U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Achieving Ducts in Conditioned Space

As codes push for greater energy savings, production homebuilders must consider ways to reduce the energy use associated with HVAC system performance. One prominent and effective approach to reduce energy use is the transition of ductwork from unconditioned space (attics, crawlspaces, basements) into conditioned space.

Figure 1. Smaller diameter homerun duct system inside a house. *Photo from Building America*

Purpose of This Fact Sheet

The purpose of this fact sheet is to help production homebuilders of single-story homes with slab-on-grade foundation in hot, dry climates to make informed decisions regarding strategies for bringing ductwork into the conditioned space of their homes. The performance, productivity, and cost implications of several common strategies are analyzed in this document to highlight the pros and cons of each approach. This is not an exhaustive analysis, and additional strategies may be available in local markets.

Project Information

- **Climate:** Hot, Dry
- **House Type:** Single-Story
- **Foundation:** Slab on Grade

Ductwork Strategies

The following duct installation strategies were considered for this analysis:

- Traditional duct system in a vented attic
- Traditional duct system in an unvented attic
- Traditional duct system deeply buried in insulation inside a vented attic
- Traditional duct system located in bulkheads and dropped ceilings inside the house
- Smaller diameter homerun duct system located in bulkheads and dropped ceilings inside the house.

A "traditional" duct system for this study consists of flex duct and duct board materials of various diameters installed in a trunk-and-branch formation with metal fittings sealed with tape and mastic paste. All strategies included a radiant barrier on the underside of the roof sheathing, except the traditional duct system in an unvented attic.

A smaller diameter homerun duct system for this study has a similar layout to a homerun cross-linked polyethylene plumbing system. There is a central manifold located at the air handling unit and multiple smaller diameter (3–4 inches) ducts stretch continuously from the manifold to the room terminations. This homerun system utilizes a minimal number of engineered airtight fittings.

Figure 2. A hot, dry climate is located primarily in the southwest United States. *Illustration from Building America*

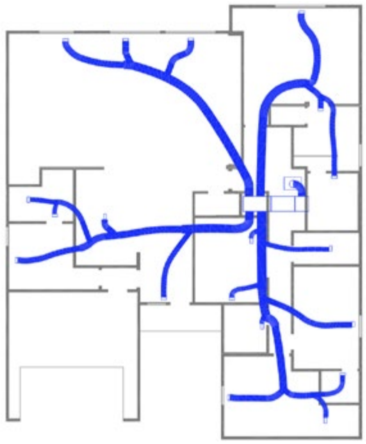


Figure 3. Traditional system, vented and unvented attic, air handler in attic

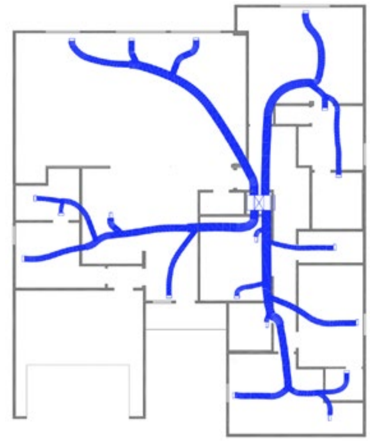


Figure 4. Traditional system, deeply buried in attic, air handler in house

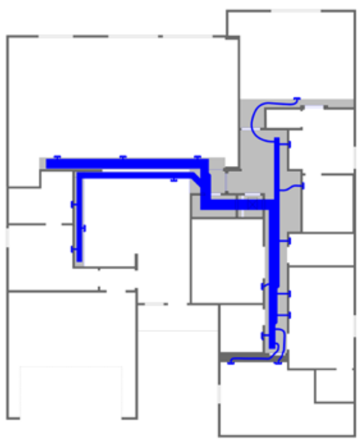


Figure 5. Traditional system, inside house

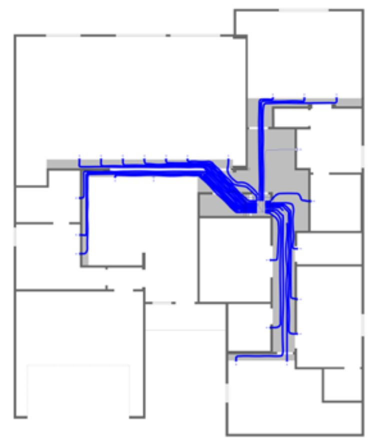


Figure 6. Smaller diameter homerun system, inside house

Illustrations from Building America

Figures 3 through 6 depict different duct strategies, including the locations of the ductwork and layouts of the systems.

Evaluation Criteria

Each duct strategy was analyzed in a 2,800-ft^2, single-story home with a slab-on-grade foundation in a hot, dry climate using the following criteria:

1. Energy Use—What is the impact of each duct strategy on the energy efficiency of the house?
2. Cost—What are the relative installed costs of each duct strategy?
3. Installation Time—How quickly can each system be installed?
4. Constructability—How easily can each system be installed, and what are the implications to trade contractors?
5. Durability—What impact does each system have on potential short- or long-term risk exposure for the builder?
6. Design, Architecture, and Aesthetics—What are the implications of the HVAC and architectural design processes, impacts to living space, and homeowner perception?

Results

Energy Use

All strategies demonstrate improved energy performance over the traditional system in a vented attic, when modeled using BEopt™ v2.8. Both systems inside the house had the lowest modeled energy use, followed by the unvented attic system and then deeply buried ductwork. The cooling and heating load reduction follows a similar pattern.

An International Code Council Energy Rating Index benefit can be achieved if a builder follows the proposed BSR/RESNET/ACCA Standard 310 (Standard for Grading the Installation of HVAC Systems). This standard has five evaluation categories: design, total duct leakage, blower airflow, blower watt draw, and refrigerant charge. Smaller, more compact duct systems that are more accessible have an easier path to design compliance. For this reason, a homerun duct system or traditional system inside the house may provide easier paths to earn the Energy Rating Index (ERI) credit available from Standard 310.

Cost

Cost evaluations were completed for each duct strategy based on total installed costs, including HVAC equipment costs and associated attic insulation costs. Material costs were collected from 2018 RSMeans residential and available retail sources. Labor costs were collected from RSMeans.

The following items were included in the total cost for each strategy:

- Duct material type, size, length, and installation labor
- Equipment cost based on associated tonnage
- Material and labor costs to construct either an interior closet or attic platform, based on equipment location, along with any dropped ceilings or bulkheads inside the house
- System commissioning and airtightness testing
- Attic insulation strategy:
    - Traditional, vented: R38 blown cellulose radiant barrier on the attic floor
    - Traditional, unvented: R38 open cell spray foam on the attic roof deck (no radiant barrier)
    - Traditional, deeply buried: 22 inches blown cellulose radiant barrier on attic floor to achieve the required 3.5 inches over the largest duct
    - Traditional in conditioned space: R38 blown cellulose radiant barrier on the attic floor
    - Smaller diameter, homerun duct system: R38 blown cellulose radiant barrier on the attic floor.

An unvented attic strategy using spray foam insulation is the most expensive, and the homerun strategy inside the house is the least expensive. Costs for each system are presented in the summary table at the end of this document.

Installation Time

Based on previous evaluations of HVAC system installation times, a traditional system inside conditioned space takes the longest to install. This is because of the time and effort required to build duct board or metal trunk lines during rough installation, and the need for the framing trade to return following rough installation to build bulkheads and frame dropped ceilings.

In contrast, the framing of bulkheads can be completed prior to rough installation for a smaller diameter homerun system, greatly reducing installation time and avoiding a repeat trip. Deeply buried ducts required additional time to install thicker attic floor insulation.

Constructability

Installers are most familiar with the vented attic system. However, this system requires installers to walk on trusses and use ladders during installation, which can be a potential safety issue. Additionally, hanging the ducts and routing them around truss members jeopardizes smooth airflow. The perimeter terminations can also be challenging to properly air seal and insulate.

Safety issues are reduced in the unvented attic system—installers can lay ductwork on the bottom cords of attic trusses, as opposed to hanging them in a vented attic, and therefore spend much less time walking on the trusses. However, installing insulation at the roof deck can be challenging and poses a potential safety risk.

With deeply buried duct systems, there are two options. The first is the installation of a containment system around some or all of the ducts, ensuring 3.5 inches of insulation coverage on the sides and tops of the ducts within the containment barriers. This method—if used—requires a separate trip by the framer, and more frequent insulation depth markers need to be added in the attic for inspection. The second option is to add 3.5 inches of attic insulation over the largest duct and then maintain this depth across the entire attic floor; this also has the advantage of increasing the overall attic R-value. There are some safety concerns with deeply buried ducts in navigating the roof trusses to install the ductwork, but these concerns are less than the vented and unvented scenarios. Due to the complexities and costs associated with the containment system, the second option (no containment system) was chosen for this study.

For a traditional duct system inside the house, capping and sealing the dropped ceiling and bulkhead areas requires additional time and effort from the framer; framing of these areas requires a separate trip following the duct rough installation. A smaller diameter homerun system also requires capping sealing and framing the bulkheads and dropped ceilings, but these are often smaller than with a traditional system and can be completed prior to the duct rough installation when the rest of the house is being framed. Safety concerns for both of these systems located inside the house are minimal.

The traditional duct system located in the attic (vented, unvented, and deeply buried) has more stock-keeping units (SKUs) in the system than the two systems located inside the house. Inside the house, the traditional system has 10 SKUs, and the homerun system has 7 SKUs. Fewer SKUs typically simplify ordering, distribution, and installation.

Deeply buried ductwork and ductwork installed inside the house are still relatively uncommon practices in hot, dry climates, and installers may be unfamiliar with these systems. Additionally, because the homerun system is new to the market, installers may require additional time to become comfortable with installing this system.

Durability

The overall condensation potential on ductwork in hot, dry climates is low, regardless of being in attics or inside the house. Condensation is not a driving factor for durability with any of the duct strategies included here. For example, in Riverside, California, the ambient dewpoint is above 60˚F for 620 hours per year, and above 65˚F just 26 hours per year. Contrast this with Orlando, Florida, where the dewpoint is above 60˚F for 5,870 hours per year.

A larger concern is the ease of air sealing ductwork based on accessibility issues, particularly when buried in insulation or routed through bulkheads and dropped ceilings. In these cases, care must be taken during installation to properly connect and seal fittings to ensure a proper air seal is achieved. In these instances, if a duct is leaky or separated from a fitting once installed, it will be difficult to access the duct for repairs.

In counting the points of connection in the traditional system (collar to plenum, collar to duct, fitting to duct, duct to boot) there are approximately 75 points where air could leak in this system. With the homerun system, there are 64 possible leakage points, reducing the likelihood of leakage and associated performance issues.

Design, Architecture, and Aesthetics

Because it has fewer SKUs and uses a single-diameter duct for the entire layout, the homerun duct system allows for a more streamlined design process. Installers that currently neglect the ACCA Manual D process may be more inclined to complete a homerun design due to its more cohesive layout.

Homeowners are most familiar with ductwork and equipment located fully in the attic, as in the case of the traditional vented and unvented attic strategies. In hot, dry climates, mechanical closets are not the norm and would lead to loss of living space and potential noise issues in the home. Ductwork inside conditioned space is unfamiliar to most homeowners and the associated bulkheads and dropped ceilings may be visually unappealing.

In a single-story, 2,800-ft^2 slab-on-grade house, 14% of total floor area is affected by bulkheads and dropped ceilings using a traditional duct system inside the house, and 7% of living space (living room, dining room, kitchen, bedrooms) is affected. The average dropped ceiling and bulkhead height is 15 inches. With a smaller diameter homerun system, 13% of total floor area and 6% of living space is affected, and the average dropped ceiling and bulkhead height is 11 inches.

Conclusion

In a hot, dry climate, the durability risks of different duct strategies are minimal due to the low condensation potential on ductwork, whether it is located inside the attic or in the house. Therefore, builders can focus on the energy, cost, constructability, and aesthetic impacts of different duct locations when considering the best strategy for their homes.

A homerun duct strategy, although new to the market and therefore unfamiliar to most installers, may be the best approach for builders given the higher energy performance, lower cost, and improved constructability over traditional duct systems. While the homerun system requires bulkheads and dropped ceilings inside the house that may be visually unappealing to builders and homeowners, these features can be smaller than similar features that utilize a traditional duct system inside the house.

With greater demands to improve the energy performance of their homes, builders are seeking cost-effective strategies that reduce energy use, diminish potential risk, and have minimal impact on their overall construction process. Bringing HVAC ductwork into the conditioned space of the home has demonstrated benefits to a home's energy performance, and several strategies exist that builders can use based on their individual performance targets and needs. ■

Ductwork Inside Conditioned Space – Hot, Dry Climates

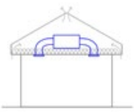
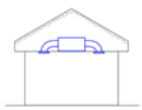
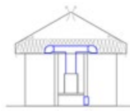
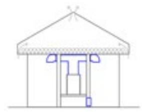
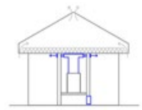
	 Traditional System, Vented Attic	 Traditional System, Unvented Attic	 Deeply Buried System	 Traditional System, Living Space	 Smaller Diameter, Homerun System
Energy Use (Btuh)	Cooling Load 31,142 Heating Load 28,186 ERI - 66	Cooling Load 28,156 Heating Load 28,966 ERI - 63	Cooling Load 27,246 Heating Load 25,651 ERI - 64	Cooling Load 25,501 Heating Load 24,389 ERI - 62	Cooling Load 25,501 Heating Load 24,389 ERI - 62
Installed Cost	$ $10,000	$$$ $20,000	$ $11,000	$$ $14,000	$ $10,000
Installation Time	2.5 Days	2.5 Days	3 Days	4.5 Days	2 Days
Constructability	**21** SKUS Installer Safety Installation Effort **0** Extra Trips	**21** SKUS Installer Safety Installation Effort **0** Extra Trips	**21** SKUS Installer Safety Installation Effort **0** Extra Trips	**10** SKUS Installer Safety Installation Effort **1** Extra Trip	**7** SKUS Installer Safety Installation Effort **0** Extra Trips
Durability	**LOW** Condesation Potential Ease of Air Sealing Ducts **75** Potential Points of Air Leakage	**LOW** Condesation Potential Ease of Air Sealing Ducts **75** Potential Points of Air Leakage	**LOW** Condesation Potential Ease of Air Sealing Ducts **75** Potential Points of Air Leakage	**LOW** Condesation Potential Ease of Air Sealing Ducts **74** Potential Points of Air Leakage	**LOW** Condesation Potential Ease of Air Sealing Ducts **64** Potential Points of Air Leakage
Design, Architecture, and Aesthetics	No Bulkheads or Dropped Ceilings	No Bulkheads or Dropped Ceilings	Mechanical Closet in House	Bulkheads and Dropped Ceilings, Mechanical Closet in House	Bulkheads and Dropped Ceilings, Mechanical Closet in House

Illustration from Building America

Building America U.S. Department of Energy

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