Improving the Energy Efficiency of Air Distribution Systems in New California Homes

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Thermal distribution systems represent the most promising opportunities for cost-effective energy savings in residential new construction. This paper describes the results of an unusual but on-going collaboration between the building industry, the environmental community, the research community, and the regulators to develop cost-effective, implementable procedures for improved heating, ventilating and air conditioning (HVAC) duct system design, fabrication, and installation.

The procedures were developed and their incremental costs and benefits were estimated. There are immediate heating and cooling energy savings of 12% or more obtainable from duct sealing alone at an incremental cost of approximately $250 per home. This incremental cost can decrease to zero with experience and competition.

Current practice for sizing ducts and HVAC systems does not properly account for duct leakage and some other duct losses, making it difficult to properly size systems that have minimal leakage. Modifications to the Air Conditioning Contractors of America (ACCA) methods and procedures for design and sizing ducts and systems are suggested.

An implementation strategy was devised to provide a practical, self-supporting means for the residential new construction industry to adopt and utilize these procedures. It involves first creating market value for builders using energy efficient mortgages and home energy ratings, which will result in market differentiation between homes with improved HVAC installations, and those with current-style HVAC installations. Second, the strategy proposes to provide credit in Title 24 for improved HVAC systems, and lastly, once there is significant market penetration of improved HVAC systems, require them as part of the energy codes.

INTRODUCTION

Thermal distribution systems provide an excellent opportunity for cost-effective energy savings in residential new construction (Modera, 1993; Modera and Jump, 1995; Modera and Wilcox, 1995; Proctor, 1995). Utility demand-side management programs have demonstrated that builders can be motivated through incentives to install improved duct systems and that heating ventilation, and air conditioning (HVAC) subcontractors can provide improved duct installations for a few hundred dollars additional cost. With the decline in utility programs, other methods to generally implement improved duct systems are required. This study resulted from a collaborative effort of the building industry (represented by the Building Industry Institute, BII, and the California Building Industry Association, CBIA), the environmental community (National Resources Defense Council, NRDC), the research community (California Institute for Energy Efficiency and Lawrence Berkeley National Laboratory), and the regulators (California Energy Commission, CEC) with a goal to develop a set of procedures for installation of tight ducts and a practical strategy for their implementation.

A survey was performed to determine how other states and organizations are encouraging improved duct systems, what they are encouraging, and their results. This information was integrated into a set of procedures that was reviewed by production builders and their HVAC subcontractors. As part of their review, potential construction costs and savings that would result from use of these procedures were estimated. Comments from the industry that helped clarify or otherwise improve the procedures were incorporated. Industry standard design procedures were reviewed and improvements developed. Based on all of this information, an implementation strategy was developed that can encourage improved duct systems in new residential construction.

The suggested procedures address three main issues: 1) duct leakage, 2) HVAC system design, 3) duct layout. In addition, the procedures include testing recommendations and criteria for leakage and airflow. The procedures suggest room-by-room loads calculations using Air Conditioning Contractors of America (ACCA) calculations, a determination of detailed duct layout, system sizing using ACCA calculations, installation using UL 181 approved materials and specified connection techniques, and tests for proper air conditioner size and charge, minimum duct leakage, and proper air flows.

This study has resulted in a set of buildable, cost-effective procedures for improved design, fabrication, installation and testing of residential HVAC systems that have been reviewed by a number of builders, HVAC subcontractors, as well as staff from the CEC, NRDC, and CBIA. An analysis of the cost of implementing these procedures and the resultant energy savings has shown that, in the short term there will be some cost to the builder, but that it will result in a very cost-effective improvement to the consumer. In the longer term, as builders and HVAC subcontractors improve their techniques, the costs can drop to zero, or even provide some savings in construction costs. In addition, as these implementation improvements occur, there are additional savings to the consumer, making this change in construction techniques even more valuable to the consumer.

The proposed implementation strategy utilizes existing market vehicles, primarily home energy ratings with integrated duct diagnostics, and energy efficiency mortgages, to produce initial market penetration. This would be followed in the next energy code change with some integration of the procedures into the California Residential Energy Efficiency Standards. It is recommended that the implementation strategy be tested as a pilot to permit close observation of implementation and its results.

IMPROVED DESIGN, SPECIFICATION AND INSTALLATION PROCEDURES

This project began with a survey of on-going residential duct programs to determine the state-of-the-art. From this information, a draft set of procedures was synthesized for California new construction. The original work statement for this project identified thirteen sources for information regarding improved design, specification and installation procedures. Of these, nine provided valuable information that was used in the development of the final draft procedures. Additional sources were identified during the survey process, and a total of fifteen contacts were made that provided valuable information that influenced development of the draft procedures (please see acknowledgments).

A factor that limited use of program information from other states was that most of the information uncovered from on-going residential programs was based on retrofit improvements to duct systems. This study was performed exclusively for new construction and focused on California construction techniques, which are primarily flexduct systems installed in the attic.

An important consideration to the installation procedures was whether they should be prescriptive or performance-based. Purely prescriptive programs, such as in Florida (State of Florida, 1993), have been developed that prescribe every detail of material and construction of the duct system. In addition, purely performance programs, such as in the Pacific Northwest (BPA, 1995), have been developed in which ducts may be installed however desired by the contractor, but they must be pressure-tested and proved not to leak more than a criterion amount of air.

The choice was made to make California procedures both prescriptive and performance based. The reasoning was that, while performance testing is thought to be required to ensure proper function, some materials need to be prescribed to ensure longevity of the tested performance. For instance, it is quite possible to install a duct system using low-quality duct tape that will perform very well initially, passing reasonable performance requirements, but that will degrade within a few years, resulting in considerable leakage. It is also very possible to use all of the best prescribed materials, but install the system so that it is not easy to detect that there are leaks. Therefore, prescriptive requirements for materials and performance criteria were both determined to be necessary for a long-lasting, quality duct system.

Two California public utilities had DSM programs for tight ducts—Pacific Gas & Electric and Southern California Gas; both were quite popular with builders, both had both prescriptive and performance elements, and both resulted in improved duct systems. These were used as the core of the proposed procedures, enhanced by elements obtained through the nationwide telephone survey (including reports gained through the survey). The enhancements include requirements for loads calculations, duct layout, duct sizing, equipment sizing, and increased testing requirements (i.e., system leakage, pressure, and airflow).

The procedures are written with a one-page summary of all requirements. That is followed by six pages of detailed information on materials requirements, suggested design, fabrication and installation procedures, and required tests and performance criteria, as well as reference sources for additional information. The procedures suggest room-by-room load calculations using Air Conditioning Contractors of America (ACCA) Manual J, a determination of detailed duct layout and sizing using ACCA Manual D, system sizing using ACCA Manual S calculations, installation using UL 181 approved materials and specified connection techniques, and tests for proper air conditioner size and charge, maximum duct leakage, proper plenum static pressures, and proper air flows.

When the procedures are followed, there are two principal, separable actions that result in energy savings, and that have identifiable costs. These actions are 1) Duct sealing, and 2) System design and layout. Industry experience has clearly shown that prescriptive installation procedures alone will not consistently produce HVAC systems that are properly sealed, and that produce proper air flows and distribution. Some testing is required to ensure that the HVAC system is properly designed and installed. The energy savings estimated for each action assumes that sufficient testing is performed to ensure that the HVAC system is performing according to the recommended criteria.

The following matrix (Table 1) has been developed to summarize the potential energy savings and estimated costs and/or savings for each element from the three different issues addressed by the suggested procedures. The cost is per home for a production builder, and assumes volume purchasing discounts as well as amortization of design costs across 25 homes. Negative costs are cost savings.

POTENTIAL IMPACTS ON THE BUILDING INDUSTRY AND ON THEIR CONSTRUCTION COSTS

Industry Survey using Proposed Procedures

Draft procedures were sent to 20 production builders and 25 HVAC subcontractors for review and comment. The reviewers were asked to comment on the practicality of the proposed procedures, to indicate what procedures they already followed, what problems they might encounter with the proposed procedures, and any additional costs or cost-savings that might be incurred due to the procedures.

Responses were obtained from 12 builders and 19 HVAC subcontractors. Their responses were used to make minor changes to the suggested procedures, to analyze costs of the procedures, and to aid in development of the implementation strategy.

Summary of Important Comments

This subsection is a summary of comments made by respondents to indicate their current view of residential HVAC practices in California, and some of the difficulties that the builders and HVAC contractors foresee in improving the HVAC systems.

It was generally held by the survey respondents that the procedures were a good idea, but that their implementation would produce additional costs and that the market would not, by itself, support these additional costs. There was also general consensus that the industry could benefit from improved regulation, but concern was expressed about any new regulations, how they might be structured, and most importantly, how they would be enforced. Many indicated that if current Uniform Mechanical Code (UMC) regulations were enforced that most duct leakage problems would be solved.

Those that had experience with high-performance (i.e., sealed) duct programs supported by utility incentives liked them. Through those programs, HVAC subs were provided with sufficient funds to install a better system and still make money. The builders also felt that they were receiving better ducts. One Southern California HVAC manufacturer said that only ¼ of the HVAC subs were able to work with the utility program requirements because of their limited experience and training. Most cost data for installing sealed ducts that was provided by builders and subcontractors came from experience in the utility programs. This cost data is therefore quite accurate in that it is based on actual experience in the installation of tight duct systems that were tested and passed program criteria.

There was general consensus that the California building industry typically does not employ ACCA or ASHRAE sizing calculations for the duct system. Rather, they are based on experience and ''rules of thumb.'' This leaves an unquantified potential for implementation problems associated with requirements for detailed load calculations, duct layouts, and duct and equipment sizing and selection. A few individuals raised the issue as to whether such a requirement would increase their paperwork, which will add costs.

The potential impacts of testing were difficult to quantify from this survey. Because testing is currently not done on a regular basis, neither builders nor HVAC subcontractors (with a few exceptions) know what tolerances are reasonable, and what the cost would be to perform the testing. In addition, there were significant concerns voiced regarding the logistics of performing testing, mostly from the builders, and what they should be expected to do if the system fails testing, especially regarding air flow requirements. This concern came from both builders and subcontractors. In general, although most understood and appreciated the necessity of some testing, and of establishing tolerances for passing, they warned against too strenuous requirements that would not be cost effective.

Reviewers of the procedures were divided on what values should be used for supply and return air flow tolerances, most contending that as proposed they are not practical. For this reason, the tolerances for supply and return air flows in the testing requirements will be treated as place-holders until there are more test data that can be used to determine reasonable values. This could be done in a pilot program.

Table 1. *Actions, Energy Savings, and Costs of Improvements to Residential New Construction Duct Systems*

DUCT SEALING

Impact	Energy Savings	Cost (production builder $)
Decreased leakage	Approximately 12% heating and cooling energy savings	$214 materials and labor plus $131 to $163 testing; Estimate $100 to $150 for both with LBNL-aerosol sealing
Increase equipment efficiency by downsizing to keep equipment capacity constant	Approximately 3%	Possible small savings from small downsize of system
Improved system capacity from decreased leakage; same amount as total increase in energy efficiency, approximately 15%	None	−$100 (savings); Potential 1/2 ton downsize
Reduced duct diameter due to equipment downsize; Probably one size decrease; Maybe none if ducts are currently too small	Insufficient data to estimate savings	−$50 (Possible savings if ducts can be substantially downsized)
Two-speed equipment improvements (especially heat pumps)	Estimate 1.7 times single speed savings (20% savings rather than 12%)	None—do not downsize equip, allow to run more at low speed
Uniform heating and cooling may provide savings through improved thermostat behavior	Insufficient data to estimate; probably less than 10%	None
Range of impacts[a]	12% to 30%	$377 to -$50 (savings)
Best estimate (short term)[b]	12%	$250
Best estimate (long term)[c]	20% to 25%	$0

System Design (Manual J and Manual D calculations)

Impact	Energy Savings	Cost (production builder $)
Increase system efficiency due to proper air flow	6%–10% cooling savings on orifice systems for 10% to 20% increase in coil air flow; No substantial savings for TXV systems	$10 ($87 average cost of Manual J and Manual D calculations spread over 25 homes, plus intermittent field tests of flows ($50 every 8 homes or $25 every 4 homes))
Potential 10% capacity increase	None	-$60 (savings); average 0.3 ton decrease
Reduced duct diameter due to equipment downsizing—produces improved system capacity (note: ducts may be too small now and there may be a resultant *increase* in size)	Insufficient data to estimate	±$; Unknown whether ducts and systems are currently too large or too small
Uniform heating and cooling; May provide savings through improved thermostat behavior; Unknown	Insufficient data to estimate; probably less than 10%	None
Range of impacts[a]	0% to 10% of cooling	$10 to -$50 (savings)
Best estimate (short term)[b]	4% of cooling	$10
Best estimate (long term)[c]	8% of cooling	−$30 (savings)

[a] Survey and estimate results
[b] Authors' best near-term estimate (some competition)
[c] Procedures part of common practice

Increases in Construction Costs

The California residential building industry has limited experience with large portions of the suggested procedures; therefore, only a limited number of respondents were willing to estimate the incremental costs that would result from implementation of the suggested procedures. When costs were estimated, respondents were questioned to differentiate costs due to requirements for design, materials and labor for fabrication and installation, and testing of the systems. All those responding with cost information had participated in a utility tight-duct program and had direct experience with the costs for those programs. The utility programs also provided most of the respondents with some experience in the costs of testing, although it was more limited. When costs were estimated from utility incentive program experience, the respondents provided their best estimates of actual cost, not incentive values; both builders and HVAC subcontractors who provided this information were very open in their discussion of costs versus incentives. A summary of cost estimates from the survey is provided in Table 2.

Some respondents were only able to provide some of the desired cost information. For instance, some respondents (both builders and HVAC subcontractors) had no experience with ACCA procedures and therefore could not estimate the time and cost required to perform them. In such cases, a high estimate (for a production builder) of the cost—deemed a placeholder value—is included in Table 2. These placeholder values were based on this researcher's recent experience outside of this survey of higher costs that are paid by builders for these calculations. High-cost placeholder values were used to minimize the likelihood that the resultant average might underestimate the cost impact to the industry, which could otherwise lead to later invalidation of the findings and resultant recommendations. Table 2 provides average costs determined both with and without the placeholder values.

It is likely that with experience, builders and their HVAC subcontractors will find methods to design, fabricate, install, and test their duct systems that are more cost-effective than the experience upon which they base their current predictions. It is anticipated that once there is recognized market value for improved HVAC systems, that due to experience and competition, the combined cost for the fabrication, installation, and testing will be closer to $250 for the recommended procedures than the average $346—$383 estimated from the survey results. In addition, as new techniques become available, these costs will be even lower. For instance, the authors estimate that the LBNL aerosol sealing technique, which combines sealing and pressure testing in a single effort, will cost $100 to $150 for production homes (Modera et al. 1996).

Decreases in Construction Costs

During the survey and bidding processes, respondents, especially HVAC subcontractors, were asked to consider and estimate potential cost savings that could result from downsizing equipment and ducts. None saw any immediate potential for such savings. This is because they either do not currently use sizing procedures such as the ACCA Manual J, D, and S procedures and have no experience or basis to estimate a savings, or because they do use these methods and assume (correctly, if all other assumptions are held constant—see Section 2 and Attachment B) that they will get the same sizing results from their calculations after adoption of the proposed fabrication and installation procedures as they do now with their current fabrication and installation procedures.

Nevertheless, it should be possible for HVAC systems to be downsized from their current values due to duct sealing. Field studies have demonstrated increases in system capacity associated with duct-system retrofits (Modera and Jump, 1995). Downsizing could be realized in practice through improved ACCA calculation methods, which would require the more widespread use of these standard calculation methods and procedures for loads and sizing, and standardization of the calculation variables, as discussed in Section 2 and Attachment B. Downsizing could also result from industry experience with sealed ducts. Builders and HVAC subcontractors should come to understand that if additional cooling and heating capacity is provided because the ducts are sealed, then a similar amount of capacity can be removed from the system requirements. This will require industry education and experience with sealed HVAC systems, but may be the quickest route to system downsizing.

If downsizing due to tight duct systems occurs, for a 3 to 3½ ton air conditioning system, which is typical in California new construction, a 15% or approximately ½ ton decrease in capacity should be possible, resulting in a cost savings of approximately $100 for a minimum efficiency, 10 SEER air conditioner (this is the approximate savings to a production builder—savings to custom builders would be greater). Savings for high-efficiency systems will be greater. Savings may also be available for downsizing the ducts; however, it is not currently known whether California duct systems are typically over, under, or correctly sized, so no savings can immediately be predicted.

VALUE OF IMPROVED AIR DISTRIBUTION SYSTEMS TO THE BUILDING INDUSTRY

Value Perceived by the Industry

There was general agreement among survey participants that the building industry needs to improve the duct systems.

Table 2. Costs of Improved Systems

Participant	Design	Fab/Installation materials	Fab/Installation labor	Leakage Testing	Total 25/design, test all	Total 1/design, test all
H1	250	250	incl	125	385	625
H2	100	50	325	250	629	725
H3	250	100	220	incl	330	570
H4	150	150	75	150	381	525
H5	82.5	50	incl	60	113	193
H6	incl	150	incl	200	350	350
H7	250	45	150	100	305	545
H8	150	30	60	160	256	400
B1	250	300	incl	250	560	800
B2	250	100	incl	250	360	600
B3	40	300	incl	250	552	590
Average with placeholders	161	139	75	163	384	538
Average without placeholders	87	139	75	131	348	432

Notes: [shaded cell] means high placeholder because no value was provided participant prefix H denotes HVAC subs and B denotes builders

The main value was perceived as improved quality of the homes. There was no consensus that these improved ducts would save builder costs by decreasing consumer call-backs, allowing for down-sizing, or decreasing liability exposure. However, it was the consensus of an industry working group, including the Technical Director of CBIA and the Chairman of the CBIA Energy Committee, that there will be real but currently not quantifiable (due to lack of data) savings to builders due to decreased call-backs, equipment downsizing, and decreased litigation costs resulting from improper heating and cooling. The savings from decreased call-backs will occur immediately, but are not currently quantifiable because there are no comprehensive data currently available regarding the frequency of HVAC call-backs—for either the HVAC subcontractor or the builder. The potential savings from equipment downsizing will occur over a longer term as the industry improves its sizing procedures and becomes convinced that with tight ducts equipment can be downsized.

There was general agreement that improved ducts could cost-effectively decrease homeowner energy use, which was good, and which could be used to help market comfortable, energy efficient homes, but that it would not *a priori* help them sell homes.

Energy Savings Potential

Recent research shows that a duct system in typical new construction is 70% to 75% efficient (these losses derive from a combination of conduction through the duct walls and leaks at the connections in the air distribution system), and that this efficiency can be improved 12% to 15% (10 to 13 percentage points) if procedures such as those proposed were implemented (Jump et al., 1996; Modera, 1993; Modera and Jump, 1995; CEC, 1995; Proctor and Pernick, 1994).

These energy savings percentages can be understood based on the following. The leakage specification of the leakage flow in cubic feet per minute (cfm) at 50 Pa pressure differential being less than or equal to 0.07 times the house floor area (ft^2) translates to the elimination of approximately 70% the duct leakage in a typical installation. For example, a 1761 ft^2 house would be allowed to have 123 cfm of leakage at 50 Pa, as compared to an average leakage of 406 cfm at 50 Pa for a typical California house of this size (Modera, 1993). The typical leakage areas correspond to leakage flows on the order of 15% of the fan flow on both the supply and return sides (Jump et al. 1996, Jump and Modera 1994), where the results from Jump were reduced to account for their somewhat larger than average leakage rates. Given these results, the reduction in supply leakage results in a 10.5% increase in energy delivery, and reducing the return leakage results in a 5.25% decrease in energy load (assuming that the energy flux across return leaks is approximately half that across supply leaks, $\Delta T_{return,winter}$ = 20-30°F versus $\Delta T_{supply,winter}$ = 40-70°F, and $\Delta T_{return,summer}$ = 10-40°F versus $\Delta T_{supply,summer}$ = 20°F). Adding in the impact of reduced air infiltration while the unit is off (0.7(fraction sealed—from procedures, also CEC, 1995; Modera, 1993)*0.2(fraction of envelope leakage in ducts—CEC, 1995; Modera, 1993)*0.33(fraction of load due to infiltration—Sherman, 19xx)*0.85 (fraction of time that equipment is not running) = <4%) yields a total savings of approximately 20%. Some of this savings is not expected to be realized because: 1) some of the leakage is to/from inside the house and new duct installations may be tighter that typical installations, at least in the short term (see CEC 1995), 2) there is some small recovery of losses to buffer zone (attic or crawl space), 3) there will be increased conduction losses if the ducts are sealed without any changes in design or insulation due to reduced flow rate through the HVAC system (see Jump et al. 1996), and 4) some of the savings will be lost due to degradation of equipment efficiency (due to relative oversizing resulting from sealing).

The most comprehensive industry-standard practices for load calculation, duct and system sizing, and system selection are available from the Air Conditioning Contractors of America (ACCA) in their Manual J (loads calculation), Manual D (duct sizing), and Manual S (system selection) publications. The use of these manuals was therefore included in the quality installation protocols developed by this project. Unfortunately, there are simplifying assumptions in these ACCA manuals that can result in incorrect loads, and non-optimal duct and system sizing.

The major concerns regarding Manual J are its assumptions that:

(1) there is no duct leakage, and
(2) the load due to duct conduction is independent of the length and design of the ducts.

The implication of the first assumption is that the actual load associated with duct losses is, in general, significantly higher than that assumed by Manual J. The second assumption implies that even if the average conduction losses in the duct-loss multipliers in Manual J are correct, the calculated room-by-room loads are incorrect due to non-uniform conduction losses. These two incorrect assumptions can lead to incorrect calculation of loads, and non-uniform heating and cooling. There are other assumptions within the Manual J method that are under control of the user which can be used to bring the calculated loads back into the correct range. These assumptions and some of the implications of their use are discussed in detail in Hammon & Modera, 1995. The two steps are:

(1) modify ACCA Manual-J duct loss/gain multipliers to account for the non-uniformity of duct losses and instruct users in its correct use, and
(2) incorporate an overall duct loss calculation procedure that determines duct losses based on actual duct lengths and velocities; this requires coordination of Manual J, duct layout, and Manual D calculations.

Implementation of these strategies are being pursed through existing ASHRAE committees and standards.

STRATEGIES FOR IMPLEMENTATION OF SUGGESTED PROCEDURES

There are several methods that could be used to implement the procedures for improved duct systems that were developed under this project. A basic tenant of the recommended strategy is that a simple, energy-code (Title 24) based strategy will not result in rapid market transformation from current practices to the proposed practices. While Title 24 has been very effective in increasing the energy efficiency of California housing, its major successes have been limited to those that are easily and quickly inspected by builders and building officials.

As discussed in Section 3, some of the duct leakage problems that exist today could be resolved by close adherence to the requirements of the UMC. However, these requirements are not easily inspected and discrepancies often go without being inspected and/or they are not noticed. The only really effective approach to ensure proper HVAC system performance is to require that the systems be tested. Testing could be done by building officials, but it is not likely that they could afford to staff such a requirement, even on a limited basis. Therefore, some alternate method needs to be devised that will result in better designs, use of better materials, improved installations, and testing of the installation. This alternate method needs to both encourage these improved practices, and compensate builders for additional costs that will occur during market transformation.

Toward this end, a market-driven strategy is recommended that establishes value in the market for improved HVAC systems. It includes code-based elements for inspectable materials and market-based credits for improved design and installation. This strategy combines additions to Title 24 mandatory features for duct-connection materials, changes in Title 24 assumptions to support credit for improved HVAC systems, changes in home energy rating system (HERS) requirements to include diagnostics, and adoption of energy efficiency mortgages (EEMs) to demonstrate value and help finance a market transformation. The steps in implementing this strategy are:

Immediately:

(1) Fix HERS reference house duct efficiency at 72%,
(2) Adopt HERS testing protocols for duct testing,
(3) Permit the HERS proposed house duct efficiency to be increased if prescribed tests are performed and criteria passed: 82% heating and cooling if ducts are adequately sealed, (12% savings from sealing only); 82% heating and 90% cooling if have adequate air flow across the cooling coil (additional 8% cooling savings).
(4) Encourage energy efficiency mortgages (EEMs) that will provide market value for improved HVAC systems, and cover the incremental cost to improve them.

In the next version of Title 24:

(1) Change the default Title 24 duct efficiency to 72%,
(2) Add duct-closure material requirements to Mandatory Measures,
(3) Add procedures to obtain credit for installation of improved HVAC systems.

Once a criterion residential new construction market penetration has been achieved:

(1) Change the default Title 24 duct efficiency to an appropriate figure based on the then current state-of-the-art,
(2) Update the Mandatory Measures as appropriate to reflect use of key duct and duct-closure materials.

Each element of this strategy is described and discussed in the following sections.

IMMEDIATE ISSUES:

Changes to California Home Energy Ratings Requirements

Consumers would demand better HVAC systems if they understood how poorly typical ducts currently perform and how much better they could be. One good way to improve the public understanding of duct issues is through home energy ratings that include diagnostic testing of the HVAC system as described in the proposed procedures. Such ratings of both new and existing homes will help educate the public, provided that the ratings contain results of HVAC diagnostics or identify that HVAC improvements would be cost-effective.

California HERS with incorporation of performance diagnostics provides an immediate mechanism for consumers to identify and quantify the quality of the HVAC system. HERS ratings that include duct diagnostics will produce a significantly lower rating for a home with leaky (typical) ducts than for a home with tight ducts. In addition, sealing the ducts should be one of the most cost-effective, and therefore highest priority changes to the home.

The largest HERS organization in California, CHEERS, is currently piloting the voluntary addition of home diagnostics to its ratings. Some raters have been trained in testing procedures that include duct diagnostics. These are valuable to both new and existing homes, and typically should result in duct improvements listed as a cost-effective option. The recurrence of this option, and the industry response that it should evoke, could, over time, drive new home builders to anticipate consumers' requests for tight ducts by incorporating tight ducts into all of their homes.

For California HERS to encourage tight duct systems, the reference house needs to assume typical, leaky ducts. For new construction, a reasonable value for typical ducts is approximately 72% efficiency, which can be improved by 12% (to 82% efficient) when sealed to leak a cfm value equal less than 0.07 times the conditioned floor area (as specified in the proposed procedures) and an additional 8% for cooling (to 90% efficient) when the air flow across the coil is approximately 400 cfm per ton. HERS ratings should assume the low efficiency unless they are tested to leak no more than the criterion amount. Such diagnostic test procedures are outlined in the proposed procedures, and need to be incorporated into California HERS certification protocols and procedures. Coordination is also required between the CEC, CHEERS and other California HERS organizations to ensure that California home energy ratings are quickly capable of rating HVAC systems in homes and that they are consistent in how that is done. There is currently an ASHRAE Standard under development that should provide a long-term defensible basis for the efficiency estimation procedures, including a protocol for dealing with houses that have yet to be built (ASHRAE 1996).

The CEC can also help promulgate this by encouraging or requiring all home energy rating systems operating in California to be able to provide home diagnostics and to integrate the results into suggested upgrades. While it may not be appropriate to require all ratings to have diagnostics (due to the likely increased cost of a diagnostic rating), it would be beneficial to have all raters trained and competent in such diagnostics.

Consumers will need to become more aware of HERS ratings, and know to ask for them. Because they are already aware of other consumer labels, such as on cars and certain appliances, it should not be difficult for them to grasp the importance and information contained in a home energy rating—they just need to know to ask for one. This sort of public awareness could be developed with assistance from the CEC.

Energy Efficiency Mortgages (EEM)

HERS ratings alone will not promulgate improved HVAC systems in new construction because of their initial incremental cost. This cost will discourage builders from utilizing HERS ratings unless the ratings have a demonstrable value. For improved duct systems to be installed in new homes, a mechanism is required to pay the initial costs of materials, installation, and testing. Both of these issues can be resolved quickly through improved EEM products.

HUD recently announced a new EEM lending guideline for new construction. Previously, the only EEM was a 2% stretch in qualifying ratios, which has had no impact on energy efficiency features in new construction because all homes that comply with Title 24 (and the MEC) are eligible, and most lenders are already stretching 2% or more to qualify borrowers for new California homes. The new lending guidelines allow the borrower, after qualifying for the home, to borrow up to an additional $8,000 or 5% of the mortgage amount (whichever is less) to cover the cost of additional energy features that are cost-effective over the life of the loan, without any additional qualification. Duct improvements easily fit within these guidelines, and, as demonstrated in Section 4, improving duct integrity is one of the most cost-effective features available.

To obtain this additional financing, a home energy rating or similar certification is required to estimate the energy and cost savings due to duct sealing, and to certify that the improvement is cost effective. Thus, if the California HERS requirements include the capability for HVAC system diagnostics, it can provide the certification mechanism required for this mortgage. The combination of HERS and EEMs form the basis of a funding mechanism that can help produce consumer pull-through of high efficiency duct systems.

If utilized, these new EEM loans could be used immediately to sell ‘‘more home’’ (one with a superior HVAC system, for instance) to the buyer for no additional monthly cost to the consumer—i.e., the consumer's combined monthly mortgage and utility bills are less than they would be for the non-EEM qualifying home. The CEC could help educate builders that tight ducts are the most cost-effective additional feature to add to their homes and that it will improve the comfort (and possibly sales) of the homes, without changing the listing price of the homes if any incremental construction cost is wrapped into this new EEM, keeping them affordable.

Builders will find that they can add value, comfort, and salability to their homes through improved HVAC systems funded through EEMs. As builders become aware of these mortgages, they will quickly grasp that they can add features to their homes without loosing potential buyers due to increased prices. The buyer need only qualify for the basic home; by using the EEM he or she can still buy the improved home because the cost of the improvement is counterbalanced by the energy-bill savings. The building industry needs to be educated in the use of these mortgages (as has begun under an existing CEC contract), and the industry also needs to appreciate the value and cost-effectiveness of the improved HVAC system as a primary enhancement, as can be demonstrated by a HERS rating with integrated diagnostics.

For this strategy to work, the HVAC subcontractors need to be trained in the proper installation of HVAC systems to achieve improved system performance. This project developed procedures that will result in an improved system cost-effectively. The combination of HVAC subcontractor training in these procedures, linked with the builder motivation through EEMs and quality assurance certification through the HERS with diagnostics, could result in rapid promulgation of improved HVAC systems.

Title 24 Assumptions and Mandatory Measures

At the next opportunity, the Title 24 default assumption for residential new construction duct efficiency should be set equal to the HERS reference house duct efficiency—approximately 72%. This should be done so that Title 24, HERS, and the market are aligned, and to provide the potential for credit to builders who build homes with more energy-efficient duct systems than is current practice. However, as this would allow builders to trade off other energy efficiency features against duct sealing, it is important to assure that the duct improvements have adequate longevity. Thus, any credit for improving duct efficiency must include a requirement with respect to the longevity of the sealing materials. Our recommendation is that this requirement on sealing materials become a mandatory measure (i.e., independent of whether a high-efficiency credit is being taken).

For tight ducts to be acceptably effective, proper materials need to be used at duct connections to provide good longevity. Currently, the most common material used in duct connections is duct tape, usually inexpensive duct tape. While there have not been definitive studies comparing longevity of different types of duct tapes and mastics, there is considerable field evidence that inexpensive cloth duct-tape dries out and within a few years fails, but that mastic lasts as long as the flexduct. There are other duct tapes being used that are claimed to last longer than the common tapes; testing and rating of these tapes for adhesive properties and longevity would be very useful. A first step has come from UL who has drafted a standard for duct tapes (UL 181 B) that will help rate tapes for their adhesive properties. This UL Standard 181 B is proposed in the procedures as a requirement for any tape closures of duct connections, and as such should become a Mandatory Measure within Title 24.

In the longer term, once improved duct systems are relatively common within the marketplace, we recommend moving the required (or standard house) efficiency back up to 82% to 85%, which would reflect the fact that improved duct installations had become common practice (and that the marginal cost should be minimal—see chart on pages 3-4). The question that remains is how to determine when we have transformed the marketplace to this point, or more specifically, when the short-term implementation strategy has become successful.

At the most basic level, this implementation strategy should be considered successful once a criterion market segment has changed their design and installation practices to result in efficient HVAC systems. Some discussion of market saturation that is beyond the scope of this report needs to occur to determine the criterion market saturation. Nonetheless, when significant market saturation, such as 25% of all new construction, occurs, then the strategy should be considered successful, and what now needs to be considered as added value should then become a requirement.

By the time significant market penetration has occurred, competition and new methods will have decreased the cost of these higher efficiency HVAC systems. In addition, the industry will have learned how to cost-effectively test and certify that their systems are as efficient as they need to be to qualify for EEMs. At that point, which is likely to occur before two Title 24 code-cycle changes, Title 24 should be changed to require the more efficient HVAC systems that the industry will have embraced. That change in Title 24 should increase the required efficiency to be whatever that significant market segment has achieved (expected to be approximately 85%), it should include a reasonable method to ensure that the ducts are as efficient as specified (some kind of testing), and should update the prescriptive requirements for materials that ensure the longevity of the improved system.

CONCLUSION

This study has resulted in a set of buildable, cost-effective procedures for improved design, fabrication, installation and testing of residential HVAC systems that have been reviewed by a number of builders, HVAC subcontractors, as well as staff from the CEC, NRDC, and CBIA. An analysis of the cost of implementing these procedures and the resultant energy savings has shown that, in the short term there will be some cost to the builder, but that it will result in a cost-effective improvement to the consumer. In the longer term, as builders and HVAC subcontractors improve their techniques, the costs can drop to zero, or even provide some savings in construction costs. In addition, as these implementation improvements occur, there are additional savings to the consumer, making this change in construction techniques even more cost-effective to the consumer.

This project has also resulted in the development of an implementation strategy that utilizes existing market vehicles, primarily home energy ratings with integrated duct diagnostics and energy efficiency mortgages, to produce initial market value and acceptance of improved HVAC systems. This would be followed in the next Title 24 code change with alignment of the Title 24 assumptions regarding duct system efficiency with the California HERs assumptions. The authors feel that this change will reinforce the market value of improved duct systems and allow the driving forces of HERs coupled with EEMs to continue. After significant market penetration has been achieved, we suggest that the Title 24 assumptions be raised to a higher efficiency, recognizing that construction practices have changed.

The final conclusion is that this project has also identified a number of alternative or supplementary means for improving the quality, energy efficiency and performance of residential duct systems that should also prove to be cost-effective. However, the analysis required prior to including those options into the proposed implementation plan was beyond the scope of this project. The options identified included: 1) practical encouragement of ductwork in conditioned spaces, 2) added duct insulation, 3) reducing duct surface by means of better layouts and register locations, and 4) reducing attic temperatures with radiant barriers above the ductwork.

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