

HIGH-PERFORMANCE HVAC FOR

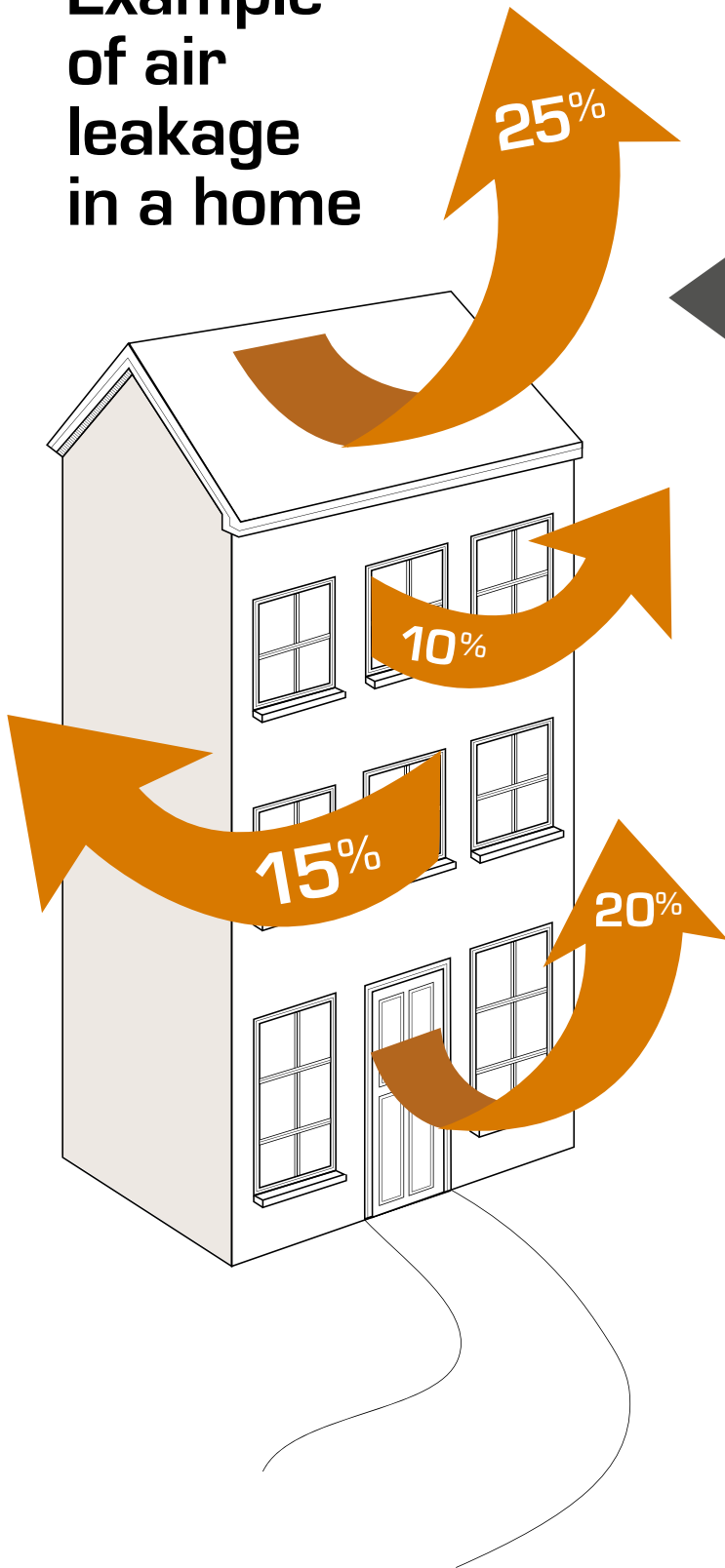
# Whole-Home System Design

High-performance home builders have adopted a design approach in which the whole home is considered a single system consisting of interdependent parts.

**Framing, walls, insulation, windows, doors, lighting, wiring, controls, power sources, HVAC**

and other components of the built environment are evaluated for performance in relation to each other and other variables including local climate and expected occupant behavior. With careful attention to how each component and variable condition relates to others, builders produce homes defined by **comfort, health, efficiency and durability**. Builders use a whole-home approach to earn recognition by constructing homes meeting or exceeding requirements such as [EarthAdvantage](#), [EarthCraft](#), [ENERGY STAR®](#) or Passive House certifications.

## Example of air leakage in a home



## High-Performance Home Choices

The foundation of energy efficiency in a high-performance home is a design where interdependent parts result in lower loads than in code-level homes. Lower loads mean less energy needed for operation of mechanical equipment to heat and cool. After ensuring the home is positioned to benefit from solar exposure, builders consider the building envelope — inclusive of foundation, walls, windows, doors, ceiling and the roof — which must resist thermal transfer and **air leakage**.

For example, builders may select **light-colored shingles** to help reflect light and heat typically absorbed by darker traditional shingles and asphalt options. By reflecting light and heat, the roof reduces the cooling load and the amount of work performed by the air conditioner. The lighter shingles complement an even more significant design choice for reducing loads: an insulated roof that resists conductive heat flow. A material's heat flow resistance is measured with an R-value rating. A home that meets the Passive House standard has a roof with an R-value between R-50 and R-90.

To **improve air tightness**, builders apply smart sheathing, with advanced joint-sealing techniques such as tapes or sealants. Improved air tightness prevents unconditioned air from entering the house which improves air quality and lowers heating and cooling loads. ACH50 stands for "air changes per hour at 50 pascals" and quantifies the number of times the air volume of a home changes within an hour at 50 pascals of pressure. While code-level homes may be designed with a blower-door measurement for air leakage of 3 ACH50, homes built to meet or exceed Passive House requirements are allowed a maximum of 0.60 ACH50 per [The Passive House Institute](#).

To **reduce heat transfer**, builders use smart framing such as 24-inch spacing for studs rather than the standard 16-inch framing; this choice allows for more insulation between the studs and less total studs to transfer energy. Builders might also install outboard insulation outside of the wall to decrease thermal bridging. The rate of heat flow through a wall assembly is measured in U-value. When installing cladding, builders might use non-conductive clips to improve the U-value of wall assemblies.

All of these design and construction choices are essential to producing an **airtight, highly-insulated thermal envelope**, which lowers loads and improves energy efficiency but are also foundational for the other characteristics of high-performance homes. For example, an insulated, air-tight external wall is less subject to condensation. Condensation occurs when the internal surface of an external wall reaches or falls below the dew point temperature. The accumulation of condensation invites the risk of mold and the degradation of walls and equipment. Reducing condensation **increases durability** and makes for a **healthier home**. The insulated building envelope, when engineered to control the flow of heat and the movement of air, is an obvious contributor to thermal comfort and also increases occupant comfort by reducing sound transmission.

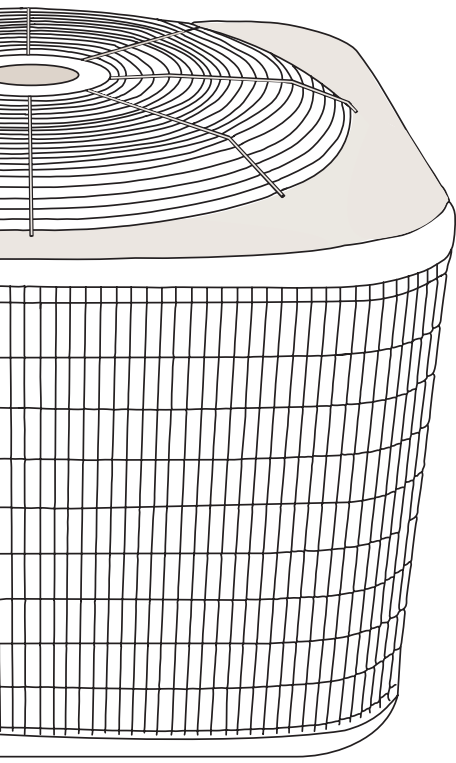
While lower loads have reduced cooling and heating requirements, builders must now match these modern high-performance building envelopes with more sophisticated HVAC systems. Traditional systems with large central air handlers delivering large volumes of conditioned air through long ductruns invite a range of challenges that are unsuitable for high-performance homes.

## Designing HVAC for High-Performance Homes

For each step in designing an HVAC system, there is an associated technical manual provided by the [Air Conditioning Contractors of America \(ACCA\)](#). The ACCA technical manuals are so widely adopted that some steps are commonly referred to by the name of the corresponding manual. After the builder has provided the HVAC contractor or mechanical engineer with detailed information concerning the **building envelope**, the HVAC contractor or engineer should perform a room-by-room load calculation (ACCA Manual J®) and not just the standard whole-home block load. Next, the project team will identify the right tonnage or system size based upon ACCA Manual S® guidelines. If the system is undersized, it will fail to provide enough heat on cold days, but if the system is oversized, it is likely to deliver poor performance.

Both sets of calculations are based upon [ASHRAE](#) design temperatures which account for the coolest and hottest days of the year. For most of the year, temperatures will not reach either extreme. Additionally, loads will change over the course of a day and will vary according to how occupants use a space. The homeowner's bedroom and home office will have radically different conditioning needs than an intermittently used workout room, for example. Designs that fail to account for this diversity in usage and the impact of changing exterior conditions can result in unnecessary energy use, discomfort and even callbacks.

HVAC systems specified for high-performance homes must be able to handle cooling and heating loads that are significantly lower than those of code-level homes. For example, a code-level, 1,500-square-foot home in Climate Zone 5 might have a design heating load of 35,000 Btu/h. That same home built with a high-performance envelope might have a heating load of 12,000 Btu/h. If this same home were built to the Passive House level, the heating load might be below 9,000 Btu/h.

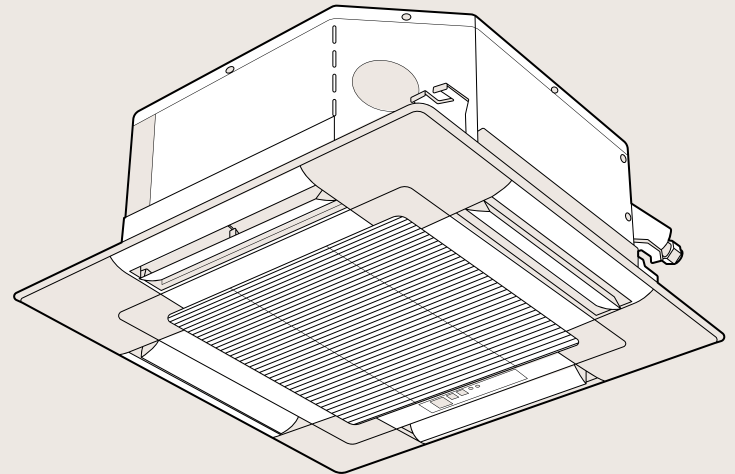


## Bigger Is Not Better

Previously, some builders may have selected oversized HVAC systems in the hopes of guaranteeing comfort and limiting callbacks but this approach is costly and inefficient, particularly in homes with tight thermal envelopes. Instead of providing comfort, **an oversized system creates temperature swings** and wastes energy by short cycling: constantly turning on and off. Short cycling also diminishes the system's ability to remove moisture. A traditional system sized for ASHRAE design temperatures — the coldest and hottest days in a particular region — will be especially vulnerable to performance issues related to short cycling. During the “shoulder season,” — the greater part of the year where temperatures are between the design day extremes — the fixed speed compressors of traditional systems leave them unable to go from maximum-capacity to low-capacity output. Additionally, oversized central air conditioners can produce negative air pressure that acts as a vacuum pulling in volatile organic compounds (VOCs) and other particulates from outside the home.

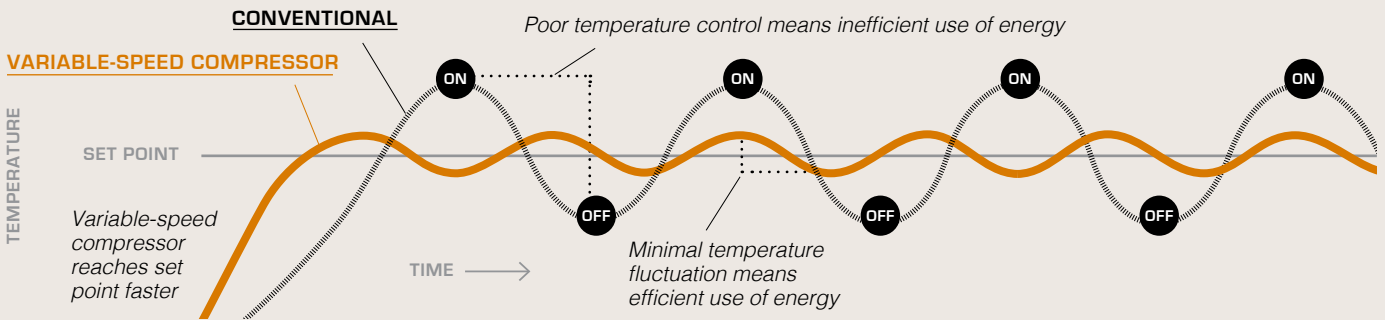
## A Better Approach

Builders apply split-ductless and ducted systems to successfully address the particular loads and challenges of high-performance homes. Available in a range of capacities to match the size and loads of any home, these highly-efficient systems feature either a single outdoor compressor or multiple small outdoor units. The outdoor equipment is connected via refrigerant lines to a single **indoor unit or to multiple indoor units**. The variety of indoor units include ductless options such as ceiling cassettes, wall-mounted units and floor-mounted units as well as ducted options such as compact, low-profile air handlers and larger, multi-position air handlers. A combination of these units may be applied together according to the home's design, efficiency goals and customer preferences.



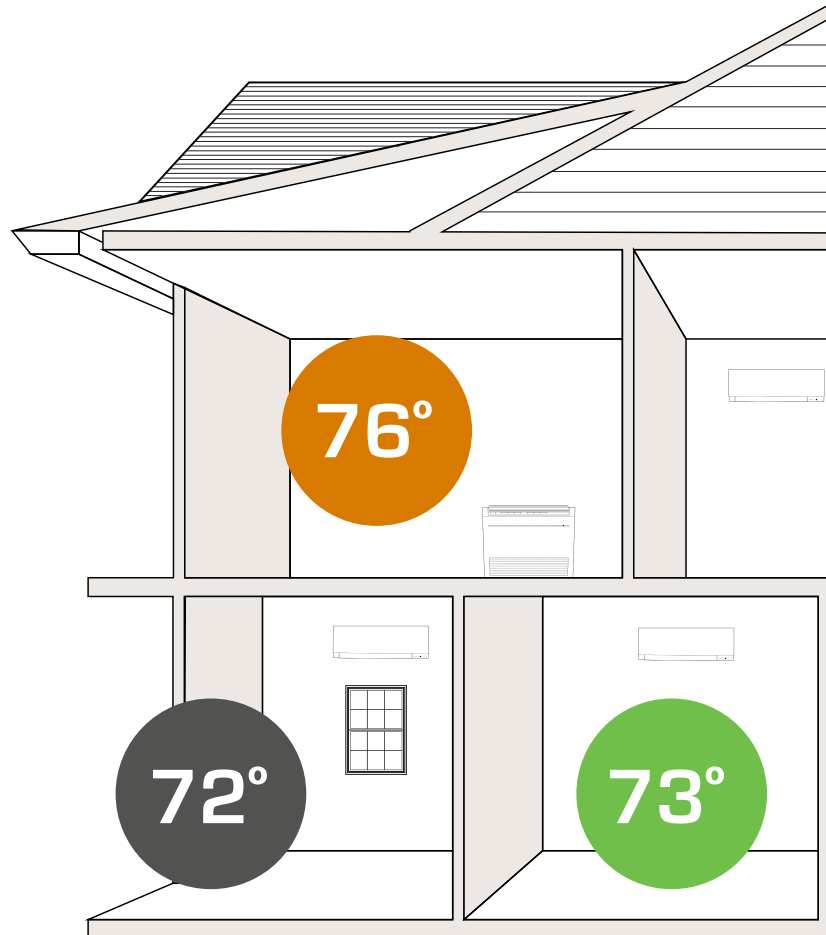
Additionally, the low amperage draw of these units compared to traditional systems makes modern split-ductless and ducted systems an ideal choice for homes that use solar, wind or hydroelectric power. Builders are now operating in an environment where global, national and local initiatives toward **reducing greenhouse gas emissions** has led to Strategic Electrification — the movement to replace fuels like oil, gas and propane with electricity produced from renewable and sustainable sources. This makes it increasingly important to consider choices like high-efficiency heat pumps that perform optimally with solar power.

These more sophisticated HVAC systems are still sized according to ACCA guidelines for load calculations, using their Air-Conditioning, Heating and Refrigeration Institute (AHRI) rated capacities but are equipped with variable-speed compressors that seamlessly adjust performance to maintain set points. This technology **conserves energy** compared to traditional systems that run at full power until reaching the set point and then stop, only to turn on again, sometimes multiple times within an hour as rooms become uncomfortable. In addition to saving energy by only using the precise amount of energy needed to meet set points, there's an added benefit of increased durability and longer life because of the minimized wear and tear. Additionally, modern split-ductless heat pump systems may incorporate air-source hyper-heating technology engineered to perform efficiently in cold climates with design temperatures below freezing.



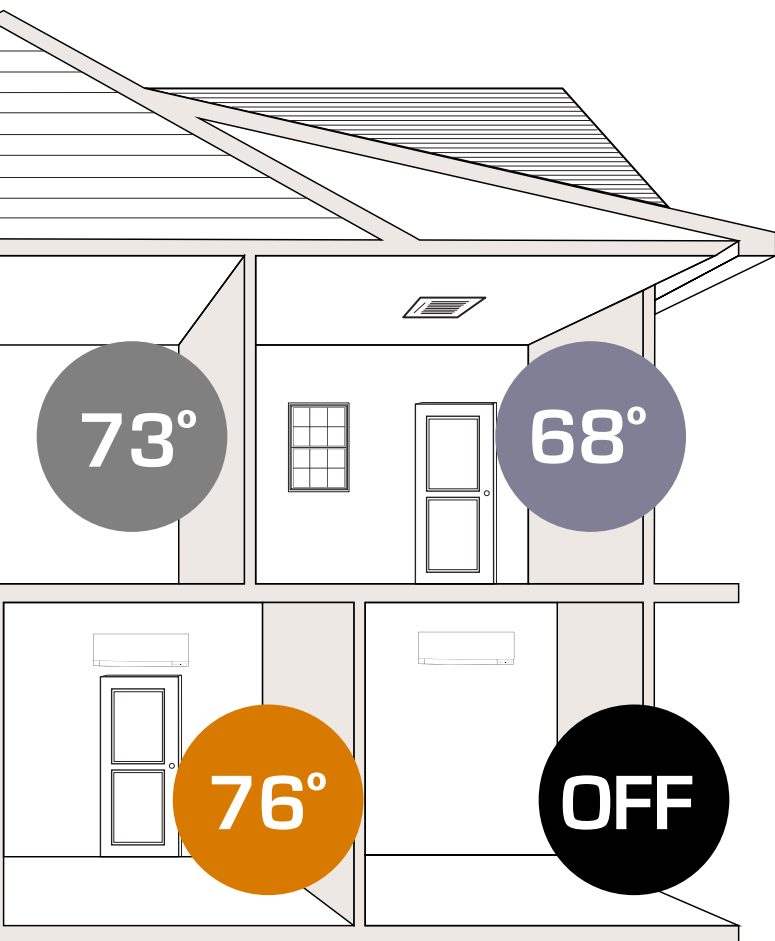
## Zoning and Occupant Preferences

Thoughtful whole-home system design considers the diversity of homeowners and how they plan to live in the home. By creating smaller comfort zones, split-ductless and ducted systems enable builders to more **fully customize the design** to limit callbacks and keep each room at temperatures that make sense for the time of day and how the room is used. No builder wants to receive complaints from new homeowners due to discomfort caused by an HVAC system that does not match their lifestyle. Designs can include comfort zones of various sizes, each controlled individually and served by its own indoor unit. Decisions concerning which rooms to include within a given zone are informed by room-by-room load calculations. It may be inefficient and unnecessarily expensive, for example, to put an indoor unit in every bedroom which may have very low heating or cooling demands. Builders will also want to carefully review the control options available with HVAC systems to ensure that homeowners can



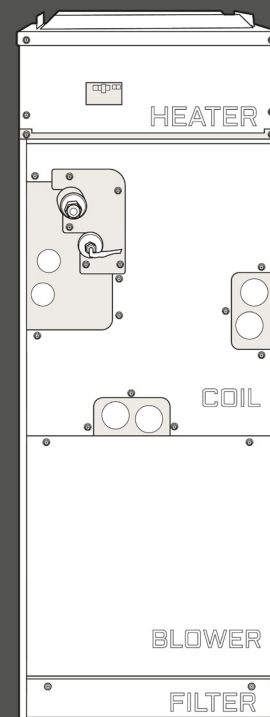
exercise precise control over their **comfort zones** from anywhere within the home and also remotely through mobile devices.

Here is an example of how load challenges were managed in a DOE Zero Energy Ready Home built by [Greenstone Homes in Spokane, Washington](#). The home has a total heating load of 21,749 Btu/h. Bedroom two is a corner room with two exterior wall surfaces and has a heating load of 3,249 Btu/h. Bedroom three is an interior room with a short exterior wall and a heating load of only 1,709 Btu/h. Neither of these bedrooms needs much heating or cooling. To properly size the cooling and heating delivered to both rooms, the builder and HVAC contractor decided to use a wall-mounted unit in bedroom two with a transfer fan to push conditioned air into bedroom three. A transfer fan in combination with the ventilation system proved to be an effective and economical way to move conditioned air into a low-load space.



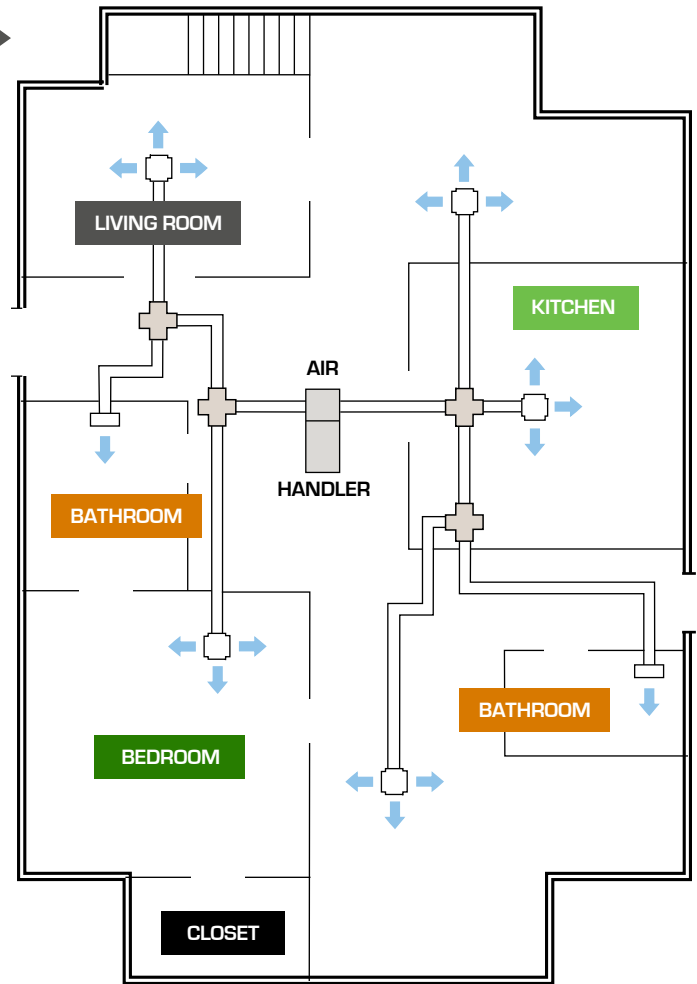
## Fully Insulated, Compact Duct Design

Split-ductless systems eliminate the need for long duct runs which compromise energy efficiency through leakage and impact occupant health by accumulating harmful particulates. Given how ducts in poorly designed systems can harbor bacteria, mold and dust mites, limiting ductwork can make for a **healthier home**. Reducing ductwork can also increase durability given how flex ductwork breaks down over time due to pests or ducts getting stepped on by occupants. That said, high-performance homes are not necessarily without ducts. For example, builders may apply compact air handlers with minimal ductwork to serve smaller zones — or perhaps a basement or first floor. In high-performance homes, builders will apply rigid ducts or metal ducts with a compact duct design to ensure ducts are kept within the thermal envelope.



In compact duct design, ducts do not run to the exterior walls as ducts do in older or code-level homes. Instead, these ducts run to the interior wall of the room and blow toward the exterior wall. With the **ducts more centralized**, this allows for shorter ductruns, which reduces the cost of ductwork and permits the installation of smaller HVAC systems and quieter fans. Builders can use compact duct design techniques in high-performance homes of various home sizes. For example, **compact duct design** will make it easier for builders to apply 10-inch large ducts in a 6,000-square-foot house fully within the thermal envelope.

For high-performance homes that include compact duct designs, the project team will design ducts to account for static pressure and CFM flow per ACCA Manual D® and follow Manual T® for duct grill termination design. All HVAC systems and ductwork should be installed within the thermal envelope and in a conditioned space. Ductwork that is outside of the conditioned space risks an energy penalty and condensation. Modern ducted units are more compact than traditional central units and are easier for builders to fit within the confines of conditioned space.

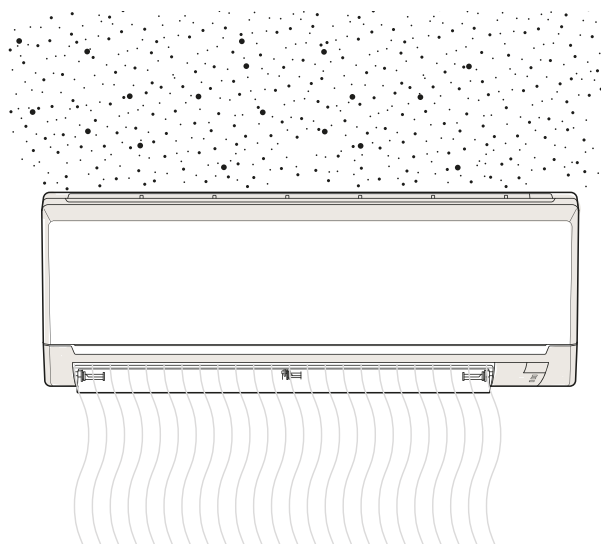


## Humidity Control in High-Performance Homes

Even in dry, arid climates where humidifiers are in use, humidity is increasingly an issue builders must address. As HVAC systems become more energy efficient, and seasonal energy efficiency ratio (SEER®) ratings rise, the systems have become less capable of removing moisture. As a variable-speed compressor runs slower during partial load conditions, the coil processes less refrigerant and is less active. While great for energy efficiency, this operation results in a warmer coil, which in cooling mode does not dehumidify effectively.

The sensible heat ratio (SHR) is a rating that describes how much cooling capacity an air conditioner allocates to sensible loads versus latent loads. If an HVAC system has an SHR of 0.6, then 60 percent of its capacity will address sensible heat and the remaining 40 percent will remove moisture. In high-performance homes, tight, insulated building envelopes and highly-efficient HVAC systems have caused sensible loads to drop dramatically. A modern HVAC system might have an SHR of 0.9 which means that 90 percent of its capacity addresses sensible heat while only 10 percent addresses moisture removal. To address latent loads — which are produced by moisture from occupants and their activities (e.g., cooking, bathing) — builders may apply a whole-home dehumidifier to complement high-performance HVAC systems.

While split-ductless indoor units are equipped with air filtration capabilities, the tight building envelopes of high-performance homes make ventilation essential for **indoor air quality**. Also, as of 2015, mechanical ventilation is required by the International Mechanical Code. Depending upon the climate, builders may choose to apply an energy recovery ventilator or a heat recovery ventilator as a specialized ventilation unit. To satisfy the Passive House standard, builders will want to apply a ventilation system with efficient heat recovery. Otherwise, the heat energy carried by exhaust air will be wasted, degrading the efficiency of the building.



## Teamwork: Components, Contractors and Builders

We encourage high-performance builders to look for an HVAC contractor who specializes in high-performance new construction. During the design process, teamwork between the builder and the HVAC contractor is essential. Other allies helpful in the HVAC design process include energy raters and HVAC manufacturers who are committed to helping high-performance builders develop the most effective HVAC strategies. For example, the [Performance Builder Program](#) at Mitsubishi Electric Trane HVAC US is available to help builders address homeowner concerns and position themselves at the forefront of building innovation.

Whole-home system design requires careful consideration of interdependent components that each play a role in determining what level of performance a design can deliver for occupants across **comfort, health, efficiency and durability**. While the building envelope is widely recognized as the foundation of high-performance, builders appreciate how HVAC designs can mean the difference between receiving callbacks from disgruntled clients versus praise from happy homeowners.



COMFORT



HEALTH



EFFICIENCY