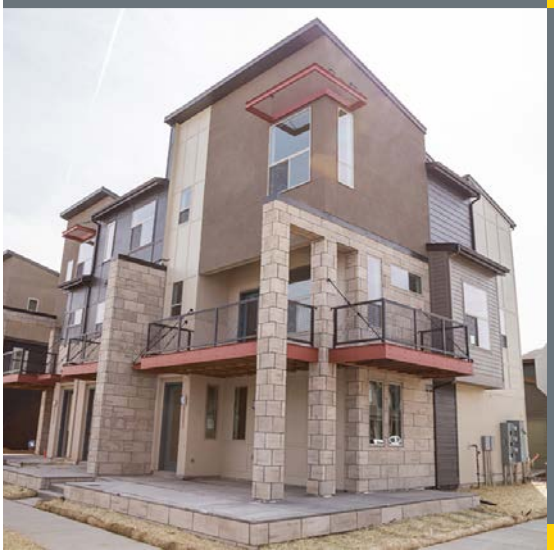
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Building America Case Study

Efficient Solutions for New and Existing Homes

Case Study: Standard- Versus High-Velocity Air Distribution in High-Performance Townhomes

Denver, Colorado

PROJECT INFORMATION

Construction: New home

Type: Three-story townhomes

Research Team: IBACOS

Builder: New Town Builders, now Thrive Home Builders

Size: 1,187 ft^2

Date completed: 2015

Climate Zone: Cold-Dry

PERFORMANCE DATA

HERS index:

- Home A: 55
- Home B: 61
- Reference Design Home: 74

Projected annual energy cost savings versus ENERGY STAR®:

- Home A: $382
- Home B: $420

Home feature differences impact the projected utility costs in the energy analysis.

Billing data: Not available

Three-story townhomes are prone to significant floor-to-floor stratification, which often leads to occupant discomfort. However, small-diameter, high-velocity (SDHV) systems could be a viable solution to the stratification issue and can help builders deliver better comfort in their high-performance homes.

Two buildings, with three occupied townhomes each, were constructed to high-performance specifications in early 2015 by New Town Builders, now Thrive Home Builders, as part of the Stapleton development featuring energy-efficient homes in Denver, Colorado. The U.S. Department of Energy Building America IBACOS team documented and compared the floor-to-floor temperature stratification of the occupied center townhome units from each of the two buildings. Performance data measured by IBACOS in the two homes helps develop the understanding around how SDHV systems can increase occupant comfort.

The floor plans and enclosures of the two units are similar with a few feature differences, having comparable airtightness and thermal performance. A key difference between the two homes is the installed HVAC system—specifically, the approach to conditioned air distribution. Home A features an SDHV duct distribution system. Home B features a conventional duct design with standard air velocity, which is currently employed in the builder's standard product. Registers for the high-velocity system are typically located on high sidewalls to avoid draft-related comfort issues. In addition, centrally locating the air handling equipment helps mitigate stratification issues in these types of multistory homes as more uniform supply air delivery temperatures can result.

The equipment used for the SDHV system is compact, having the advantage of being able to be located in closets. A disadvantage of a standard system is that it must be located at the periphery of the building due to its larger size.

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KEY ENERGY-EFFICIENCY MEASURES

HAVC

- Home A: SEER 14 AC, Electric
  Home B: SEER 13 AC, Electric
- Home A: Gas, 96.0 AFUE
  Home B: Gas, 92.1 AFUE
- Home A: $15,000 installed*
  Home B: $7,000 installed*
- Well-sealed R-4 flex ducts in conditioned space; duct leakage to outside = 47 cfm @ 25 Pa
- Kitchen and bath fans vented to outside

*Includes equipment, ductwork, and installation costs.

ENVELOPE

- R-38 blown ceiling insulation in vented attic
- R-23 grade-1 blown insulation in 2 x 6 frame wall
- Double-pane, low-e, vinyl windows, U = 0.310, SHGC = 0.300
- Tightly sealed houses:
  - o Home A: 3.49 ACH50
  - o Home B: 2.73 ACH50

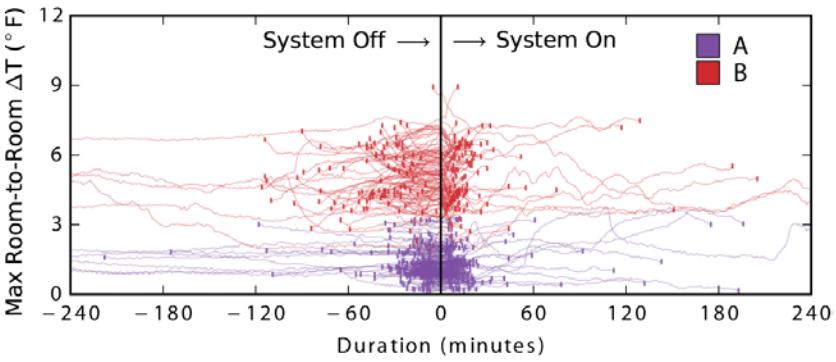
LIGHTING, APPLIANCES, AND WATER HEATING

- 100% ENERGY STAR-qualified lighting
- ENERGY STAR exhaust fan
- Home A: Tankless water heater, natural gas, 96.0 AFUE
- Home B: 40-gallon-tank water heater, natural gas, 62 AFUE

For more information see the Building America report *Comparative Cooling Season Performance of Air Distribution Systems in Multistory Townhomes* at *https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/65315.pdf*.

Image credit: All images were created by the IBACOS team.

The plot of measured performance data below illustrates how room-to-room temperature differences compare for the two air distribution approaches. The purple data lines in the graph represent Home A's SDHV system, and the red lines represent the conventional system in Home B. Each line to the right of 0 on the plot indicates maximum room-to-room temperature differences measured continuously during an HVAC system "on" cycle. The line length represents the system "on" time, with some "on" cycles lasting 4 hours. Lines to the left of 0 indicate periods of temperature drift between cycles, with up to 4 hours of "off" cycle showing in the plot, from –240 min to 0. When a system "on" cycle begins at 0 time on the x-axis, room-to-room temperatures already vary to some degree.



Plotting can aid in the analysis of systems. Differences in indoor conditions between the two homes become clear when all of the HVAC systems' cycles are displayed in unison and are color coded.

The two systems generally show similar system runtimes; however, stratification is significantly more pronounced with the conventional system, as shown by the red lines being generally above the purple lines in the plot. Several factors lead to this stratification. First, the higher velocity of the SDHV system provides better air mixing. Second, the SDHV system's smaller air handler can be located in a closet on the middle floor rather than on the first floor in the garage, leading to more uniform supply air temperatures because of the shorter duct runs. Third, stratification is lower because of improved system balancing, and SDHV systems are more adaptable to achieve balanced airflow. These factors lead Home A to have much lower room-to-room temperature differences than those of Home B.

Lessons Learned

- Small-diameter, high-velocity systems can achieve less room-to-room temperature variation. Improved air mixing is one reason for this.
- Centrally locating air handlers when stratification risks exist can deliver more uniform supply air temperatures, reducing temperature stratification.
- In these test homes, the conventional duct systems were not well balanced. It is more challenging to properly balance a conventional system than an SDHV system. Balanced airflow reduces stratification and room-to room temperature issues.
- Occupants reported that both systems struggled to provide adquate temperatures on the top and bottom floor in summer and winter, respectively. No concerns with noise were reported with either system.

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The U.S. Department of Energy Building America Program is engineering the American home for energy performance, durability, quality, affordability, and comfort.

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