CALIFORNIA ENERGY COMMISSION

Residential Duct Placement: Market Barriers

Market Barriers—Identifications and Approaches to Overcome Them (product 6.4.2b)

TECHNICAL REPORT

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PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

This document is one of 33 technical attachments to the final report of a larger research effort called *Integrated Energy Systems: Productivity and Building Science Program* (Program) as part of the PIER Program funded by the California Energy Commission (Commission) and managed by the New Buildings Institute.

As the name suggests, it is not individual building components, equipment, or materials that optimize energy efficiency. Instead, energy efficiency is improved through the integrated design, construction, and operation of building systems. The *Integrated Energy Systems: Productivity and Building Science Program* research addressed six areas:

- Productivity and Interior Environments
- Integrated Design of Large Commercial HVAC Systems
- Integrated Design of Small Commercial HVAC Systems
- Integrated Design of Commercial Building Ceiling Systems
- Integrated Design of Residential Ducting & Air Flow Systems
- Outdoor Lighting Baseline Assessment

The Program's final report (Commission publication #P500-03-082) and its attachments are intended to provide a complete record of the objectives, methods, findings and accomplishments of the *Integrated Energy Systems: Productivity and Building Science Program*. The final report and attachments are highly applicable to architects, designers, contractors, building owners and operators, manufacturers, researchers, and the energy efficiency community.

This attachment, "Residential Duct Placement: Market Barriers" (Attachment A-30) provides supplemental information to the program's final report within the **Integrated Design of Residential Ducting & Air Flow Systems** research area. The attachment contains one report:

- **Market Barriers—Identifications and Approaches to Overcome Them.** This report identifies barriers to the market acceptance of building homes with ducts in conditioned space, and provides strategies which may be used to overcome these barriers.

The Buildings Program Area within the Public Interest Energy Research (PIER) Program produced these documents as part of a multi-project programmatic contract (#400-99-413). The Buildings Program includes new and existing buildings in both the residential and the non-residential sectors. The program seeks to decrease building energy use through research that will develop or improve energy efficient technologies, strategies, tools, and building performance evaluation methods.

For other reports produced within this contract or to obtain more information on the PIER Program, please visit www.energy.ca.gov/pier/buildings or contact the Commission's Publications Unit at 916-654-5200. All reports, guidelines and attachments are also publicly available at www.newbuildings.org/pier.

ABSTRACT

The "Residential Duct Placement: Market Barriers" attachment was produced as a part of the Integrated Design of Residential Ducting & Air Flow Systems project. This was one of six research projects within the *Integrated Energy Systems: Productivity and Building Science* Program, funded by the California Energy Commission's Public Interest Energy Research (PIER) Program.

Poorly performing residential duct systems installed in unconditioned space can have a significant effect on energy use and comfort. This report identifies barriers to the market acceptance of building homes with ducts in conditioned space, and provides strategies that may be used to overcome these barriers. Overcoming the barriers may require the involvement of government agencies in addition to building contractors and subcontractors.

The market barriers fall into two general groups, technical and commercial. Technical issues involve difficulties in actually constructing homes with ducts in conditioned space that have the desired duct system performance. Technical barriers include retraining subcontractors, code issues, limitations on the use of asphalt shingles, energy credits, measurement issues, duct access, and equipment sizing issues. Commercial issues involve problems that reduce consumer demand for homes with ducts in conditioned space. Commercial barriers include additional cost, loss of floor space, and issues regarding interior register locations.

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Key words: home building, duct, conditioned space, unconditioned space, air handler, air leak, infiltration, energy efficient home, residential building code, energy code

Market Barriers – Identification and Approaches to Overcome Them

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Integrated Design of Residential Ducting and Airflow Systems

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ABOUT PIER

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission, annually awards up to $62 million to conduct the most promising public interest energy research by partnering with research, development and demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

1. Buildings End-use Energy Efficiency
2. Industrial/Agricultural/Water End-use Energy Efficiency
3. Renewable Energy
4. Environmentally Preferred Advanced Generation
5. Energy-Related Environmental Research
6. Strategic Energy Research.

This project contributes to #1 above, the PIER Buildings Program Area. For more information on the PIER Program, please visit the Commission's Web site at: www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200. For other public reports within the *Integrated Energy Systems — Productivity and Building Science* project, please visit www.newbuildings.org/PIER

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OBJECTIVES

This report identifies barriers to the market acceptance of building homes with ducts in conditioned space, and provides strategies which may be used to overcome these barriers. Overcoming the barriers may require the involvement of government agencies in addition to building contractors and subcontractors.

The market barriers fall into two general groups: technical issues, which involve problems and difficulties in actually constructing homes with ducts in conditioned space which have the desired duct system performance; and commercial issues, which involve problems which reduce consumer demand for homes with ducts in conditioned space.

INTRODUCTION

New houses in California typically are built with the air handler and ductwork located in the unconditioned attic. The ductwork is commonly built with ductboard plenums and flex duct, insulated to R4.2, or sometimes R6 (code requirement is R4.2). In recent years, numerous studies have found large energy losses from these systems, primarily due to air leaks in the air handler and duct system, but also including heat conducted through the duct material. These losses are especially deleterious in the summer when solar radiation can elevate the attic temperature well above the outdoor air temperature. Previous studies have found that typical duct systems can lose as much as 40% of the space conditioning energy consumed by the HVAC system.

Air leaks on the supply side of the system are lost to the unconditioned attic and eventually to the outdoors, while leaks on the return side result in unconditioned air being brought into the system, increasing the space conditioning load. Unbalanced leakage (for example, large supply leaks with small return leaks) can significantly affect the air pressure in the house resulting in increased infiltration and the corresponding increase in space conditioning loads. Leakage can also cause comfort problems by reducing supply air flow to the house or to individual rooms, and by increasing infiltration.

The problem of duct leakage has primarily been addressed through a variety of programs aimed at reducing leakage in the duct system. These include several utility company programs which provided training to duct installers followed by duct leakage testing. The Title 24 ACM manual now includes a credit for ducts with tested leakage below 6% of system airflow. These programs have reduced typical duct leakage in new construction, but few builders take advantage of the Title 24 energy credit. It is believed that typical duct leakage values are now around 20% to 25% of system airflow. And, ducts are still located in the unconditioned attic where the leaks and thermal conduction is lost to the outdoors.

Placing ducts inside conditioned space requires changes from conventional building practice in a number of areas. It is expected that as homes are built with ducts in conditioned space, that problems will be identified and opportunities for improved methods developed.

To date, relatively few homes have been built with ducts in conditioned space. An exception to this statement is homes with systems in basements, common in northern climates. In California, however, most homes are built with a slab on grade, and the duct system in the attic. Pulte Homes, working with the USDOE Building America Program, has been building homes in Arizona, Nevada and now California, putting the ducts and air handler in an Unvented Conditioned Attic. A few homes have also been built using the Dropped Ceiling approach, mostly in the southeast, again in cooperation with Building America. Finally, some homes have been built in the Shasta, California area with insulation and HVAC work done by Rick Chitwood, using Dropped Ceilings.

MARKET BARRIERS

Market barriers are issues which prevent California homes from being built with ducts in conditioned space. There are two main actors in the decision to build a home with ducts in conditioned space: the builder and the consumer. Getting a home built with ducts in conditioned space requires agreement between these two parties that the home should be built and will be purchased that way. Any issue which prevents or reduces the likelihood or reaching that agreement is a market barrier. In addition, even if the two parties agree, and the home is built with ducts in conditioned space, if the construction process is not successful at achieving desired duct efficiency, the causal issues are also market barriers.

Market barriers, then, fall into two main classes. These are: technical issues and commercial issues. Technical issues relate to problems with actually building homes with ducts in conditioned space and which achieve the desired level of duct system efficiency. Commercial issues relate to factors which cause homes with ducts in conditioned space to be less desirable to homebuyers. Also, some approaches to building ducts in conditioned space have issues which do not apply to other approaches, while some issues apply to all approaches.

In the discussion below, each issue will be discussed, and then potential means of addressing the issue will be described.

Technical Issues

Technical issues inhibit the ability of the builder to successfully construct a home with ducts in conditioned space which provides the desired distribution system efficiency.

Retraining of subcontractors

Constructing a house with ducts in conditioned space requires changes from conventional practices by the contractor and one or more subcontractors. Some of these changes are direct, for example, framing must be done differently to provide a dropped ceiling. Other changes are indirect – the security system installer must not punch holes in the air barrier above a dropped ceiling or plenum truss without sealing the hole after wiring is installed. Another way of saying this is that there are some new things that need to be done (direct) and some conventional practices that must not be done (indirect).

Often, subcontractors will be resistant to changing their conventional practices. Change introduces uncertainty, delay, and risk. Crews may be intent on completing the job as rapidly as possible, and the need for a change in approach slows them down. Uncertainty can be very uncomfortable.

A significant problem related to this issue, particularly for smaller builders, is that the subcontractor, or the subcontractor's crews, change from house to house. Training provided on one house will often not carry over to the next house.

Builders: The primary means of addressing this issue is to get the subcontractors to "buy in" to building homes with ducts in conditioned space. As ducts in conditioned space gain energy credits in Title 24, houses with ducts in conditioned space will become more prevalent, and the subcontractors who are familiar with building them will have an advantage over their competitors. Workers want to do work they can be proud of – give them the chance by explaining how the energy benefits are achieved

Secondly, the builder must provide the subcontractors with clear objectives and methods. Providing clear and complete guidance to the subcontractors minimizes the uncertainty inherent in new procedures, and gives them confidence that the job can be successful. The guideline material being developed under this project is intended to help fill this role.

Larger builders have had success by keeping particular subcontractors teams busy on their projects. This way the teams can be trained initially, and the training stays on the site. Additional training is then required only as personnel changes due to normal turnover, or as refinements to building procedures are identified.

Testing is very important in the process of contractor (and builder) training. Testing the leakage of the duct system to the outdoors shows how successful the job has been, providing feedback on the procedures used. If leakage to the outside is high, testing can also be used to identify where the leakage is occurring so repairs can be made, and improvements can be made on the next house.

Testing can also be used in an integrated plan which includes incentives to the subcontractors based on performance targets for the test results. Provide training with clear procedures laid out. Set a minimum acceptable value for leakage to the outdoors, based on cfm/square foot of floor area. Place one coordinator in charge of ensuring that the subcontractors work together, and that indirectly involved trades don't put holes where they shouldn't. Set a minimum acceptable value for leakage to the outdoors, based on cfm/square foot of floor area. Test the completed system. Require any value above the target to be repaired until the minimum is met. For any leakage value below the minimum, provide an incentive, far example, a cash bonus, possibly scaled to the degree that the goal was exceeded.

Government: Providing instructional materials that builders can use to educate themselves and their subcontractors is the first step in addressing the training needs of the industry. Working with the builder's associations to provide training materials may be an excellent way to distribute such materials widely.

Training materials should be focused by approach (dropped ceiling, conditioned unvented attic, plenum truss) and by user (builder, HVAC, insulation and air sealing, framing, others). Materials can either be a series of focused documents or a single document with focused sections.

Code issues

Most building codes require that attics be ventilated. This is not an issue for the dropped ceiling or plenum truss approaches, but it prohibits use of the conditioned vented attic approach.

Builders: The builder should approach the local building department with credible technical information on the success of unvented attic construction, requesting that the code be changed or an exemption be granted. The technical basis for the code requirement is twofold. First, in cold climates, attic venting helps to prevent ice dam formation and condensation in the attic. Second, attic venting helps lower the temperature of roofing materials in hot climates. Recent research, however, has shown that attic venting is necessary only in the coldest climates (see *Venting of Attics and Cathedral Ceilings*, Rose and TenWolde, ASHRAE Journal, October 2002, page 26). Cold weather issues clearly do not apply in most of California.

As to the hot weather issues, homes are currently being built successfully in Arizona; Las Vegas, NV; and Banning, CA, with unvented attics with tile roofs. The modest temperature increases expected in the roofing materials with unvented attics do not affect the life of tile or wood shake roofs. (See below for further information on asphalt shingles.) Due to the increased roofing temperature, there is also an increase in cooling loads with unvented attics. This increase in load, however, is more than offset by the increased efficiency of the HVAC distribution system.

Government: The CEC can prepare materials which can be used by builders in requesting code changes or variances from the local authority. The CEC could also prepare and distribute to local code authorities a package of technical information . . . These materials would be technical briefing packages which present technical information showing that attic venting is not necessary in most locations in California. The CEC can also propose changes to the California Building Code which provide a climate based limit on when attic venting is required.

Local government, of course, can assist adoption of ducts in conditioned space by reviewing their building code and determining whether an attic venting requirement is necessary, or if it can be replaced by alternate requirements.

Limitations on use of asphalt shingles

One value of attic ventilation is to provide cooling to the roof deck in warm conditions. This is especially important when asphalt shingles are used. Installing asphalt shingles in an unvented attic will, in most cases, violate the manufacturer's instructions and void the warranty. The lack of attic ventilation in hot conditions will usually result in increased shingle temperatures, which may shorten their service life.

Builders: For unvented attics in hot climates, the preferred approach is to use tile or wood shake roofing. The projects that have been built with conditioned, unvented attics in hot climates have been built with tile roofs.

In milder climates, with lower peak temperatures, the temperature of the shingles should not exceed temperatures expected with vented attics in hotter climates. A builder can work with their shingle supplier or manufacturer to identify alternative installation techniques that the manufacturer would accept. For example, white shingles will absorb less solar radiation, and will stay cooler than dark shingles. Use of white shingles in selected climates should be able to meet temperature criteria that would be achieved on vented roofs with other colors or in hotter climates. A larger builder might have better leverage with a manufacturer to do this initially, with the manufacturer in a position to lose business to another manufacturer or to tile. Once the manufacturer accepts alternate installation procedures with one builder, other builders should be able to use the same procedures.

Government: CEC can provide technical information to assist builders in their interactions with roofing manufacturers, or they can approach manufacturers directly. For example, CEC might develop a table of the expected peak temperature of asphalt shingles of different colors under different conditions over vented or unvented attics. (Perhaps such information has been assembled under the Building America program. Alternatively, some simple field experiments might be conducted.) The CEC could work with manufacturers to identify acceptable configurations over unvented attics, and assist the manufacturer in revising their installation instructions and warranty materials.

Energy credits

Many energy efficiency measures are included in the Title 24 requirements or in the Alternative Compliance Manual. This inclusion provides an important benefit to the builder. Particularly for those items included in the ACM method, energy credits allow the builder to design a home to meet minimum efficiency standards while tailoring the design to best fit the buyer's needs and desires at the lowest cost. The Title 24 ACM procedures are not currently designed to address ducts in conditioned space. Modifying the ACM procedures to accurately address ducts in conditioned space will provide an incentive for builders, potentially allowing equal or better energy efficiency at lower cost. Lacking such coverage, builders are likely to invest in alternative efficiency measures, which may not provide equivalent energy savings.

Government: Include energy credits for ducts in conditioned space in the ACM. Base the credit on test data, for example, supply leakage to outdoors per square foot of floor area. Reports to be prepared under this project will discuss energy benefits of ducts in conditioned space in more detail.

Some builders feel that quality control should be included in the energy credit methodology. There are concerns that efficiency measures may be included by some builders in a low quality way, which mitigates against achieving good efficiency, but receives the same credits as if installed in a high quality manner. This puts the high quality builder at a competitive disadvantage.

Measurement issues

Corresponding to the issue of including coverage of ducts in conditioned space in the Title 24 ACM procedures, test methods must be provided which adequately characterize the efficiency gains achieved. These test methods must be as simple as possible to perform, while still providing sufficient detail on the performance of the duct system. Depending on construction quality and design approach selected, the energy savings can vary substantially. It will be important to test homes built with ducts in conditioned space, both for use in awarding or verifying energy credits, and also to provide feedback to builders so they can identify problems in their construction techniques and make improvements.

Builders: Test the performance of houses built with ducts in conditioned space using methods identified in Deliverable 6.6.1, *Test Methods*. Use testing to identify problems with the construction techniques used and repair deficiencies found. Use the results to work with subcontractors to improve procedures for succeeding projects.

Government: Include specific test methods in the energy credit procedures, and require testing of houses applying for credits. It may be possible to decrease the fraction of houses tested as a builder gains experience building houses with ducts in conditioned space. In particular, builders who have consistently low leakage in their houses might be rewarded with decreased testing requirements.

Duct access

The dropped ceiling approach, in particular, creates a fairly small space for installing ductwork. Often, this space is sealed in drywall, with no access to the interior. This makes repair or inspection of the ductwork difficult or impossible. Normally, this is not a significant issue, but should the ductwork prove to be particularly leaky, for example, after performance testing, repair of the ducts may be difficult.

Builders: Take particular care with the integrity of the ductwork inside the dropped ceiling to ensure high quality joints and sealing that will last the life of the house. Consider providing an access hatch into the duct space.

Equipment sizing issues / benefits

The increased distribution efficiency that results from building the ducts in conditioned space also means that the peak cooling or heating load will decrease. Most equipment sizing calculations include substantial safety factors, often resulting in systems which are oversized by 50% to 100% or more. This oversizing is exacerbated by the increased system efficiency. Equipment oversizing to this degree can result in reduced equipment efficiency and reduced comfort due to short cycling. It also increases cost, because larger equipment is being purchased and installed than necessary. It may also be possible to downsize the ducts, providing additional savings.

Builders: Work with the HVAC contractor to perform careful sizing calculations on initial houses to determine the proper size of equipment required. Avoid use of "rules of thumb." Limit oversizing to no more than 30%. Make sure that ductwork is properly installed to provide adequate airflow to all rooms, thereby avoiding comfort issues which might be misdiagnosed as insufficient capacity. Ensure that the system is properly charged with refrigerant and is providing the design cooling capacity.

Commercial Issues

Commercial issues tend to reduce desire for houses with ducts in conditioned space among consumers. In general, marketing and sales programs will need to be used to promote the advantages of houses with ducts in conditioned space. Energy credits in

Title 24 allow the builder to optimize the design to minimize the costs and include desirable features, while still providing good energy efficiency.

Publicity in the media on ducts in conditioned space can also play a role in increasing interest on the part of potential consumers. Material on ducts in conditioned space can be included in energy efficiency materials prepared by the CEC for distribution to consumers and to the press.

Additional cost

It is likely that houses built with ducts in conditioned space will incur additional costs in their construction. The increases are offset to some extent by reduced ductwork costs (by using interior supply locations the duct runs are shortened) and possibly by downsizing of the HVAC equipment.

Builders: Utilize any available energy credits to optimize the design of the house to provide the best energy efficiency at the lowest cost. Make energy efficiency an integral part of the marketing of the house. Promote the reduction in annual or monthly energy costs which should more than offset increased mortgage payments. Consider participation in a program which provides a guarantee on monthly average energy consumption. Point out that reducing energy consumption reduces the monthly costs which are subject to price fluctuations, whereas mortgage payments are fixed (particularly for retirement communities where residents will often be on fixed incomes).

Government: Provide energy credits which accurately reflect the energy benefits provided by building ducts in conditioned space. This will allow the builder to optimize the house design to provide the most attractive features with a given energy efficiency level. Include ducts in conditioned space as a featured energy efficiency measure in promotional materials provided to consumers and the media.

Loss of floor space

When the dropped ceiling approach to placing ducts in conditioned space is used, the preferred location for the air handler is in a closet inside conditioned space. This location is not required, some homes have been built with the air handler above the dropped ceiling in the unconditioned attic. This option is less desirable. The air handler is typically quite leaky, and air losses in the attic result in the same negative effects as air losses from ducts in unconditioned space. The air handler will also be exposed to the extreme temperatures of the attic, resulting in energy losses due to conduction through the air handler casing.

If the air handler is located in a closet in conditioned space, however, there is a loss of usable floor space to the occupant. Usable floor and storage space (the space would probably be a closet instead) is a primary metric of home size. Clearly, it is a market advantage to maximize this space.

Builders: This aspect of ducts in conditioned space should be minimized in marketing materials. If mentioned at all, the accessibility of the air handler for routine maintenance might be mentioned as an advantage. Location in occupied space should also be used to make the air filter location more accessible than the typical ceiling return grille. This can also be promoted as a means of improving air quality through frequent filter changes.

Government: Provide energy credits that include location of the air handler in determining the magnitude of the credit. Studies have shown that the air handler cabinet is often very leaky, and placing it in unconditioned space can have a significant impact on energy performance.

Evaluation of the impact of locating the system air filter at the ceiling return register on IAQ and system airflow might also be undertaken. Particularly with high ceilings, common in new homes, access to the filter is difficult, and filter changes are not likely to occur as regularly as desired. If the filter becomes completely clogged, the airflow through the system will be reduced, possibly affecting system efficiency. This factor might also be included in an energy credit, although surveys of occupant behavior would be required to determine if such an effect is significant.

Loss of ceiling height

When the dropped ceiling approach is used, the ceiling height in hallways and other ancillary spaces is reduced. This may have a negative impact on the aesthetics of the home, reducing the salability of the house. This effect is related to the width of the hallway, with narrower hallways appearing "too compressed."

Builders: Utilize house designs which minimize the effect of having the hallways appear cramped, such as avoiding long hallways, ensuring the hallway has plenty of light, (preferably natural light), and using architectural details at the end of the hall to disguise the change in ceiling height. If these options are not satisfactory, the Cathedralized Attic approach or Plenum Truss approach can be used instead, since these methods do not require ceiling height reductions.

Interior register locations

Supply registers located near the exterior walls have been standard practice for many years. As a result, some consumers may be uncomfortable with interior supply locations. Some people in the industry fear that interior register locations may be perceived as "cheap."

Builders: Be proactive in marketing the energy benefits of ducts in conditioned space, along with the high efficiency windows, envelope insulation and low air leakage which provide comfort without having ducts at the perimeter. Explain that the high efficiency building envelope avoids uncomfortable drafts which were offset in the "old days" with supply registers at the perimeter. If high quality supply registers are used, promote their ability to mix the supply air throughout the room, providing uniform comfort.

Government: Include interior register locations, and the discussion of why they are successful in promotional materials describing ducts in conditioned space that are distributed to consumers and the media.