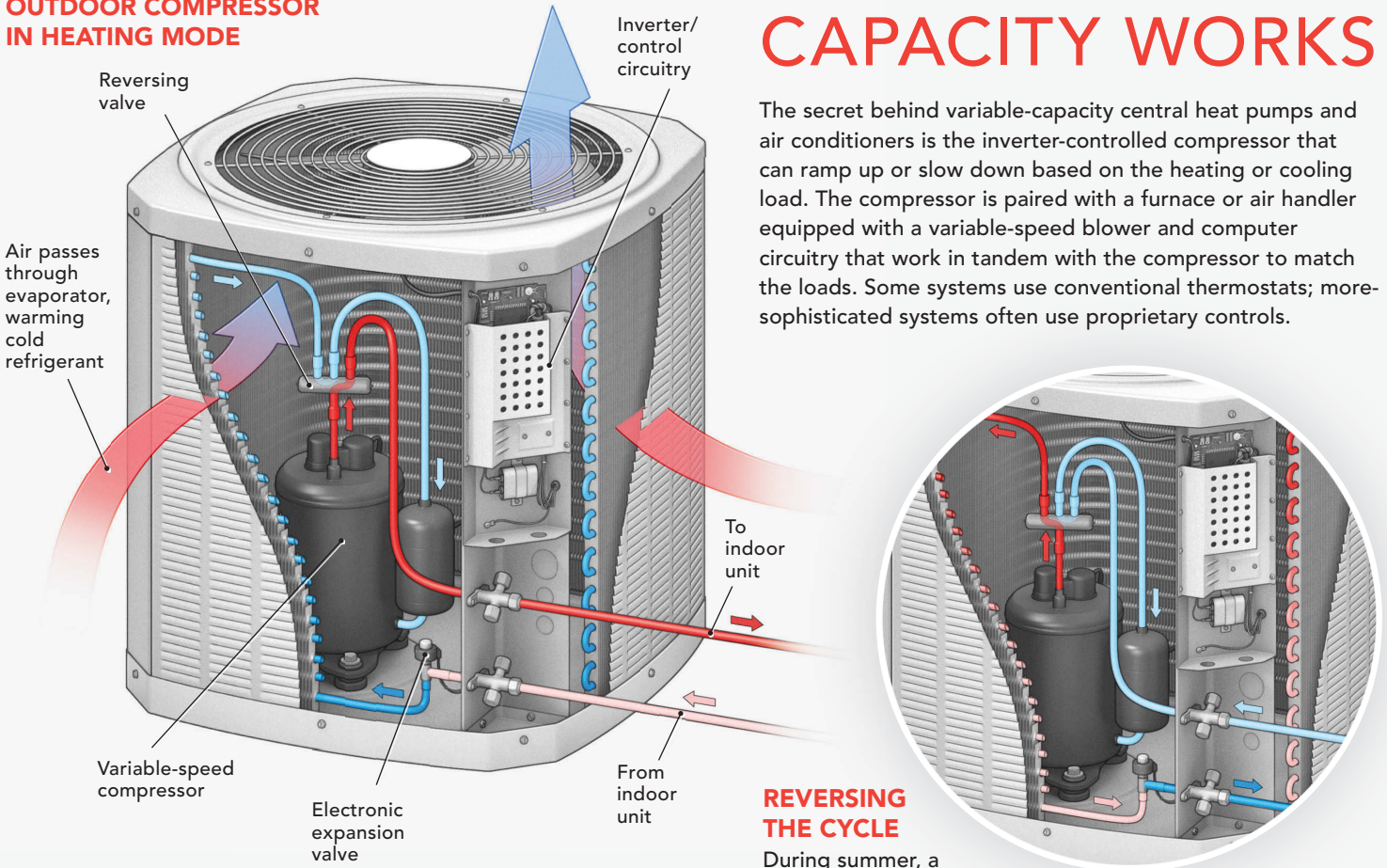


**INDOOR AIR HANDLER
IN HEATING MODE**

HOW VARIABLE CAPACITY WORKS

The secret behind variable-capacity central heat pumps and air conditioners is the inverter-controlled compressor that can ramp up or slow down based on the heating or cooling load. The compressor is paired with a furnace or air handler equipped with a variable-speed blower and computer circuitry that work in tandem with the compressor to match the loads. Some systems use conventional thermostats; more sophisticated systems often use proprietary controls.

**OUTDOOR COMPRESSOR
IN HEATING MODE**



REVERSING THE CYCLE

During summer, a variable-capacity heat pump reverses the refrigeration cycle and works like a central air conditioner. Warm indoor air is blown over the coil and the compressed refrigerant absorbs heat as it changes from a liquid to a gas. The warmed refrigerant is returned to the outdoor unit where it is cooled before it's compressed again.

REFRIGERANT TEMPERATURE/STATE



WHAT'S ON THE MARKET?

Variable-capacity heat pumps and air-conditioners are available from all major heating and cooling equipment manufacturers. Typically only their higher-end equipment is variable-capacity. In addition to providing greater comfort and efficiency, these appliances are quieter and have more features than mid-tier and entry-level equipment. Heat pumps, which heat and cool, are used in the middle and southern parts of the U.S., where subzero temperatures are rare. In northern climates, a variable-capacity air conditioner, which only cools, is usually paired with a gas-or propane-fueled forced-air furnace with a variable-speed blower, because central heat pumps stop making adequate heat at about 5°F.

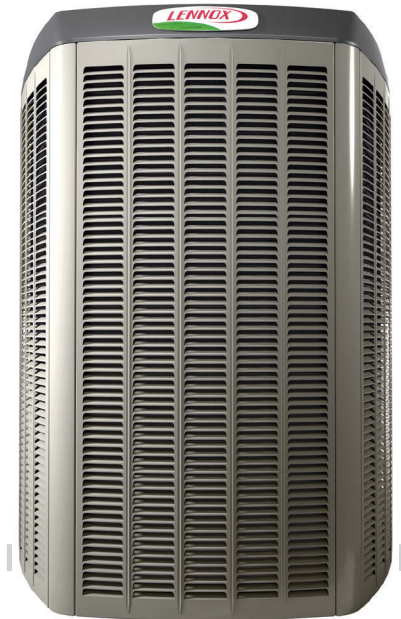


CARRIER INFINITY 24 HEAT PUMP

Cooling SEER Up to 24 Cooling EER Up to 16
Heating HSPF Up to 13 Noise level 51 db

LENNOX XC25 AIR CONDITIONER

Cooling SEER Up to 26
Cooling EER Up to 15.5
Noise level 59 db



cation. In 2019 he built his own high-performance house and wanted a similarly high-performance HVAC system.

Mark told me that the variable-speed compressor and ECM (electronically commutated) blower on his Lennox gas furnace and XC25 air conditioner not only make his house quiet and comfortable, they should last longer than single-speed compressors and blowers. “Every time you start an electric motor you’re wearing it out, so when you’re running the system for long periods without constant starts and stops, it’s easier on the components and they last longer,” he said.

Reduced energy consumption—In a variable-speed system, fans and compressors run at reduced capacity for most of the year. A 20% reduction in speed results in a 50% reduction in energy consumption. According to Mark, his electric bill has been reduced by 30% due to his system’s ability to match the capacity to the load.

Hi-tech HVAC for the rest of us

There’s a perception that variable-capacity equipment is the exclusive domain of high-end HVAC equipment, but that’s changing; you can often find variable-speed mid-tier equipment too. Cameron Prince, an engineer and product manager for Allied Air Enterprises, makers of Concord, Ducane, and Allied HVAC equipment, told me that they recently released their Lynx line of variable-capacity 18-SEER heat pumps and air conditioners. This equipment, which has all the advantages of more-expensive central equipment, uses mainstream 24v thermostats, which many people prefer to the sophisticated touchpads that advanced systems are often paired with.

Some homeowners want to control and monitor their system from their smartphone or tablet. If you want this capability, make sure the system you’re considering is compatible. I asked Eric about the control

app Bryant offers with their system. He said the original version was clunky and hard to figure out, but the recent version is more functional.

Even the more affordable offerings in the variable-capacity segment are built better than the “builder boxes,” as entry-level equipment is sometimes derisively described. Outdoor units generally have additional sound insulation and the cabinets are more rust-resistant. They have more sophisticated self-diagnostics for troubleshooting, and higher-end units can remind you when it’s time for filter changes and annual service. And Mark told me that in general, variable-speed equipment tends to be made of higher-quality components.

One thing to keep in mind is that while you can often replace a failed outdoor unit and leave the indoor coil in place with a conventional system, variable-capacity compressors need a compatible air handler and sometimes a proprietary thermostat. As Eric put it, “You may also need the manufacturer’s own thermostat, not a Nest.”

Help for contractors

For a couple decades now, I’ve been critical of the HVAC industry. I feel most techs and business owners are poorly trained; despite decades of appeals by engineers and building scientists to do a better job right-sizing HVAC equipment and ductwork, they still rely on rule-of-thumb sizing and often do a bad job designing and installing ducts. A variable-capacity heat pump or air-conditioning unit won’t help deeply flawed ductwork, but it can help with oversizing. Recent Facebook comments made by an anonymous Florida HVAC contractor gave me a deeper understanding of the difficulties HVAC installers face when sizing equipment.

In response to other contractors with attitudes similar to mine, he said that when he gets aggressive with Manual J calculations, equip-



ALLIED AIR PRODUCTS LYNX HEAT PUMP

Cooling SEER Up to 18 Cooling EER Up to 11
Heating HSPF Up to 10 Noise level 60 db



RHEEM RP 20 HEAT PUMP

Cooling SEER Up to 20 Cooling EER Up to 14
Heating HSPF Up to 11.5 Noise level 59 db



TRANE XV20i AIR CONDITIONER

Cooling SEER Up to 21 Cooling EER Up to 14
Noise level 43 db

ment can end up undersized because of the building envelope, which is outside his control. This can happen when the framer leaves major air leaks that aren't otherwise controlled or the insulation contractor misses part of the thermal boundary. On an especially hot day when the house won't get below 80°F, the client isn't going to call the general contractor or the insulation contractor, they're going to call the HVAC contractor. If they can't track down the offending envelope failure, they could be on the hook for bigger equipment to make the clients comfortable.

Variable-capacity central equipment gives contractors a cushion of extra capacity without the energy and comfort penalty of oversized conventional equipment. Recognizing this fact, manufacturers typically stick to full-ton increments of cooling for variable-capacity heat pumps and air conditioners, compared to the half-ton increments offered with single- and two-stage equipment. The variable capacity also allows contractors to match different heating and cooling loads.

In cooling climates, where the heating load may be half the cooling load, the system can match the actual loads without short-cycling. In heating climates that need less summertime cooling, variable-capacity systems can better match those lower loads too.

Some techs are resistant

Despite the advantages of variable-capacity equipment, you may have to interview a slew of prospective HVAC contractors to find one willing to step outside their comfort zone and install one of these systems. Mark and Eric told me that they went through a list of HVAC contractors before they found someone interested in installing the equipment they wanted. HVAC contractors are often hesitant to offer it. Cameron had the best explanation as to why that

I've heard yet: "Since the beginning of air conditioning in the '50s, the equipment has always been single stage, so it's what contractors are familiar with, and in fairness to them it's simple, reliable, and inexpensive."

There's also hesitation by some homeowners who may worry about the added complexity of these systems. In a switch from fossil fuels to a renewable-energy grid, heat pumps are part of the solution, and technological improvements make them practical for all but the coldest parts of the United States—but old perceptions persist. Eric told me that the contractor who installed his system was forced to deactivate the heating function on another customer's variable-capacity central heat pump, because they "didn't want to heat their house with an air conditioner."

One of the things it's smart to discuss with a potential HVAC dealer is the availability of spare parts for a variable-capacity system. The components inside one and two-stage central equipment in the entry and middle levels is pretty universal and spare parts are easy to find. When you move to variable-capacity systems, the components are more proprietary and parts can take longer to get, which can be a real problem during a heat wave or cold snap.

Phillip Oglesby, who's in charge of training and customer education at Rheem, says that once HVAC techs have one or two variable-capacity installations under their belt, he expects they'll find the technology way less scary. He says his company has been working hard to train its dealers on the advantages of variable-capacity systems, offering in-person and online training. I think as more contractors get comfortable with the equipment, we'll see it more and more. □

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