Realizing 5-30% Energy Savings Potential of HVAC Systems

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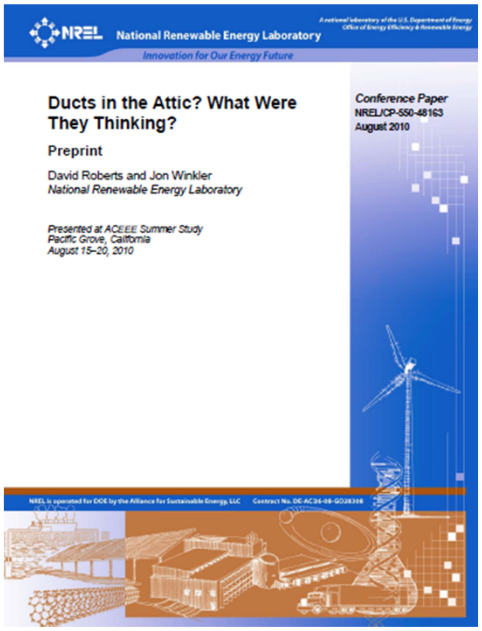
Research Question

What are the achievable energy savings from common modifications to existing residential HVAC equipment?

We've Been Here Before



Green Production Building—Moving Ducts Inside

Savvy builders can finance green features with the money homeowners would have spent on higher utility bills.

by Ryan Kerr

The green production builder is responding to clients' wishes to build with the new goal of promoting better occupant health and environmental stewardship. The best part? Savvy builders can finance green features with the money homeowners would have spent on higher utility bills. The utility bill savings are generated by what is possibly the greenest building practice of all—energy efficiency.

The Building Industry Research Alliance (BIRA) is focused on supporting the design and construction of near zero energy homes as part of DOE's Building America program (see "About the Building America Program and BIRA"). As a member of BIRA, I have the privilege of working with some of the brightest building industry professionals to study advanced technologies and designs that promote Building America's ideal of net zero energy homes. Even when energy-saving features do in fact save energy, additional work is needed to make them cost-effective in production home construction. The first step is to move from design to practice. The second step is market transformation. And market transformation is taking hold in Washington State, as two production builders implement a highly efficient, yet underutilized, design concept: moving ducts inside conditioned space.

On a trip to visit BIRA research partners in the Pacific Northwest, I met with two production home builders who were moving all their homes' HVAC systems out of unconditioned attics, crawlspaces, and garages and into interior spaces. From the theoretical perspectives of technology and design, this technique is neither new nor advanced. From the construction perspective, however, it is hardly a mainstream practice, and it represents a very significant step toward increasing a home's heating and cooling energy efficiency. In the world of production building, change means time, liability, and money. Thus builders are reluctant to adopt any new technique—but now that home buyers are beginning to recognize the value of energy efficiency, change can mean profit. The techniques used by our two builder partners are brilliant in their simplicity. And they are affordable, both in first costs, because they make use of construction efficiencies, and in operational costs, because they save energy. This article discusses each builder's approach to moving the HVAC system inside, and lays the groundwork for other builders to do the same.

Moving Ducts Inside. So What?

ASHRAE suggests that building professionals collaborate to bring ducts inside:

Ductwork costs and system energy use can be reduced when the home designer/architect, builder, subcontractors, and HVAC installer collaborate to place ducts in conditioned spaces and minimize duct runs. Residential duct systems in unconditioned spaces can lose a significant percent of the energy in the air they distribute. These losses can be almost entirely eliminated by simply locating ducts in the conditioned space (insulated building envelope), which is a cost-effective way to increase heating and cooling equipment efficiency and lower utility bills. (Modera, cited in ASHRAE 2004, p. tk)

Let's see how each of our two builder partners responds to this suggestion. Then we'll look at some caveats, as well as some alternative techniques.

Quadrant Homes: Advanced Energy for the Beginning Homeowner

Quadrant Homes began building homes in the Seattle area in the 1960s. Today it builds more than 1,000 homes a year, mainly for entry level buyers. Quadrant is the largest builder in its geographic region and boasts industry-leading annual profit margins.

Quadrant Homes has obtained notable market results using an even-flow predictable scheduling scheme, in which it begins seven homes per day and finishes each house in precisely 54 days. Quadrant follows recognized lean principles (as used by companies like Toyota), in which completion is achieved by maximizing effectiveness in both the product design and manufacturing stages. This includes balancing work so all stages flow evenly, and continuously improving its design and manufacturing techniques for efficiency and good design, while meeting customer needs.

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We Learned:

- Ducts matter
- Ducts outside conditioned space are a problem
- There are cost-effective solutions for new construction

But What if Ducts Are Inside…

Problem Statement

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HVAC equipment is not performing as efficiently as expected when installed in the field

- Oversized equipment
- Poorly performing & undersized distribution systems
- Low airflow
- Equipment cycling
- High static pressures
- System not meeting the load profile of the building

Problem Statement

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Background

- Typical air distribution systems only 60-75% efficient[1]
- More than half of all equipment may be oversized[2]
- Traditional utility programs only incentivize replacing the equipment

How do we fix this?

- Collect field data on which modifications have the most energy savings potential and are the most cost effective.

1. Improving the Efficiency of your duct system, US DOE
2. Pigg, Scott, 2008. “Central air conditioning in Wisconsin – a compilation of recent field research”, Energy Center of Wisconsin Report No. 241-1

Estimated Costs & Energy Savings

Measure	Cost	Gross Annual Therm Savings	Gross Annual kWh Savings	Simple Payback
Total system efficiency upgrade	$2500	230	700	11.6 yrs
Duct renovation	$2000	155	465	13.9 yrs
Combustion tune-up	$175	50	100	4.3 yrs
Air balancing	$325	25	135	10.9 yrs

- **Based on data collected from work done in Iowa, average costs and energy savings from sample homes.**
- **Duct renovation includes an additional or larger return and larger filter rack**
- **Payback based on $0.60/therm gas; $0.11/kWh electric**
- **Costs should go down as market grows.**

Project has two parts:

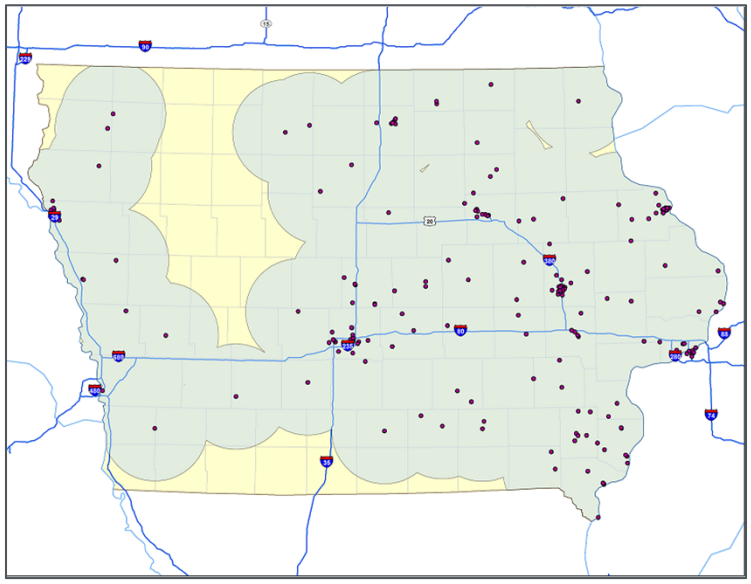
1. Uses trained HVAC contractors to identify:
   - Which system deficiencies are most common
   - What costs are associated with correcting these deficiencies

2. Collects energy use data on homes that have undergone recommended modifications to determine
   - What level of energy savings was achieved
   - Which modifications are the most cost effective

Experiment

Scope, Part 1

- Involves HVAC contractors trained through MEEA/ESI's SAVE certification program.
- Conducted throughout the state of Iowa
- Cold climate zone
- HVAC Contractors identifying which system deficiencies are most common and what level of energy savings can be expected.



MEEA's network of trained contractors

Experiment

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Scope, Part 1

- Contractors taking system measurements to narrow down where deficiencies occur.
  - Static Pressures
  - Airflows
  - System Temperatures
- Contractor measurements not used to quantify savings for this project.
- Homeowner will elect to make some or all of the recommended corrections.

Examples of Common System Modifications

Modification	Examples
Duct Renovation	Increase size of return or supply Replace restrictive transitions Straighten/extend flexible ducts Replace restrictive transitions Repair damaged or poorly installed duct joints
Adding Duct Insulation	Install or increase duct insulation
Test and Balance System	Adjust airflow delivered to each room
Combustion/Refrigerant Adjustment	Test and adjust combustion efficiency Test and adjust refrigerant charge
Clean Coils and Heat Exchangers	Clean or replace cooling coils Clean heat exchangers and heating coils
Add or Replace Filter	Replace restrictive or dirty filter Add return air filter grille/housing
Adjust Fan	Increase fan speed to required air flow Clean and repair fan motor
Repair/Remove Grills	Remove/Replace grilles/register Tighten connections at boots/grilles

Experiment

Scope, Part 2

- Post modification energy savings will be determined on four homes.
  - Homes identified based on part 1
  - Conduct a weather normalized utility bill analysis
- From this we can determine:
  - Which modifications have the most energy savings potential
  - Which modifications are the most cost effective

Experiment

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Technical Approach

- **Measurements will be taken using industry accepted standards**
  - ASHRAE 152
  - ASHRAE 111
  - Calibrated and having recommended levels of accuracy
- **Temperatures**
  - Supply/Return
- **Static Pressures**
  - Digital pressure transducer
- **Airflows**
  - Most appropriate method based on the system/location
  - Flow Plate, Duct-Pressurization/Flow Measurement Device, Traverse
- **Combustion**
- **Fuel Consumption**
  - Fuel input to equipment
  - Weather normalized utility bill analysis
- **Housing Characteristics**
- **Nameplate data**

Expected Results and Follow On

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Expected Results

- Energy savings associated with common system modifications
  - Utility bill analysis
- Costs associated with common system modifications
- Data to be used by utilities in program design

Follow-on testing

- Detailed energy savings tests on a select number of homes (entire heating/cooling season)
  - Sub metering
  - Long term monitoring
- Compare results with lab tests on same equipment