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| **Docket Number:** | 17-BSTD-01 |
| **Project Title:** | 2019 Building Energy Efficiency Standards PreRulemaking |
| **TN #:** | 218024 |
| **Document Title:** | Prohbit Ducts in Attics and Exterior Wall Cavities |
| **Description:** | Electronic copy of a hard copy letter submission requesting the California Energy Commission lobby the state legislature to adopt legislation prohibiting ductwork in attics and exterior wall cavities. Included for reference are an NREL Conference Paper and Energy Vanguard Blog post. |
| **Filer:** | Adrian Ownby |
| **Organization:** | Robert L. Finke |
| **Submitter Role:** | Public |
| **Submission Date:** | 6/12/2017 12:54:00 PM |
| **Docketed Date:** | 6/12/2017 |

**ROBERT L. FINKE**
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May 30, 2017

Christopher Meyer, Officer Manager
Building Standards
California Energy Commission
1516 9th Street, Mail Stop No. 37
Sacramento, CA 95814

Re: Proposed Revision to Residential Building Code to prohibit HVAC ducts in attics

Dear Mr. Meyer:

The purpose of this letter is to request the support of the California Energy Commission to lobby the California legislature to adopt legislation that would amend the residential building codes in California to prohibit the placement of HVAC ductwork in attics and exterior wall cavities. Placing HVAC ducts in attics and exterior walls of houses wastes a significant amount of energy and leads to unnecessary expenditures for equipment and repairs. This practice is a noticeable disservice to homeowners in California, Arizona and many other states.

I am a retired real estate developer and general contractor who built primarily commercial and industrial structures in 26 different states. I also built a few houses. During my 40 year career, I never built a structure with HVAC ductwork located outside the conditioned air envelope (i.e. outside the insulated building walls and ceiling)...because such an installation is a well known waster of energy. Anyone with a basic understanding of physics should know that it is foolish to place ductwork carrying cooling air at 55°F in an attic that may have an ambient air temperature ranging from 100°F to 150°F. Similarly, a duct carrying heating air at 110°F should not be placed in an attic with an ambient air temperature that may range from 10°F to 50°F. Insulating a duct in an attic only slows the rate of heat transfer...it doesn't stop it.

Enclosed is a copy of the widely circulated Conference Paper (NREL/CP-550-48163, dated Aug 2010) titled "**Ducts in the Attic? What Were They Thinking?**" published by the U.S, Department of Energy. This report summarizes several research studies demonstrating that HVAC ducts in an attic add 15% to 30% to a homeowner's annual utility bills for heating and cooling. The conclusions of this report are not new. The wastefulness of placing HVAC ductwork in an attic has been well known by mechanical engineers and HVAC equipment manufacturers for nearly 100 years, but building codes adopted in many states allow this practice.

In addition to wasting energy, placing HVAC ductwork in the attic requires a builder or homeowner to pay for the cost of installing and maintaining larger than necessary heating and cooling equipment...to overcome the energy lost in the attic.

As an experienced builder, I can tell you that placing HVAC ductwork in an attic is not an easy task…especially working around manufactured roof truss components and low slope roofs. As the roof structure becomes more complicated, the quality of the ductwork installation declines. As the structure ages, ductwork joints start leaking and insulation effectiveness erodes. Repairing HVAC ductwork in an attic is difficult and expensive. All of these problems and unnecessary expenses can be avoided…if the HVAC ducts are not placed in an attic.

Based on my experience, I think there is only a very small cost premium associated with placing HVAC ductwork within the conditioned air envelope and enclosing the ductwork with a drywall soffit or dropped ceiling. Placing the ductwork inside the building envelope also means that the builder will spend less on the cost of the central heating and cooling equipment. The U.S. Department of Energy Conference Paper estimates that the net premium cost for placing HVAC equipment inside the building envelope might be about $1000 for a typical house. This extra initial cost is probably repaid within four (4) years through lower utility bills for heating and cooling.

If HVAC ductwork is located within the insulated building envelope, then minor duct leakage really doesn't matter because all of the heated or cooled air remains within the conditioned space (i.e. no waste).

Every American homeowner would enjoy a direct cost saving benefit if all Residential Building Codes were amended to prohibit the placement of HVAC ductwork in attics and exterior wall cavities. Many states have adopted public policy initiatives to reduce energy use, but, apparently, the rather simple and highly effective option of eliminating HVAC ductwork in attics has been largely overlooked. Requiring the placement of HVAC ductwork within the conditioned space of every house might, in the long term, reduce nationwide power consumption and generation requirements for houses by 20%. That would be noticeable energy conservation and money well spent.

Thank you for your consideration of this proposal.

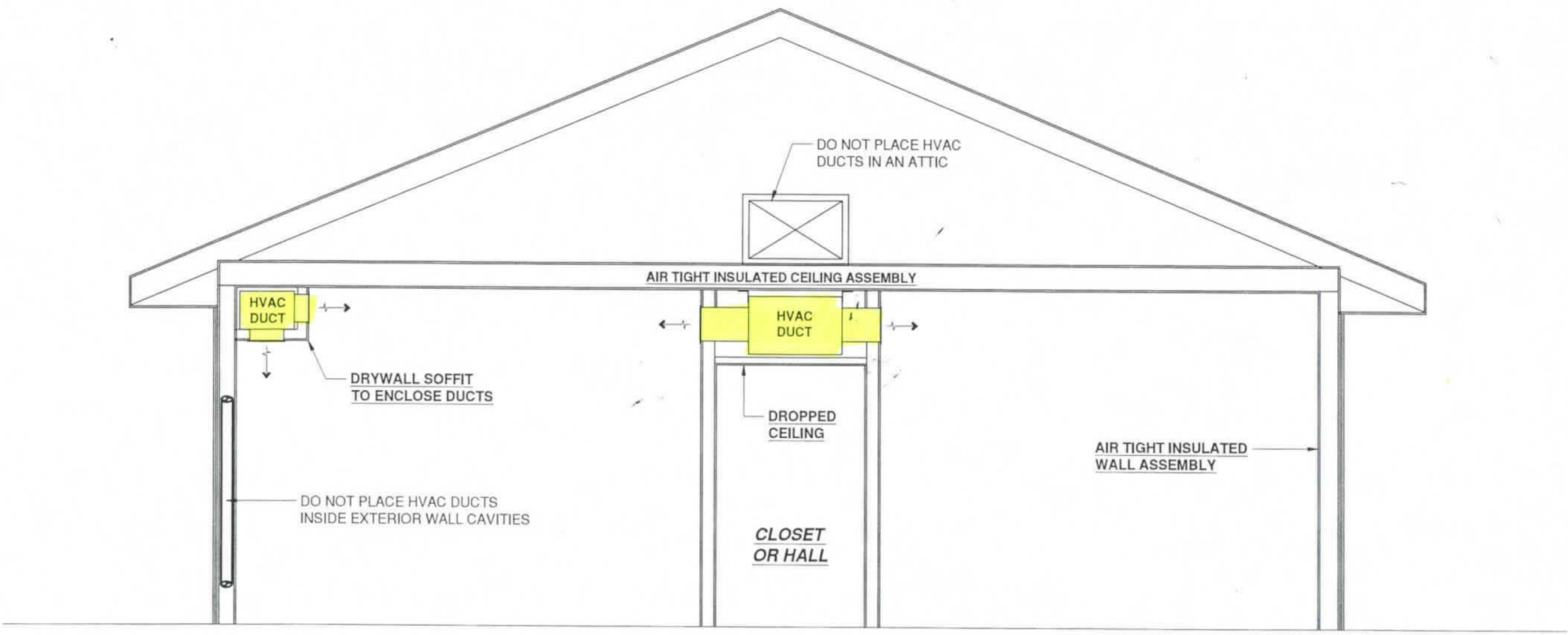
Sincerely,

Phone: 916-654-4052

Robert Finke

Robert L. Finke

# AN ENERGY SMART HOUSE



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Office of Energy Efficiency & Renewable Energy

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Conference Paper
NREL/CP-550-48163
August 2010

# Ducts in the Attic? What Were They Thinking?

## Preprint

David Roberts and Jon Winkler
*National Renewable Energy Laboratory*

*Presented at ACEEE Summer Study*
*Pacific Grove, California*
*August 15–20, 2010*

NREL is operated for DOE by the Alliance for Sustainable Energy, LLC Contract No. DE-AC36-08-GO28308

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# Ducts in the Attic? What Were They Thinking?

*Dave Roberts and Jon Winkler, National Renewable Energy Laboratory*

## ABSTRACT

As energy-efficiency efforts focus increasingly on existing homes, we scratch our heads about construction decisions made 30, 40, 50-years ago and ask: "What were they thinking?" A logical follow-on question is: "What will folks think in 2050 about the homes we're building today?" This question can lead to a lively discussion, but the current practice that we find most alarming is placing ducts in the attic.

In this paper, we explore through literature and analysis the impact duct location has on cooling load, peak demand, and energy cost in hot climates. For a typical new home in these climates, we estimate that locating ducts in attics rather than inside conditioned space increases the cooling load 0.5 to 1 ton, increases cooling costs 15% and increases demand by 0.75 kW. The aggregate demand to service duct loss in homes built in Houston, Las Vegas, and Phoenix during the period 2000 through 2009 is estimated to be 700 MW.

We present options for building homes with ducts in conditioned space and demonstrate that these options compare favorably with other common approaches to achieving electricity peak demand and consumption savings in homes.

## Background

Heat exchangers are designed to transfer as much heat as possible from one fluid to another. The heat exchanger we commonly find in a solar storage tank is an immersed coiled tube; we move solar heated water through the tube and it heats the water in the tank. In a good solar storage system, we place the coil at the bottom of the tank and strive for temperature stratification in the tank so we bring the hottest water in the system (from the collectors) in contact with the coldest water in the system (from the cold-water mains, settled at the bottom of the storage tank).

This is oddly similar to the configuration we see in many homes being built in cooling-dominated climates – we place tubes (with hundreds of square feet of surface area) carrying the coldest fluid in the system (55°F air leaving the air-conditioning unit) immersed in the hottest fluid in the system (150°F attic air). The only difference is, in this system we ***don't*** want heat exchange. Heat exchange is a bad thing because we don't need to cool the attic air (it's outside our enclosure) and we certainly don't want to heat the air we just paid the electric utility to cool. So, to overcome this serious design flaw we create energy codes that require us to put some goop on joints and wrap an inch or so of insulation around the tubes. Feels a bit like bubble gum and a bandage – MacGyver would be proud. In fact it reminds us of some of the old homes we see where someone stuffed wadded-up newspapers into the walls or poured sawdust on the attic floor in an attempt to improve on construction practices of the time. You can almost hear the old-timer as he's working to "fix" things – "What the heck were they thinking Myrtle?"

**Figure 1. Ducts in an Unconditioned, Vented Attic**

Source: ducts.lbl.gov. Used by permission of LBL.

We know placing ducts in a vented, unconditioned attic is a bad idea because we've modeled it (Siegel, Walker & Sherman 2000; Walker 2001; Hendron et al. 2002; Hedrick 2003b; Kinney 2005). We know it's a bad idea because we've measured it (Jump, Walker & Modera 1996; Hedrick 2003a). In fact, we know even when it is done pretty well (which is rare), it reduces system efficiency by about 20% – not a trivial number. People spend big bucks trying to save 20%. Or even bigger bucks to produce that amount of electricity with sexy solar panels. And the worst part is that it's a pretty permanent situation. Fifty years from now, after we've evolved to the point where we agree this is a bad idea, it will be really hard to change things. It's kind of like figuring out how to go back and insulate walls in millions of homes built in the first half of the $20^{th}$ century. Actually, it's worse than that.

And here's what's really strange. Electric utilities hand out money for things that have far less impact. They might give you $500 to upgrade to a SEER 15 air conditioner because it's cheaper than building a new power plant. We'll take it! Then we'll take our fancy SEER 15 air conditioner (which will probably last 15 years or so and is really easy to upgrade) and hook it up to a lousy delivery system (which will likely be around for 100 years and is really hard to improve), effectively turning it into a SEER 12 unit (Neal 1998).

Most of us agree it's better and cheaper to reduce demand than to increase supply. So let's see what it saves, what it's worth, and what it costs to move ducts inside the building enclosure, and compare that to other popular efficiency measures that electric utilities commonly pay for.

## What it Saves

### Savings Reported from Previous Studies and Reports

Table 1 provides an overview of the energy, demand, and cost savings estimated from some earlier studies. Long and short of it – ducts in attics are about 80% efficient at best, add ½ to 1 ton to the cooling load, and increase peak demand by about 1 kW.

**Table 1. Sampling of Measured and Predicted Savings From Previous Studies**

| Reference | Type | Highlights |
|---|---|---|
| Jump, Walker & Modera 1996 | Measured | Average distribution system efficiency of 76% after repair in Sacramento, CA. |
| Siegel, Walker & Sherman 2000 | Modeled | Predicts 1.0 kW electric demand savings and 55% daily energy savings when moving typical new duct system from vented attic to cathedralized attic space and reducing A/C sizing in Sacramento, CA. |
| Walker 2001 | Modeled | Shows distribution system efficiencies of ~75% for R-4.2, 10% leakage duct system in attics during cooling season in Sacramento and Phoenix. |
| Hendron et al. 2002 | Modeled | At duct leakage levels allowed under 2009 IECC, modeling indicates about 20% cooling energy savings and 1.0 kW of demand reduction from cathedralizing attic in Las Vegas. |
| Hedrick 2003a | Measured | Measured duct leakage-to-outside averaged 29 cfm25 in 16 CA homes with ducts inside conditioned space – some using drop ceilings, some with cathedralized attics – a fraction of the leakage allowed by code and commonly found in new homes with ducts in the attic. |
| Hedrick 2003b | Modeled | California statewide average energy savings for a 2-story, single-family home is predicted to be 3,400 kWh/year from moving ducts inside conditioned space. Associated predicted demand savings ranged from 0.8 to 3.3 kW, depending on climate. |
| Kinney 2005 | Modeled | Predicts about \$220 to \$240 in annual energy cost savings when reducing duct leakage to outside from 30% to 4% and reducing conductive losses using R-30 insulation (essentially moving ducts inside conditioned space) in Phoenix and Las Vegas. |

### Our Analysis

We looked at three cooling-dominated climates (Houston, Phoenix, and Las Vegas) where standard construction practice is to place ducts in the attic. In the first part of the analysis we used ASHRAE Standard 152-2004 (ASHRAE 2004) calculation procedures to estimate the energy penalty associated with locating the ducts in the attic. We then used an annual building simulation tool (BEopt 0.9 software[1]) to estimate the annual energy savings and peak demand reduction associated with relocating the ducts to conditioned space.

[1] The BEopt software tool was developed at NREL to identify optimal building energy designs aimed at minimizing the total of the amortized cost of improvements and the cost of energy. It produces designs that minimize combined construction and energy costs by using the DOE-2.2 and TRNSYS energy simulation programs to automate a sequential search technique for locating least-cost solutions on a path toward net zero energy. The software and underlying methodology are described in detail by Christensen et al. (2005, 2006) and Horowitz et al. (2008).

The prototypical house used in our analysis is a 2-story, 2500 sq. ft., slab-on-grade home with R-13 walls, R-30 vented attic, and 0.3 solar heat gain coefficient (SHGC) windows. The house has a SEER 13 air-conditioner, gas furnace, complies with ASHRAE Standard 62.2 for ventilation requirements, and is assumed to be fairly tight with a 0.0003 specific leakage area (SLA). The ducts are located in the vented[2] attic and assumed to be well insulated and well sealed with R-8 insulation and 5.5% leakage on the supply side and 4.5% leakage on the return side. This duct system, characterized in the BEopt software as "tight," can be considered pretty well constructed, exceeding the minimum requirements of the 2009 IECC.

ASHRAE Standard 152-2004 establishes a methodology for calculating the distribution system efficiency (DSE) [3] of a ducted system. We used appropriate cooling system capacities and air flow rates for our example home and Standard 152 procedures to calculate DSEs for the three locations. The results are shown in Table 2.

**Table 2. ASHRAE Standard 152 Calculated Distribution System Efficiency**

| | Houston | Phoenix | Las Vegas |
|---|---|---|---|
| Equipment Cooling Capacity (kBtu/hr) | 36.0 | 48.0 | 42.0 |
| Cooling Fan Flow (cfm) | 1200 | 1600 | 1400 |
| Cooling Supply Duct Leakage (cfm) | 66 | 88 | 77 |
| Cooling Return Duct Leakage (cfm) | 54 | 72 | 63 |
| Cooling Design DSE | 71% | 72% | 73% |
| Cooing Seasonal DSE | 79% | 82% | 81% |

The average DSE for the three locations on the design day, which would be considered the day of the season when cooling demand is highest, is 72%. This means that on the hottest day of the summer, 28% of the air-conditioner output is ultimately lost. Over the entire cooling season the average loss in cooling capacity is 20%. So in a climate where the air-conditioner is likely used for eight to nine months of the year, 20% of the cooling produced by the air-conditioner is simply thrown away by the distribution system.

The obvious alternative is to place the ducts in conditioned space. Here, most of the air leakage and thermal losses of the distribution system would go into cooling the living space. The end result is that the cooling system design load, energy consumption, and peak demand imposed on the utility are reduced.

To estimate reductions in annual cooling energy usage, peak load, and peak demand, BEopt 0.9 software was used to simulate the prototype house over the course of an entire year, in the three climates previously mentioned, with the ducts first located in the attic and then moved to the living space. In BEopt, ducts in living space are assumed to have a DSE of 100% (an admittedly optimistic assumption and difficult to achieve in practice). Table 3 shows the percent reduction from the baseline case (ducts in the attic) to the case with the ducts located in conditioned space.

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[2] Attic vent area set to 1 sq. ft. per 300 sq. ft. of attic floor area.

[3] Modera (1993) provides a pretty clear definition of DSE: *the ratio of the energy that would be consumed by a house using a given piece of heating or cooling equipment, to the energy consumed by that house with the thermal distribution system connected to that same piece of equipment.*

Table 3. Savings Due to Moving Ducts Inside Living Space

| | Houston | Phoenix | Las Vegas |
|---|---|---|---|
| Reduction in Required A/C Capacity | 24% | 24% | 23% |
| Reduction in Annual Cooling Electricity Usage | 17% | 16% | 14% |
| Reduction in Peak Cooling Demand | 22% | 23% | 22% |

Let's take a closer look at what these savings mean. On average (for this particular home), the cooling system can be reduced by nearly 0.8 tons of capacity. The capital cost savings associated with this capacity reduction will be realized every time the air-conditioning unit is replaced, (about every 15 years), because the ductwork will be used for the life of the home. According to the Energy Information Agency, the average price of electricity in these three cities during 2009 was 12.13 ¢/kWh (EIA 2009), meaning on average the homeowner would save more than $80 per year to cool their home. (This does not include additional savings attributed to heating the home during the winter.) The peak demand placed on the utility, which occurs on the hottest day of the year, is also reduced on average by more than 0.75 kW. These savings ultimately reduce the need to construct additional generation and distribution capacity as new homes are added to the utility system. Time-of-use rates, likely to become more common with the advent of smart grid technologies, will increase the cost of running air-conditioning units during periods of peak demand, further bolstering our case for moving ducts out of the attic.

## What it Costs

There are several approaches to building homes in cooling-dominated climates with ducts located inside the enclosure: (1) cathedralizing the attic – moving the thermal and air barrier from the attic floor to the roof deck; (2) using drop ceilings and soffits below the attic floor; (3) in 2-story homes, using the space between floors; and (4) using a scissor-truss to create a plenum below the attic and above the living space. The fourth approach is not widely used. The first three have been used by quite a few builders so there is a fair bit of cost data in the literature. Ultimately, the best approach, and associated cost, will depend on each builder's current construction practices.

**Figure 2. Schematics of Four Approaches To Moving Ducts Inside Conditioned Space**

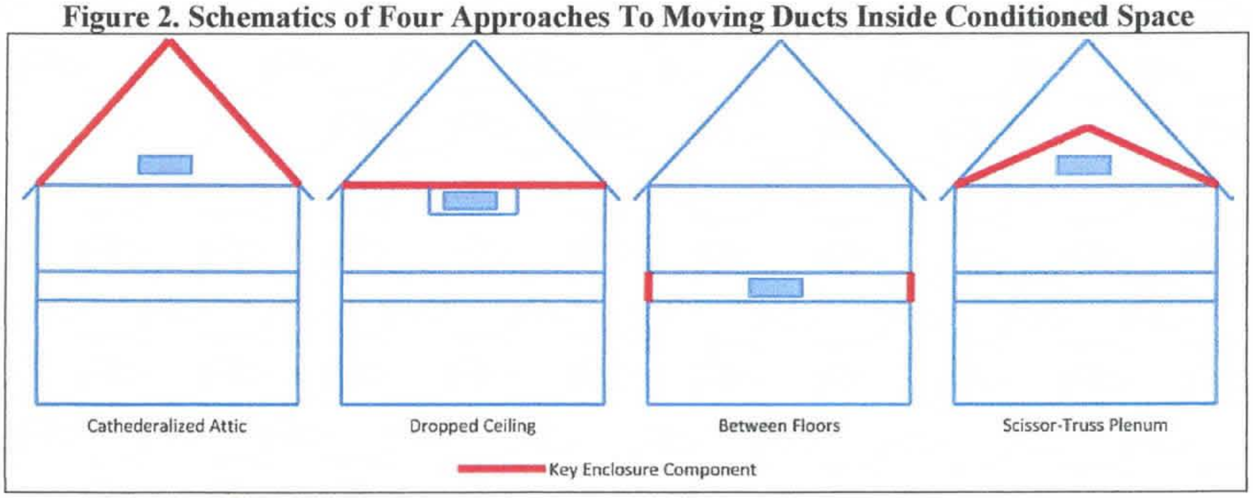


**Figure 3. Examples of Dropped Ceiling and Between Floor Locations During Construction**


Source: Janet Mcilvane, FSEC (left) (used by permission of FSEC) and IBACOS, Inc. (right) (NREL PIX 14234).

Kerr (2008) provides an overview of an approach taken by two production builders in the Northwest. Both used space between the first and second floors (one used open-web trusses) and added furnace closets to get the air handler into conditioned space. The estimated cost to make the change was $500.

Lubliner et al. (2008) report stipulated costs of $650 for utility programs in the Northwest developing demand-side programs that encourage relocation of the duct system to the conditioned space. They state that one production builder in the Northwest added $675 to the price of its homes to cover this cost.

Hedrick (2003b) estimated additional construction costs for approaches 1, 2, and 4 using three methods of estimation for various house sizes. Cost estimates for approach 4, the plenum truss, were quite high, approaching $4000. The costs for approaches 1 and 2, however, ranged from $800 downward to a ***saving*** of $800 for single-family homes. This did not include the savings from downsizing the air conditioner, furnace and air-handling unit, which were estimated to be $1100 to drop from a 4-ton to a 3.5-ton unit or from a 3.5-ton unit to a 3-ton unit.

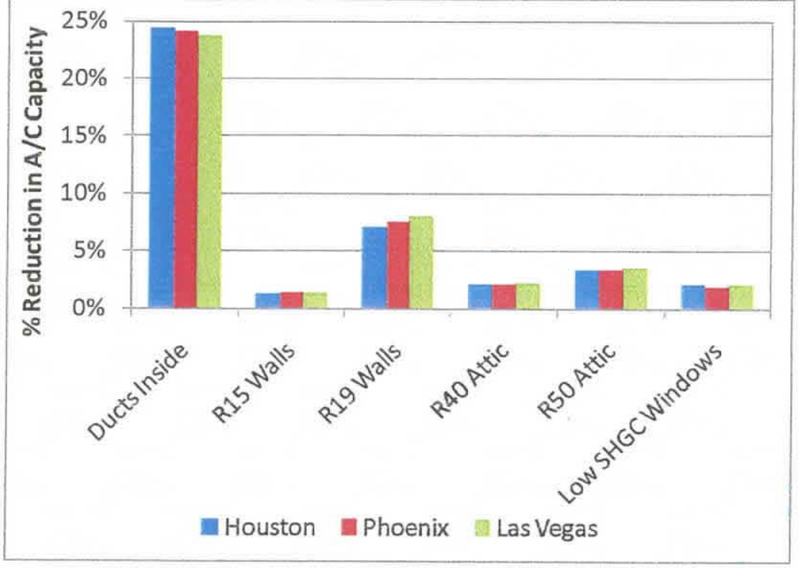
DOE (2010) reports that Tommy Williams Homes in Gainesville, Florida used ducts in conditioned space to meet the Builders Challenge program requirements and produce a net-zero energy home. Ken Fonorrow (2010), the builder's home energy rater, reports the estimated additional cost to move the ducts into dropped ceilings is $800, not including savings associated with downsizing the air-conditioner.

## How it Compares

The easiest way to put the savings attributed to relocating ducts to conditioned space into perspective is to compare it to other energy efficiency upgrades (most of which are often given more attention in energy codes and utility programs than the relocation of ductwork). We used BEopt to compare moving the ducts into the conditioned space to upgrading the wall R-value, upgrading the attic floor R-value, using low SHGC windows, and installing a higher SEER air-conditioner.

Of the energy efficiency upgrades included in the analysis, moving the ducts into conditioned space led to the most significant reduction in the required air-conditioner capacity. Incrementally enhancing the building envelope over the prototype home slightly reduces the need for cooling, but not significantly compared to relocating the ducts. Upgrading the SEER rating of the air-conditioner does nothing to dramatically influence the air-conditioner capacity and only decreases the amount of energy required to provide a certain amount of cooling, thus the effect of SEER was not included in Figure 4.

**Figure 4. Reduction in Required Cooling Capacity for Various Efficiency Upgrades**




In terms of the amount of electricity required to cool the home over the course of the year, relocating the ducts slightly out performs upgrading to even a SEER 17 air-conditioner (see Figure 5). However, relocating the ductwork is a one-time expense that is amortized into the cost of the mortgage. The air-conditioning unit, by contrast, is an upgrade that will need to be repurchased. Again, incrementally enhancing the building envelope goes only so far to reduce the energy consumption required to cool the home.

Relocating the ducts to conditioned space reduces peak demand far more than any other energy efficiency upgrade included in the analysis (see Figure 6). The SEER 15 air-conditioner reduces peak demand more than the SEER 17 air-conditioner, which is contrary to expectations, because the SEER 17 unit is a two-speed unit and can operate at low stage to save energy when the cooling load is not as high, the energy efficiency ratio (EER) for the SEER 17 unit at stage 2 cooling is slightly lower than that for the SEER 15 unit. Thus, on the hottest of days the SEER 17 unit will draw more power. Upgrading the attic insulation levels and windows does little to reduce demand. R-19 walls show modest improvement over the R-13 walls.

Figure 5. Reduction in Cooling Electricity Usage for Various Efficiency Upgrades

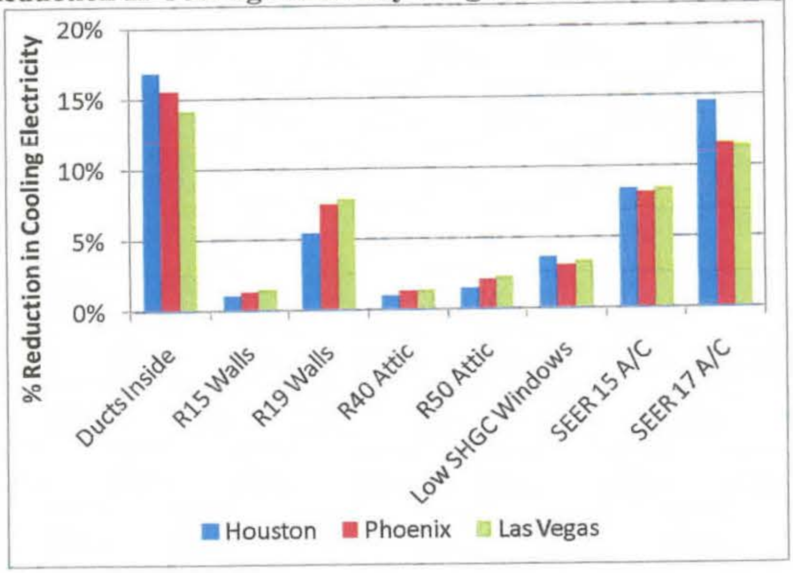
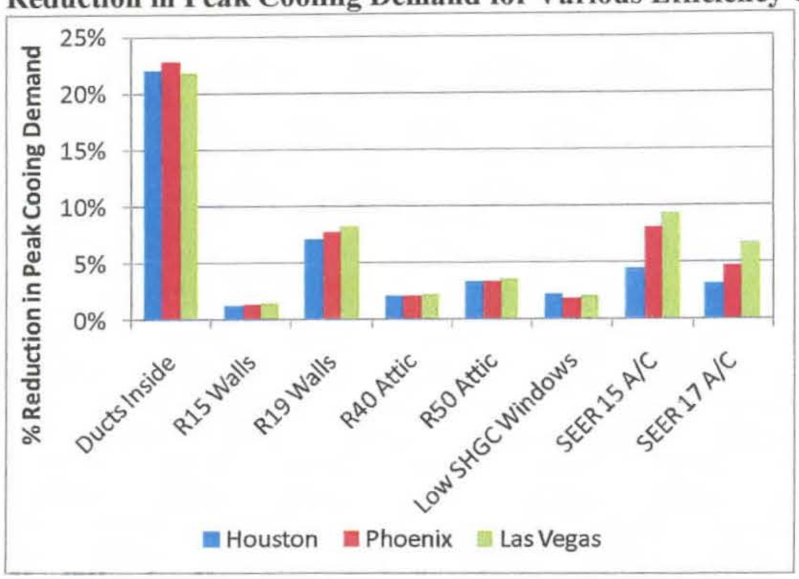



Figure 6. Reduction in Peak Cooling Demand for Various Efficiency Upgrades

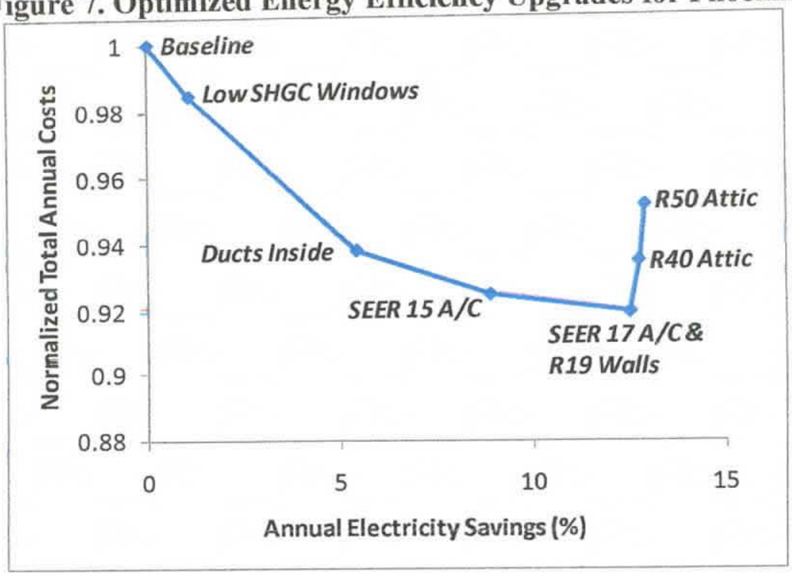



Selecting energy efficiency upgrades should be based not only on the potential savings but on the expected total cost, including the initial capital cost, energy bill savings, and replacement cost after a given number of years. BEopt was selected to perform this analysis, in part, because it is well suited to optimize the order in which these upgrades should be selected. Only the results for Houston are shown in Figure 7, but the results for the other two cities display similar trends. The total normalized cost relative to the baseline is plotted on the y-axis and the annual electricity savings on the x-axis. Total normalized cost includes the amortized incremental capital cost of the energy efficiency measure, including replacements during the 30-year mortgage, and the associated energy cost savings. Values less than 1.0 indicate energy cost savings are greater than the incremental mortgage and replacement costs.

The first selected energy efficiency measure is upgrading to low SHGC windows, because this option has the most negative slope relative the baseline point. However, the annual energy savings are minimal (1%). Moving the ducts inside is the next preferred option. The percent energy savings per unit cost are slightly higher than upgrading windows, but moving the ducts has the most dramatic effect on annual energy savings. The next preferred option is to upgrade to a more efficient SEER 15 air-conditioner. As can be expected, the electric consumption is most cost-effectively lowered by moving the ducts inside and upgrading the windows before upgrading the air-conditioner.

The final three points deal with wall and attic insulation levels. R-15 walls do not show as a preferred option because of their small incremental benefit over the code R-13 walls and the fact that R-19 walls reduce the framing factor by moving to 2x6 studs spaced 24 inches on center. There is little energy savings associated with higher attic insulation values in these cooling-dominated climates.

**Figure 7. Optimized Energy Efficiency Upgrades for Phoenix**




## A Utility Perspective

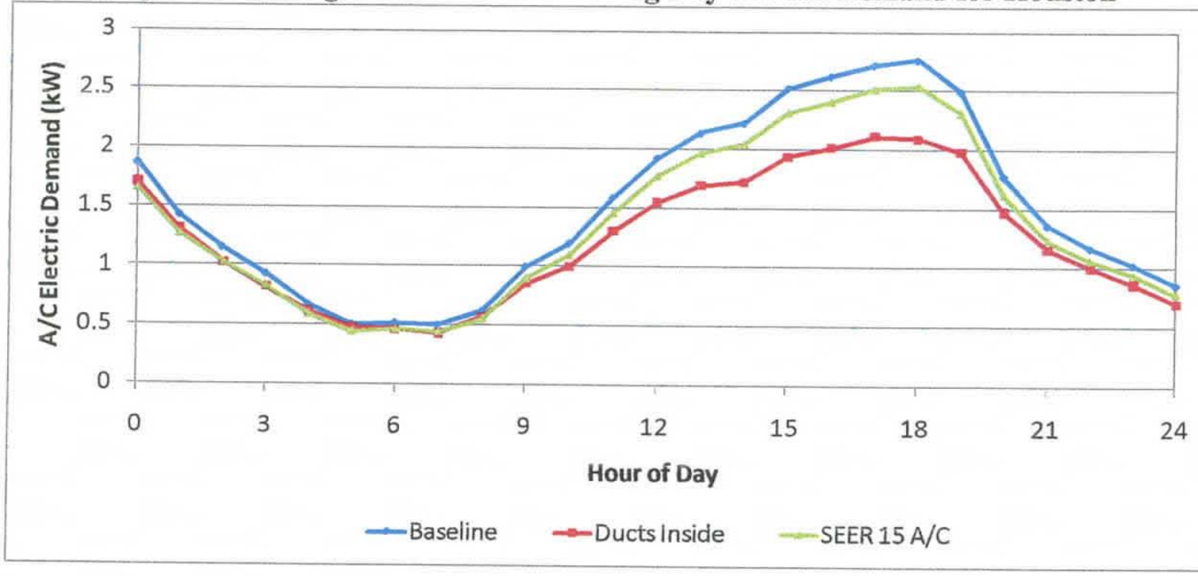
Most electric utilities have programs aimed at reducing system peak demand or overall electrical consumption. The programs generally involve utility investment in energy efficiency measures. In buildings this usually comes in the form of payments for specific technologies (e.g., compact fluorescent lamps) or performance targets (e.g., ENERGY STAR Qualified Home). The size of the payments or rebates is usually based, in part, on the avoided cost to the utility of generating a kilowatt-hour of electrical energy or building the next kilowatt of capacity.

Peak demand for utilities in cooling-dominated climates is generally driven by air-conditioning. Demand-side programs from these utilities tend to target air-conditioning, paying incentives for measures that reduce cooling during periods of system peak. Common measures include low solar heat gain windows, high-efficiency air conditioners, and direct load control. In existing homes, measures might include solar screens, duct insulation and sealing, and air conditioner tune-ups. We could not find any utility that offers direct incentives to design and build homes with ducts in conditioned space.

Our analysis indicates payments to incentivize builders to move ducts out of attics would be a wise investment for utilities in cooling-dominated climates. For example APS, an electric utility serving the Phoenix area, will pay $425 for a SEER 14 air-conditioner (APS 2010). Figure 6 shows moving the ducts inside will save more than twice the peak demand as the air-conditioner, so one might conclude that APS could pay an $800 incentive for a builder to move the ducts. Similarly, CenterPoint and Entergy, two utilities serving the Houston area, will pay $477/kW and $0.16/kWh for duct sealing in existing homes (DSIRE, 2009). Based on our estimates of demand and energy savings for Houston, similar rebates might total $380 for moving a duct system from the attic into conditioned space in new homes. And finally, according to the DSIRE website (2009), NV Energy, which serves the Las Vegas market, was paying $280 to upgrade to a SEER 14, 4-ton air conditioner in 2009. Again, referring to the results in Figure 6, one might conclude that a $500 rebate for homebuilders would be appropriate for moving the ducts.

The BEopt simulations results in Figure 8 emphasize the impact of shaving peak demand. The high demand associated with air-conditioning generally occurs over the span of only a few hours in the evening. The additional capacity required by the electric utility to meet the peak cooling demand is being fully utilized for several hours of the day on the hottest days of the year. Thus, the demand offset by relocating the ducts to conditioned space in new construction will ultimately reduce the need for additional installed capacity and improve the load factor for the electric utility.

**Figure 8. Cooling Demand Profile During Day of Peak Demand for Houston**




The accumulation of potential savings is startling. According to the U.S. Census Bureau (2010), approximately 930,000 single-family homes were built between 2000 and 2009 in the combined markets of Houston, Phoenix, and Las Vegas. Assuming all these homes were constructed with ductwork in the attic, and using our savings estimate of 0.75 kW per home, nearly 700 MW of new installed capacity could have been avoided if all these homes had been built with ducts inside conditioned space.

## Summary

Building a home in a hot climate with ducts located in the attic is a bad idea. Moving the ducts inside the thermal enclosure during construction is relative inexpensive and will reduce electric consumption for cooling about 15%, will reduce demand by about 0.75 kW, and will reduce needed cooling capacity by 0.5 to 1 tons. Spending money to move the ducts inside is a better investment than other commonly incented energy efficiency measures.

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# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



**1. REPORT DATE** *(DD-MM-YYYY)*
August 2010

**2. REPORT TYPE**
Conference paper

**3. DATES COVERED** *(From - To)*

**4. TITLE AND SUBTITLE**
Ducts in the Attic? What Were They Thinking? Preprint

**5a. CONTRACT NUMBER**
DE-AC36-08-GO28308

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**
D. Roberts and J. Winkler

**5d. PROJECT NUMBER**
NREL/CP-550-48163

**5e. TASK NUMBER**
BE10.1001

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

**8. PERFORMING ORGANIZATION REPORT NUMBER**
NREL/CP-550-48163

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

**10. SPONSOR/MONITOR'S ACRONYM(S)**
NREL

**11. SPONSORING/MONITORING AGENCY REPORT NUMBER**

**12. DISTRIBUTION AVAILABILITY STATEMENT**
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT** *(Maximum 200 Words)*
As energy-efficiency efforts focus increasingly on existing homes, we scratch our heads about construction decisions made 30, 40, 50-years ago and ask: "What were they thinking?" A logical follow-on question is: "What will folks think in 2050 about the homes we're building today?" This question can lead to a lively discussion, but the current practice that we find most alarming is placing ducts in the attic. In this paper, we explore through literature and analysis the impact duct location has on cooling load, peak demand, and energy cost in hot climates. For a typical new home in these climates, we estimate that locating ducts in attics rather than inside conditioned space increases the cooling load 0.5 to 1 ton, increases cooling costs 15% and increases demand by 0.75 kW. The aggregate demand to service duct loss in homes built in Houston, Las Vegas, and Phoenix during the period 2000 through 2009 is estimated to be 700 MW. We present options for building homes with ducts in conditioned space and demonstrate that these options compare favorably with other common approaches to achieving electricity peak demand and consumption savings in homes.

**15. SUBJECT TERMS**
duct; ventilation; attic; conditioned space; duct location

| 16. SECURITY CLASSIFICATION OF: a. REPORT | b. ABSTRACT | c. THIS PAGE | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| Unclassified | Unclassified | Unclassified | UL | | 19b. TELEPHONE NUMBER *(Include area code)* |

**Standard Form 298** (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

F1147-E(10/2008)

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# Energy Vanguard Blog

## Case Closed: Get Those Air Conditioning Ducts out of the Attic

*Posted by Allison Bailes on Mon, Jun 20, 2011*

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Remember that article I wrote about ducts installed against the roof deck and how I said it was probably the absolute worst single location for installing ducts? Well, in the comments, Dave Roberts, a senior engineer at the National Renewable Energy Lab (NREL), wrote about a paper he co-authored last year and included a link to it. Up against the deck may be the worst place in the attic to install ducts, but Roberts shows that putting them in the attic at all is the worst place in the house you can install ducts.

The report, *Ducts in the Attic? What Were They Thinking?*, summarizes the research that's been done about putting ductwork in unconditioned attics and basically says it's about the stupidest thing we do in homes that do a lot of air conditioning. I encourage you to download and read this report. If you're building or remodeling a home, make sure the general contractor (if it's not you) and the HVAC contractor get copies.

I love the analogy they use to introduce one of the main problems with this location. "Heat exchangers," they write, "are designed to transfer as much heat as possible from one fluid to another." Comparing this configuration to a solar water heater, they make the case that putting air conditioning ducts in a hot attic is an effective

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way to heat up the conditioned air as it travels from the air handler to the conditioned space inside the home.

If you've studied heat transfer at all, you may recall that the rate at which heat moves from a warmer to a cooler body depends on the temperature difference, which we abbreviate as $\Delta T$. An attic can get up to about 130° F in the summer, and the conditioned air entering the ducts is about 55° F or so. With hundreds of square feet of ductwork surface area in the attic and a $\Delta T$ of 75° F, the air coming out of the vents in your home will be significantly higher than 55° F. Throw duct leakage into the mix, and the problems are even worse.

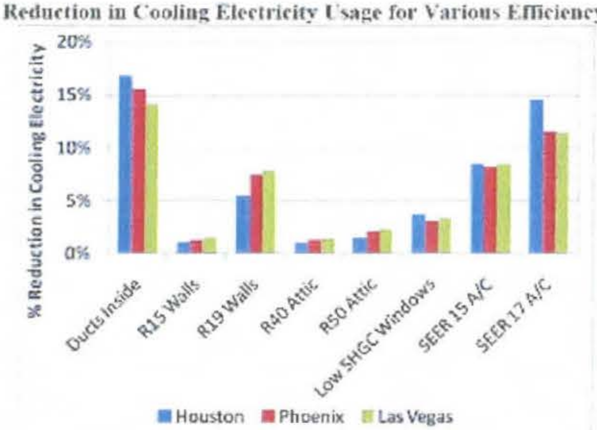
What Roberts and his co-author Jon Winkler did, in addition to reviewing the literature about this topic, was to model the savings possible when you relocate the ducts from an unconditioned attic to the conditioned space inside the building envelope. They chose Houston, Phoenix, and Las Vegas as the locations for their modeled houses. The table below summarizes the main results.

**Table 3. Savings Due to Moving Ducts Inside Living Space**

| | Houston | Phoenix | Las Vegas |
|---|---|---|---|
| Reduction in Required A/C Capacity | 24% | 24% | 23% |
| Reduction in Annual Cooling Electricity Usage | 17% | 16% | 14% |
| Reduction in Peak Cooling Demand | 22% | 23% | 22% |

In addition to comparing ducts in the attic to ducts inside the building envelope, Roberts and Winkler also looked at electricity savings of other measures, such as adding insulation, installing better windows, and using higher efficiency air conditioners. The table below shows that moving the ducts inside is the first thing you should do to save the amount of electricity you use.

**Figure 5. Reduction in Cooling Electricity Usage for Various Efficiency Upgrades**




In addition to saving on air conditioning operating costs, the upfront cost of cooling equipment is lower in efficient homes. Roberts and Winkler looked at moving the ducts inside compared to other building envelope improvements, and again, moving the ducts inside beats all the other methods for achieving this objective, as shown below.

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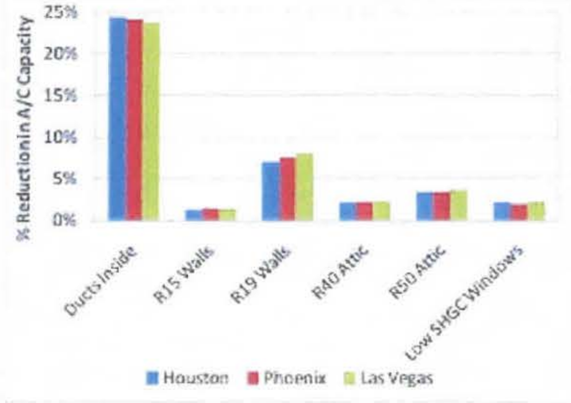
**Figure 4. Reduction in Required Cooling Capacity for Various Efficiency Upgrades**




This report, which the authors delivered at the ACEEE (American Council for an Energy Efficient Economy) Summer Study in August 2010, shows definitively that putting ducts in attics in cooling dominated climates is a practice that needs to end.

Download the paper here: [*Ducts in the Attic? What Were They Thinking?*]

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**Tags:** **HVAC**, **design**, **building enclosure**, **heating & cooling distribution**

**M. Johnson** 6/20/2011, 4:01:47 AM

Very impressive research. One thing would be nice to see in the future, would be case studies where people actually relocate ducts without building a new house.

**Ira Eisenstein** 6/20/2011, 4:23:49 AM

It's great that we have research to support this but isn't it "intuitively obvious"?
If you're trying to get cold air to a room, you don't run the duct through the hottest place in the house.
In the winter, the exact opposite happens...
You're trying to get warm air to a room, and the duct is running through the coldest part of the house.

It's done this way because it's easier and cheaper to run a flex duct through a wide open space than to fit it through and around floor



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