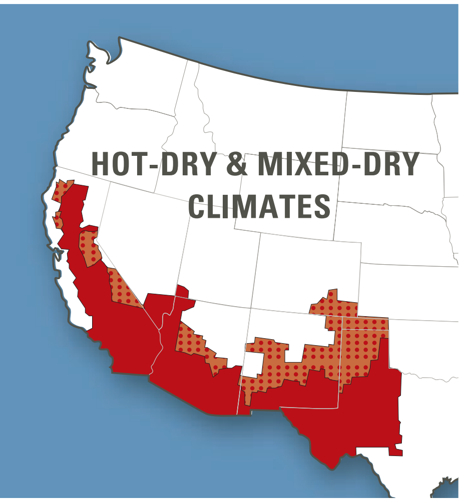
Volume 9

Building America Best Practices Series



Builders Challenge Guide to **40% Whole-House Energy Savings** in the Hot-Dry and Mixed-Dry Climates

Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

Prepared by

Pacific Northwest National Laboratory & Oak Ridge National Laboratory

October 2009

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Building America Best Practices Series: Volume 9

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

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www.buildingamerica.gov

Preface

This best practices guide is the ninth in a series of guides for builders produced by the U.S. Department of Energy's Building America Program. This guide book is a resource to help builders design and construct homes that are among the most energy-efficient available, while addressing issues such as building durability, indoor air quality, and occupant health, safety, and comfort. With the measures described in this guide, builders in the hot-dry and mixed-dry climates can achieve homes that have whole house energy savings of 40% over the Building America benchmark (a home built to mid-1990s building practices roughly equivalent to the 1993 Model Energy Code) with no added overall costs for consumers.

These best practices are based on the results of research and demonstration projects conducted by Building America's research teams. Building America brings together the nation's leading building scientists with over 300 production builders to develop, test, and apply construction practices. Building America homes attempt to meet energy-efficiency goals at no net increased costs to the homeowners. To recognize builders that are producing the most efficient, sustainable, and comfortable homes on the market, DOE created Builders Challenge. Homes that qualify for this Builders Challenge must meet a 70 or better on the EnergySmart Home Scale (E-Scale). Both programs are described in detail inside this document.

Building America's early years were focused on the general objectives of developing strong relationships with production builders and helping builders achieve energy-efficiency levels about 15% above code. This document represents a step up from those early efforts. Building America has continued to develop systematic building strategies that meet more challenging efficiency goals over time. Currently, Building America achieves energy savings of 40% greater than the Building America benchmark home.

Note, since 1993, the national model energy codes have evolved and become more stringent while achieving greater energy efficiency than previously published codes. The national energy codes are revised on an 18-month cycle. The most recent versions are the 2009 International Energy Conservation Code (IECC) and the 2009 International Residential Code (IRC). The recommendations in this document meet or exceed the requirements of the 2009 IECC and 2009 IRC.

Building America welcomes reader feedback on all volumes of the Best Practices Series.

Please submit your comments via e-mail to:

George James (George.James@ee.doe.gov)

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Chapter 1.
Welcome

> "People ask me, 'Why did you choose to build this way?' I say, 'Why *wouldn't* you build this way?'"

Nat Hodgson, Vice President of Construction for the Las Vegas Division of Pulte Homes and Communities of Del Webb

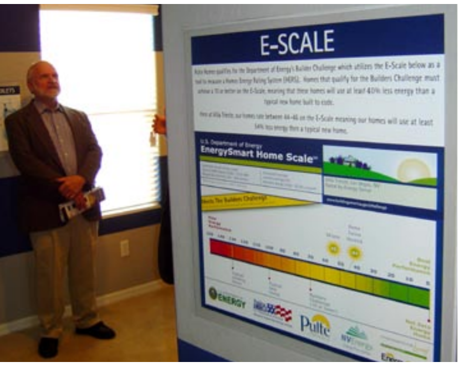
Builders are speaking, and we are listening: constructing efficient, durable, and comfortable homes makes economic sense—for the builder, the consumer, the real estate professional, and the environment.

As highlighted in our case studies, builders are sharing that high-performance homes are selling more quickly than their competitors' homes (in some cases twice as fast), that they are receiving far fewer callbacks from customers to solve service issues, and that their teams are energized by the whole-house and team approach. And, the message is coming from builders of all sizes. In fact, eight of the nation's ten largest builders in 2008 were Building America partners.

Consumers are sharing with their builders that their energy-efficient homes produce significantly reduced energy bills and are healthy, durable, and comfortable to live in.

If you are a builder, this guide provides a starting point for building high-quality, energy-efficient homes that achieve 40% in whole house energy savings (including space conditioning, water heating, lighting, and other loads such as appliances), with no added overall costs for consumers when utility savings are considered.

If you are a designer, this guide provides practical building science guidance on key principles and components for designing energy-efficient homes in the hot-dry and mixed-dry climates. You will learn how these climates affect the building envelope and components. You will learn how all of these components inter-relate and how viewing the house as a system can help you achieve higher levels of building performance. Information on managing moisture, air leaks, and thermal performance is provided. A checklist summarizes all of the measures in one place (Chapter 10).



(top left) Rick Davenport, the director of Masco's Environments for Living, affixes a Builders Challenge label to a model home at the 2009 International Builders Show.

(bottom left) Ed Pollock, of the U.S. Department of Energy's Building America Program, talks with builders in a showroom for Builders Challenge homes.

(right) Another Building America house sells in the hot-dry climate. *(Photo source: ConSol)*

If you are a business manager, this guide describes why building energy-efficient homes makes business sense. You will find out how much consumers value energy efficiency. You will see how the quality management that supports energy efficiency also supports your business model through reduced callbacks and higher customer satisfaction. You will see examples of how successful builders sell energy efficiency and gain market advantage by building high-performance homes. You will learn how to put building science to work for your company.

If you are a site supervisor or trades person, this guide contains handy checklists for scheduling, training, quality assurance, and commissioning inspections and step-by-step, easy-to-follow illustrated instructions for adding key energy-efficiency technologies.

If you are a real estate professional or appraiser, this guide documents for the hot-dry and mixed-dry climates the latest energy-efficient technologies and approaches, and how these work together as a system (the whole-house approach) to increase a home's comfort, savings, performance, and value – the factors that help sell homes.

If you are the consumer, this guide provides information about the Builders Challenge E-Scale so that you can differentiate an energy-efficient home from a home simply built to code. With this information, you can understand and communicate with your builder why you value an energy-efficient home.

For all of us, we believe once you understand the benefits of building high-performance homes, you will respond, "Why wouldn't you build this way?"

Building America welcomes reader feedback on all volumes of the Best Practices Series. Please submit your comments via e-mail to: George James (George.James@ee.doe.gov). You can learn more about Building America and download additional copies of this document, other best practices, and research reports at www.buildingamerica.gov.

Energy-savings labels, such as the EnergySmart Home Scale for the Builders Challenge, may be subject to state and/or local requirements. Therefore, please check state and local requirements before using energy-savings labels. Where state laws or regulations differ from the guidelines suggested here, state law or regulation shall govern.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 2.
The Business Case for Building High-Performance Homes

The number one reason identified by builders for building energy-efficient homes is to differentiate themselves from their competition (NAHBRC 2007).

Building America has worked with production builders since 1995 to improve the energy efficiency, durability, comfort, environmental performance, and quality of new homes. As of summer 2008, the program had contributed directly to the energy-efficient construction of more than 40,000 homes, and builders and vendors that have worked with Building America have influenced over a million new homes.

The technologies and management systems that have come out of this work are presented in later chapters. This chapter presents the sometimes surprising and profitable business models that have worked for innovative builders cooperating with Building America. We invite you to use the information in this guide to lead your company to increased profits and greater customer satisfaction.

"Strong, sustainable building practices can help a builder differentiate themselves in a competitive market-place, while still keeping focused on the bottom line."

Jeff Jacobs, then of Centex Homes, currently President of Building Advisory, LLC

CHAPTER TOPICS

Builders and Building America

Building America works with the nation's premier building scientists to conduct research and bring knowledge to builders to help them produce better homes. This knowledge has been gained from private-public partnerships involving builders all over the country working with DOE. Many builders have adopted the program's principles and improved the performance of their houses and companies. Over 300 builders and vendors have partnered with Building America, including seven of the ten largest builders in the nation. This Best Practices guide contains results from this research in a form that your company can immediately put into use to increase your homes' efficiency, comfort, and durability. Learn more about Building America at www.buildingamerica.gov.

> "We were doing a lot of things wrong—not on purpose, we simply didn't know any better. Building America taught us how to build the right way. Artistic now offers an energy use and comfort guarantee on every home it sells."
>
> *Jerry Wade, President of Artistic Homes, Albuquerque, New Mexico*

> "Energy-efficiency is now a primary concern of housing consumers….survey and focus group research makes it 'loud and clear' that buyers are willing to spend a little bit more to improve energy efficiency because this is an issue that 'hits the pocketbook'."
>
> *Gopal Ahluwalia, NAHB's Vice President of Research, National Builder News 4/16/07*

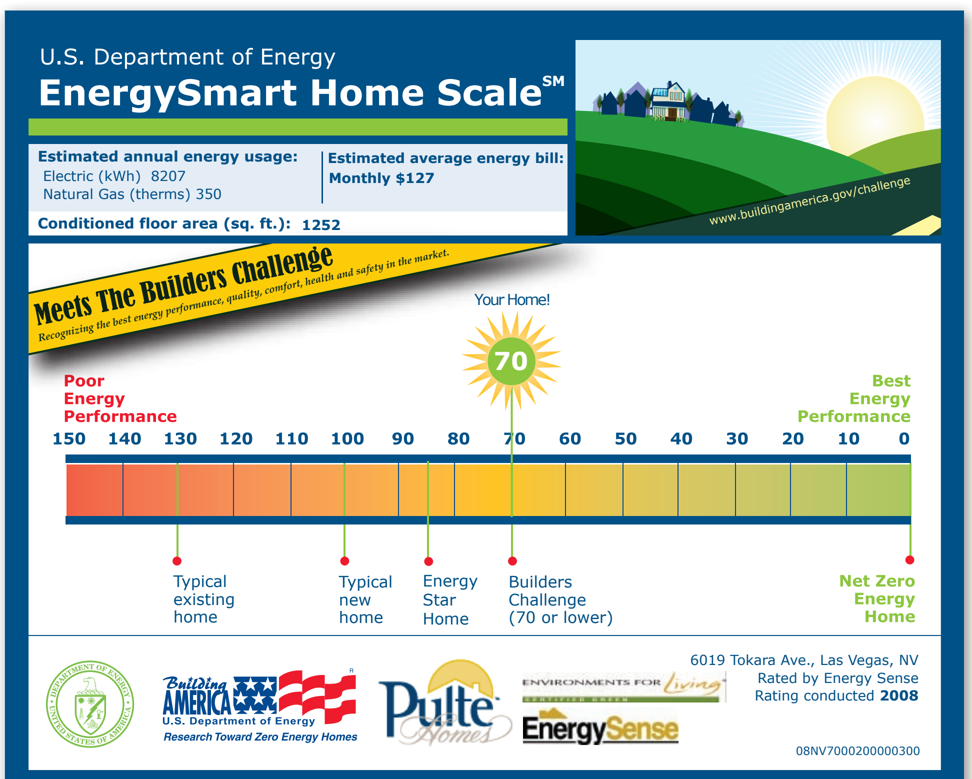
> **Pulte Las Vegas** stepped up to the Builders Challenge in 2008 certifying more than 500 homes as Builders Challenge Homes. Pulte Vice President of Construction Nat Hodgson said the higher energy performance and the higher quality that goes along with it have set his product apart in the Las Vegas valley. The Builders Challenge label helps drive the message home for buyers. The label prominently features the E-Scale, which uses an index of 0 to 100 with 0 being the ultimate goal, a net zero energy home. A code minimum house would score 100; Builders Challenge homes must score 70 or lower. "Buyers understand it because it's like miles per gallon for a car. It's a simple way to compare one home to another. Only in this case, the lower the score, the better."
>
> *Nat Hodgson, Vice President of Construction for the Las Vegas Division of Pulte Homes and Communities of Del Webb*

On the Path to Zero Energy

Building America's early years were focused on the general objectives of developing strong relationships with production builders and helping builders achieve energy-efficiency levels about 15% above code.

This document represents a step up from those early efforts. The program is now developing systematic building strategies that meet more challenging efficiency goals over time. Currently, Building America is working to achieve source energy savings of 40% greater than the Building America benchmark home (a home built to the 1993 MEC, which was typical of construction practices of the mid 1990s, when the program began).

DOE has posed a challenge to the homebuilding industry—to make available cost-effective net-zero energy homes for all Americans by 2030. Homes that qualify for this Builders Challenge must meet a 70 or better on the EnergySmart Home Scale (E-Scale). The E-scale allows homebuyers to understand—at a glance—how the energy performance of a particular home compares with others. The E-scale is based on the well-established Home Energy Rating System (HERS) index, developed by the Residential Energy Services network (RESNET). To learn more about the index and HERS raters visit www.natresnet.org. The HERS index is based on the 2006 IECC. A house built to the 2006 IECC would have a HERS index of 100. A house with a HERS index of 70 would be 30% more efficient than one built to IECC 2006. California builders, note that in California the HERS index is based on Title 24 -2008. For an explanation of how California builders can qualify for the Builders Challenge see www1.eere.energy.gov/buildings/challenge/printable_versions/homesinca.html. Through the Builders Challenge, participating homebuilders have an easy way to differentiate their best energy-performing homes from other products in the marketplace, and to make the benefits clear to buyers. To learn more about the Builders Challenge and find tools to help market your homes, visit www.buildingamerica.gov/challenge.



Eight of the nation's ten largest builders are Building America partners. Nineteen of Building America's 288 Partners made *Builder Magazine*'s Builder 100 List of the top 100 builders of 2008 (based on home sale closings). While overall U.S. home sales dropped by 37% from 2007 sales and new home starts dropped 40.5%, ten of Building America's partners moved up in the Builder 100 rankings.

Ranking	Building America Partner
1	DR Horton
2	Pulte
3	Centex
4	Lennar
5	KB Home
8	The Ryland Group
9	Beazer Homes USA
10	Meritage Homes Corp
11	Habitat for Humanity International
12	Taylor Morrison Homes
13	Standard Pacific Corp
16	Shea
17	David Weekley Homes
27	Mercedes Homes
32	William Lyon Homes
49	John Wieland Homes and Neighborhoods
51	Mattamy U.S. Group
64	Castle & Cooke
74	William Ryan Homes

Building America builders ranked highest in 25 of the 33 new home markets surveyed in JD Powers' 2008 survey of homebuyer customer satisfaction. These builders include some of the best known names in the business: Pulte and its Del Webb and DiVosta Homes brands, Centex, John Wieland Homes, David Weekley Homes, Shea Homes, D.R. Horton's Cambridge Homes, Standard Pacific Homes, and Medallion Homes. These builders bundle energy efficiency with other attributes valued by their customers, such as affordability, comfort, and quality construction. Centex and Pulte tied for top rankings in new home quality with each ranking highest in 7 of the 33 U.S. home markets surveyed by JD Powers in 2008.

The Business Case for Energy Efficiency

The world of new home construction is not the same place it was five years ago. The pace of new construction is down in most markets, and the public's awareness of energy efficiency and green building is up. Although the downturn has affected all builders, in markets around the country builders who emphasize energy-efficient construction are outselling their competition.

McGraw Hill Construction (2008) reports that the new construction green building market is expected to be worth up to **$140 billion** by 2013, with the combined commercial and residential green renovation market at over **$200 billion**. In 2005, the size of the green homebuilding market was at $2 billion and the green remodeling market was about $120 billion. Most of the features listed by McGraw Hill in defining a green building involved energy efficiency. The report points out that green construction can help differentiate builders and stabilize their business in a struggling market.

The business case for high-performance, energy-efficient construction is straightforward:

1. Consumers prefer energy-efficient homes.
2. Builders can use energy efficiency and other high-performance features to gain competitive advantage.
3. Building science, integrated design, and quality management deliver more energy-efficient, durable, and green buildings. Making the proper choices of materials and properly sizing equipment will minimize builder risk and increase the value of new homes.
4. Consumer preference and competitive advantage lead to more and faster sales.
5. Building America homes can meet energy-efficiency goals at no net increased costs to homeowners when added costs are balanced with utility savings.

> "Our carbon footprint is small. That's a great side effect of building to Builders Challenge, and something more buyers are paying attention to."
>
> *Nat Hodgson, Vice President of Construction for the Las Vegas Division of Pulte Homes and Communities of Del Webb*

Centex is a Building America builder at Windemere in San Ramon, CA

> "I don't expect any builder to lose money making energy-efficient houses, and they won't as long as they let the buyer know what they are getting for their money. We need to tell them, 'You are going to love it the day you move in because it's a great house. You are going to love it a year from now because we thought about comfort and operating costs.'"
>
> *Jeff Jacobs, then of Centex Homes, Northern California Division, now president of Building Advisory*

Building Science and the Bottom Line

While the building science technologies described here substantially increase the energy efficiency, comfort, health, durability, and environmental friendliness of your homes, they do not have to substantially increase costs for you or your homebuyers. Building America's approach offers these benefits:

Cost Savings – Building science offers tools to help you identify climate-appropriate designs, choose the right building materials and practices, and select and size building systems correctly. Higher prices in one area can often be offset by savings in other areas.

Neutral Costs – Building America performance packages are designed to be cost neutral to consumers. When increased mortgage costs are balanced with utility bill savings, the net result is that consumers end up paying no more in annual costs.

Reduced Risks, Increased Productivity, and Fewer Callbacks – Applying building science reduces the risk of significant construction defects and helps to eliminate the more mundane problems that cost money to fix. If you reduce the time your crews are working on callbacks, you increase the time they can be working on new product.

Incentives – In addition to financial incentives for energy-efficient homes, some local governments offer streamlined permitting processes for green projects. Qualifying criteria vary, but programs typically include energy-efficiency improvements. Here are two examples:

- **Scottsdale, AZ** – All qualified green building projects receive fast track plan review service. The City also provides promotional materials including job site signs for builders and inclusion in a directory of participating builders that is published in marketing materials and on the city's website www.scottsdaleaz.gov/greenbuilding/Incentives.asp

- **San Diego County, CA** – The county does not charge for the building permit and plan check of residential photovoltaic systems. Green buildings receive accelerated plan review and a 7.5% reduction in fees. www.sdcounty.ca.gov/dplu/greenbuildings.html

Prescriptions – State and local governments are taking a carrot and stick approach to encouraging efficiency. The building science recommendations in this document can help meet these requirements. Here are some prescriptive programs:

- **Marin County, CA** – This county requires that new homes exceed the state code, Title 24, by 15% for Tier 1 or 35% for Tier 2. www.co.marin.ca.us/depts/CD/main/comdev/advance/sustainability/greenbuilding/sfdeeo/sfdeeo.cfm

- **The California New Solar Homes Partnership** – requires that homes exceed the California building code (Title 24) by 35% to receive state incentives for homes with solar electric systems. The California Public Utility Commission has established the goal that new homes will be zero-energy homes by 2020. www.gosolarcalifornia.org/nshp/

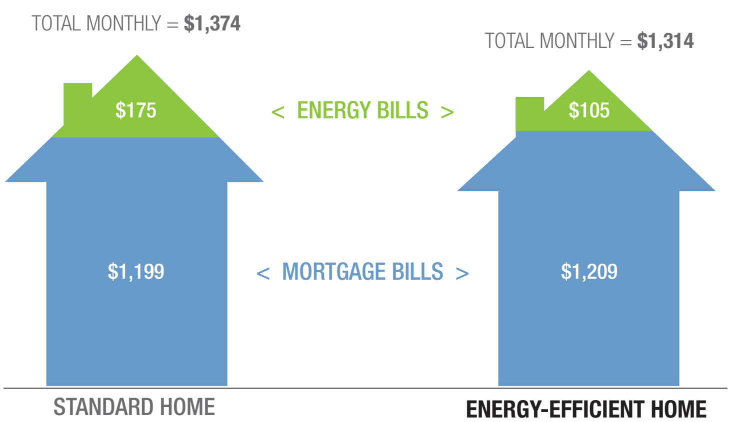
How Much Does it Cost to Reach 40% Energy Savings? One Example in the Hot-Dry Climate

LESS COST ← CONVENTIONAL → MORE COST

Savings	Costs
Advanced Framing	
• R-21 wall insulation	+ $263 ADDED COST
HVAC System	
- $600 SAVINGS	• SEER 13, 2-ton downsize of air conditioner
• Ducts in conditioned space	+ $947 ADDED COST
- $146 SAVINGS	• Downsize furnace
Higher Efficiency Windows & Lighting	
• ENERGY STAR Lighting	+ $197 ADDED COST
• Low-E, argon-filled windows	+ $1,031 ADDED COST
Total Savings	**Total Costs**
- $746 SAVINGS	**+ $2,438 ADDED COSTS**
TOTAL COST DIFFERENCE =	**+ $1,692 ADDED COST**

This cost analysis performed by the National Renewable Energy Laboratory is based on a 2-story, 2,500 square foot house in Sacramento, CA, and shows one example of costs (and savings) from implementing measures to achieve 40% energy savings compared to the Building America benchmark (a home built to MEC 1993). The energy savings are expected to translate into dollar savings per year.

Monthly cost comparison shows homeowners save money each month even when energy features add $1,710 to the mortgage amount



Our example assumes a base price on the house of $200,000, an energy-efficiency upgrade cost of $1,710, and a 30-year mortgage at 6% interest. We estimate that monthly energy bills will be about $105 after energy savings of about $70 per month in the 40% more energy-efficient home.

"People ask me, 'Why did you choose to build this way?' I say, 'Why *wouldn't* you build this way?' Consumers tell us they want it. Energy costs are continuing to go up. This is the best tool we have to fight back. As an industry, we need to do this."

Nat Hodgson, Vice President of Construction for the Las Vegas Division of Pulte Homes and Communities of Del Webb

"Energy efficiency has been a selling point with my customers, something that sets me apart. People appreciate that I'm thinking out of the box in a way that makes sense to them and saves them money in the long run."

Barrett Burr, Builder, Olympia, Washington

"I wanted to do the best I could as cost effectively as I could afford. This was not the bank's money – it was my money, so doing it right was very important to me."

Lee Rayburn, developer of Centennial Terrace in Tucson, Arizona. Impressed by the Building America systems approach he observed at the Civano development, he asked Building America partner Building Science Corporation (BSC) for guidance in designing Centennial Terrace.

(top) Grupe credits green features with increasing foot traffic to help sell houses faster than its competitors.

(bottom) Buyers flocked to Centex's energy-efficient homes at Windemere in San Ramon, CA.

"We are selling at a pace that is double that of our competition. If just 20% of this increased sales rate is due to the solar and green features, then the Grupe Green program has paid for itself."

Mark Fischer, senior vice president at Grupe, a Stockton, California-based production builder

"Sales were quick, I think because the homes were well designed...buyers really love the energy savings."

Lee Rayburn, developer of Centennial Terrace in Tucson, Arizona, where energy bills run $60-70 per month compared to typical local bills of $300-400/month.

Consumer Preferences

Customer satisfaction matters to your company's future and energy efficiency matters to your customers. Surveys show that consumers want energy efficiency and they are willing to pay for it. It's not just a question of being more appealing, it's a question of turning your customers into one of your greatest assets. Here are some of the latest market survey findings.

- In its 2006 Energy Pulse survey, the Shelton Group found that 86% of Americans would choose one home over another based on its energy efficiency. Yet 78% of the homeowners who were polled reported that nobody talked to them about energy efficiency during the buying process (*National Builder News*, April 9, 2007).
- When surveyed by the National Association of Homebuilder's Research Center (NAHBRC) in December of 2007, energy improvements topped homeowners' choices for how they would spend an extra $5,000 on their new homes.
- 90% of new homebuyers are willing to spend more for energy efficiency – up to $17,000 more (McGraw Hill 2007; similar findings in Johnston 2000 and NAHB 2002).
- 80% expressed a willingness to buy a home in which utility bill savings offset an increased mortgage payment (NAHBRC 2006).
- Eight out of 10 Americans believe that homebuilders should offer solar on new homes (Roper 2006).
- A survey by Whirlpool Corporation found 84% of respondents listing energy efficiency as the most important factor in their appliance purchases (*Builder Magazine* March 27, 2009).
- 78% of recent homebuyers said that if their builders had recommended solar water heating, they would have seriously considered the purchase (NAHBRC 2004).
- Energy efficiency is the #1 upgrade sought by buyers (*Professional Builders Magazine* 2001).
- Consumer research organization J.D. Power found that truly delighted homebuyers (those rating their builders a 10 on a 10-point scale) recommend their builder to nearly twice as many people as the average new-homebuyer (J.D. Power 2005).
- A survey conducted for the National Association of Home Builders (NAHB 2007) confirms that a desire for greater energy efficiency drives consumers to choose a green-built home.
- McGraw Hill (2007) points out that 50% of green homebuyers are highly likely to recommend a new green home. This same report says that 85% of green homeowners are happy with their new green homes. Buyers in the western region of the United States, where the hot-dry and mixed-dry climates are located, are the most knowledgeable about green homes in the nation and most likely to seek out a green home builder.
- Pulte, a Building America partner and frequent winner of consumer satisfaction competitions, received positive referrals from 93% of its customers.
- Word-of-mouth referrals typically make up to 30% of a builder's referrals (Farnsworth 2003) and are the most likely way that consumers learn of green home builders (McGraw Hill 2007).
- Buyers rate energy efficiency as a home builder's most important product-related reason for referring new customers (*Professional Builder Magazine* 2003).

Competitive Advantage

Market research shows buyers want energy efficiency, and they are willing to pay more for it. Also, if your homes have it, you are likely to outsell your competition. Qualifying for programs such as the Builders Challenge and ENERGY STAR provides an easy way to show consumers that your company's homes are a cut above the competition. Ideas for marketing energy-efficient homes are discussed in Chapter 4.

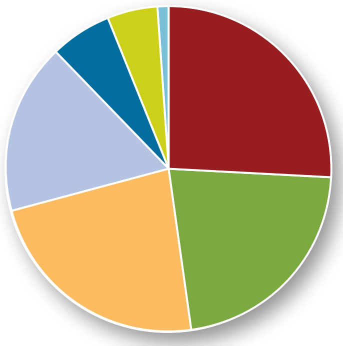
Boosting the Bottom Line

Competitive advantage is a desirable trait, especially in a down market. However, being desirable to consumers is not the whole picture. Building America builders in California have leveraged their competitive advantage into a business plan that works for them while delivering a premium house to their consumers.

Grupe Homes of Stockton, California, builds green homes that include integrated photovoltaic systems. Grupe's homes use about 50% less energy than typical homes. One Grupe home was the first California home certified under the Builders Challenge; it received an E-Scale score of 47. Grupe discovered that their houses sold more than twice as fast as their competition's. Building America worked with other solar home builders who experienced similar results in 2006-07.

This increased absorption rate meant more than just moving more product. Grupe's managers concluded that they could anticipate substantial financing savings by selling out their project sooner than they had projected. In a project of 144 houses, these savings would amount to a windfall of $14 million. That profit is net after taking out $2.6 million of added expenses for equipment and advertising for the energy efficiency, solar, and green features of the homes. Grupe found a way to sell superior houses at prices similar to their competitions' standard houses and still make a substantial profit (Willard et al. 2008).

How homeowners would spend an extra $5,000 on their new homes *(Figure source: NAHBRC)*



- **26%** would pay for energy improvements
- **22%** for new countertops
- **23%** for other
- **17%** for upgraded flooring
- **6%** for upgraded appliances
- **5%** for upgraded bathroom features
- **1%** for new siding

"I love the construction; I love that they're very well put-together. When you compare the energy savings across time, there was no question where to buy."

Owner of a near zero-energy home built by Building America builder Premier Homes, Roseville, California. as quoted in a Rand Corporation report, 2006.

"Building America helps us with our reputation within the building community. Our reputation on the street is that if you want a good quality home you go to Pulte."

Alan Kennedy, Vice President of Construction for Pulte Tucson

For More Information on the Business Side of Building

Builders Magazine. 2008. "Builder 100."
www.builderonline.com

Dakin, Willard, David Springer, and Bill Kelly. 2008. "Case Study: The Effectiveness of Zero Energy Home Strategies in the Marketplace." In *Proceedings of the 2008 ACEEE Summer Study on Energy Efficiency in Buildings,* American Council for an Energy-Efficient Economy, Washington D.C.

Farnsworth, Christina. 2003. "The Weakest Link." *Builder Magazine*, December 2003.
www.builderonline.com/business/the-weakest-link.aspx

J.D. Power and Associates. 2008. "2008 New-Home Builder Customer Satisfaction Study."
www.jdpower.com/homes/articles/2008-Homebuilder-Customer-Satisfaction-Study

Johnston, David. 2000. "New Home Buyer,"
www.greenbuilding.com/knowledge-base/new-home-buyer

Maynard, Nigel F. 2009. "New Survey Finds Energy, not Water, Drives Appliance Purchases."
Builder Magazine, March 27, 2009.
www.builderonline.com/appliances/survey-finds-energy-drives-appliance-purchases.aspx

McGraw Hill Construction. 2007. *The Green Homeowner - Attitudes & Preferences for Remodeling and Buying Green Homes*.
http://construction.ecnext.com/coms2/summary_0249-258442_ITM_analytics

National Builder News. 4/9/07. "Builders Need to Make Energy Efficiency a Selling Point."
National Builder News Online.
www.nbnnews.com/NBN/issues/2007-04-09/Front+Page/index.html

National Builder News. 4/16/07. "In a Down Housing Market, Green Demand Exceeds Supply."
National Builder News Online.
www.nbnnews.com/NBN/issues/2007-04-16/Front+Page/index.html

NAHB. 2007. "Energy Efficiency Ranks #1 In Consumer Green Building Priorities."
National Association of Home Builders
www.nahb.org/news_details.aspx?newsID=5599

NAHB. 2002. "What 21st Century Home Buyers Want." National Association of Home Builders, Washington, D.C.

NAHBRC. 2007. *Building America Challenge Survey of Builders and Consumers*. Proprietary survey commissioned by DOE and conducted by the NAHBRC as part of the Annual Consumer Practices Survey. National Association of Home Builders Research Center, Upper Marlboro, MD.

NAHBRC. 2006. *The Potential Impacts of Zero Energy Homes*. National Association of Home Builders Research Center, Prepared for the National Renewable Energy Laboratory, Golden, CO.
www.toolbase.org/PDF/CaseStudies/ZEHPotentialImpact.pdf

NAHBRC. Focus Marketing Services, and Symmetrics Marketing Corporation. 2004. Analysis of the Solar Water Heating Marketing Research Studies Conducted for the Solar Buildings Program. NAHBRC, Upper Marlboro, MD.

Professional Builder. 2003. "Customer Service Standard Setters." September 2003.
www.housingzone.com/ProBuilder/article/CA464895.html?q=customer+service+standard+setters

Roper. 2006. "Solar Survey," Proprietary survey commissioned by Sharp Electronics and conducted by Roper. Reported in various publications (e.g. *Builder News*, December 2006) and described in press release dated June 21, 2006, released by Sharp Electronics.
http://solar.sharpusa.com/files/sol_dow_solarsurvey_062106.pdf

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 3.
Business Management Tools

Builders learn quality management concepts at a Building America workshop, conducted by IBACOS.

Builders are as much about business as they are about buildings. Part of the equation of building high-performance homes is developing business systems to encourage innovation, but also to ensure consistent production.

This chapter introduces four practices to aid in construction planning and management:

- quality management
- value engineering
- integrated design
- prototype development.

These four practices can individually bring value to management processes, but they work best when applied as part of an overall management system suited to an individual business. These four tools are process and design focused. They emphasize product value and functionality. For businesses to prosper, return on investment (ROI) must also be an important criteria.

"We have seen a direct impact on our quality through the Building America Program. We are able to build a better product because of our consistent approach [in implementing Building America practices]."

Josh Robinson, Vice President of Operations for Pulte, North Inland Empire Division of Southern California

Building Quality

Whether you want to build for market entry or upscale consumers, a quality management program provides the tools and processes that can help you consistently achieve desired results. If you choose to build high-performance homes that meet aggressive efficiency goals, a quality management system likely will be necessary to consistently meet those goals.

Three terms are often used when describing quality programs: quality management system, quality assurance, and quality control. These terms are described below, based on the definitions provided by the American Society for Quality (ASQ) (www.asq.org).

- **Quality Management System:** a process to achieve maximum customer satisfaction at the lowest overall cost to the organization while continuing to improve the process. A quality management system is a formalized system that documents the structure, responsibilities, and procedures required to achieve effective quality management. A related term – total quality management – refers to all members of an organization participating in improving processes, products, services, and the culture in which they work.

CHAPTER TOPICS

Pulte Las Vegas Division has certified over 780 homes as Builders Challenge homes – more than any other builder.

- **Quality Assurance:** the planned and systematic activities that provide confidence that a product fulfills requirements for quality. These activities may include tests, such as blower door tests, inspections, checklists, and systematic training.

- **Quality Control:** the operational techniques and activities used to fulfill requirements for quality. These techniques include evaluations, such as statistical studies to evaluate product variation, expected failure rates, and corrective actions.

Many companies formalize their quality management processes and tools. Other companies simply incorporate tools into their business practices that help to improve quality. Some companies choose to become certified under third-party quality assurance programs.

As efficiency levels become more aggressive, quality installation and design become ever more important parts of the equation. So as builders pursue energy efficiency to help improve quality, Building America recommends that builders take steps to improve quality processes to prepare for high-performance home building. Quality management processes offer many tools to help manage needed changes and to improve operations over the long term.

The quality management "wheel" on the next page shows how quality management processes could work for a builder. The key concept is that information flows both to and from each part of the company including subcontractors. The figure also shows where quality assurance tools can be used during the construction process.

Plans and Specifications

Plans and specifications are the most familiar parts of construction documents. Plans should show elevations, floor plans, and details of the elements needed to show codes officials that projects meet code minimums. Plans and materials schedules are important for ordering materials. Plans and specifications address the following building features related to energy efficiency. These are only examples and other features may also be explicitly included in construction documents. (Construction documents are described more fully in Chapters 11 and 12 and also come up in the other sections of this chapter.)

- Provide framing diagrams and details to spell out advanced framing techniques and the placement of all framing members (more information is in Chapter 7).

- Show duct sizes and layouts on floor plans and elevations (more information is in Chapter 9).

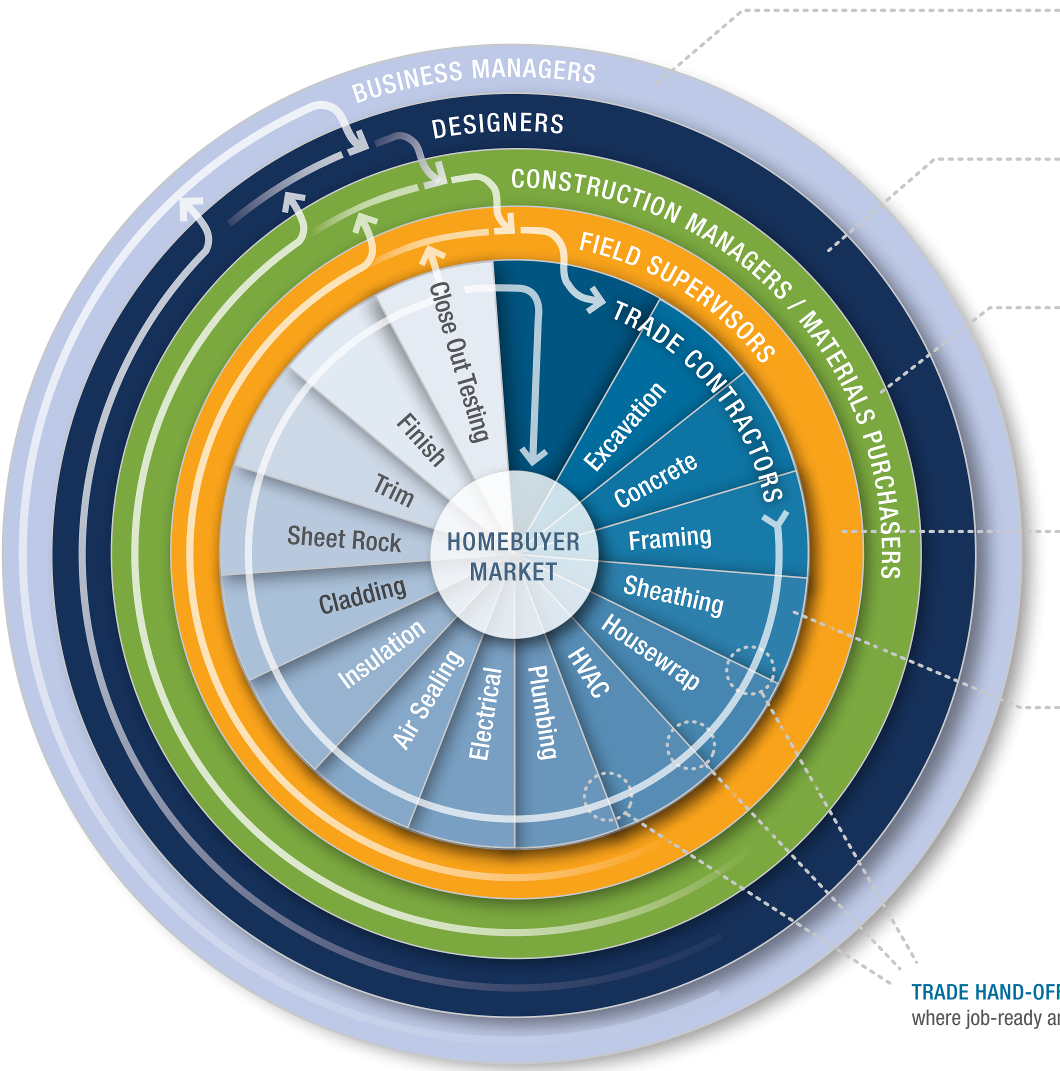
- Indicate methods, materials, and locations where sealing is needed to form the house air pressure barrier (more information is in Chapters 7 and 8).

- Specify the approach to be taken to meet vapor barrier code requirements (more information is in Chapters 7 and 8).

- Indicate methods, materials, and locations where liquid moisture barriers will be installed. Examples may include housewrap, sealing materials, flashing systems, gutter systems, and grading requirements (more information is in Chapters 7 and 8).

- Provide plans and details for all specialized building features, such as sealed and conditioned attics, sealed and conditioned crawlspaces, sealed and insulated air handler closets in garages, and radon control measures. (All of these features are described in the later chapters of this document.)

Quality Management Process Wheel



1 **BUSINESS MANAGERS** Share house designs with company divisions. Develop and support implementation of a quality management system.

2 **DESIGNERS** Ensure construction documents include clear diagrams of critical details and specifications for required materials and equipment.

3 **CONSTRUCTION MANAGERS / MATERIALS PURCHASERS** Interact directly with trade contractors to develop mutually agreeable scopes of work, checklists, and test and inspection protocols. Interact with customer to manage expectations and assure satisfaction.

4 **FIELD SUPERVISORS** Work with trade contractors to ensure coordination, installation according to the plans and specifications, compliance with local code, and completion of company quality assurance processes.

5 **TRADE CONTRACTORS** Ensure that the project is ready for your work to start. Perform work according to plans, specifications, manufacturer's installation instructions, and local code. Perform final inspection to ensure work is performed according to your own standards and those of the builder. Assure that the project is ready for next trade to begin work.

TRADE HAND-OFFS
where job-ready and job-complete checklists are done.

Scopes of Work

A scope of work is a description of the specific work that builders expect trade contractors to perform. Every contract, including those executed with only a nod and a handshake, incorporates a scope of work. If a clear understanding of the task and expectations of how it will be completed are not conveyed to the trade contractors, expectations for what a task entails can be all over the map. The bottom line is that builders and consumers should get what they pay for.

As materials change and techniques evolve, scopes of work must change to keep up. Front offices should give construction managers, trade contractors, and designers plenty of opportunity to review and update scopes of work. These reviews can happen any time, but are especially important before big trade contracts are initiated and just after projects are completed.

Scopes of work should take into account sequences of work that are unfamiliar to trade contractors. A good example of this situation is the installation of duct chases.

"By using a Building America consultant, not only do we get third-party cred-ibility, we ourselves become incredibly educated about the things we can do to save energy while building sustainable and beautiful communities."

Mark Fischer, senior vice president at Grupe, a Stockton, California-based production builder (as quoted in the San Francisco Chronicle July 2, 2006)

Pulte's systematic approach at its Sun Lakes development in Banning, California, included working with Building America to design an energy-efficient envelope and HVAC system, offering homebuyers a limited number of options, pre-assembling components on the ground wherever possible, and using a unique construction process called the DiVosta method. Homes were built five at a time on alternating sides of the street to keep the same subs employed on the entire project. This consistent process allowed Pulte to take homes start to finish in 55 days, at energy savings of 20% over California's Title 24 requirements, with performance guaranteed under the Environments for Living program. Even in a slower construction market, builders looking to cut costs without cutting corners could benefit from these streamlined construction methods.

"Building America is a way to manage risk, potential litigation issues, and building systems failures."

Josh Robinson, Pulte Sun Lakes project manager and a Pulte Vice President

RELATED STANDARDS AND PROCEDURES

ISO 9000, Quality Management Systems www.iso.org

2009 International Energy Conservation Code, Section 104.2 "Information on construction documents," International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html

Job-Ready and Job-Complete Checklists

The job-ready checklist, to be completed jointly by the site supervisor and trade contractor, includes all items that must be installed or prepared on the jobsite—by other trade contractors—before work can begin. Items in the job-ready checklist are not directly under the control of the trade contractor getting ready to work, but they directly affect his or her ability to successfully and efficiently complete the job. The job-ready checklist should be part of the scope of work because it highlights the ways in which one trade contractor's work is connected to another's and encourages trade contractors to think of their individual work as part of a larger whole.

The job-complete checklist is the mechanism by which the trade contractor certifies that the work has been completed to the high standard expected and by which the site supervisor agrees that the work was completed satisfactorily. To verify that the high-performance features of the home were constructed correctly according to the scope of work, performance testing is often part of a job-complete checklist. The job-complete checklist holds both the builder and the trade contractor responsible for proper implementation and appropriate inspection of the scope of work. Properly defined and implemented, the job-complete checklist functions both as a part of the job-ready checklist for subsequent trade contractors and as a field authorization of payment for the completed work.

The final judge of quality is the consumer. If a builder consistently meets consumer expectations, the rewards are tremendous. Consumer research organization J.D. Power found that truly delighted homebuyers (those rating their builders a 10 on a 10-point scale) recommend their builder to nearly twice as many people as the average new homebuyer (J.D. Power 2005).

For More Information on Quality Management

ASQ. 2003. *ISO 9001:2000 Interpretive Guide for the Design and Construction Project Team*. American Society for Quality Press, Milwaukee, WI. www.asq.org.
Note: As of June 2009, a 2008 version of ISO 9001 is in the process of being implemented.

2009 International Energy Conservation Code. Section 103.2, "Information on Construction Documents." International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html

ISO 9000. *Quality Management Systems*. www.iso.org.

NAHBRC. 2000. *Quality Assurance System for Wood Framing Contractors: National Quality Housing*. National Association of Home Builders Research Center. www.pathnet.org/si.asp?id=478

NAHBRC. 2008. *Scopes of Work for High-Performance Homes*. Prepared for the National Renewable Energy Laboratory by the National Association of Home Builders Research Center, Upper Marlboro, MD.

Integrated Design

The integrated design process, including energy-efficiency modeling and appropriate system sizing, is at the heart of Building America recommendations. Integrated design is a process by which all the various building subsystems are evaluated for the local climate and their interrelationships are analyzed, planned, and optimized. The goal is to gain value at every step of the design process (value engineering) rather than relying solely on negotiation and procurement to manage costs. The Durability and Energy Efficiency Checklist (Chapter 10) includes best practices that should be considered for all new house models.

Treasure Homes' Fallen Leaf project was named a California Green Builder Community by the California Building Industry Association for its energy efficient and green building practices. *(Photo source: Treasure Homes)*

Before World War II, a house was often designed and built under the watchful eye of a single person. As construction projects have become more complex and expertise has become more specialized, the decision-making, design, and construction processes have been divided among managers, designers, site superintendents, vendors, subcontractors, and the trades. Along with increasingly diverse teams, building materials and construction techniques have also multiplied and become more technical.

The integrated design process invites today's larger design and construction teams to share information and insights to achieve the kind of whole-house perspective and understanding that previously came with a single master builder.

Builders who use the integrated design approach focus on whole-house performance. They start by looking at how all the systems in the house (HVAC, insulation, walls, ceilings, and windows) work together to achieve a house that performs well in terms of energy efficiency, air quality, and moisture management. This investment in up-front planning is especially worthwhile for production builders because they reap the benefits with multiple applications of a particular model.

In contrast, builders using typical design practices often start by emphasizing cost and size. With these external factors decided, they move through a linear process ending with house construction; building performance is considered as an afterthought or not at all.

Traditional Design Processes

Typically a design process includes the following steps.

Programming:

In this conceptual development and planning stage, the price range, square footage, number of stories, lot sizes, general features, and styles are determined.

Schematic Design:

Preliminary designs are developed including floor plan sketches, number of bedrooms, major options, basic circulation and function locations, as well as some elevation concepts.

Design Development:

Preliminary structural, mechanical, electrical, and plumbing plans are drawn.

Construction Documents:

Final working drawings and specifications are ready for bidding and code approval.

The traditional design process tends to be linear, with input coming sequentially. Sometimes design decisions are made before the input is available. Sometimes the input is not part of the formal design process, but comes in the field where access to information is limited and decisions must be based on the materials, expertise, and conditions at hand. Within this process, it is possible that system sizing and computer modeling may not happen until construction begins if at all. HVAC equipment may not be sized until the installer shows up on the project site, and important decisions such as routes and sizes for ducts may not occur until installation work begins in the field.

"Our initial objective was to meet the requirements of the top tier of the Sacramento Municipal Utility District (SMUD) energy efficiency program. ConSol, a Building America partner, showed us how we could take the next step to meet the standards of the California Green Builder program. Once we were there, we met … the Building America requirements as well."

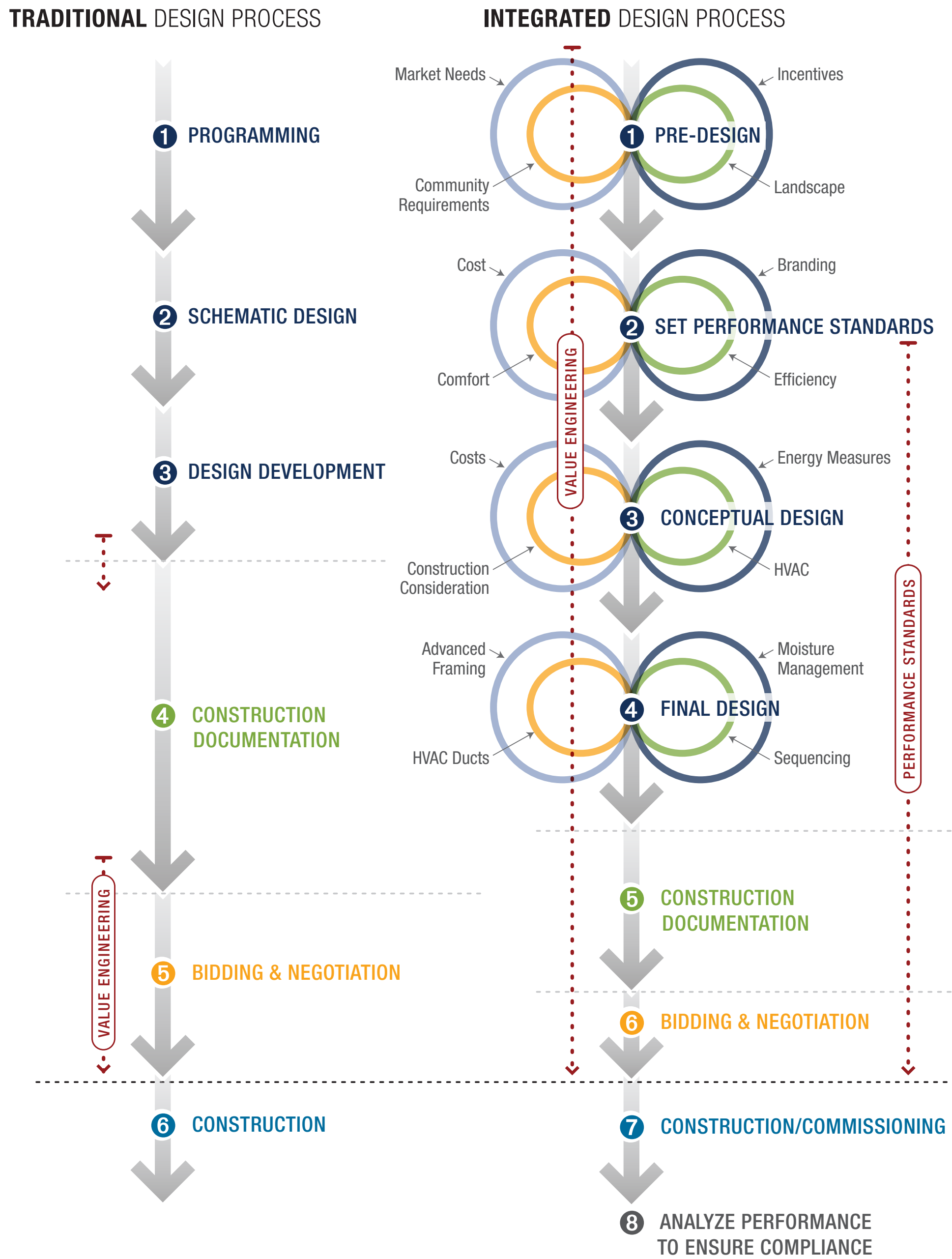
Jim Bayless, President of Treasure Homes, Sacramento, California

Artistic Homes' first true zero energy house was completed in 2008. Artistic now offers a zero energy package upgrade on every home it builds.

"At first, Building Science Corporation provided training on techniques and systems. There was a lot to absorb and a little reluctance on our part. It isn't easy to convince builders to change their habits! But now, after a 10-year relationship, we're pushing the envelope with *them*. We want to be on the cutting edge of this technology, because we know it works."

Tom Wade, a principle of Artistic Homes, New Mexico's number one home builder in 2006, with 800 homes built using Building America-recommended processes.

Traditional Versus Integrated Design Process



The Integrated Design Process loops in design input at every stage of development. *(Adapted from IEA 2003)*

Integrated Design Process

A key idea behind integrated planning is that decisions about all building systems, including equipment selection, sizing, and placements, are made within the design process, not as afterthoughts in the field. The decisions are made with the help of analytical tools and the input of all relevant disciplines. Rather than a linear traditional process, the integrated process involves looping in ongoing input from relevant sources.

The following are steps within the integrated design process.

Pre-Design – Bring together a diverse and knowledgeable team. The makeup of the team and members' roles will vary depending on the project or objective under consideration. Community design may benefit from ecologists, landscape architects, or solar planners. House designs may need input from architects or designers, structural engineers, framers, and HVAC contractors. Solving a particular installation challenge could involve the site supervisor and the relevant trades. For larger-scale efforts, select a facilitator to carry the process forward and set up a schedule of needed meetings.

Set Performance Standards – Early in the design process, establish standards that the house model will be expected to achieve. Measure progress against these standards at each step. Use market data to determine the level of quality, performance, size, and cost the new house will achieve. Performance areas may include moisture management, indoor air quality, energy efficiency, HVAC comfort, and any certification requirements (for example, compliance with green building programs, achieving a HERS index score needed to meet company requirements or to qualify for a tax credit, or compliance with a comfort and energy performance guarantee program).

Conceptual and Preliminary Designs – Gain team feedback during all phases of design and construction. Use an energy specialist to test out design assumptions and simulate possible solutions. It is important to work with framing and other contractors, especially HVAC contractors, to identify conflicts and develop solutions before houses go into production. Consider more than one solution and select the ones showing the most promise at meeting goals. By integrating design decision making, all parties benefit. For example, the mechanical contractor can aggressively size the HVAC equipment knowing that the thermal envelope is well insulated, properly air sealed, and third-party inspected.

Final Design – Create specific drawings and system designs. Generate architectural, framing, HVAC, electrical, and plumbing drawings that specify locations for equipment chases and runs. Develop framing plans showing the location of every stud, floor truss, and roof truss. HVAC drawings should specify duct sizes and locations, including chases designed to carry ducts inside conditioned space. Some builders create a single system design that can be approved, installed, and warranted by any installing contractor on most of their home models. This can apply for many systems in the house including but not limited to framing, electrical, plumbing, and HVAC.

Construction Documentation – Base construction documents on the final design. In addition, the documents should include statements of work for all subcontractors, specifying installation requirements and checklists for self- and third-party verification.

Construction/Commissioning – Build the houses to the designs. After ducts are in and sealed but before insulation and sheetrock are added, conduct duct leakage tests. After insulation is added, conduct visual inspections for compaction and voids. After sheetrock and wall surfaces are added, check whole house air leakage, temperature evenness, room pressures, ventilation, and CO_2 levels. Confirm that specified appliances and lighting are installed.

Analyze Performance to Ensure Compliance – Work with consultants or in-house experts to ensure home designs will meet performance standards. Use computer models to simulate energy consumption and size HVAC equipment. Evaluate checklists for green programs.

In July 2007 the Whole Systems Integrated Process Guide (WSIP) 2007 for Sustainable Buildings & Communities, ANSI/MTS Standard WSIP 2007, was approved by the American National Standards Institute (ANSI). The document codifies a specific integrated design process.

When Pulte Tucson, a Building America partner, took over as master developer at the planned community of Civano in Tucson, they overcame difficulties experienced by the previous builders to construct more than 1500 homes, meeting the strict requirements of Civano, including numerous "green" requirements and a 50% reduction in energy use over code. "Pulte is successful at Civano because they are using Building America building science concepts. They are applying a much more scientific approach to make their homes affordable and efficient."

Al Nichols, Professional Engineer and Plans Reviewer for Civano

For More Information on Integrated Design

ANSI. 2007. ANSI/MTS 1.0 *Whole Systems Integrated Process Guide (WSIP) 2007 for Sustainable Buildings & Communities*. Institute for Market Transformation to Sustainability. American National Standards Institute http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2FMTS+1.0+WSIP+Guide-2007

BC Green Building Roundtable. 2007. *Roadmap for the Integrated Design Process Part One: Summary Guide*. Prepared by Busby Perkins+Will and Stantec Consulting for Metro Canada. Vancouver, B.C. www.metrovancouver.org/buildsmart/design/Pages/Integrateddesignprocess.aspx

International Energy Agency. 2003. *Integrated Design Process Guideline*. Prepared by sol*id*ar planungswerkstatt atchitects and engineers and Architeckten B+S for the IEA. www.iea-shc.org/task23/design.htm

Value Engineering

Value engineering has its roots in World War II. While coming up with creative substitutions for building supplies in the face of wartime shortages, staff at General Electric developed a process that had the unintended consequences of reducing costs and improving products. Value engineering has evolved into a systematic method to improve the value of goods and services by examining approaches to meeting function. Value can be increased by either meeting function more efficiently or reducing cost. Value engineering within the construction design process was developed in the 1960s.

Optimum value engineering for framing, also referred to as advanced framing, is one example of how value engineering can reduce construction costs while maintaining or improving functionality. More information on advanced framing can be found in Chapter 8. Advanced framing can be an important design feature, but value engineering can be applied to all aspects of home design.

Much of Building America's research is aimed at helping builders choose more efficient construction materials and methods to make their buildings more efficient. Building America's research takes into account energy efficiency, as well as other important aspects of functionality, such as structural needs, durability, comfort, and health. Improved quality control also means fewer call backs which leads to more customer referrals.

Value engineering is an important part of quality management and integrated design. Production builders are in a very good position to take advantage of value engineering. The investment made up front in the design process pays off in the many homes where those improved designs are applied. Value engineering is not just about reducing cost, it's about selecting the systems with the best value and recognizing synergies within the integrated design process.

For More Information on Value Engineering

Moser, Cliff. 2007. "Using Active Value Engineering for Quality Management," *Practice Management Digest*, American Institute of Architects.

SAVE International. 2007. *Value Standard and Body of Knowledge.* Accessed 07/30/2008 www.value-eng.org/pdf_docs/monographs/vmstd.pdf

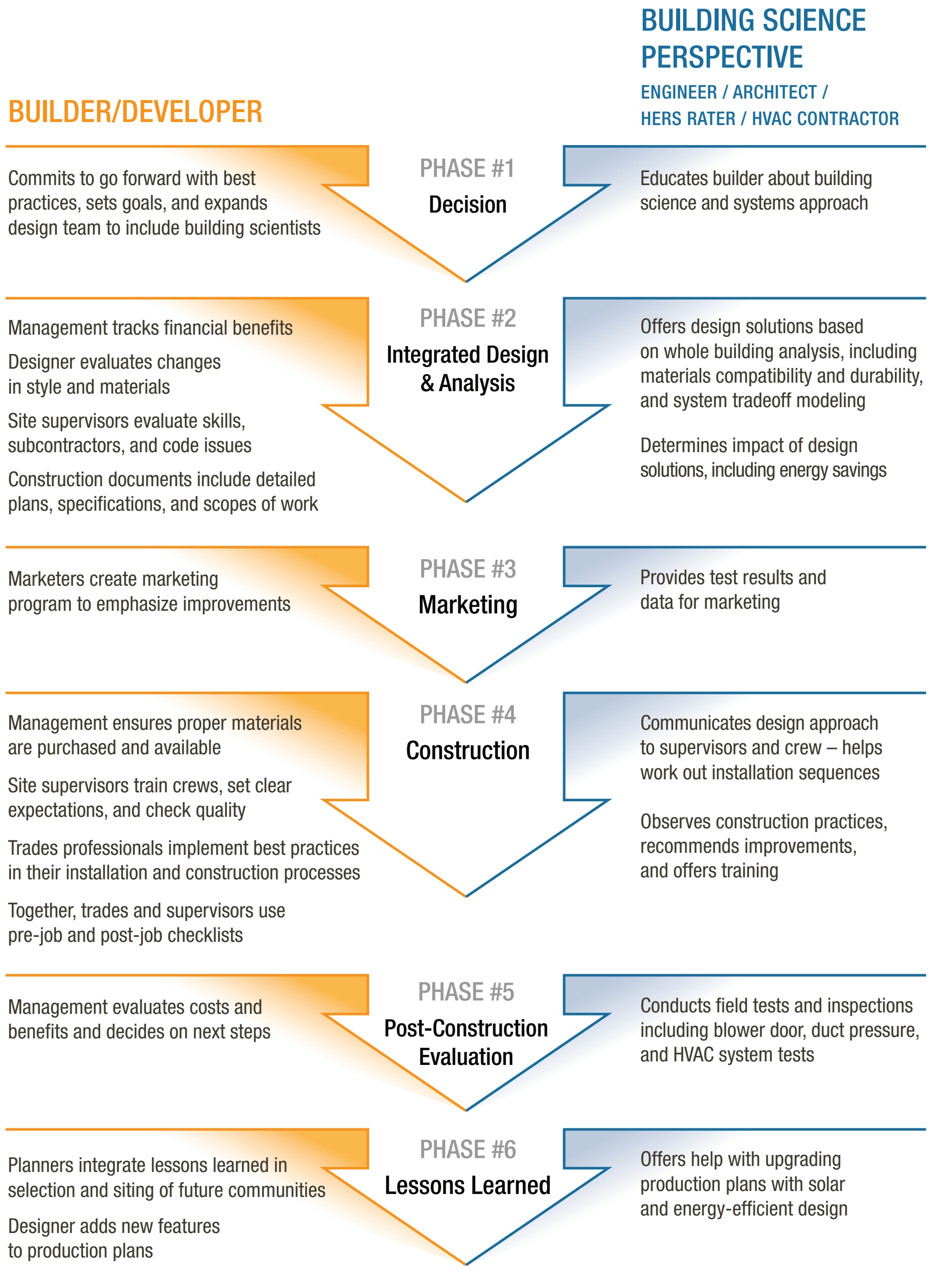
"It scared us half to death at first. It's a challenge for builders to step out of their comfort zone, and we had no experience with ICFs (insulated concrete forms) at all. The people we worked with are the best in the business. They appreciated the challenge and the opportunity to learn something new as much as we did. And some of the techniques we learned on this project – such as building with ICFs – are techniques we still use and recommend today."

Steve Jones, president of Merlin Contracting, builder of National Association of Home Builders (NAHB) 2004 New American Home, in Sahara Lake, Nevada, which included unique desert climate features such as ICF foundation walls, a SIPs roof, copper-clad sunshades and roof covering, the air handler and ducts in conditioned space, and a heat recovery ventilator to cut heating and cooling costs by more than 50%.

Managing Innovation with Prototypes

Many builders choose to try out Building America technical ideas in a prototype house. The prototype experience enables the builder to experiment with new materials, products, and construction practices with minimal costs and risks. After building one or a few prototypes, the builder decides what features they will carry forward into their regular construction. This chart shows a process for working with building scientists, such as a Building America team, a Home Energy Rating System (HERS) professional, an engineer, or an architect, to build the prototype house. The building scientist could be a company designer who has become familiar with this document and has taken other Building America training.

Process for Building a Prototype High-Performance Home



Clarum Homes built four zero-energy research homes at Borrego Springs, California, to test wall materials and cooling systems in hot, dry environments. (*Photo source: Clarum Homes*)

Clarum Homes, which has been incorporating energy efficiency into its production homes in California since 2001, uses prototype projects to test new technologies in new markets. In 2006 Clarum teamed with Building America research partners (the Building Industry Research Alliance and the Consortium for Advanced Residential Building) to build four prototype homes in the Anzo Borrego Desert. Clarum used the four homes with their identical floorplans to test three different kinds of exterior wall systems, three different cooling systems, and two kinds of space heating. Then, they monitored the homes for a year and a half to collect data on construction schedule, production feasibility, energy efficiency, product lifecycles, embodied energy, and cost and energy savings.

Building America Best Practices Series

Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 4. Selling Performance

Sales display in the education center at the "Zero Energy" Fallen Leaf community in Sacramento, California.

The number one reason builders give for building energy-efficient homes is to differentiate their product from their competitors (NAHBRC 2007)—and it works. Building America has worked with many builders who have successfully included energy efficiency and solar energy in their business plans. Consumers want the value and comfort high-performance homes offer, and builders want the customers.

However, the sales do not happen by themselves. To recoup the investment builders make in energy efficiency and quality management, they must:

- Brand and label their products for fast and easy differentiation
- Train their sales staff to educate consumers
- Demonstrate the products and explain the value added to consumers
- Package energy efficiency features and solar to encourage their sale
- Get the business name and products in front of the public.

"It is an opportunity to set ourselves apart as a small builder. The market will be wanting more energy efficiency as time goes on and we want to stay ahead of it."

John Ralston, Vice President of Sales and Marketing for Premier Homes of Roseville, California

Branding and Labeling

Branding and labeling offer two methods for gaining consumer attention and confidence. When consumers recognize a brand and associate that brand with positive attributes, they are more willing to consider purchasing that product. Brands and labels can also offer information to buyers to help them know that your product is what they are looking for.

Creating recognizable brands that resonate with consumers is difficult. Large corporations that rely on consumer sales spend millions of dollars on campaigns to keep their brands fresh but familiar. This investment pays off best when products involve multiple, frequent purchases from many consumers. Most builders do not fit this equation very well—builders typically sell their products in limited markets, and consumers tend to hang onto the purchase for a long time.

For builders of energy-efficient homes, there are ways that builders can successfully brand their products. An easy approach is to partner with certification programs that invest in brand recognition. These third-party brands offer certification that a builder's products meet a set of standards. ENERGY STAR and the Builders Challenge are examples of recognizable brands

CHAPTER TOPICS

Consumers recognize ENERGY STAR products as being energy efficient and good for the environment.

"Many builders out there have their own energy efficiency programs, and each one is called something different. The U.S. Department of Energy is known and respected. It lends credibility if you can say you are meeting the DOE's Builders Challenge standard, as opposed to meeting a program criteria you came up with yourself."

Chris Kelly, Vice President of Operations for Pulte Phoenix Division.

U.S. Department of Energy Builders Challenge

DOE has posed a challenge to the homebuilding industry—to make cost-effective net-zero energy homes available to all Americans by 2030.

that help consumers know that an appliance or a home is energy efficient. Qualifying for these nationally known programs will give your energy-efficiency efforts instant credibility.

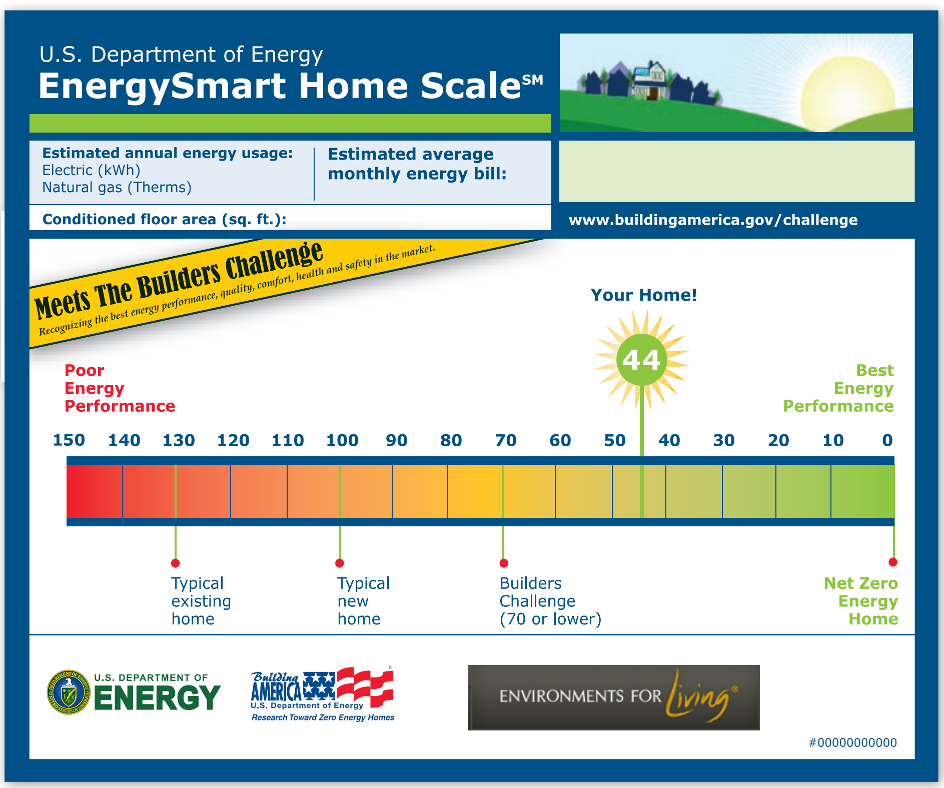
Consumers recognize ENERGY STAR products as being energy efficient and good for the environment. The brand label can be found on many consumer products ranging from computers and dishwashers to lights and homes. Homes that qualify for the ENERGY STAR for Homes label are generally about 15% more energy efficient than current building code requirements. Thus, the homes that exceed the Building America benchmark by 30% to 40% should qualify for ENERGY STAR.

Whether or not builders choose to brand their homes ENERGY STAR, many of the products that go into the home (or are on display in model homes) carry the ENERGY STAR label.

Homes that achieve a 70 or lower on the HERS Index and that meet specified quality criteria can qualify for DOE's Builders Challenge. Chapter 2 describes this program and the label that is attached to qualifying homes. In addition to providing the Builders Challenge brand, the label also provides useful information for consumers. The label incorporates the E-Scale, a ranking of energy efficiency based on the HERS Index. Like a miles-per-gallon rating, this index gives consumers an easy way to compare and distinguish competing houses.

Both the ENERGY STAR (www.energystar.gov) and the Builders Challenge (www.buildingamerica.gov/challenge) websites provide brochures and other marketing materials that help to sell the brands.

DOE's Builders Challenge program has formed national partnerships with leading green building programs, including the National Association of Home Builders' National Green Building Program™, the U.S. Green Building Council's LEED for Homes program, and MASCO's Environments for Living®. In addition there are a host of regional energy-efficiency programs providing recognition to builders.



Builders who are investing in energy-efficient, green, healthy house, or renewable energy technologies or practices, should seek qualification with Builders Challenge, ENERGY STAR, and other national and regional programs promoting these efforts. Their branding and labeling efforts are excellent vehicles for leveraging your marketing dollars.

Many Building America builders choose to offer their homeowners an energy-use guarantee through Masco Home Service's Environments for Living program. The program was developed in 2001 with Advanced Energy Corporation and Building Science Corporation, a Building America team lead. Under Environments for Living, the home's heating and cooling energy use are estimated and Masco guarantees the homeowner that Masco will pay them the difference if their energy bills are higher than the calculated estimate. For homes at the Environments for Living gold and platinum level, Masco also offers a comfort guarantee promising the temperature at the thermostat will not vary more than three degrees from the temperature at the center of any conditioned room within that thermostat zone. The gold level requires that homes perform 15% above code (2006 IECC) and qualify for the U.S. EPA's ENERGY STAR® label. The platinum level requires that homes perform 30% above IECC, and qualify for the U.S. DOE's Builders Challenge program.

Treasure Homes and Grupe Homes in California devote entire rooms to interactive displays showing solar and energy efficiency technologies.

"If you are going to put it in, be prepared to train your whole organization on why it's a good deal, especially sales staff. You have to train them so that they can tell potential buyers why solar is so great."

Mark Fischer, Senior Vice President, The Grupe Company, Stockton, California

Sales Training

Having properly trained sales staff is key to helping buyers understand and appreciate the value of energy efficiency, solar, and green features. As the first builder to qualify homes for the Builders Challenge in California, the Grupe Company realized the importance of training.

Grupe's approach to training involved the entire staff. Tools were developed for the sales team that included a technical sales resource binder, four hours of formal training, and ongoing training. Training covered:

- Financial benefits for homeowners
- Solar power for homes
- Energy efficiency features
- Utility information
- Environmental benefits
- News coverage
- Frequently asked questions.

Sales staff at Bob Ward Homes in Maryland received tours of their highly efficient prototype home while it was under construction. Then, they hosted open house events and gave tours for local builders, realtors, students, and media. Detailed signage was developed to help explain efficiency features.

Some builders offer homebuyers an Environments for Living energy savings guarantee.

Building America partner Clarum Homes of Palo Alto, California, combines energy efficiency and solar power features in its Enviro-Home package to reduce homeowner energy bills by up to 90%. The package includes a tankless gas water heater, a high-efficiency furnace, foam-wrapped building envelope, increased insulation, roof radiant barrier, advanced HVAC technology, tightly sealed ducts, low-emissivity energy-efficient windows, ceiling fans, fluorescent lighting, water conserving plumbing fixtures, and water conserving landscaping. (*Figure source: Clarum Homes)*

(above) Some builders market their energy-efficient features in information rooms that show potential buyers cut aways and side-by-side displays of building science technology versus code minimum techniques.

(right) Builders use signage in model homes and sales offices to sell the quality of energy-efficient homes. *(Photo source: NREL).*

"Right now it's a buyers market. There is a great deal of pressure to lower our sales prices, but we know we are giving buyers a better product, and our buyers tell us this. Most of our sales are through word of mouth. Homebuyers don't always understand the value of what they are getting until they've lived in the home a few months and start seeing their utility bills. Then, they can't wait to talk about it with their friends."

Nat Hodgson, Vice President of Construction for the Las Vegas Division of Pulte Homes and Communities of Del Webb.

Building America builders have won 88 National Association of Home Builders Research Center Energy Value Housing Awards through 2009. Beginning with the 2010 awards cycle, builders can earn points for participation in DOE's Builders Challenge program and can apply for Builders Challenge certification through the EVHA application process.

Make It Real

Pulte homebuyers in Phoenix know they are getting more in a Builders Challenge home the minute they step into the Cabrillo Pointe sales office. "The Builders Challenge HERS scale is visible as soon as you walk in the door. It shows how our homes compare to typical construction," says Chris Kelly, Vice President of Operations for Pulte Phoenix Division.

A challenge for builders of energy-efficient homes is showing consumers the actual hardware they are purchasing. Most energy-efficiency improvements are hidden away in walls and attics invisible to buying eyes. Making energy improvements "real" to the consumer can include tours of houses under construction, cut-aways, displays in model homes, posters, videos, and special rooms dedicated to displays of energy-efficiency features and products.

Package Energy Efficiency

A review of the consumer preference information presented in Chapter 2 shows that most homebuyers need to be told about the energy features of a home. Once they have it explained to them, most buyers say they will purchase specific measures. Other survey data show that, although consumers need to be educated, they prefer that builders package efficiency measures rather than having to make the choices themselves. This suggests that consumers respect the builders' and designers' expertise to put together good energy-efficiency packages.

Reach Out to the Media

Nothing is more cost effective than sending out a news release to local media to announce business news and other company activities. News related to energy efficiency can include partnering with the Builders Challenge, reaching new best scores for your area in the HERS Index, hitting milestones in numbers of energy-efficient houses built, winning awards for energy efficient and green construction, trying out new technologies, offering tours of houses under construction, or cooperating with research organizations such as colleges or DOE. News releases can cover your company's involvement in educational activities, for example, teaching school children about energy efficiency or other charitable actions.

Green building ads attract the attention of today's environmentally conscious consumers.

Companies that try out new technologies or apply technologies on a big scale have found much in the way of media exposure. Builders who installed photovoltaic systems have found coverage in *The New York Times*, on the major televisions networks, and in the local press.

How Industry Leaders Sell Energy-Efficient Homes

The National Association of Home Builders (NAHB) Research Center sponsors an annual award competition called the Energy Value Housing Award. The center has compiled the winning builders' marketing techniques into a document that is available on the Web at www.nahbrc.org/evha.

Here are some of the best practices recommended by the NAHB Research Center (NAHBRC 2002) and other sources:

- Educate customers and sales professionals. Show buyers how living in an energy-efficient home will benefit them with lower household costs. Vital to customer education is an informed sales staff and team of local sales professionals.
- Walk-throughs and model homes can be invaluable educational tools for both buyers and sales staff. Recent research suggests just how important model homes, models of house features, and other educational tools are to shoppers (Farnsworth 2003). Model homes with display cutaways of energy features such as insulated attics and wall sections help them understand the energy-efficient construction process. Use labels, flags, and banners to create a fun, self-explanatory message to give buyers a focus while they drive or walk the development. Treasure Homes used a falling leaves motif to guide buyers through energy efficiency displays at its Fallen Leaf development.
- Information centers make energy features tangible. The more builders tell consumers about energy-efficient features, the more consumers want them. Grupe, a production home builder in California, turned the garage of one of its model homes into a "Grupe Green" showroom for training sales staff and educating potential buyers.

"You have to educate homebuyers so that they understand that buying a zero-energy home is simply a different way to buy energy. It's hard to understand this when you amortize the costs, but it makes a lot more sense to the average person if you can show them that this is an investment, and in fact, it adds value to the home so that they can sell it for a greater return later."

Bob Walter, Morrison Homes, Elk Grove, California

Building America builder Artistic Homes, one of New Mexico's biggest home builders, conducts open house seminars to educate homeowners, potential buyers, and even other builders on cost-effective, healthy, and energy-efficient techniques.

Heather's House – Dallas builder Don Ferrier attracted national attention when he invited a local news reporter to document the construction of a contemporary, energy-efficient, and affordable home he was building for his daughter Heather. Ferrier sought the Builders Challenge designation, LEED Platinum certification (first in Texas), and American Lung Association Health House certification (first in the nation under the new 2006 criteria). The house was the 2007 gold winner for NAHBRC, and won awards from the National Association of Home Builders, the Structural Insulated Panel Association, and the Dallas Home Builders Association. In addition, numerous news media picked up the story including HGTV, Oprah's *O at Home* magazine, NBC Nightly News, *Mother Earth News*, *Consumer Reports*, trade journals, and several green construction blogs and e-magazines. Heather opened up the home for tours and more than 5,000 people have gotten a first-hand look at the home's light, energy-efficient interior.

- Training sessions can be an effective tool for educating sales staff and professionals. Use slides, sample products, and energy bills as aids. One builder offered onsite workshops for other area builders and held open houses for consumers and schools. All of these activities were covered by local and national press.

- One way to educate consumers is to emphasize an energy-efficiency upgrade when signing the final papers. One builder has a wall of testimonials, photos, and examples of utility bills in his waiting room. All prospects are given an opportunity to view this "wall of fame" before the final sale is made. Another builder has the buyer meet with the building site supervisor after the sale is made. This person gives them one more chance to sign up for energy-efficiency upgrades, from a builder's perspective, what a better house they will get.

- Publications are an educational tool that customers and sales professionals can take home. Develop your own brochures or books or give away reprints of magazine articles, ENERGY STAR brochures, or Building America brochures. Don't overlook vendors and trade associations. They can provide excellent materials, often at no charge. For example, excellent information on window performance is available at the Efficient Windows Collaborative website at www.efficientwindows.org/index.cfm. Also, give potential buyers a checklist so they can compare the energy-saving measures in your homes with those of other builders (see Appendix I).

- Advertising can be used to explain the energy-efficiency advantages and distinguish builders from their competition. One builder created an ad campaign based on "$60," a figure they guaranteed monthly electric bills would not exceed for the first year. They ran ads on billboards, the sides of buses, signs on their property, and in the newspaper.

- The Internet and compact disks are other forums for presenting your education and advertising messages. Some marketers suggest that all builders should have a website, even if it is simple and offers only limited information. CDs with brochures or slide shows can be given to potential buyers to take home and replay your message.

- Seek out free publicity.

- Offer energy-efficiency guarantees. Energy performance guarantees can help convince buyers that energy savings are real. Partnerships with outside companies can help to establish guarantees. For example, some insulation manufacturers offer home inspections, tests, and cost guarantees.

- Make buyers aware of energy-efficient mortgages.

- Take advantage of the diagnostic testing data available on your homes. If your company follows the best practices in this guide, you will have blower door and duct tightness test data and a HERS score to share with buyers. Use these data to inform your customers and distinguish your houses from the competition. If you cannot provide testing for free, make it available as an option for homebuyers to purchase.

For More Information on Marketing

Builders Challenge
www.buildingamerica.gov/challenge

ENERGY STAR
www.energystar.gov

Environments for Living
www.environmentsforliving.com

Farnsworth, Christina. 2003. "The Weakest Link." *Builder Magazine*, December 2003.
www.builderonline.com/article-builder.asp?channelid=55&ar ticleid=375&qu=consumer+survey

National Association of Home Builders Research Center. 2009. Green Building Program.
www.nahbgreen.org

Sikora, Jeannie. 2002. *Energy Value Housing Award Guide: How To Build and Profit with Energy Efficiency in New Home Construction.* National Association of Home Builders Research Center, Upper Marlboro, MD.
www.nahbrc.org

U.S. Environmental Protection Agency. EPA Indoor airPLUS labeling program for new homes.
www.epa.gov/indoorairplus/about.html

U.S. Environmental Protection Agency. EPA WaterSense water-saving labeling program: New Homes.
www.epa.gov/watersense/pp/new_homes.htm

U.S. Green Building Council
www.usgbc.org

Building America U.S. Department of Energy Research Toward Zero Energy Homes

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 5. The Hot-Dry and Mixed-Dry Climates

The hot-dry and mixed-dry climates of the desert southwest run from west Texas and the Oklahoma panhandle west though the bottom portions of New Mexico and Arizona, and include most of California. Small portions of the southern parts of Nevada, Utah, and Colorado are included in the hot-dry and mixed-dry regions. These climates experience the sunniest, warmest, and driest weather in the United States. However, the eastern portions of the climate region include areas known for strong storms.

In addition to describing the hot-dry and mixed-dry climates, this chapter also provides information on

- solar energy siting and design
- xeriscaping
- earthquakes
- areas of historic severe storms
- areas where wildland fires have occurred.

"Building America achieves superior performance by applying measures that work with the local climate. The principles that go into the design of Building America houses are sophisticated but not complicated. I would encourage any builder who is interested in near zero-energy construction to talk to us and give it a try."

George James, DOE Manager of Building America's new construction program

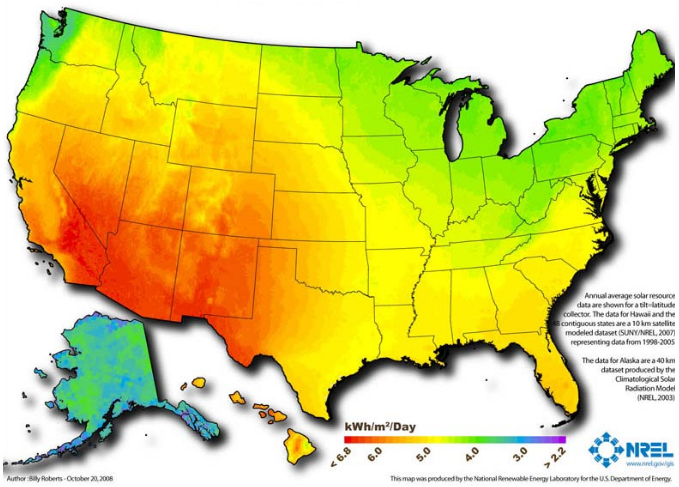
CHAPTER TOPICS

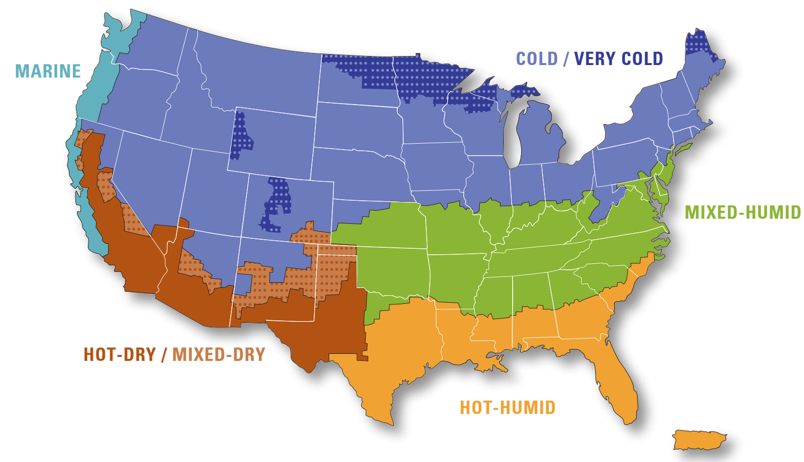
Climate Description

The hot-dry and mixed-dry climates are defined as follows:

- A hot-dry climate generally receives less than 20 inches (50 cm) of annual precipitation and the monthly average outdoor temperature remains above 45°F (7°C) throughout the year.
- A mixed-dry climate receives less than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (50°F basis) or less, and the average monthly outdoor temperature is above 45°F (7°C) except during the winter months.

A large swath of the hot-dry region, stretching from southern California to Phoenix, Arizona, experiences a period of 5-6 weeks in late summer with moderately high humidity that is uncharacteristic of this otherwise hot-dry region. Individual locations within the broad general regions can vary substantially. For a specific location, designers and builders should consider local weather records, local experience, and the micro-climate around a building. Elevation, incident





(left) Average kilowatt hours per day of solar power resource available in U.S. www.nrel.gov/gis/solar.html

(right) U.S. Climate regions.

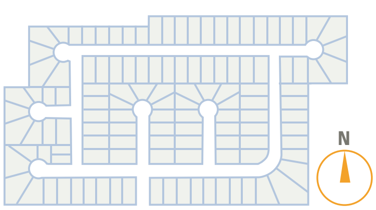
solar radiation, wind, the shade of adjacent buildings, location on the north side of a mountain, nearby water and wetlands, vegetation, and undergrowth can all affect the micro-climate.

Hot-dry and mixed-dry climates bring several challenges for home building. The intense solar radiation imposes a large thermal load on houses, increasing cooling costs, adversly affecting comfort, and damaging home furnishings.

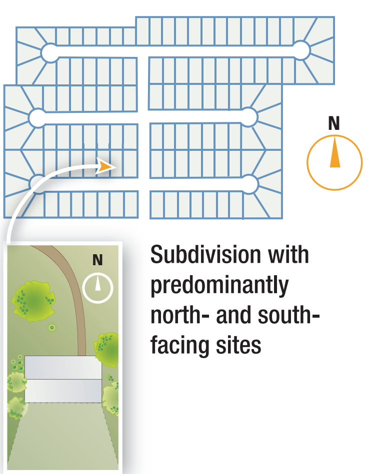
Annual precipitation in these climates is typically less than 20 inches. Nevertheless, a brief period of heavy rain can deposit several inches of water onto and around a building. Besides rain, improper irrigation can be a major moisture source; leaks can cause significant damage, and indoor sources of moisture can be a problem. If water collects in an area that cannot quickly dry, deterioration of building components may occur.

Climate is the overarching system that literally surrounds buildings. Solar power potential, the impact of shade, and extreme weather are three climate issues discussed here.

Plan subdivision lot lines and roads for predominantly north and south orientation



Typical Subdivision



Subdivision with predominantly north- and south-facing sites

For More Information on Climate Description

Briggs, R.S., Lucas, R.G., and Taylor, T.; Climate Classification for Building Energy Codes and Standards: Part 2 - Zone Definitions, Maps and Comparisons, Technical and Symposium Papers, ASHRAE Winter Meeting, Chicago, IL, January, 2003

Solar Orientation

Humans have always sought out methods to manage solar energy, to use the sun's heat and light only when and where desired. Solar exposure in the hot-dry/mixed-dry climates is the most intense in the United States.

Achieving the 40% level of energy savings does not require orienting homes in any particular direction. However, making the best use of the sun brings many advantages. If it is possible to consider orientation at the site development level of the homebuilding process, one virtually no-cost option for improving energy performance is to subdivide for solar orientation. Alternately, on larger lots that do not have to "respect the street," site planning can be undertaken to optimize the orientation of the house for passive solar benefit.

A better understanding of available solar energy and improvements in window technologies have done much to increase flexibility in site planning while still giving consumers the value of solar energy. Still, site planning should take advantage of southern window and roof exposures. Trees, houses, and community buildings can be positioned to plan for potential solar panel installations. Where community and private pools are installed in new construction, solar water heating systems should be included as part of the initial design.

Positioning buildings to get the maximum amount of sun means selecting windows and overhangs to help manage the solar energy. Thoughtful design for your climate and site will increase the value for consumers by making the sun an ally. Windows should be selected to manage the quantity of solar heat gain allowed into the house. Roofs can be designed with overhangs to shade and protect windows and doors. Overhangs may take the form of eaves, porches, or other design features such as awnings, pergolas, or trellises. Single glazing is not recommended, but when a house has clear single glazing, light colored interior shades, overhangs, and combinations of shading devices significantly reduce energy costs.

Where sun is ample and cooling dominates utility bills, windows with a low solar heat gain coefficient (SHGC), low emissivity, and high visible light transmittance will help to block both infrared and ultraviolet light while allowing visible light into the spaces. These windows protect furniture, carpeting, and other surfaces from fading, greatly increase occupant comfort, and yield great energy cost reductions for all conditions even with no shading. For more information on window ratings and performance and shading, see Chapter 8 of this guide and also see the Efficient Windows Collaborative website at www.efficientwindows.org.

Overhangs should be sized to account for differences in sun angles, elevation, window height and width, and wall height above the window. For example in Albuquerque, a 4-ft window positioned 12 inches below the overhang would need an overhang extending 19 inches for optimum shading. Free and low-cost computer programs and tools are available to help. A free program telling you the angle of the sun for any point in the country is available at www.susdesign.com/sunangle/. Latitude, longitude, and elevation data can be obtained at www.wunderground.com/calculators/solar.html. Optimal overhang dimensions can be calculated at www.susdesign.com/overhang/index.html. For a listing of free and available-for-purchase energy models, including solar design tools, see DOE's Building Technologies Program website at www1.eere.energy.gov/buildings/info_software.html. A low-cost sun angle calculator is available from the Society of Building Science Educators at www.sbse.org/resources/sac/index.htm. Overhangs also provide protection from rain, hail, and the effects of overheating and ultraviolet radiation on siding and windows.

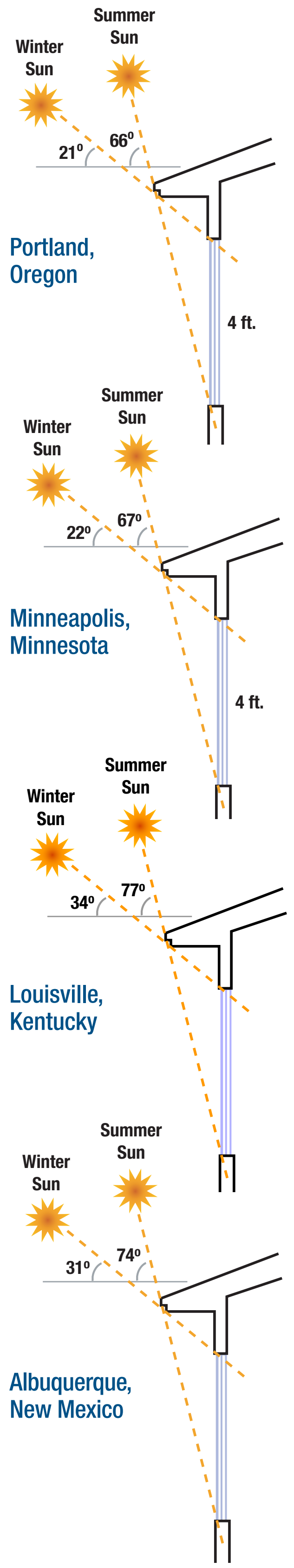
For More Information on Solar Orientation

University of Oregon. Sun charts available free at http://solardat.uoregon.edu/SunChartProgram.html

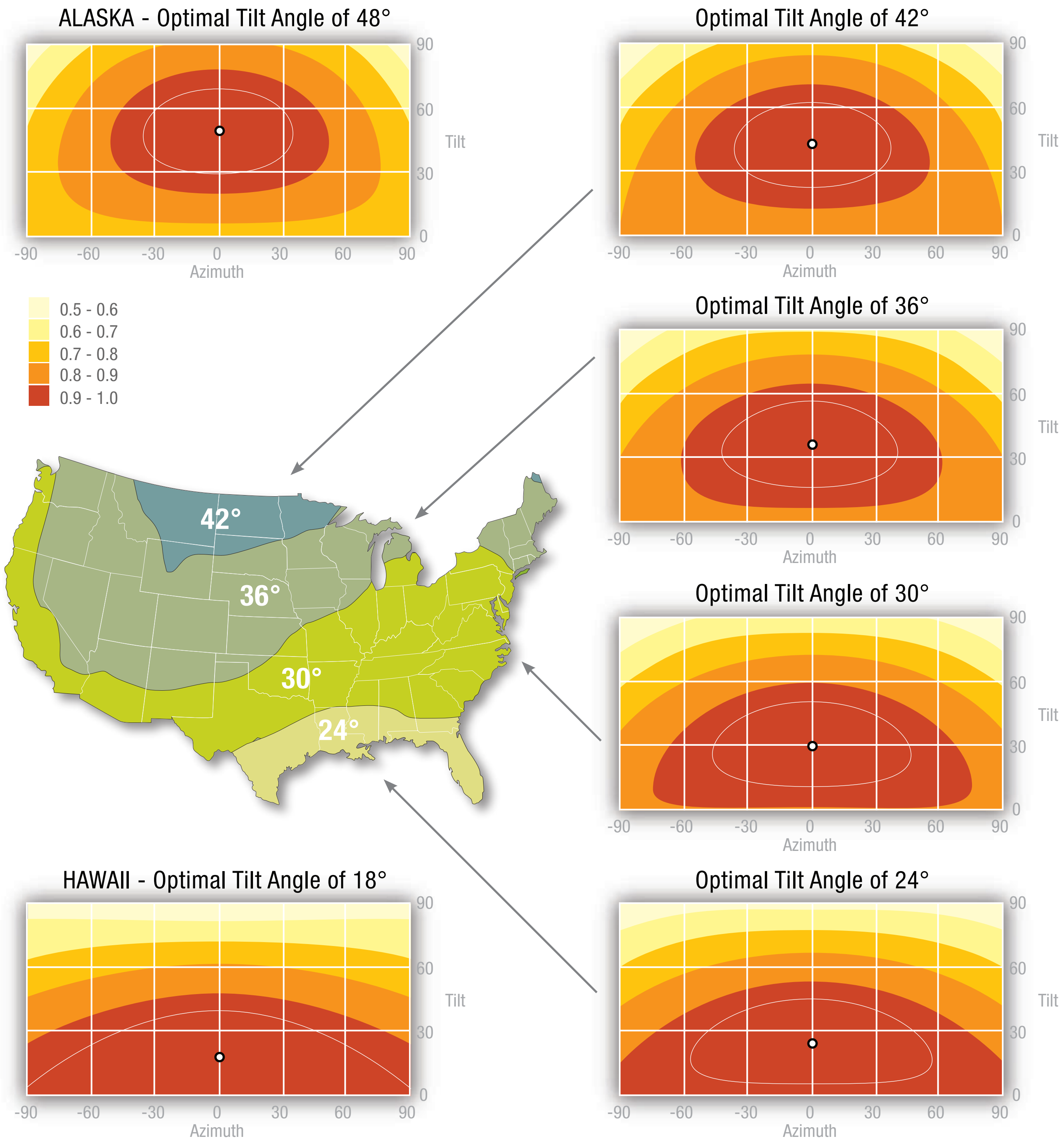
DOE. 2007. *Building America Best Practices Series for High-Performance Technologies: Volume 6, Solar Thermal & Photovoltaic Systems*. For more information on planning for solar orientation, www.buildingamerica.gov

Viera, R.K., K.G. Sheinkopf, and JK Stone. 1992. *Energy-Efficient Florida Home Building*. 3rd printing. Florida Solar Energy Center. FSEC-GP-33-88. Cocoa Beach, Florida.

Sun angles vary by latitude



Optimal Roof Tilt and Orientation for Solar Photovoltaic Power Systems



Roof tilt and southern orientation (azimuth) is quite flexible for the entire U.S. (Adapted from Christensen and Barker 2001). The map identifies optimal tilt angles for the shaded regions on the map. The charts show the percentage of solar energy available in each of the regions as the tilt and azimuth (orientation) change. For example, in the portion of the country where the optimal tilt angle is 30° (most of the country), at an azimuth of 0° (due south) the tilt can run from flat (0°) all the way to 55° and still receive 90% to 100% of available energy. If the tilt is at the optimum of 30°, the azimuth could vary to about 65° either east or west and still receive 90% to 100% of the available energy.

Deciduous shade trees can cut cooling loads during summer months.

Shade

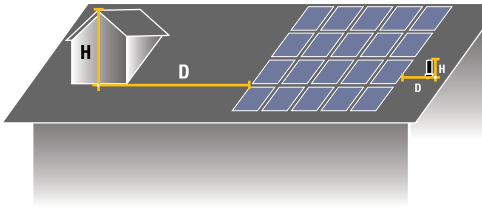
Shade can be provided by the intentional planting or preservation of trees. Tree preservation increases salability. Native trees are the most beneficial to the environment. The NAHB reports in its survey of buyers, *What 21st Century Home Buyers Want*, that over 80% of respondents in the West rated trees as essential or desirable (2002b, page 61). In 1992, the Florida Solar Energy Center (FSEC) estimated that a treed lot in Florida may increase the value of a home by as much as 20%. American Forests and the NAHB (1995) found that mature trees may add from $3,000 to $15,000 to the value of a residential lot.

Trees also bring value by providing shade. It is far better to prevent the sun's heat from reaching a house than to attempt to manage it once the heat enters. Deciduous shade trees can block summer sunlight before it strikes windows, walls, and roofs, dissipating the heat absorbed in their leaves to the air where it can be carried away by the breeze. However, when roof-mounted photovoltaic panels and/or solar water heating systems will be used, care must be taken to locate them or your trees so the panels are not shaded. This dual purpose can be achieved by carefully selecting the variety of tree for height and width.

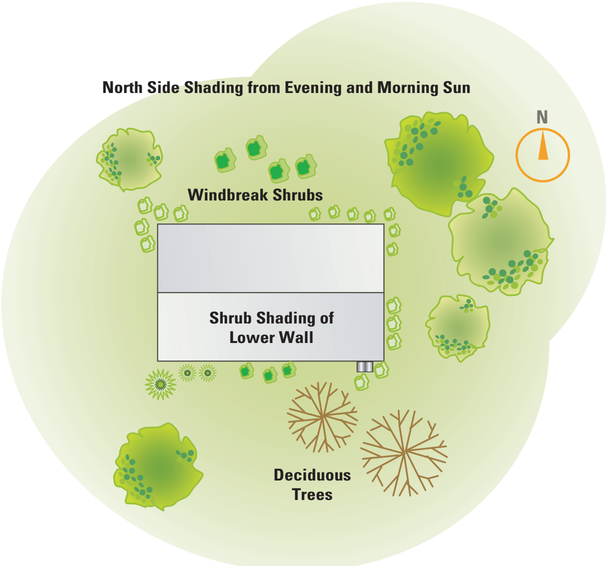
Truly cool neighborhoods have trees. A study in Florida has shown that a subdivision with mature trees had cooler outside air with less wind velocity than a nearby development without trees (Sonne and Viera 2000). The development with a tree canopy had peak afternoon temperatures during July that were 1.1°F to 3.1°F (± 0.7°F) cooler than the site without trees. The total effect of shading, lower summer air temperature, and reduced wind speed can reduce cooling costs by 5% to 10% (McPherson et al. 1994).

For reducing cooling requirements, trees are most effective when carefully located to cast shade on the roof, windows, walls, and air conditioners, and when located on the side of the home receiving the most solar exposure. Shade to the southwest and west is especially important for blocking peak solar gain in the summer in late afternoon. Depending on the species, trees more than 35 feet from the structure are probably too far away for shade. Plants too close to air conditioner or heat pump condensing units can block airflow reducing operating efficiency.

Be careful not to shade solar equipment (e.g., roof-mounted photovoltaic panels and solar thermal water heating panels). A simple rule of thumb is that any potential shading structure should be twice as far away from the solar equipment as the structure is tall. In addition, a detailed evaluation of the southern horizon can be used to predict shading issues arising from things that are not part of the home. Site evaluations use sun charts or digital tools to assess how obstructions such as trees, buildings, or chimneys will fall between the solar panel and the sun at various times of the year.



For houses with solar photovoltaic roof panels, any potential shading structure should be twice as far away from the PV array as it is tall (D = 2 * H)



Careful landscaping can preserve roof-top solar exposure and provide shading to help control solar gain through windows.

Pulte Tucson used xeriscaping at its developments at Copper Moon *(top)* and Civano *(bottom)*. *(Photo source: Pulte Tucson)*

For More Information on Shade Trees

American Forests and the National Association of Homebuilders. 1995. Building Greener Neighborhoods: Trees as Part of the Plan. NAHB, Washington, D.C. www.nahb.org/product_details.aspx?forsaleID=26

McPherson, G.E., D.J. Nowak, and R.A. Rowntree (eds). 1994. Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project. U.S. Department of Agriculture, Forest Service, Northeastern Research Station, www.treesearch.fs.fed.us/pubs/4285

Sonne, J.K. and R.K. Viera. 2000. "Cool Neighborhoods: The Measurement of Small Scale Heat Islands." Proceedings of the 2000 Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy, Washington, D.C. www.aceee.org/conf/bldindex.htm

Xeriscaping

In the dry Southwest, irrigation can be the largest portion of a household's water consumption. Lots should be landscaped to take advantage of plants that use less water than traditional turf-dominated approaches. Many communities have been faced with increased demands on existing water supplies. Consequently, there is a greater focus on water conservation, not just in times of drought, but in anticipation of future population growth. Water can no longer be considered a limitless resource. Conserving water through creative landscaping has engendered the new term "xeriscaping." The term is taken from the Greek *xeros*, meaning dry, in combination with landscape.

The goal of xeriscaping is to create a visually attractive landscape that uses plants selected for their water efficiency. Properly maintained, a xeriscape can easily use less than one-half the water of a traditional landscape. Once established, a xeriscape should require less maintenance than turf landscape. By grouping plants with similar water needs together in specific zones, a xeriscape can use water more efficiently. Low-water-use plants should be grouped together, away from high-water-use plants and turf. Take advantage of warm or cool micro-climates (the actual climatic conditions around your property, which can be influenced by the placement of walls and shade trees) to create areas of interest and diversity.

A well-planned and well-maintained irrigation system can significantly reduce a traditional landscape's water use. For the most efficient use of water, irrigate turf areas separately from other plantings. Other irrigation zones should be designed so low-water use plants receive only the water they require. Proper irrigation choices can also save water. Turf lawns are best watered by sprinklers. Trees, shrubs, flowers, and groundcovers can be watered efficiently with low-volume drip emitters, sprayers, and bubblers.

The information presented here was adapted from the Albuquerque Bernalillo County Water Utility Authority website www.abcwua.org/content/view/73/63. Many jurisdictions in dry landscapes have information, including potential rebates and other incentives.

For More Information on Xeriscaping

The Colorado Water Wise Council www.xeriscape.org

The Xeriscape Council of New Mexico www.xeriscapenm.com

The High-Country Xeriscape Council of Arizona www.xeriscapeaz.org

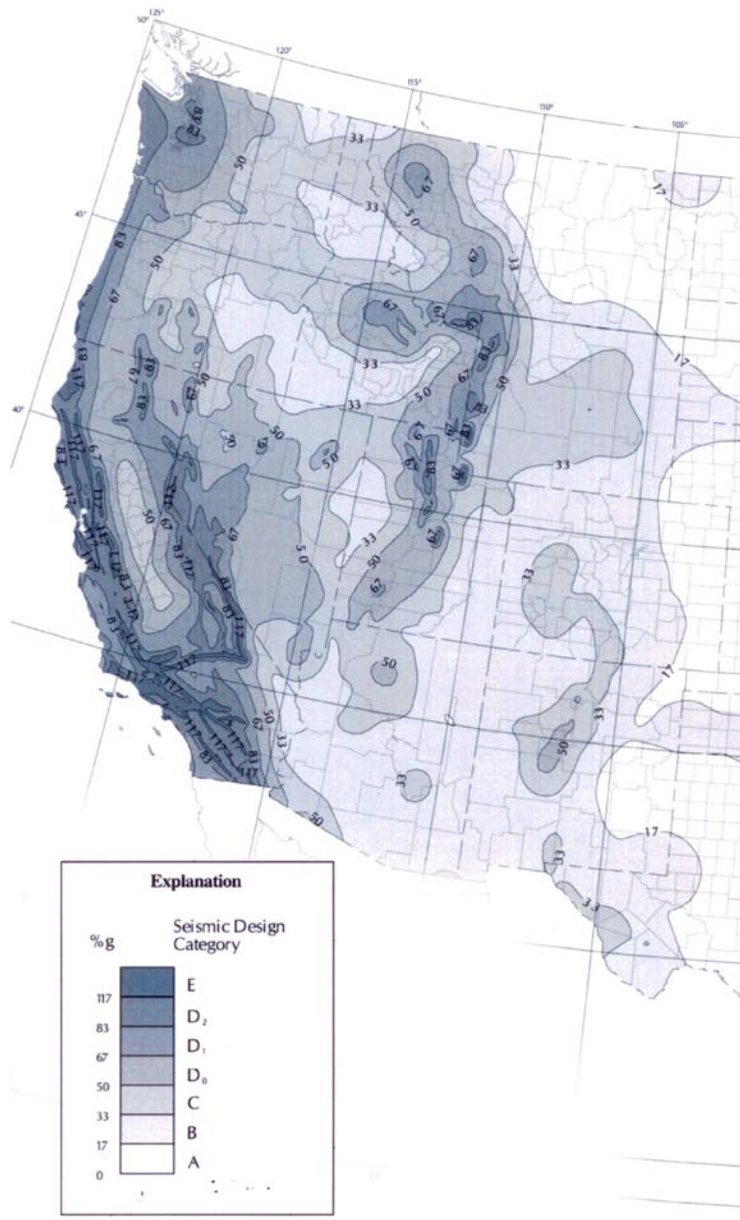
California Integrated Waste Management Board www.ciwmb.ca.gov/organics/xeriscaping

Earthquakes

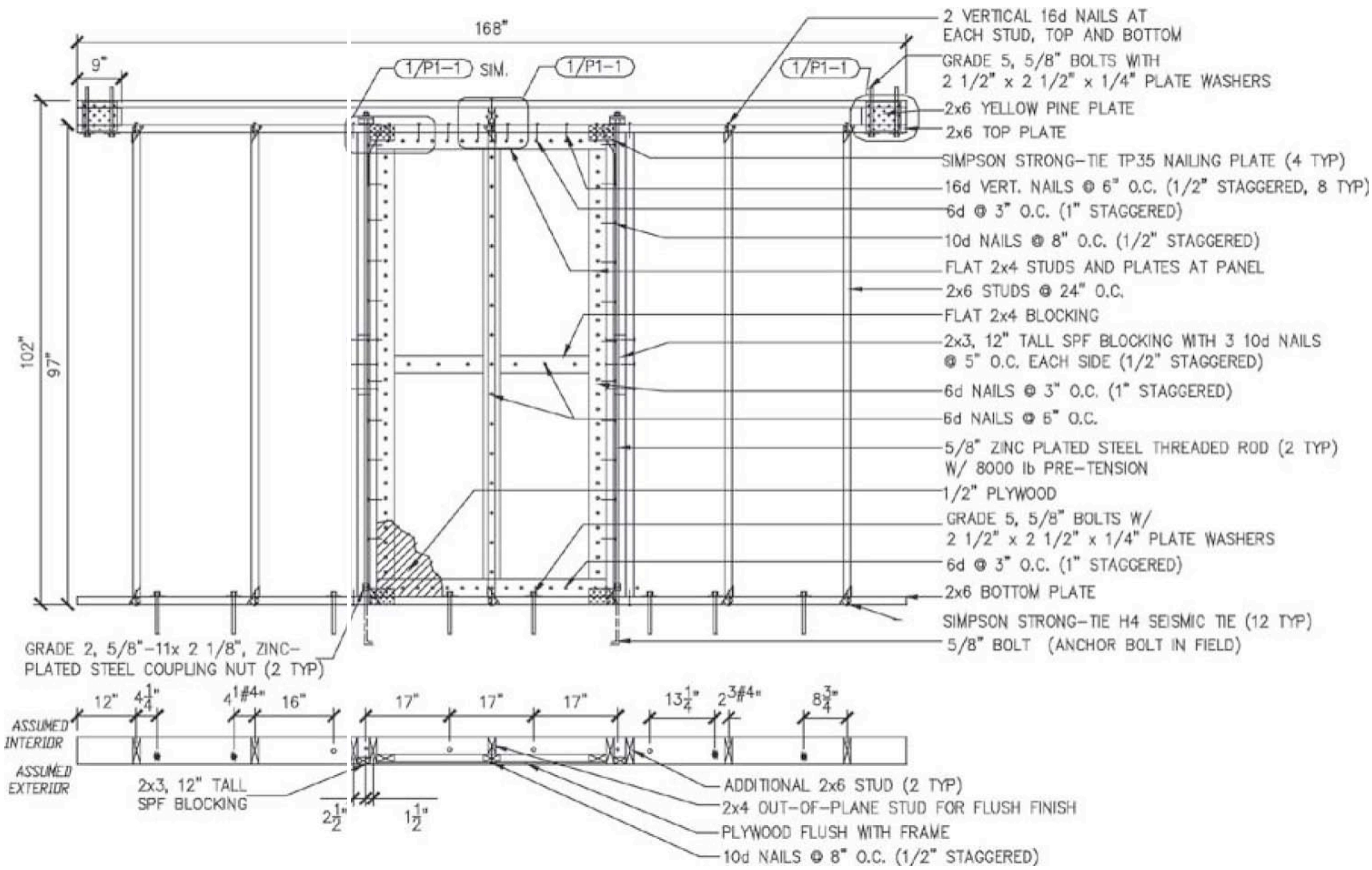
Earthquakes are a part of life in portions of the hot-dry climate, especially many locations in California. The International Residential Code (IRC) addresses seismic provisions in Section R301.2.2. General limitations associated with construction in earthquake prone areas are:

- **The Seismic Design Category (SDC)** – buildings in SDCs A through D_2 may be designed per IRC while buildings in SDC E require engineered design (unless provisions R301.2.2.1.1 and R301.2.2.1.2 of the IRC are met).
- **The Assembly Weight** – Weight of roof plus ceiling, floor, and interior and exterior wall assemblies are limited in SDCs D_1 and D_2 and townhouses in SDC C (refer to IRC section R301.2.2.2.1).
- **Number of Stories** –
  - o Wood, light-framed buildings are limited to two stories plus cripple walls in SDC D_2 (R301.2.2.4.1 and Table R602.10.1)
  - o Cold-formed, steel-framed buildings are limited to two stories above grade in SDCs D_1 and D_2 (R301.2.2.4.1)
  - o Masonry walls are limited to one story and 9 feet between lateral supports in SDCs D_1 and D_2 (R606.11.3.1 and R606.11.4).
- **Story Height** – In all SDC's building story height is limited by the following limits on bearing wall clear height plus a maximum of 16 inches for the floor framing depth:
  - o Wood light frame......... 12 ft (R301.3, Item 1 Exception)
  - o Cold-formed steel........ 10 ft (R301.3, Item 2)
  - o Masonry.................... 12 ft plus 8 ft at gable ends (R301.3, Item 4)
  - o ICF .... 10 ft (R301.3, Item 4 and R611).

Additional information on design and construction in earthquake-prone areas including above-code recommendations; detailed figures for foundations and foundation walls, floor construction, walls, roof-ceiling systems, chimneys, fireplaces, balconies and decks; and checklists for builders, designers, and plan checkers can be found in the *Homebuilder's Guide to Earthquake Resistant Design and Construction* (FEMA 232-2006) at www.fema.gov/library/viewRecord.do?id=2103.



Seismic Design Categories for the Western United States from the 2006 International Residential Code, Appendix D.



This advanced framing wall panel for seismic regions was designed and tested by Building Science Corporation and the U.S. Army Construction Engineering Research Laboratory (CERL) with funding by DOE's Building America program. The panel was designed to provide lateral capacity that is as good as or better than traditional plywood-sheathed shear panels, while not interfering with the installation of insulation sheathing directly to the framing members. It has an allowable design capacity of 650 lb/ft or 2,600 lb per panel.

For More Information on Earthquakes

FEMA. 2006. *Homebuilder's Guide to Earthquake Resistant Design and Construction.* Federal Emergency Management Agency www.fema.gov/library/viewRecord.do?id=2103

ICC. 2006 International Residential Code® (IRC) for One- and Two-Family Dwellings. International Code Council. Section R301.2.2 contains seismic provisions. Code available at www.iccsafe.org/e/prodshow.html?prodid=3100L06&stateInfo=pdfabhakTnlauacc5809l4

ICC. 2007 Supplement to the IRC www.mag.maricopa.gov/main/download.asp?item=8845

USGS. Earthquake Hazards Program. For probability maps, etc. http://earthquake.usgs.gov/research/hazmaps/

Wilcoski, James. 2001. *Design Guidance for Inset Wood Shear Panels*, Building Science Corporation. www.buildingscienceconsulting.com/resources/walls/wood_shear_panels.pdf

Extreme Weather

Parts of the hot-dry and mixed-dry climates in Oklahoma and Texas skirt a section of the country prone to tornadoes. However, the hot-dry and mixed-dry climates have milder winds and are less likely to have severe storms than the nearby area known as "tornado alley."

Proper structural fastening and impact-resistant windows, doors, and skylights are critical for surviving high winds. Proper use of roofing materials can help roofs withstand high winds and protect against severe rains. This document does not provide detailed information on disaster survival, but the following sources provide structural details and guidance and a listing of building materials acceptable for high wind areas.

- **Federal Emergency Management Agency** – Building a Safe Room Inside Your Home. www.fema.gov/plan/prevent/saferoom/index.shm
- **Federal Alliance for Safe Homes** – FLASH, Inc. Designed primarily for Florida, this website contains generally applicable information about building to resist high winds, wild fires, and floods. Blueprint for Safety. www.blueprintforsafety.org
- **Institute for Business and Home Safety** – The IBHS has building guidelines and public information. www.DisasterSafety.org
- **U.S. Department of Energy** – A training program for home inspectors to identify hazards. http://apps1.eere.energy.gov/weatherization/training_centers.cfm
- **NOAA** – Information on the probability of severe thunderstorms can be found at www.nssl.noaa.gov/hazard/

Some parts of the hot-dry and mixed-dry climate zones experience severe thunderstorms. Here storm clouds linger over Albuquerque, New Mexico. *(Photo source: Jay Blackwood, National Weather Service)*

Wildfires

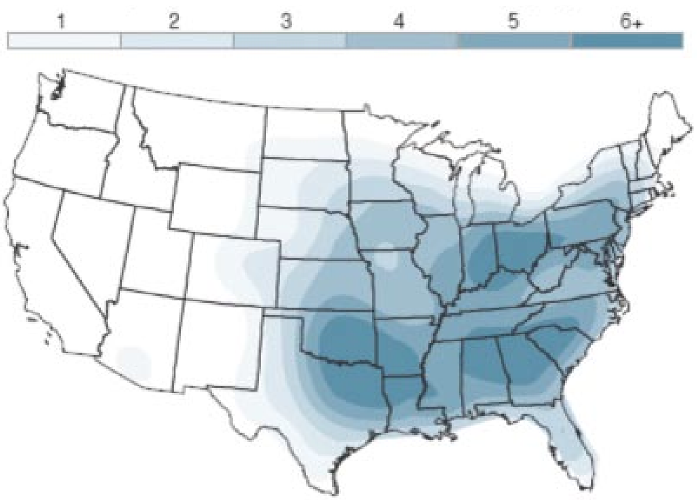
Parts of the hot-dry climate in the west have experienced severe wild fires. Home construction in wooded areas, forest management practices, and changing climate patterns have combined to make wild fires a serious risk. Information on code and property management practices to help survive fires is available at the following websites.

- **Firewise** – U.S. Forest Service and the U.S. Department of the Interior www.firewise.org
- **Wildfire** – A site designed for those living in or visiting areas prone to wildfires. www.fema.gov/hazard/wildfire
- **Living with Fire** – A site for homeowners in the Great Basin www.utahfireinfo.gov/prevention/livingwithfire/intro.htm
- **FEMA** – 2004. *At Home in the Woods: Lessons Learned in the Wildland/Urban Interface*. Federal Emergency Management Agency, U.S. Department of Homeland Security, Washington, D.C. Available at www.fema.gov/hazard/fire/pubs/athome_woods.shtm

Wildfires are a threat in the hot-dry and mixed-dry climate zones. *(Photo source: U.S. Forest Service)*

Severe Thunderstorm Risk

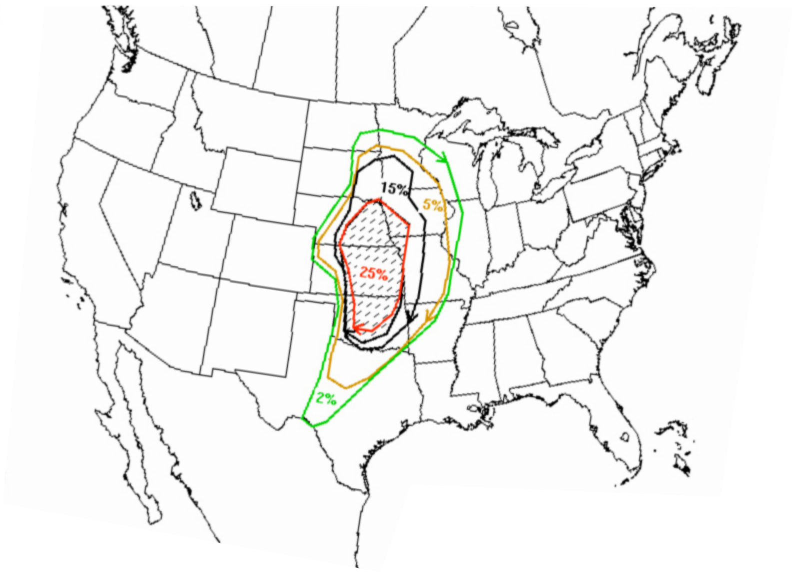
Number of days per year areas experienced severe thunderstorms with winds greater than 58 mph



Based on data from 1980-1999 *(Figure source: NOAA)*

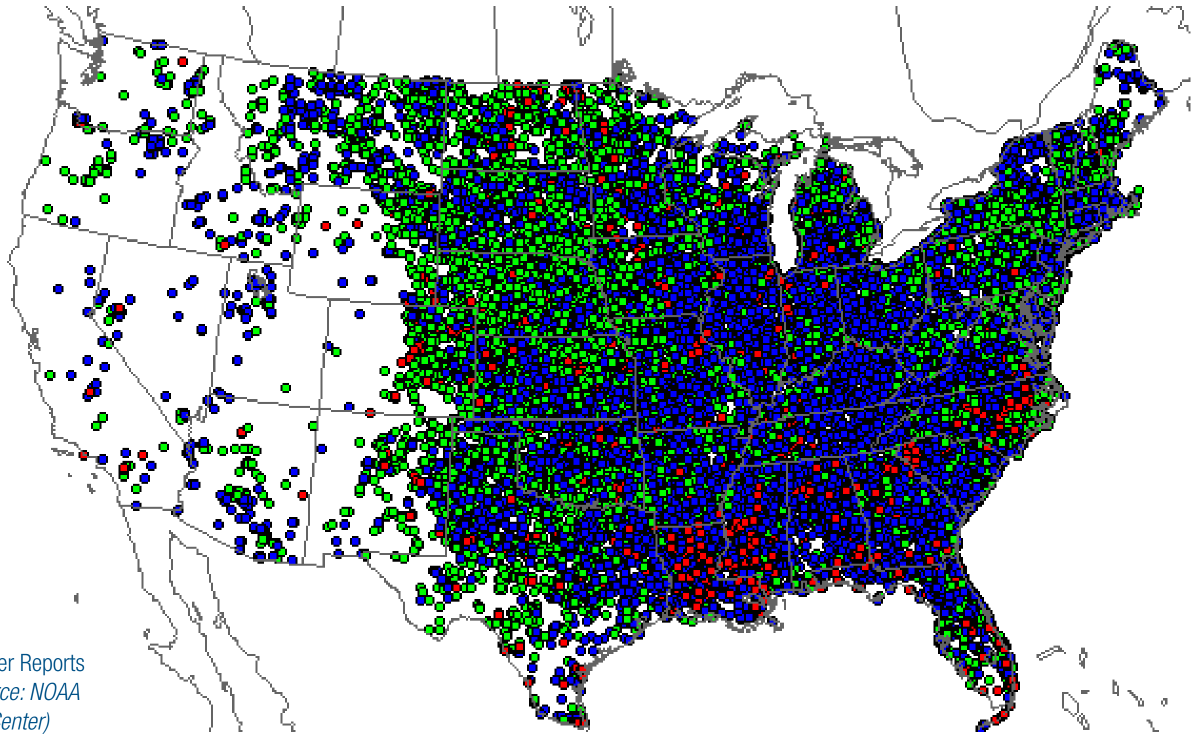
Tornado Risk

Percentages represent annual probability of a tornado occurring. Hatched area ≥10% probability of F2–F5 tornadoes within 25 miles of a point



Severe Storm Reports 2008

● = tornadoes ● = wind damage ● = large hail



U.S. Severe Weather Reports 2008. *(Figure source: NOAA Storm Prediction Center)*

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 6.
Building Science Basics – Let the Forces Be With You

This chapter introduces fundamental principles of building science. It describes the dynamic forces that drive the movement of moisture, air flow, and heat in homes. This background information helps to explain the underpinnings of the best practices described in later chapters. In applying building science, the goal is to design and build houses that work within the bounds of natural forces, and in some cases to put these forces to work for occupant comfort and building efficiency.

"Most builders view each aspect of the house – the electrical work, the plumbing, the framework – as separate jobs, but the Building America approach views each area as part of the whole. …If you view the *whole house* as the system… it's not only easier, you end up with a better product."

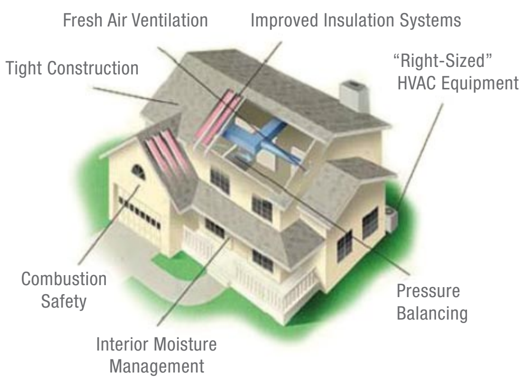
Lee Rayburn, developer of Centennial Terrace in Tucson, Arizona

CHAPTER TOPICS

Building Science and the Systems Approach

Perhaps the most important step in design is recognizing that interrelated elements make up an overall, sustainable system. No one piece can be changed without affecting all related pieces.

This simple proposition applies to all of the elements that make up a system; it allows for many kinds of trade offs. In cars, lightweight frames may be translated into smaller brakes, a smaller engine, and smaller tires. Or, that same change may be used to produce more speed.



Pulte Las Vegas takes a systems approach with its homes that combines advanced framing, increased insulation, and improved air sealing with right-sized HVAC, mechanical ventilation, transfer grilles, and jump ducts for lower utility bills and guaranteed comfort. *(Figure source: Pulte Las Vegas)*

In houses, this systems approach recognizes the interaction of windows, attics, foundations, mechanical equipment, and all other elements, assemblies, and components. Changes in one or a few components can dramatically change how other components perform, impacting overall building energy use, comfort, and durability. Recognizing and taking advantage of this fact, and applying appropriate advances in technology and testing, can result in cost and performance payoffs, both for builders and buyers of new homes.

When builders design houses to work well as a system, not only do they save energy, they also are better able to withstand the elements. (*Photo source: Leif Juell, Alternative Power Enterprises, Inc.)*

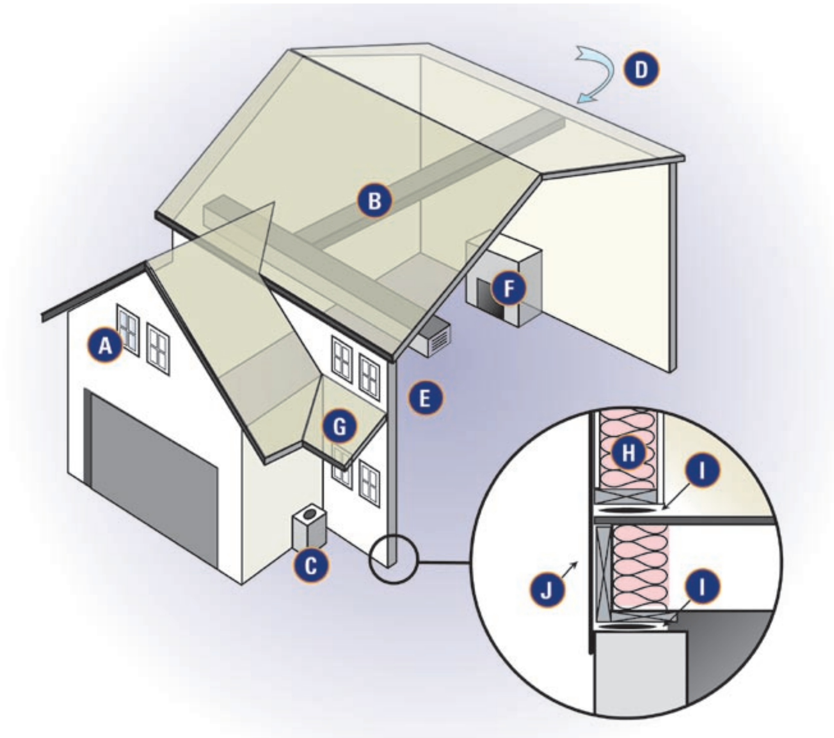
Building America has embraced the systems approach and combined it with the technology development and testing that make up building science. The Florida Solar Energy Center, a Building America team member, has described building science on its website as follows:

> *As with other scientific disciplines, building science provides an intelligent approach to understanding complex systems and diagnosing problems. Over time, this approach builds up knowledge, tools, and tests that make the science and the building product more efficient and more powerful.*

The challenge to builders and designers is to carefully evaluate the costs and benefits of new and existing building approaches and to consider the effects on their overall building system, choosing the materials and techniques that make sense. Building science relies on modeling and experimentation to test theories and hypotheses. One of the benefits of working with Building America is that the program has conducted these experiments and done the research so that individual builders don't have to. Working with Building America recommendations takes much of the guess work out of the design process. The recommendations have been tested in field applications that include the construction of multiple houses in community-scale projects.

The Systems Approach to House Design

In a system-designed house all the parts are designed to work together for a healthy, durable home that minimizes call backs to the builder while cutting energy, maintenance, and repair costs down the road.



A. **Efficient Windows:** Help to control and reduce ultraviolet light that can fade carpets and furniture, helping to keep your belongings looking like new and keeping window areas cooler and more comfortable to sit near. Window flashing protects against water leaks.

B. **Compact and Tightly Sealed Duct Runs:** Short, straight duct runs in conditioned space yield better airflow with less chance for leaks and fewer contaminants like humidity and dust from attics or crawlspaces. Leaky ducts are a major contributor to mold problems. Multiple return air paths ensure balanced air pressure for less drafts and more balanced temperatures throughout the house. Ducts are in conditioned space.

C. **Right-Sized and High-Efficiency HVAC Equipment:** Costs less to install than bigger equipment, saves energy, and is designed to comfortably handle heating and cooling loads.

D. **Ventilation:** Exhaust fans remove moisture and pollutants. A controlled, filtered air intake ensures plenty of fresh air.

E. **Dehumidifier:** Ensures that indoor humidity levels are kept at a comfortable level. This measure is not a Builders Challenge requirement but is recommended by Building America in humid climates.

F. **Sealed Combustion Appliances:** Reduce moisture buildup and ensure the removal of combustion gases. We recommend against non-vented combustion appliances such as non-vented fireplaces or heaters.

G. **Overhangs:** Provide shade, reduce cooling load, and direct water away from the house.

H. **Insulation:** Holds comfortable temperatures in conditioned spaces and helps control noise. For insulation level recommendations visit www.ornl.gov/sci/roofs+walls/insulation/ins_16.html

I. **Air Sealing:** Stops drafts, helps keep humidity and garage contaminants out of the house, and creates a barrier to rodents and insects.

J. **Well-Designed Moisture Barriers and Drainage:** Avoid expensive structural damage and help stop humidity, mold, and mildew.

Water

Looking at properly designed roofs, most observers can see how rain is pulled by gravity down overlapping surfaces, such as roofing shingles and flashing, to drain away from the house. Although homes are not faced with constant rain in the hot-dry/mixed-dry climates, moisture management is still an important topic. Drenching downpours can overload drainage systems; improperly placed irrigation can cause unwanted moisture.

Liquid moisture can also originate in the ground and flow upwards. This uptake is due to capillary action that is related to the adhesive properties of water. Water is attracted to other water. This is called cohesion. Water is also attracted to other materials. This is called adhesion. Capillary action allows water to climb up into seemingly solid materials through pores in the material. The same mechanism causes water to climb a straw in a glass of water. The narrower the straw, the higher the water will climb. A capillary break is a non-permeable material that blocks the capillary flow of water from the ground (see the next section on vapor for a discussion of permeability).

When moisture is trapped inside walls, mold can grow unchecked causing damage to the walls and health impacts for the occupants. *(Photo source: EPA; photo by Terry Brennan)*

Vapor

Unlike moisture in its liquid form, water vapor travels wherever air flows. Air is vapor's heavy lifter. Where there are air leaks, there are vapor leaks. Diffusion can also force vapor through materials and into places it shouldn't be, such as wall cavities. Differences in vapor pressure and temperature are the forces that drive diffusion. Vapor diffusion moves moisture from areas of higher vapor pressure to areas of lower vapor pressure, and from areas of higher temperature to areas of lower temperature.

This sprinkler was placed too close to the house's foundation wall. Moisture seeped through the concrete block causing water stains and mold inside. *(Photo source: EPA; photo by Terry Brennan)*

Air movement is by far the most important mechanism for moving vapor. If you seal up air leaks in the building envelope, both inside and out, most vapor transport will be blocked from getting inside structural cavities.

The installation of air barriers involves systematically and continuously sealing air leaks. Methods for creating air barriers are described in the sections on air sealing throughout this document. Continuous means that the barrier extends over the entire envelope of the structure, but the barrier may be made up of many materials. The interior gypsum board may be incorporated into the air barrier, along with studs, draft-stopping materials, housewraps, and rigid insulation, but the seal must be continuous.

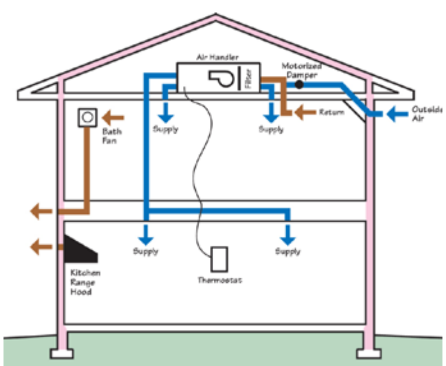
Vapor retarders (sometimes called vapor barriers) are materials that block diffusion because they are impermeable. A perm is a unit of measurement based on the amount of water that passes through a material over a fixed period of time. Four classes of permeability have been established. Here are the classes along with examples of materials (adapted from Lstiburek 2006):

CLASS 1 - Vapor impermeable (0.1 perm or less): polyethylene film, glass, aluminum foil, sheet metal, foil-faced rigid insulation, and other foil-faced materials.

CLASS 2 - Vapor semi-impermeable (1.0 perm or less and greater than 0.1 perm): oil-based paints, most vinyl wall coverings, unfaced extruded polystyrene greater than 1 inch thick, kraft-faced fiberglass insulation, smart vapor retarders.*

***Smart vapor retarders** are engineered materials that are designed to change their permeance at specific relative humidity levels *(Lstiburek 2006)*.

Treasure Homes of Sacramento installs rigid foam under stucco siding to serve as an insulation layer and exterior vapor barrier.



Building Science Corporation designed an HVAC system that included mechanically controlled ventilation using the furnace air handler along with point source ventilation in the kitchen and bath. *(Figure source: Building Science Corporation)*

CLASS 3 - Vapor semi-permeable (10 perms or less and greater than 1.0 perm): plywood, bitumen-impregnated kraft paper, oriented strand board, unfaced expanded polystyrene, unfaced extruded polystyrene (1-inch thick or less), building paper, and one coat of most latex paint.

CLASS 4 - These are examples of vapor permeable (greater than 10 perms) materials: unpainted gypsum board and plaster, unfaced fiberglass insulation, cellulose insulation, dimensional lumber, and masonry.

Vapor retarders can block the entry of vapor. However, vapor retarders can also block vapor's exit. It is important that moisture not get trapped inside of walls. Walls need to dry to the interior, the exterior, or both.

To avoid trapping moisture in walls, Building America recommends that vapor retarders (equivalent to Class 1 or 2, e.g., polyethylene plastic sheets) not be placed on the interior side of the building envelope between gypsum board and insulation. Vinyl-coated wall paper is not recommended on the walls or ceilings that form the building envelope of homes in the hot-dry and mixed-dry climates. Polyethylene vapor barriers may be required by building codes in some jurisdictions but code changes are anticipated. Engineered wall designs that do not require vapor retarders may be approved by building officials.

One wood-frame wall construction detail that provides condensation control is to use an exterior insulating sheathing in addition to traditional cavity insulation. One example would be an R-4 rigid foam product under lapped siding with furring strips spacer in between. In general, insulating sheathing is not necessary to meet the 40% savings goal. However, insulating sheathing has significant benefits, particularly in the areas of moisture control. During the heating season, insulating sheathing helps to maintain the temperature of the wall cavity above the dew point, avoiding condensation. Inwardly driven moisture from reservoir claddings such as brick and stucco (which can hold water), can be controlled by using insulating sheathing. Additionally, the use of insulating sheathing of sufficient thickness allows the removal of interior vapor barriers and vapor retarders, because it reduces the probability of condensation inside the wall, thereby enhancing the inward drying of the assembly.

During periods of hot, humid weather, insulating sheathing acts as a vapor retarder and helps prevent moist outdoor air from entering the wall, reducing the potential for condensation inside the walls of air-conditioned homes.

Air Flow

Air enters a home through openings in walls, cracks around doors and windows, and at intersections of building assemblies. Key points of air entry include rim joists where foundations meet floors and walls, where walls and floors for upper stories join together, and where walls intersect the roof. The pressure difference between indoor and outdoor air (or between indoor air and soil gas) is the driving force of air infiltration. Plugging air leaks is one way to slow down infiltration.

Air movement can affect how well insulation works. When outside air is pushed through insulation in places such as attics, walls, or crawlspaces, it robs the insulation's ability to slow down heat loss. This process is called wind wash or air intrusion. Using baffles, dams, and wind blocks in attics keeps ventilation ports open and directs air away from the insulation.

Controlled air movement in the right place is beneficial. Allowing a ventilation space behind wall cladding allows the material to dry out without contaminating housewraps, sheathing, or other wall components. Wall venting behind brick veneers is especially important. Under the right conditions, energy from the sun can push vapor through wet brick with the force of a steam boiler. Ventilation cavities behind brick help to dissipate this vapor before it is injected into the framed cavity.

Crawlspaces and attics are other areas in homes that have traditionally used passive ventilation to dissipate moisture. Crawlspaces are not common in the hot-dry/mixed-dry climate region and vented crawlspaces are not recommended (Lstiburek 2004). Measures to block moisture uptake from soil are necessary. Sealed and conditioned crawlspaces work best, along with proper grading and rain management. According to the Residential Requirements of the 2006 IRC, sealed crawlspaces are permitted as long as they are mechanically vented or conditioned and exposed earth is covered with a continuous vapor retarder. In the 2009 IRC, the requirement specifies vapor retarders are required to be "Class I vapor retarders." (See 2006 and 2009 IRC, Section 408.3.)

Researchers and builders have developed methods of building unvented, conditioned attics. Ventilation directly beneath the roofing deck may be employed in these systems. Sealed attics are not necessary to reach 40% reductions in energy efficiency, but offer a strategy for creating conditioned space to house HVAC equipment and duct work, provided the attics are carefully air sealed.

Planned ventilation is needed to provide a healthy and comfortable indoor environment. Relying on air leakage to provide ventilation and combustion air is unreliable. By its nature, infiltration is not a reliable form of ventilation. It depends on pressure and temperature differentials that change constantly. Air leaks may also carry with them moisture that can cause structural or mold problems. Combustion in furnaces, fireplaces, dryers, and cooking appliances requires air. If multiple combustion or exhaust systems are drawing air at the same time and if these appliances are not all direct vented to the outdoors, there is a chance that flue gases can be drawn into a home rather than expelled outdoors. Mechanical ventilation and sealed combustion systems are described in Chapter 9.

Heat Transfer

Much of what building an energy-efficient house is about is keeping heat where you want it and away from where you don't want it. Heat travels via three mechanisms: conduction, convection, and radiation.

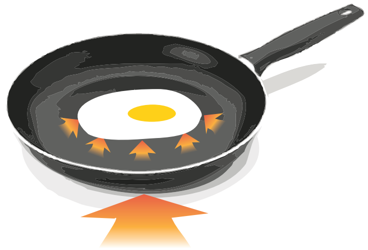
Conduction

Conduction is the movement of heat through a material. It is the cause of a hot handle on a sauce pan simmering away on a range top. Heat flows from warm areas to cold areas. The larger the temperature difference between the areas the faster heat will flow.

The ability of materials to resist heat flow influences conduction. Insulation is very good at resisting conducted heat flow. Dimensional lumber is not very good at resisting heat flow. Insulation gaps inside of walls are also not very good at resisting heat flow and can allow cold surfaces to form near the surface of interior walls. Cold surfaces not only cause problems because they are uncomfortable, but also because moisture will condense there and can cause structural problems. The best way to slow down conduction is to add insulation to

Conduction

Heat transferred by contact, like the hot pan that fries an egg or the hot asphault that burns bare feet.



Convection

Warm water or air that rises, cools, and falls, like the warm air currents that birds ride or the hot water that rises in a perk coffee pot.

Radiation

Heat transferred though space by rays, like rays of sun that warm your skin if the rays are not blocked by a building or tree.

building envelope assemblies. It is important that insulation be installed to fill all voids in the building envelope. It is easiest to fill voids using blown-in insulation of various types. Blown cellulose or fiberglass insulation for example flows almost like a liquid, filling in areas behind wiring and framing where batt insulation might be compressed or blocked. Blown foam is applied as a liquid and also fills voids that may be difficult to reach with batts. Batts work best in large, uninterrupted areas.

The rate at which heat flows through a material is described using two terms: R-value and U-value. Resistance to heat flow is called R-value. The higher the R-value the more resistant a material is to heat conduction. R-values can be added together to calculate how well an entire assembly will resist heat flow.

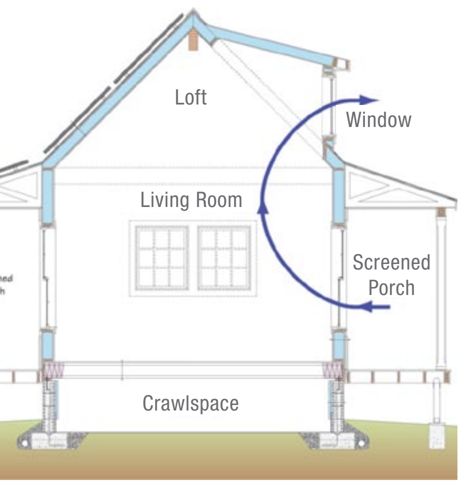
Conductivity is described using U-value. Conductivity refers to how well a material or assembly conducts heat. It is inversely proportional to R-value. If the U-value is high, then the R-value is low. If the U-value is low, then the R-value is high. From an energy-efficiency perspective, high R-values and low U-values are good. U-values may be calculated for an entire assembly or for an individual component. But U-values for a number of components cannot be added together to calculate the overall U-value for an assembly such as a wall.

One way to slow down heat flow is to maintain temperatures in a conditioned space that are close to the temperatures outside the space. Mud rooms and enclosed porches can help to temper outside temperatures. In hot climates, shade from overhangs or trees may help to cool outside air near a house.

Another factor that influences heat conduction is the area of the surfaces separating a conditioned and non-conditioned space. Ways to reduce surface area include:

- Designing the home to be as compact as possible. Smaller buildings have smaller surface areas.
- Building up instead of out. A two-story house with a given square footage of living area will have about half the roof area and half the ground contact area of a single-story house with the same square footage.
- Avoiding cantilevered floor areas in bays and balconies. The floors and overhangs expand the building envelope and can be difficult to insulate and seal.
- Sealing off roof areas over porches and other overhangs so that those spaces are isolated from the building envelope.
- Minimizing excessive head room. High ceilings add to conditioned space, require more surface area to enclose, and encourage convective currents (see the next section).

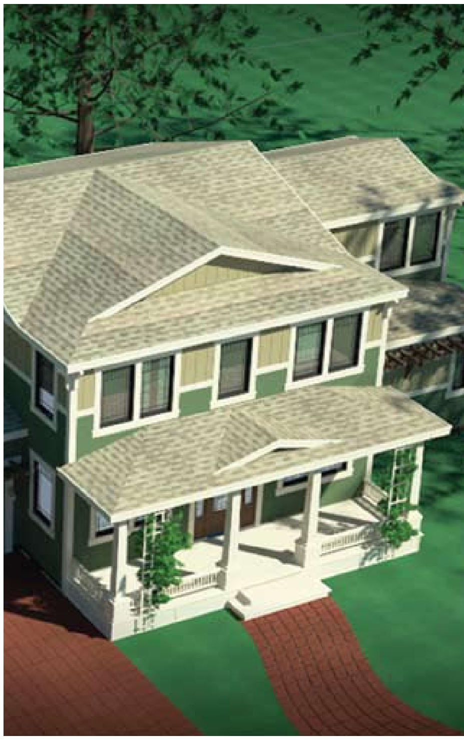
Insulation is usually hidden away behind finished surfaces but it does the most to block heat loss through conduction. Rigid insulation can also help to block air movement. Rigid foam exterior insulation can also serve as a rain barrier and drainage plane.



Building America's Building Science Consortium used convection to help cool this structural insulated panel (SIPs) cottage in Georgia. Cool air from the screened porches is drawn into the building's interior where it heats up and is pulled up and out the second-story windows, drawing more air in through the shaded first-story windows.

Convection

Convection is the movement of heat via a gas or liquid. Warm air becomes buoyant, while cold air tends to sink. Convection is the force that draws hot air up a chimney. This force is sometimes called the stack effect. The ability of the air to carry water vapor is directly related to how warm it is. Warmer air can carry much more vapor than cooler air. Designers and builders can use convection as a natural way to cool and ventilate a home, but it can cause problems in the wrong places and circumstances.



Light-colored roofing, like the roofing specified for the Environments for Living demonstration house at the 2009 International Builder Show in Las Vegas, can help minimize heat gain from solar radiation. Reflective roofs help keep homes (and surrounding neighborhoods) cool and help offset carbon emissions.

In cooler climates, heated air tends to rise to the top of tall structures. Warmer air becomes buoyant and can carry more moisture than cool air. Near cold surfaces, such as inefficient windows, cooler air drops. As the air cools below the dew point, it must give up some of its moisture, which then condenses on the cold surface. This is why drinking glasses containing ice "sweat" in the summertime.

In air conditioned structures, colder air sinks, drawing in warmer air. The warmer air can carry moisture; so as it cools this moisture may condense inside structural assemblies or on the surface of walls. The warm, moist air will also make for a clammy feeling of discomfort. Occupants call for more cooling and the problem gets worse.

Convective air currents can set up wherever differences in air pressure drive air movement. This applies to the house as a whole, and to smaller spaces. Convective loops can occur in cavities inside walls where there are voids in insulation, in attics, even between tight-fitting blinds and inefficient windows. Differences in temperature between the conditioned space and outdoors can create enough of a pressure difference inside a wall cavity to form a convective loop.

The most effective strategies for stemming convective heat losses are to avoid air temperature differentials inside structures, to fully fill insulated cavities with insulation (no voids), and to seal air leaks. Properly installing adequate insulation eliminates cold spots in walls and structural cavities. Sealing air leaks blocks air movement and minimizes the temperature differentials that occur from mixing conditioned and unconditioned air.

Radiation

Radiation is the movement of heat by infrared rays. Much of the heat from a woodstove is in the form of radiation. The key to radiation is that, unlike conduction or convection, this process does not involve a molecular connection between the source and the recipient of the heat. That is one reason a person sitting across the room feels toasty from a radiant heater, such as a woodstove. Heat can be transferred through a vacuum via radiation; this is how heat from the sun is transferred to earth through the vacuum of space.

Radiant heat can influence comfort. In a house with a reasonable indoor temperature, radiant heat from a hot window or wall can influence the comfort level of building occupants. In cold climates, heat radiating from occupants to a cold window or wall can make them feel colder. On the other hand, when indoor warming is needed, an occupant exposed to radiant floor heating may feel warmer than the air temperature suggests.

Techniques for controlling solar radiation heat gain include tree shading and radiant barriers installed in the attic. Light colored roofing material can minimize solar heat gain. Researchers at Lawrence Berkley and Oak Ridge national laboratories have been working with industry partners to study "cool roofs." These are white and cool colored tile, shingle, and metal roofs that stay cooler in the sun by virtue of high solar reflectance and high thermal emittance. Early research in Florida showed that white reflective roofs would reduce cooling energy consumption by 18%-26% and peak demand by 28%-35% (Parker, Sherwin, Sonne, and Moyer 2002). Cool roofs could have impacts globally as well as for the individual homeowner. According to LBNL, "a program to install cool roofs, cool pavements, and trees over about 30% of the surface of the Los Angeles basin has been predicted to lower the outside air temperature by about 5°F. Cooler outside air improves air quality by slowing the temperature-dependent formation of smog. Decreasing the outside air temperature in the Los Angeles basin by 5°F [3 K] is predicted to reduce smog (ozone) by about 10%, worth about $300M/yr in avoided emissions of smog precursors (e.g., NO_x)" (Levinson 2009).

At night, a house can radiate heat to a clear night sky. The resulting cooling can lead to condensation in attics and roof wetting. Researchers are exploring way to use radiation to the night sky as a passive way to cool homes.

Occupants

Occupants are a force unto themselves, not tied directly to climate or building dynamics but able to strongly influence building performance. Occupant comfort and costs are at the center of design considerations. But as the building operators and maintainers, occupants can do much to correct or unbalance a system. Providing correct information in the form of owners manuals and marketing materials can help occupants make decisions that will contribute to their home's longevity, comfort, and efficiency.

Occupants have an enormous impact on the energy performance of homes in the selections they make in appliances, entertainment systems, computers, tools, and other electric equipment. These plug loads make up about 40% of energy loads in homes. As builders and researchers figure out how to make thermal, lighting, and ventilation equipment more efficient, these loads will become more and more important in how energy is managed in homes.

More Information on Moisture Management, Air Flow, and Heat Flow

American Society for Testing and Materials (ASTM) E-2112-07. "Standard Practice for Installation of Exterior Windows, Doors and Skylights." ASTM. www.astm.org/Standards/E2112.htm

ASTM E 2266. "Standard Guide for Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion." ASTM available for purchase at www.astm.org/Standards/E2266.htm

Buildernews Magazine, May 2004, "Housewrap Felt or Paper: Comparing specs on weather barriers," www.buildernewsmag.com/index.php?option=com_content&view=article&id=1168%3AHousewrap+Felt+or+Paper%3A&Itemid=107

Building Science Corporation. Homeowner Information Resources. www.buildingscienceconsulting.com/resources/homeowner.htm

Fenestration Manufacturers Association (FMA) / American Architectural Manufacturers Association (AAMA) 100-07. "Standard Practice for the Installation of Windows with Flanges or Mounting Fins in Wood Frame Construction." Available from AAMA's online store at www.aamanetstore.org/pubstore/ProductResults.asp?cat=0&src=100

HGTVpro.com. "Improved Stucco Systems." Article available at www.hgtvpro.com/hpro/bp_exterior_finishes/article/0,2617,HPRO_20149_4243887,00.html

IBACOS. 2002. "Moisture Issues in Homes with Brick Veneer." IBACOS article available at www.eere.energy.gov/buildings/building_america/pdfs/db/36397.pdf

International Residential Code (IRC). 2009. Section 408.3, "Unvented Crawl Spaces," International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3110S09.html

Levinson, Ronnen. 2009. *Cool Roof Q &* A, Lawrence Berkeley National Laboratory. http://coolcolors.lbl.gov/assets/docs/fact-sheets/Cool-roof-Q%2BA.pdf

Lstiburek, Joseph W. 2004. *Conditioned Crawl Space Construction, Performance and Codes*, Research Report – 0401, Building Science Corporation, www.building science.com

Lstiburek, Joseph. 2008. "Concrete Floor Problems," BSI-003, Building Science.com, www.buildingscience.com/documents/insights/bsi-003-concrete-floor-problems.

Lstiburek, Joseph. 2006. *Building Science Digest 106: Understanding Vapor Barriers*. Building Science Press. Waterford, MA. www.buildingscience.com/documents/digests/bsd-106-understanding-vapor-barriers

Lstiburek, Joseph W. 2003. *EEBA Water Management Guide*. Energy and Environmental Building Association. Minneapolis, MN. www.eeba.org/bookstore/prod-Water_Management_Guide-9.aspx

Lstiburek, Joseph. 2001. "Brick, Stucco, Housewrap and Building Papers," RR-0105, Building Science.com, www.buildingscience.com/documents/reports/rr-0105-brick-stucco-housewrap-and-building-paper/

Parker, D., J. Sherwin, J. Sonne, N. Moyer. 2002. *Comparative Evaluation of the Impact of Roofing Systems on Residential Cooling Energy Demand in Florida*. Florida Solar Energy Center , Rpt: FSEC-CR-1220-00, available at http://securedb.fsec.ucf.edu/pub/pub_show_detail?v_pub_id=4120

Straube, John. 2001 "Wrapping it Up," *Canadian Architect*. May 2001. www.cdnarchitect.com/issues/ISarticle.asp?aid=1000115982

U.S. Department of Energy (DOE). 2000. "Technology Fact Sheet on Weather-Resistive Barriers." Available on the Web at www.toolbase.org/PDF/DesignGuides/weatherresistantbarriers.pdf

U.S. Department of Energy. 2009. *"Residential Requirements of the 2009 International Energy Conservation Code"* DOE Building Energy Codes Program, PNNL-SA-65859, www.energycodes.gov/training/pdfs/2009_iecc_residential.pdf

U.S. Environmental Protection Agency. *Mold Course - Introduction to Mold and Mold Remediation for Environmental and Public Health Professionals*. Referenced 6/18/2009, www.epa.gov/mold/index.html.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 7.
The Overall Building Envelope

The building envelope is the boundary that separates interior comfort from exterior conditions. The basic shell is the first line of defense against the elements and forms the architectural style of the house. Perhaps most important to a builder's success, it is the first thing that buyers see from the curb and often the most important selling point for the house.

The building envelope is much more complex than just the visible shell of the building. The envelope actually encompasses three boundaries:

- The thermal boundary consists of the building assemblies surrounding the space that is purposefully cooled or heated. This boundary is where insulation should be located.
- The pressure boundary is the point at which inside air and outside air are separated. This boundary is where air sealing should occur. Proper sealing stops air and vapor penetration into building cavities. Thermal and pressure boundaries should be aligned.
- The weather barrier includes screens to shed rain.

Insulated concrete form (ICF) walls form a solid thermal boundary for the NextGen 2009 home in Las Vegas. *(Photo source: iShow.com, Inc.)*

"Advanced framing is such a simple thing but very few builders are doing it. It is a selling point with customers. The performance characteristics are easy to point out to the customer and it's easy to carry the energy saving concepts through to other items like high-performance windows, more insulation, and air sealing."

Builder Barrett Burr, Olympia, Washington

CHAPTER TOPICS

Building America partner John Wesley Miller's homes at Armory Park del Sol beat the Building America benchmark by 50% thanks in part to a building envelope that includes masonry walls with external rigid insulation and R-38 attic insulation.

This chapter describes three strategies that apply to the overall building envelope: advanced framing, insulation, and air sealing. These strategies involve the entire house envelope and directly address the thermal and pressure boundaries.

Specific practices that apply to particular assemblies, such as foundations, walls, and roofs, are described in the next chapter. These strategies include housewraps, flashings, and other approaches that apply to moisture control in the building shell.

Advanced Framing

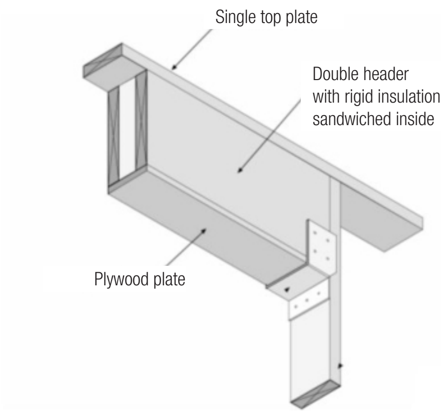
Optimal value engineering or *advanced framing* refers to framing techniques that require less lumber than standard framing practices but provide all the needed structural strength. These strategies require simple modifications to framing practices. By using less framing material, these strategies make room for more insulation to be installed while saving resources and reducing waste. These recommendations apply to standard framing using dimensional lumber. Other energy-efficient framing materials not described here include structural insulated panels, insulated concrete forms, and steel framing.

In a Building America study (described in the PATH Toolbase) advanced framing resulted in 50% reductions in installation and materials costs along with a 7% increase in the amount of wall cavity area that could be insulated. The net result was about a 30% reduction in annual heating and cooling costs. The simple measures taken in this project included single top plates, 24-inch on-center 2x6 wall studs, and standardization of window and door openings to match the 24-inch layout.

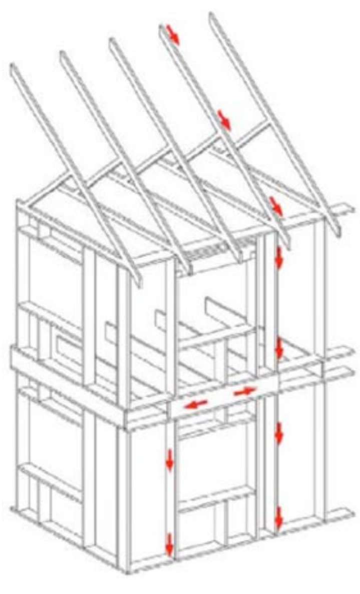
Construction documents should include a detailed framing plan that illustrates where framing members are to be placed and the types of corners, window jacks, header size and type, and other features to be incorporated. A sampling of advanced framing techniques includes:

- **Two-foot module design.** Starting with the foundation, the house exterior dimension footprint should be based on 2-foot increments. Because sheet goods come in 4-foot by 8-foot dimensions, this will result in much less waste and you will often see significant savings in framing members as well.

- **Frame 24-inch on-center.** Typical practice is to frame walls, floors, and often roofs at 16-inch on-center. However, 24-inch on-center walls are structurally adequate for most residential applications. Even though the stud size is increased from 2x4 to 2x6 on load-bearing walls, changing stud-spacing from 16 to 24 inches can reduce framing lumber needs significantly. Confirm with local building officials, as some jurisdictions in high-wind areas may not allow 24 -inch on-center (PATH).



Closed Insulated Double Header
Insulated headers are one advanced framing technique. *(Figure source: CARB)*



Advanced framing techniques include aligning wall studs with trusses and using single top plates.

- **Align framing members and use a single top plate.** Double top plates are used to distribute loads from framing members that are not aligned above studs and joists. By aligning framing members vertically throughout the structure, the second plate can be eliminated. Plate sections are cleated together using flat plate connectors. For multi-story homes that are framed with 2x4s, this may increase the stud size on lower floors to 2x6; however, there is still typically a net decrease in lumber used.

- **Size headers for actual loading conditions.** Headers are often oversized for the structural work that they do. Doubled-up 2x6 headers end up in non-load-bearing walls. Doubled-up 2x12 headers end up in load-bearing walls, regardless of specific loading conditions. Nonbearing walls do not need structural headers. Proper sizing may allow for the use of insulated headers in which foam insulation is sandwiched between lumber.

- **Ladder-block exterior wall intersections.** Where interior partitions intersect exterior walls, three-stud "partition post" or stud-block-stud configurations are typically inserted. Except where expressly engineered, these are unnecessary. Partitions can be nailed either directly to a single exterior wall stud or to flat blocks inserted between studs. This technique is called "ladder blocking" or "ladder framing." This also creates room for more insulation.

- **Use two-stud corners.** Exterior wall corners are typically framed with three studs. The third stud generally only provides a nailing edge for interior gypsum board and can be eliminated. Drywall clips, a 1x nail strip, or a recycled plastic nailing strip can be used instead. Using drywall clips also reduces opportunities for drywall cracking and nail popping, frequent causes of builder callbacks.

Two-stud corners with drywall clips use the least wood and give the best thermal performance.

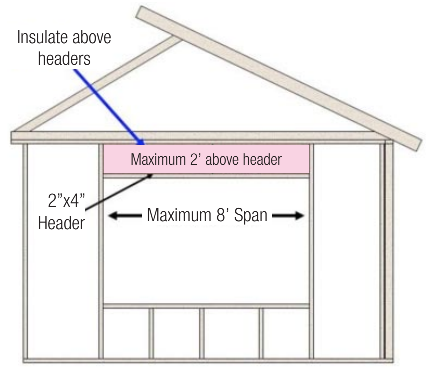
- **Eliminate redundant floor joists.** Double floor joists are often installed unnecessarily below non-load-bearing partitions. Nailing directly to the sub-floor provides adequate attachment and support. Partitions parallel to overhead floor or roof framing can be attached to 2x3 or 2x4 flat blocking.

- **Use 2x3s for partitions.** Interior, non-load-bearing partition walls can be framed with 2x3s at 24-inch on-center or 2x4 "flat studs" at 16-inch on-center.

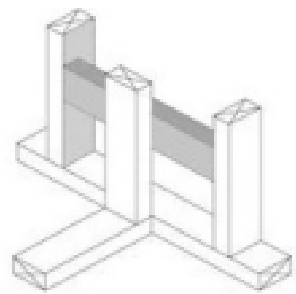
For More Information on Advanced Framing

NRDC. 1998. *Efficient Use of Wood in Residential Construction.* Natural Resources Defense Council, Washington, D.C. www.nrdc.org/cities/building/rwoodus.asp

IBACOS. 2003. Best Practices: Optimum Value Engineering. Available on the Building America website at www.eere.energy.gov/buildings/building_america/pdfs/db/35380.pdf



Using single 2x4 headers instead of double 2x6 headers in non-load-bearing walls allows space for insulation.



Ladder blocking where exterior walls intersect interior walls provides space for insulation and cuts back on thermal bridging.

Using dry wall clips or a 1x nailer strip to avoid the third stud in corners provides more room for insulation and reduces lumber.

Lstiburek, Joseph. 2005. “The Future of Framing Is Here,” *Fine Homebuilding*, November 2005, No. 174, p. 50-55.

NAHB Research Center. “Advanced Framing Techniques: Optimum Value Engineering (OVE),” Available at www.toolbase.org/Construction-Methods/Wood-Framing/advance-framing-techniques accessed 6-4-08

PATH. ToolBase Techspecs: Advanced Framing Techniques. www.toolbase.org/pdf/techinv/oveadvancedframingtechniques_techspec.pdf

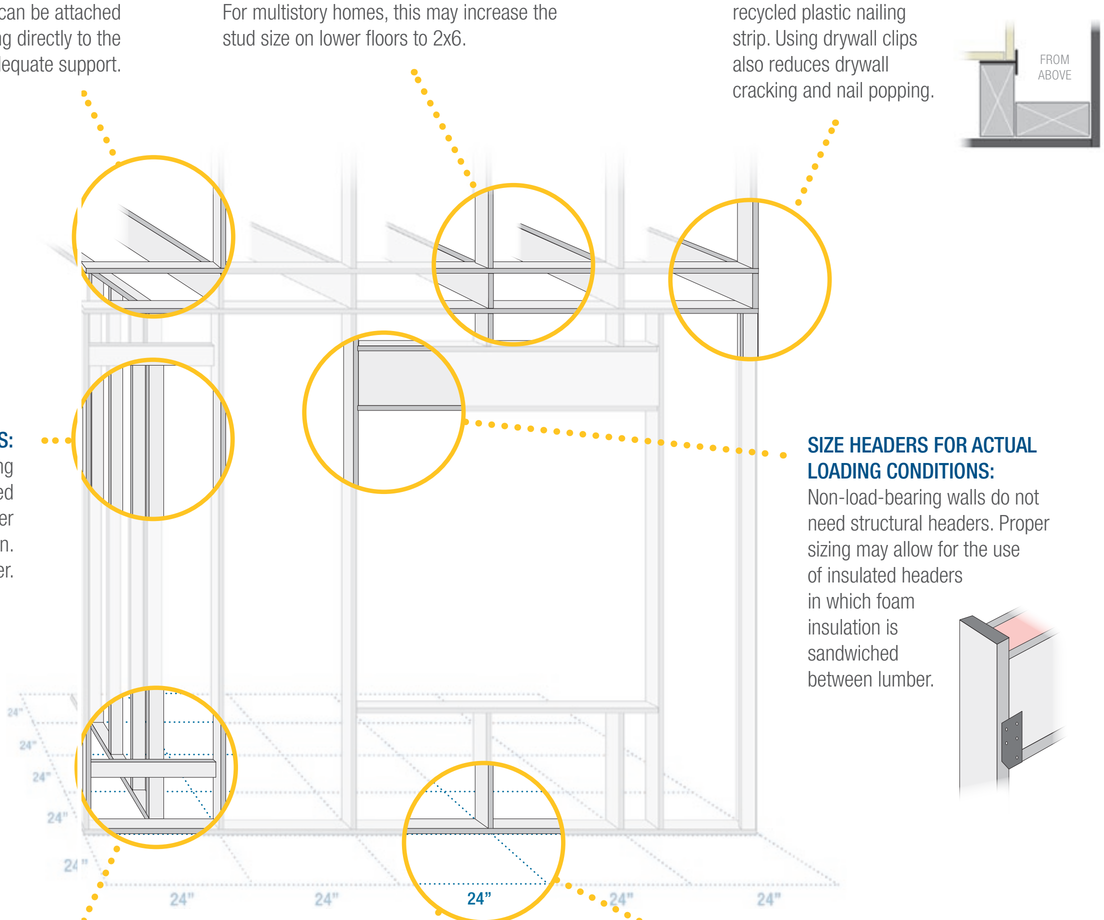
U.S. Department of Energy (DOE). 2002. Advanced Wall Framing. 6-page fact sheet by the U.S. Department of Energy www.nrel.gov/docs/fy01osti/26449.pdf

Advanced framing techniques can reduce lumber costs while providing more space for insulation

ELIMINATE REDUNDANT FLOOR JOISTS: Double floor joists aren’t needed below non-load-bearing partitions. Partitions parallel to overhead floor or roof framing can be attached to 2x3 or 2x4 blocking. Nailing directly to the sub-floor provides adequate support.

ALIGN FRAMING MEMBERS AND USE A SINGLE TOP PLATE: Plate sections are cleated together using flat plate connectors. For multistory homes, this may increase the stud size on lower floors to 2x6.

USE TWO-STUD CORNERS: Rather than using a third stud as a nailing edge for interior gypsum board, use drywall clips, a 1x nailer strip, or a recycled plastic nailing strip. Using drywall clips also reduces drywall cracking and nail popping.



USE 2X3s FOR PARTITIONS: Interior, non-load-bearing partition walls can be framed with 2x3s at 24-in. on center or 2x4 “flat studs” at 16-in. on center.

SIZE HEADERS FOR ACTUAL LOADING CONDITIONS: Non-load-bearing walls do not need structural headers. Proper sizing may allow for the use of insulated headers in which foam insulation is sandwiched between lumber.

LADDER-BLOCK EXTERIOR WALL INTERSECTIONS: Partitions can be nailed either directly to a single exterior wall stud or to flat blocks inserted between studs.

TWO-FOOT MODULE DESIGN: Starting with the foundation, the house footprint should be based on 2-foot increments. Layouts should be based on this 2-foot grid to minimize material waste.

FRAME 24-IN. ON CENTER: 24-in. on center studs are structurally adequate for most residential applications. Even when the stud size must be increased from 2x4 to 2x6, 24-in. spacing can significantly reduce framing lumber needed.

Insulation Materials

Insulation is usually hidden away behind finished surfaces, but insulation is the material that does the most to block heat loss through conduction. Rigid insulation can also help to block air movement, and may be used as a screen in a rain barrier system. By increasing the R-value of walls toward the exterior, rigid insulation can also be helpful in managing vapor.

Insulation comes in a variety of forms, some of the common options are described here. Average R-values are listed in the table below.

Common Insulating Materials (R-values per inch of insulation)

INSULATING MATERIAL		Avg. R-Value per Inch
FIBERGLASS	• Unfaced batt, standard density	R-2.9 to R-3.8
	• Unfaced batt, high density	R-3.7 to R-4.3
	• Blown fiberglass	R-2.2 to R-2.7
POLYSTYRENE (expanded or extruded)	• Rigid foam board	R-3.8 to R-5.0
	• Loose fill	R-2.3
POLYISOCYANURATE	• Rigid board	R-5.6 to R-8
	• With foil facing	R-7.1 to R-8.7
POLYURETHANE	• Spray foam or foam board	R-7 to R-9
	• Foam board with foil facing	R-7.1 to R-8.7
	• Soy-based polyurethane spray foam	R-3.7
OTHER	• Cellulose, blown	R-3.6 to 3.8
	• Mineral wool, rock or slag, batt or loose	R-3.7
	• Cotton batt	R-3.4
	• Sheep's wool batt	R-3.5
	• Strawbale	R-2.4
	• Plastic PET	R-3.8 to R-4.3

Source: DOE Energy Savers website
http://www.energysavers.gov/your_home/insulation_airsealing/index.cfm/mytopic=11510

Blankets or Batts: Blankets in the form of batts or rolls are flexible products made from mineral fibers, typically fiberglass. Two producers are manufacturing batts made from cotton and polyester mill scraps. Batts are available in widths suited to standard wall, floor, and attic framing spaces. Continuous rolls can be hand-cut and trimmed to fit. They are available with or without vapor retarder facings. Standard fiberglass batt insulation features R-values between R-11 (3.5-inch thick) and R-38 (12-inch thick). High-performance (medium- and high-density) fiberglass batts with greater R-values per inch of thickness are also available. If you choose to use other types of insulation, such as blown-in, batts can be installed in areas that may become inaccessible as construction unfolds; for example behind shower inserts, beneath stairs, or in rim joists. Batts also make good dams in attics around access points or other areas where blown-in insulation should be held back. Batts are not air barriers. Batt facing can form an undesirable vapor retarder. Unfaced batts are recommended for the hot-dry/mixed-dry climates.

Blown-In: Blown-in, loose-fill insulation includes loose fibers or beads that are blown into building cavities or attics using special pneumatic equipment. Netting may be stapled to studs to hold blown-in insulation in place before gypsum board is installed. Another form of blown-in insulation is fibers, such as cellulose made from recycled newspaper that is mixed

(1) Batt insulation. *(2)* Blown-in insulation. *(3)* Foamed-In-Place. *(Photo source: Sam Garst) (4)* Here, spray foam is applied along the underside of the roof deck to provide a conditioned and non-vented attic space for ducts and air handlers.

"You really can't overdo insulation. It is relatively cheap compared to other components of the house and you will pay for under-insulating for the life of the house."

Homeowner Sam Garst

Masonry walls are insulated with interior rigid insulation.

One thing that really sets Pulte Las Vegas apart from the competition is its attic insulating technique. Rather than distributing the cellulose insulation along the ceiling deck, Pulte applies it along the underside of the roof line, holding it in place with netting stapled to the roof struts, providing a conditioned attic space. "We can get temperatures over 105°F several days in a row in Las Vegas in the summer. Unconditioned attics can get up to 150°F. Mine stay about 80°F. It's not rocket science to figure out that if you're sending your ducts through the attic, you are going to have to work a lot harder to cool your living space to 78°F when you've got 150°F attics than when you've got 80°F attics."

Nat Hodgson, Vice President of Construction for the Las Vegas Division of Pulte Homes and Communities of Del Webb

Pulte Tucson uses blown cellulose for cathedralized insulation of the attic. They also use it in the walls. "It is a mixture of recycled newspapers and a fire retardant. We apply it wet to the walls before sheet rocking; it sticks to the walls and dries in place."

Rich Michal, Pulte Tucson Civano Project Manager

with a wet adhesive and sprayed into the wall cavity, then allowed to set in the walls making it resistant to settling. An advantage of blown-in insulation is that it easily takes the form of the cavity into which it is blown. Blown-in insulation will also fill spaces behind and around potential obstacles, such as electrical boxes, wiring, and plumbing. The blown-in material can provide some resistance to air infiltration if the insulation is sufficiently dense, but blown-in insulation should not be considered an air barrier.

Spray Polyurethane Foam (SPF): Foamed-in-place polyurethane foam insulation can be applied by a professional applicator using special equipment to meter, mix, and spray the insulation into cavities where the foam hardens in place. Some polyurethane foams are made with up to 20% soy-based oil stock rather than 100% hydrocarbon-based oil. Sprayed foam makes an excellent air seal and can be used to reach hard-to-get-at places. Critical points where this type of foam is especially useful include complicated intersections of building elements with odd shapes and many joints. These types of areas include band joists at the intersection of the foundation and floor or where upper-story floors intersect the wall. The intersection of the ceiling, walls, and attic is another complex area where foam-in-place insulation can provide an air seal and insulation.

Spray foam comes with either an open cell (OC SPF) or closed cell (CC SPF) structure. An open-cell structure allows air to move between the cells within the insulation; these may be produced using water as a blowing agent. Closed-cell foam is more rigid and dense with each cell forming a bubble that captures the gas inside of it. Closed-cell foam contains special gases that make it expand and give it greater R-values. Open-cell foam is less dense, has a lower R-value rating, and is generally less expensive. Both types of foam are excellent air sealers. High-density, closed-cell foams have greater resistance to bulk liquid and vapor and may serve as both air and vapor barriers. Spray foam companies have converted to using a non-ozone depleting blowing agent, but these agents may still have global warming potential.

Rigid Insulation: Rigid insulation is made from fibrous materials or plastic foams that are pressed or extruded into sheets and molded pipe coverings. These provide thermal and acoustical insulation, strength with low weight, and coverage with few heat loss paths. Insulation sheets may be faced with a reflective foil that reduces radiant heat transfer when facing an air space. Foil facing also makes the board nearly impervious to water and vapor and so should be used with caution. Rigid foam insulation may be used in combination with other insulation types, such as on the exterior of walls that are filled with cellulose or fiberglass. Foam sheets that may be in contact with the ground should be borate-treated for termite resistance. Rigid fiberglass insulation is used on the exterior of basement walls and can form a moisture screen.

Rigid insulation sheets may be applied to the exterior of wall assemblies as insulating sheathing. This approach helps to seal air leaks, block thermal bridges where framing lumber spans the wall, provide a drainage plane, and create additional R-value near the exterior surface of the wall. The last point is important because vapor inside a wall assembly may reach cold enough surfaces inside the wall that the vapor condenses. Insulation on the outside of the wall helps to temper the temperature and avoid condensation. This is especially beneficial where outdoor temperatures are low and indoor temperatures are warm. Here is a summary of rigid insulation materials.

- **Polyisocyanurate – 6 to 6.5 R-value per inch** – typically foil-faced rigid sheet; it should not be used in contact with soil because it absorbs moisture; foil facing is a vapor barrier and should be used with caution; a non-ozone-depleting blowing agent is used (pentane).

- **Extruded Polystyrene (XPS) – 5 R-value per inch** – more consistent density and greater compressive strength than EPS, preferred material for soil contact or as rain barrier because resistant to liquid moisture penetration. 2010 is the EPA deadline to switch to a non-ozone depleting, VOC-free blowing agent. For example, Dow announced June 11, 2009, that it had completed conversion of its Styrofoam brand XPS plants in the U.S. to VOC-free production.

- **Expanded Polystyrene (EPS) – 3.6 to 4.4 R-value per inch** – beadboard; non-ozone-depleting blowing agent (pentane); spaces between beads can absorb water; not a vapor retarder; often used in structural insulated panels and insulating concrete forms; comes with borate treatment making it resistant to insects; requires a capillary break between soil and insulation; comes in many densities and grades.

- **Fiberglass** – drainable and resistant to insect degradation; excellent for soil contact.

Insulation in non-vented attics is applied directly under roof sheathing. In this example cellulose and carefully sealed joints are used to form a conditioned and non-vented attic. *(Photo source: Pulte Homes)* Note, permeable insulation can only be used at roof decks in unvented attics in the hot-dry/mixed-dry climate zone. In other climate zones, insulation applied along a roof deck in unvented attics must be air impermeable.

Reflective Insulation Systems: Reflective insulation systems are fabricated from aluminum foils with a variety of backings such as roof sheathing, craft paper, plastic film, polyethylene bubbles, or cardboard. The resistance to heat flow depends on the heat flow direction; this type of insulation is most effective in reducing downward heat flow and requires an air space adjacent to the reflective surface. There are no R-values for reflective insulation because R-values apply to conduction and reflective barriers reflect radiant heat. Reflective systems are typically located between roof rafters, floor joists, or wall studs. Reflective insulation placed in walls must be perforated.

If a single reflective surface is used alone and faces an open space, such as an attic, it is called a radiant barrier. Radiant barriers are sometimes used in buildings to reduce summer heat gain and winter heat loss. They can be effective in the hot-dry and mixed dry climates at reducing peak cooling loads, especially if ductwork or cooling equipment is located in the attic. All radiant barriers have a low emittance (0.1 or less) and high reflectance (0.9 or more). Thermal emittance refers to a material's ability to release absorbed heat. Surfaces with a high thermal emittance will radiate heat gained back into the space.

As a general rule, the reflective surface of a radiant barrier should face downward so that dust cannot collect on the surface. As the level of ceiling insulation increases, the value of a radiant barrier is diminished. The California Energy Commission allows use of radiant barriers to comply with Title 24. They suggest that the barrier can be installed in any of the following ways: 1) draped over the truss/rafter (the top chords) before the upper roof

Centex of Northern California used a system it calls "zero defect" wall insulation in homes in San Ramon to help achieve energy savings of almost 40% over the Building America benchmark. It includes 2x6 framing to accommodate R-23 blown fiberglass in walls for more consistent fill than fiberglass batts, R-38 in the ceiling to cover ducts, and careful caulking and sealing of all joints and penetrations to reduce air leakage.

Radiant barriers can significantly reduce solar heat gain through the roof.

"Simple inclusions like additional attic insulation and tankless water heaters are immediately cost effective for our homeowners."

Jeff Jacobs, then of Centex Homes, Northern California Division, now president of Building Advisory

Sealing gaps between floor joists with spray foam provides a good air seal that prevents the flow of heat, cold, and pollutants from unconditioned space to conditioned space.

decking is installed, 2) spanning between the truss/rafters (top chords) and secured (stapled) to each side, or 3) secured (stapled) to the bottom surface of the truss/rafter (top chord) with a minimum air space between the top surface of the radiant barrier and roof decking of at least 1.5 inches at the center of the truss/rafter span. The radiant barrier should have a minimum gap of 3.5 inches between the bottom of the radiant barrier and the top of the ceiling insulation to allow ventilation air to flow between the roof decking and the top surface of the radiant barrier, and should have a minimum of 6 inches (measured horizontally) left at the roof peak to allow hot air to escape from the air space between the roof decking and the top surface of the radiant barrier. If the barrier is installed in enclosed rafter spaces where ceilings are applied directly to the underside of roof rafters (i.e., cathedral ceilings), a minimum air space of 1 inch should be provided between the radiant barrier and the top of the ceiling insulation, and ventilation must be provided for every rafter space. Vents should be provided at both the upper and lower ends of the enclosed rafter space. Alternatively roof sheathing is available with the radiant barrier already laminated directly to the underside and perforated by the manufacturer to allow moisture/vapor to transfer through the roof deck. CEC's specific requirements are described in CEC 2005.

Air barriers are systems made up of materials designed and constructed to control airflow between a conditioned space (indoors) and an unconditioned space (outdoors or a garage).

Research in Florida shows that an attic radiant barrier can save 10% to 15% on heating and cooling in a typical Florida home (FSEC 1988). A recent article in DOE's building codes newsletter, *Setting the Standard*, indicates a savings level of between 5% and 10% in warm, sunny climates (DOE 2009).

The article describes the rules for determining R-values for reflective insulation materials. R-value determinations for reflective insulation (and all other insulation products) must be in compliance with Federal Trade Commission regulations (FTC rule 16 CFR 460, Section 5 – www.ftc.gov/bcp/rulemaking/rvalue/16cfr460.shtm#5). The R-values for multi-layer reflective insulation systems vary according to whether they are used in attics, walls, or floors, and the product label must list separate values for each orientation. The R-value for a radiant barrier depends on the surface emittance, the orientation relative to the heat flow direction, and the thickness of the air space. R-values of radiant barriers in open spaces can range from 1.32 to 4.55, with the higher values corresponding to downward heat flow (attics in the summer and floors in the winter).

"There are plenty of ways to create a more energy-efficient home; solar power is one way, but insulation and a tight seal can go a long way to achieve this as well."

Bob Walter, Morrison Homes, Elk Grove, California

For More Information on Insulation

ASHRAE. 2009. *ASHRAE Handbook of Fundamentals.* American Society of Heating, Refrigerating, and Air-Conditioning Engineers. www.ashrae.org/publications/page/158

CEC. 2005. Residential Alternative Calculation Method (ACM) Approval Manual For Compliance with California's 2005 Energy Efficiency Standards, California Energy Commission. www.energy.ca.gov/title24/2005standards/res_manual_errata/4Q-05/ch8/R-Page_8-31.pdf

Consortium for Advanced Residential Buildings. Steven Winter Associates (CARB-SWA). 2009. *Open-Cell vs Closed-Cell Foam Guide*. www.carb-swa.com/Resources

ENERGY STAR. Builder Option Packages (BOPS) with recommended insulation levels by county. www.energystar.gov/index.cfm?c=bop.pt_bop_index

Florida Solar Energy Center (FSEC). 1988. *Consumer Facts about Radiant Barriers*. FSEC-FS-37-88. FSEC, Cocoa, FL. www.fsec.ucf.edu/en/publications/pdf/FSEC-FS-37-88.pdf

Krigger, John and Chris Dorsi. 2009. *Resident Energy: Cost Savings and Comfort in Existing Buildings*, 5th Edition, Prentice Hall (previous editions published by Saturn Resource Management).

Mathis, R. C. 2007. *Insulating Guide.* Building Science Press. Westford, MA. Available for purchase at www.eeba.org/bookstore/prod-Insulating-Guide-8.aspx

Parker, Danny and John Sherwin. 1998. "Comparative Summer Attic Thermal Performance of Six Roof Constructions." TO-98-17-3. *1998 ASHRAE Annual Meeting*, Toronto, Canada. www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-337-98.pdf

Parker, Danny. 2001. *FPC Residential Monitoring Project: New Technology Development Radiant Barrier Pilot Project*. FSEC-CR-1231-01. Florida Solar Energy Center, Cocoa, FL. www.radiantbarrierdoneright.com/FSEC.pdf

Roos, Carolyn. 2008. *Principles of Heat Transfer*. WSUEEP07-004. Washington State University, Extension Energy Program, Olympia, WA. www.eenergyideas.org/documents/factsheets/PTR/HeatTransfer.pdf

U.S Department of Energy (DOE). 2009. "Cool Down with 'Reflective Insulation' Materials." *Setting the Standard*. January 2009. Available on page 4 at www.energycodes.gov/news/sts/pdfs/standard_january09.pdf

U.S. Department of Energy (DOE). 2008. *Insulation Fact Sheet*. DOE/CE-0180. DOE's insulation calculator for recommended insulation levels. www.ornl.gov/sci/roofs+walls/insulation/ins_16.html.

U.S. Department of Energy (DOE). 1991. *Radiant Barrier Attic Fact Sheet*. DOE/CE-0335P. www.ornl.gov/sci/roofs+walls/radiant/rb_01.html

U.S. Department of Energy (DOE). Recommended insulation levels by zip code. www1.eere.energy.gov/consumer/tips/insulation.html

Air Sealing

Unintentional air flow (through wall penetrations, leaks around doors and windows, and cracks in the roof) robs a home of warm or cool air, serves as a pathway for moisture flow, and decreases comfort levels. Controlling air infiltration is one of the most cost-effective and simplest energy-efficiency measures in modern construction practices. Extensive air sealing is one of the primary 40% improvement strategies.

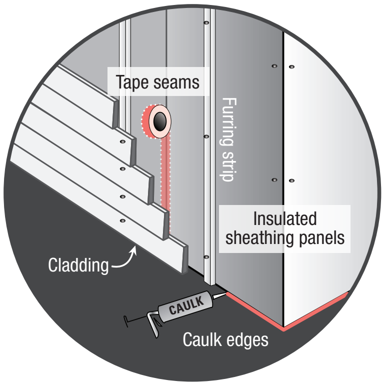
Good caulking and sealing will reduce the infiltration of dust and dirt (and even bugs) that can enter homes through cracks and holes. The materials and approaches recommended here are common and time tested. However, these measures must be carefully installed to be effective and must be installed in the proper construction sequence before cavity areas are covered up by fixtures or walls.

Sealing against air leakage is primarily done for thermal reasons, but when coupled with appropriate mechanical ventilation, this procedure also assists in maintaining good indoor air quality for the occupant. This combination helps to provide controlled air rather than relying on pressure and temperature differences. Air leaks also carry water vapor; if this water vapor condenses, it can cause mold and other moisture problems.

(left) Bob Ward Companies used an exterior wall sheathing consisting of a 1/8th inch layer of laminated fiber board covered with 1/8-inch of extruded polystyrene foam board. This layer goes on the exterior side of the studs under the stone or wood siding. Joints are taped so the foam board serves as an air barrier as well, eliminating the need for housewrap. The sheathing moves the dew point surface to the outside of the framing member, reducing the potential for condensation and moisture damage within the wall cavity. *(Photo source: Bob Ward Company)*

In this figure, OSB and foam form the air barriers to isolate the garage from living space.

Framing is sequenced to install an air barrier between the porch roof cavity and conditioned space.



An exterior air barrier system, like rigid foam insulating sheathing, can provide a continuous air barrier when seams are taped or caulked. Furring strips attached over the foam allow the foam to act as a drainage plane and the space to serve as a ventilation gap, which is especially important under porous claddings like brick and stucco.

One of the key strategies in the control of airflow is the use of continuous air barriers. Air barriers are systems made up of materials designed and constructed to control airflow between a conditioned space (indoors) and an unconditioned space (outdoors or a garage).

An important job for air barrier systems is separating garages from conditioned spaces. Garages are often used to store products that can emit toxic compounds. Internal combustion engines can be dangerous sources of carbon monoxide and other air pollutants. Tight sealing between conditioned spaces, including air handler closets, and the garage is critical to keep pollutants out of the house.

Air barrier systems can be located anywhere in the building envelope – at the exterior surface, the interior surface, or anywhere in between. Exterior air-barrier systems avoid complex intersections between partition walls and joist cavities between stories. These systems help block winds that can diminish insulation effectiveness (wind washing).

Building America researchers have worked with three building approaches that provide innovative solutions to air barriers and thermal bypasses. These approaches push the air barrier towards the exterior of the building shell, making it easier to avoid sealing around complex building features, such as electrical outlets, plumbing, lights, fireplaces, and stairs. The three approaches are

- conditioning crawlspaces and basements, or using slabs
- installing insulated exterior sheathing, with sealed seams
- conditioning attics.

The installation of high-efficiency furnaces and water heaters can also help control air leakage. Natural gas fired condensing furnaces achieve combustion efficiency levels greater than 90%. These direct-vent furnaces and water heaters are sealed combustion systems that intake and exhaust air through plastic pipes that do not require a vertical chimney. Eliminating the chimney (which is designed to move air out of the house) removes the need to seal the chimney and its chase from unwanted air and thermal leaks. A direct-vent fireplace can also eliminate the need for a chimney entirely. Ducts located in conditioned space also eliminate penetrations through the building shell and avoid the intake of unconditioned air that occurs through duct leaks. More information on these systems is included in Chapter 8.

Sealing critical framing elements along with the interior gypsum board and exterior sheathing (or both) can provide a continuous building envelope air-barrier system. Exterior stucco may also serve as an air barrier. In this approach, primary reduction of air-leakage openings is shared by the framer, the gypsum-board installer, and/or the exterior sheathing installer.

Using gypsum board as part of the air barrier system typically involves applying the boards over gaskets, adhesive, or caulk. Look for adhesives and caulks with low or zero VOC (volatile organic compounds) emissions. One listing of green building products (www.BuildingGreen.com) includes adhesives that have VOC levels of 50 grams per liter or less. Water-based adhesives and caulks have lower VOC emissions than solvent-based products. Ensure that adhesives are compatible with all materials they will come in contact with, especially foam insulations.

Air Sealing Details

Air sealing begins at the sill plate, where a gasket should be installed between the foundation and the plate.

The greatest challenges for air sealing are at the intersections of different building assemblies: the bottom plate where exterior walls meet the subfloor; band joists between stories; kneewalls; and cantilevers which may incorporate elements of walls, floors, and roofs. One way to ensure continuous sealing at complex intersections is to use spray-in-place foams as both an insulator and a sealant. The foam can be applied much more quickly than caulking individual assembly pieces.

Air leakage through sub-floor sheathing installed over unconditioned spaces such as vented crawl spaces, unconditioned garages, or cantilevered floors over exterior walls can be controlled by sealing all panel joints.

Tubs, shower stalls, and one-piece manufactured tub/shower enclosures installed on exterior walls can be the source of the largest area of air leakage when uncontrolled. Rigid sheathing material should be installed on the interior surfaces of exterior walls and sealed to framing and sub-floor sheathing before tubs and showers are installed. Thin, non-insulating sheathings can be installed in a manner that allows the installation of interior gypsum board sheathing over sheathing edges without noticeably altering wall thickness. With one-piece manufactured tub/shower enclosures, the entire height of the interior surface of the exterior walls should be sheathed. This requires the installation of cavity insulation before the installation of the interior sheathing.

Where fireplaces are installed on exterior walls, air leakage can be as significant as air leakage at tubs and shower stalls. Fireplace enclosure framing should be lined on the interior with rigid sheathing material, much like a small room, with the top, bottom, and sides sealed. Gypsum board, plywood, wafer board, and foil-covered pressed paper can provide satisfactory performance when sealed. This will also greatly reduce callbacks for cold drafts coming from fireplaces.

Interior soffit assemblies above cabinetry on exterior walls or adjacent insulated ceilings and attics also require air sealing. Where the ends of soffit assemblies or framing boxing in mechanicals intersect exterior walls, the "footprint" of the soffit or framing against the exterior wall should be enclosed with sheathing.

Window and door openings can be sealed by the framer sealing the window or door unit to the rough framing with foam, caulk, or other sealant. Alternatively, the drywaller can return the gypsum-board interior finish to the window or door unit and seal the joint with caulk.

Interior utility chases or dead spaces between two closely spaced walls, dropped ceilings, and split levels require special attention. Sealing responsibilities are shared between framers and drywallers at dropped ceilings and split-levels. Blocking is installed and sealed by the framers; gypsum board is installed and sealed by the drywallers.

In addition to the seal between gypsum board and framing elements, penetrations for electrical boxes, light cans, and plumbing must be gasketed, caulked, or foamed. The gap between light cans and gypsum board, visible beneath the trim, should be caulked. If left unsealed, this gap can be responsible for 50% of the air leakage through a light can.

(top) Holes for wiring are sealed with foam.

(middle) Unsealed holes for pipes can leave large gaps for air and bugs to pass through.

(bottom) Thorough air sealing and locating ducts in conditioned space are two ways the Loudon County Habitat for Humanity affiliate improves the efficiency of its homes. (*Photo source: Linda Morrison of Loudon County Habitat for Humanity)*

The intersection of walls, ceilings, and attic trusses must be sealed in non-vented attics. This example uses gaskets and canned spray foam for the seal.

Attic access openings and flue pipe penetrations located within conditioned spaces should also be sealed. Whole-house fans require a cover that can be installed during the heating season in an airtight manner. Some whole-house fan units come equipped with airtight covers. Those units that do not can have removable covers site-manufactured in a similar manner to removable attic access covers.

Careful sealing is needed where walls abut non-conditioned spaces. These include kneewalls, as well as walls next to cavities over porches or decorative exterior soffits, such as "eyebrows."

The Six-Sided Puzzle

One way to envision advanced framing, insulation, and air sealing strategies working together is to consider that each cavity within the building shell forms a box with six sides. A wall cavity box may be made up of framing studs, interior gypsum board, exterior sheathing, a top plate, and a bottom plate. Each joint involves a crack where air may leak. In combination, advanced framing, insulation, and air sealing can go far to building an efficient and comfortable home if builders pay attention to all six sides of wall cavity boxes.

- Advanced framing reduces the total number of boxes, reduces the number of joints requiring sealing, and makes more room for insulation.
- Insulation should fill the entire void within each box to control heat flow and maximize envelope performance
- Each intersection in the box represents a joint that should be sealed to reduce air flow.

The Thermal Bypass Checklist

The ENERGY STAR for Homes program has compiled the Thermal Bypass Checklist, a comprehensive list of potentially vulnerable spots in the building envelope. The checklist identifies 25 points to inspect throughout the home, covering all major components of the building envelope including exterior walls, floors, ceilings, attics, and shafts. Builders can use the checklist to verify the integrity of the air barriers in the building envelope. The ENERGY STAR website contains the thermal bypass checklist and additional guidelines for installing insulation and air sealing.

See the *ENERGY STAR Qualified Homes Thermal Bypass Inspection Checklist* on the following page.

For More Information on Air Sealing

ENERGY STAR. 2008. "Thermal Bypass Checklist"
www.energystar.gov/index.cfm?c=bldrs_lenders_raters_thermal_bypass_checklist

ENERGY STAR. 2008. "ENERGY STAR Qualified Homes: Thermal Bypass Checklist Guide," ENERGY STAR.
www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/TBC_Guide_062507.pdf

International Code Council (ICC). 2009. *2009 International Energy Conservation Code*, Section 402.4 "Air Leakage," International Code Council (ICC), Falls Church, VA. Available at
www.iccsafe.org/dyn/prod/3800S09.html

Lstiburek, Joseph. 2006. *Building Science Digest 104: Understanding Air Barriers*. Building Science Press, Waterford, MA. Available at www.buildingscience.com/documents/digests/bsd-104-understanding-air-barriers

ENERGY STAR Qualified Homes
Thermal Bypass Inspection Checklist

Home Address:____ City:____________________ State:______

Thermal Bypass	Inspection Guidelines	Corrections Needed	Builder Verified	Rater Verified	N/A
1. Overall Air Barrier and Thermal Barrier Alignment	**Requirements:** Insulation shall be installed in full contact with sealed interior and exterior air barrier except for alternate to interior air barrier under item no. 2 *(Walls Adjoining Exterior Walls or Unconditioned Spaces)*				
	All Climate Zones:				
	1.1 Overall Alignment Throughout Home	☐	☐	☐	☐
	1.2 Garage Band Joist Air Barrier (at bays adjoining conditioned space)	☐	☐	☐	☐
	1.3 Attic Eave Baffles Where Vents/Leakage Exist	☐	☐	☐	☐
	Only at Climate Zones 4 and Higher:				
	1.4 Slab-edge Insulation (A maximum of 25% of the slab edge may be uninsulated in Climate Zones 4 and 5.)	☐	☐	☐	☐
	Best Practices Encouraged, Not Req'd.:				
	1.5 Air Barrier At All Band Joists (Climate Zones 4 and higher)	☐	☐	☐	☐
	1.6 Minimize Thermal Bridging (e.g., OVE framing, SIPs, ICFs)	☐	☐	☐	☐
2. Walls Adjoining Exterior Walls or Unconditioned Spaces	**Requirements:** • Fully insulated wall aligned with air barrier at both interior and exterior, **OR** • Alternate for **Climate Zones 1 thru 3**, sealed exterior air barrier aligned with RESNET Grade 1 insulation fully supported • Continuous top and bottom plates or sealed blocking				
	2.1 Wall Behind Shower/Tub	☐	☐	☐	☐
	2.2 Wall Behind Fireplace	☐	☐	☐	☐
	2.3 Insulated Attic Slopes/Walls	☐	☐	☐	☐
	2.4 Attic Knee Walls	☐	☐	☐	☐
	2.5 Skylight Shaft Walls	☐	☐	☐	☐
	2.6 Wall Adjoining Porch Roof	☐	☐	☐	☐
	2.7 Staircase Walls	☐	☐	☐	☐
	2.8 Double Walls	☐	☐	☐	☐
3. Floors between Conditioned and Exterior Spaces	**Requirements:** • Air barrier is installed at any exposed fibrous insulation edges • Insulation is installed to maintain permanent contact with sub-floor above including necessary supports (e.g., staves for blankets, netting for blown-in) • Blanket insulation is verified to have no gaps, voids or compression. • Blown-in insulation is verified to have proper density with firm packing				
	3.1 Insulated Floor Above Garage	☐	☐	☐	☐
	3.2 Cantilevered Floor	☐	☐	☐	☐
4. Shafts	**Requirements:** Openings to unconditioned space are fully sealed with solid blocking or flashing and any remaining gaps are sealed with caulk or foam (provide fire-rated collars and caulking where required)				
	4.1 Duct Shaft	☐	☐	☐	☐
	4.2 Piping Shaft/Penetrations	☐	☐	☐	☐
	4.3 Flue Shaft	☐	☐	☐	☐
5. Attic/ Ceiling Interface	**Requirements:** • All attic penetrations and dropped ceilings include a full interior air barrier aligned with insulation with any gaps fully sealed with caulk, foam or tape • Movable insulation fits snugly in opening and air barrier is fully gasketed				
	5.1 Attic Access Panel (fully gasketed and insulated)	☐	☐	☐	☐
	5.2 Attic Drop-down Stair (fully gasketed and insulated)	☐	☐	☐	☐
	5.3 Dropped Ceiling/Soffit (full air barrier aligned with insulation)	☐	☐	☐	☐
	5.4 Recessed Lighting Fixtures (ICAT labeled and sealed to drywall)	☐	☐	☐	☐
	5.5 Whole-house Fan (insulated cover gasketed to the opening)	☐	☐	☐	☐
6. Common Walls Between Dwelling Units	**Requirements:** Gap between drywall shaft wall (i.e., common wall) and the structural framing between units is fully sealed at all exterior boundary conditions				
	6.1 Common Wall Between Dwelling Units	☐	☐	☐	☐

Home Energy Rating Provider: ________________ Rater Inspection Date: __________ Builder Inspection Date: __________

Home Energy Rater Company Name: ____________________ Builder Company Name: ____________________________

Home Energy Rater Signature: ________________________ Builder Employee Signature:___________________________

Posted 06/02/08

U.S. Department of Energy
Research Toward Zero Energy Homes

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 8.
Building Envelope Sub-Assemblies

In its simplest form, building envelopes are cubes that incorporate three parts: the floor, four walls, and a roof. In actuality, these assemblies are parsed and combined to form combinations of rectangles, triangles, and even domes. Building homes that deliver comfort, durability, and energy performance requires paying attention to the details of each assembly. This chapter provides guidance on controlling liquid and water vapor, air flow, and heat flow in the foundation, wall, and roof assemblies.

CHAPTER TOPICS

Foundation Assemblies

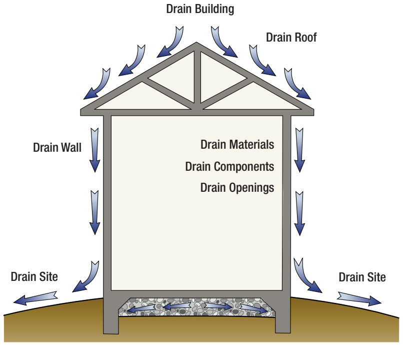
Foundations form the solid underpinning for house structural integrity; they also provide the boundary between the house and the ground. Monolithic slab-grade beam assemblies are the predominant foundation system in the hot-dry and mixed-dry climates. In these systems, the foundation also serves as the floor.

Foundation Moisture Control

Grading around a home is also part of rain management. Proper site grading directs surface water away from building foundations and walls. The steeper the slope away from the building, the better the water will drain. Slabs and crawlspaces should always be above the surrounding grade. Basement floors should be higher than the surrounding drainage system. Driveways, garage slabs, patios, stoops, and walkways should all drain away from the structure. See EEBA's *Water Management Guide* (Lstiburek 2006) for more information.

Landscaping is a critical element in the marketability of a house. However, plants must be placed to avoid interfering with visual inspections of termite access. Plants also can be used to shade foundations and reduce cooling loads. Plants should be kept at least 18 inches from the finished structure, with any supporting irrigation directed away from the finished structure. Plantings may be selected to shade the foundation edge, especially on the southwest corner of the structure. Choosing native plants results in the need for less irrigation and less chance for irrigation water to create a moisture problem in the house. Decorative ground cover—mulch or pea stone, for example—should be thinned to no more than 2 inches for the first 18 inches from the finished structure.

Drain all water away from the structure



(Figure adapted from Building Science Corporation)

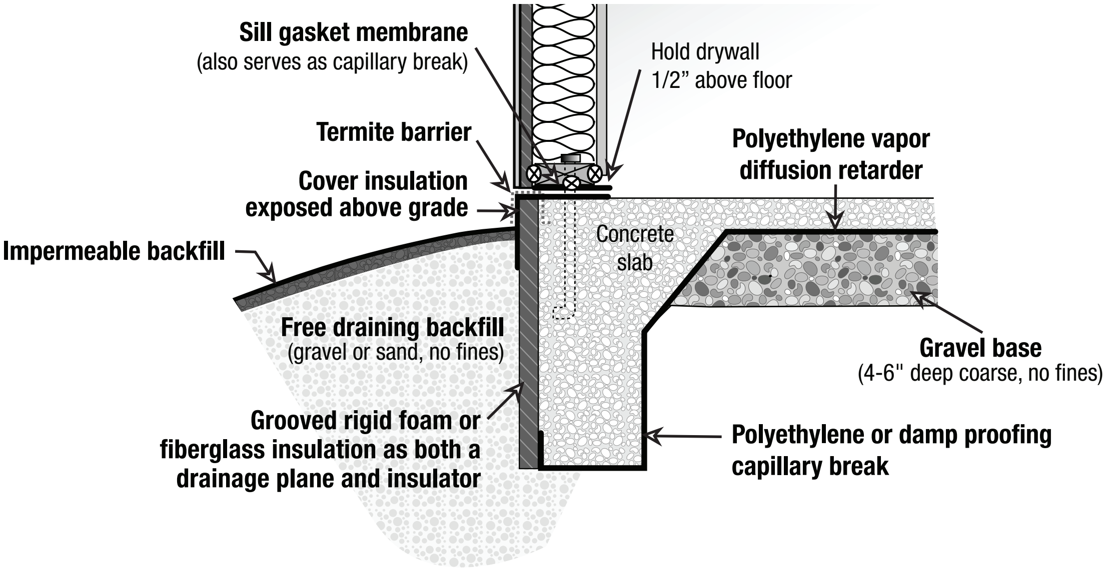
This foundation moisture management approach uses a dimpled-plastic drainage plane and damp proofing on the exterior side of the foundation wall. Landscape filter fabric keeps soil from clogging the gravel around the perforated drainage pipe. A gasket keeps moisture from migrating up through the footing into the treated sill plate.

Here, a damp proof coating and exterior rigid fiberglass insulation are applied to the foundation wall below grade

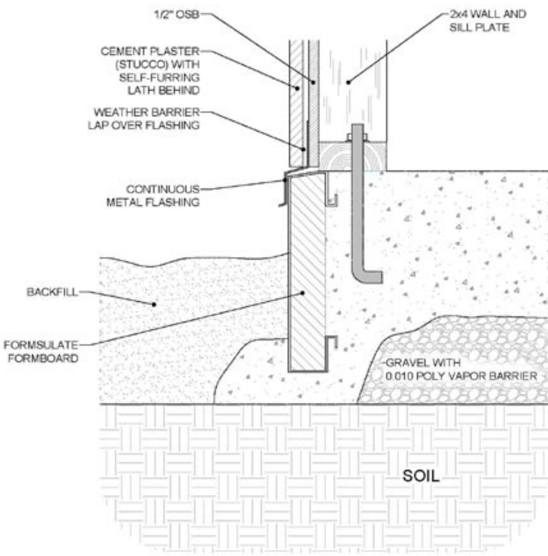
Moisture control practices are especially important wherever building components touch the ground. Liquid can wick from the ground and be carried into building assemblies. The following practices apply to all foundation systems:

- Keep all untreated wood materials away from contact with earth and concrete.
- Design the house structure with overhangs, gutters, drainage planes, and flashing to shed rainwater and conduct it away from the house.
- Slope the earth away from the house and ensure that no irrigation strikes near the foundation as described in the Drainage section.
- Use a sill gasket for air sealing and to block wicking through concrete foundation into wood sill.
- Install a protective shield such as metal flashing, a plastic L bracket, or a membrane to keep capillary water from wicking into the wall from the foundation. This material can also serve as a termite shield.
- Exterior foundation wall insulation provides a protective coating at above-grade applications. Examples of protective coverings for exterior, above-grade insulation include flashing, fiber-cement board, parging (stucco type material), treated plywood, or membrane material (EPDM flexible roofing). New insulating foam board products (PVC sheathed) are also entering the market. Insulating the edge of a slab provides an easy path for termites to enter wall framing. Insulation products with termite barriers or termite flashing are a must.
- Damp-proof all below-grade portions of the exterior foundation.
- Place a continuous drainage plane over the damp proofing or exterior insulation on foundation walls to channel water to the foundation drain and relieve hydrostatic pressure. Drainage plane materials include special mats, high-density fiberglass insulation products, and washed gravel. All drainage planes and foundation drains should be protected with a filter fabric to prevent dirt from clogging the drainage channels.

Examples of slab insulation and moisture management



Davis Energy Group of the CARB Building America team developed a new method for insulating slab perimeters that is ideal for extremely hot climates and mixed dry climates. The method, which is still being tested, uses termiticide-treated rigid foam insulation encased in PVC as the form for the concrete foundation.



- Maintain a surface grade of at least 5% for at least 10 feet around and away from the entire structure.
- Drain driveways, garage slabs, patios, stoops, and walkways away from the structure.
- Specify and show in details that 6-mil polyethylene sheeting is to be placed directly beneath the slab. The sheeting should continuously wrap the slab as well as footings up to grade.
- Specify that footings poured independent of slabs or foundation walls are to be treated with a bituminous damp-proof coating, masonry capillary-break paint, or a layer of 6-mil polyethylene plastic to isolate the footing from the remainder of the assembly.
- Do not place a sand layer between the vapor retarder and the concrete slab. Differential drying and cracking is better handled with a low water-to-concrete ratio and wetted burlap covering during initial curing.
- Place a 4-inch-deep, ¾-inch gravel bed directly beneath the polyethylene sheeting to act as a capillary break and drainage pad.
- Damp proof the exposed portion of the foundation with latex paint or other sealants.

Controlling Air Infiltration in Slab Foundations

The foundation details should indicate that a sill gasket be installed between the foundation and the bottom plate of the exterior framed wall to control air infiltration. This gasket also serves as a capillary break.

Controlling Heat Flow in Foundations

Slabs in the hot-dry climate are generally not insulated, even at the perimeter, because of the low overall heating load. However, slab insulation may be a strategy for extremely hot desert climates. Slabs in the mixed-dry climate should be insulated at the perimeter with a minimum of one inch of rigid fiberglass or extruded or expanded polystyrene foam board insulation treated with termiticide in combination with a termite barrier in areas prone to termite infestation.

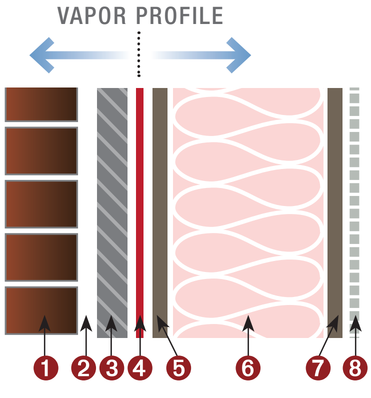
Other Foundation Issues

Pest Control

The following pest control notes should be included on construction documents and details:

- Use local code and Termite Infestation Probability (TIP) maps to determine environmentally appropriate termite treatments, bait systems, and treated building materials for assemblies that are near soil or have ground contact.
- Thin decorative ground cover to no more than 2 inches within 18 inches of the foundation.
- Keep plantings at least 18 inches from the foundation (taking into account root growth) with supporting irrigation directed away from the finished structure.
- Specify an environmentally appropriate soil treatment and a material treatment for wood materials near grade.

An ideal residential wall includes control layers providing rain, air, vapor and thermal barriers *(based on Lstiburek 2009)*.



1. Brick veneer/stone veneer
2. Drainage cavity
3. Exterior rigid insulation – extruded polystyrene, expanded polystyrene, fiberglass
4. Housewrap
5. Non-paper-faced exterior gypsum sheathing, plywood, or oriented strand board (OSB)
6. Insulated wood stud cavity
7. Gypsum board
8. Latex paint or vapor semi-permeable textured wall finish. No vapor barrier on inside (no polyethelene sheeting, no vinyl wall paper)

Taped rigid foam insulation can serve as a drainage plane and air barrier as well as a thermal boundary behind a stucco cladding. If using housewrap instead, never apply stucco directly to plastic housewrap. Provide a drainage space to prevent wetting of the housewap or use two layers of textured building paper.

Radon Control

Measures taken to control foundation moisture are also important first steps in controlling radon. Under-slab gravel provides a path for radon and other soil gas to escape to the atmosphere rather than being drawn into the house. The vapor retarder helps to block soil gas entry into the house.

For information about radon levels in your area, see the EPA website: www.epa.gov/iaq/whereyoulive.html. The EPA divides counties into one of three zones based on radon-level potential. The EPA recommends that all homes built in Zone 1 areas (high radon potential) have radon reduction systems. EPA's "Model Standards and Techniques for Control of Radon in New Residential Buildings" discusses techniques for controlling radon with various foundation types. One approach for radon control in high radon potential areas is to provide a sub-slab to roof vent system.

Additional Information on Foundation Moisture Control, Crawlspace Insulation, Basement Insulation, and Slab Insulation

Lstiburek, Joseph. 2004. *Builders Guides*. Guides to mixed humid, hot-dry, mixed-dry, and cold climates for purchase at www.eeba.org/bookstore.

Lstiburek, Joseph. 2006. *EEBA Water Management Guide*, available for purchase at www.eeba.org/bookstore/prod-Water_Management_Guide-9.aspx

Lstiburek, Joseph. 2008. *Concrete Floor Problems*, BSI-003, Building Science.com. www.buildingscience.com/documents/insights/bsi-003-concrete-floor-problems

U.S. Environmental Protection Agency. *Model Standards and Techniques for Control of Radon in New Residential Buildings*. Cited 6/18/09. www.epa.gov/radon/pubs/newconst.html#Principles.

Wall Assemblies

In most homes, the walls are the most prominent feature. Approach a house from the street, and it is the cladding color and texture, the doors, and the windows that first catch your eye. Walls form the boundary between indoors and out, keeping out the elements. Together with the floor and ceiling, they form the building envelope.

Controlling Liquid Water in Walls

Walls in all climates should be constructed with flashing and drainage planes to direct water away from the structure and to the exterior. Special flashing and tape are needed at critical areas such as seams, windows, and penetrations. It is essential that materials are lapped shingle fashion to direct water down and out, away from the wall assembly.

Overhangs

Overhangs should be included in the design to keep water away from walls and penetrations and to provide shade. Sizing of overhangs for purposes of shading is described in Chapter 5.

Drainage Planes

Elevation drawings should specify building paper, housewrap, or taped insulating sheathing (rigid foam insulation) behind the exterior cladding to serve as a drainage plane. This drainage plane can sometimes also serve as the exterior air barrier.

Housewrap, building paper, or impregnated felt should be part of the exterior wall system that protects the building from water penetration. The surface formed by these materials is called a drainage plane, house membrane, or rain barrier. None of these materials are waterproof, but they will shed rainwater that penetrates exterior cladding. They can prevent liquid water from wicking through, while remaining sufficiently vapor permeable ("breathable") for outward drying (Straube 2001). By helping to keep building materials dry, these membranes improve building durability, decrease maintenance costs, and reduce the risk of moisture-related problems such as pests, mold, and rot.

Most building paper is UV-resistant, whereas recommended housewrap exposure limits may vary by manufacturer. Check with manufacturers if outdoor exposure will exceed a month. One person can usually install building paper, while housewrap requires two people. However, housewrap is available in wide sheets that can cover an entire one-story wall surface in a single pass.

During construction and operation, it is important that housewraps remain clean. Surface contaminants interfere with the wrap's ability to hold out water. Once wetting of the housewrap or building paper surface occurs, material pores in the housewrap or building paper become filled, allowing transport of liquid-phase water across the housewrap or building paper via capillarity or hydrostatic pressure (gravity).

Some cladding can contaminate wraps if the two are in direct contact. For example, water-soluble extractives in wood such as tannins and wood sugars in redwood and cedar can contaminate the surface of housewraps and building papers. Back-priming or back-coating wood clapboards and trim helps to isolate the surfactants in the wood from the housewrap or building paper surface. Back priming is also recommended on all wood and cementatious cladding systems to avoid water uptake and possible warping.

Providing an airspace between wood or fiber cement cladding and housewraps using 1x4 furring strips ("cedar-breather"), an air gap, contoured housewrap, or some other spacer reduces the quantity and time liquid phase water is trapped in the exterior of the wall assembly.

Stucco should never be installed in direct contact with any of the plastic-based housewraps. A drainage space between stucco and plastic housewraps is essential to control liquid phase water penetration. Bonding typically does not happen between stucco and building papers. However, two layers of building paper behind stucco are needed for minimal drainage. (Lstiburek 2008).

If building paper is used as a drainage plane in areas prone to severe storms, use two layers to increase resistance to leakage at fasteners and allow for more flexible installation.

Details should be provided for flashing for all intersections of the wall with roofs and other building elements, and for flashing for all windows and doors and other penetrations through the wall.

(top) Windows should be flashed in accordance with ASTM E2112-07.

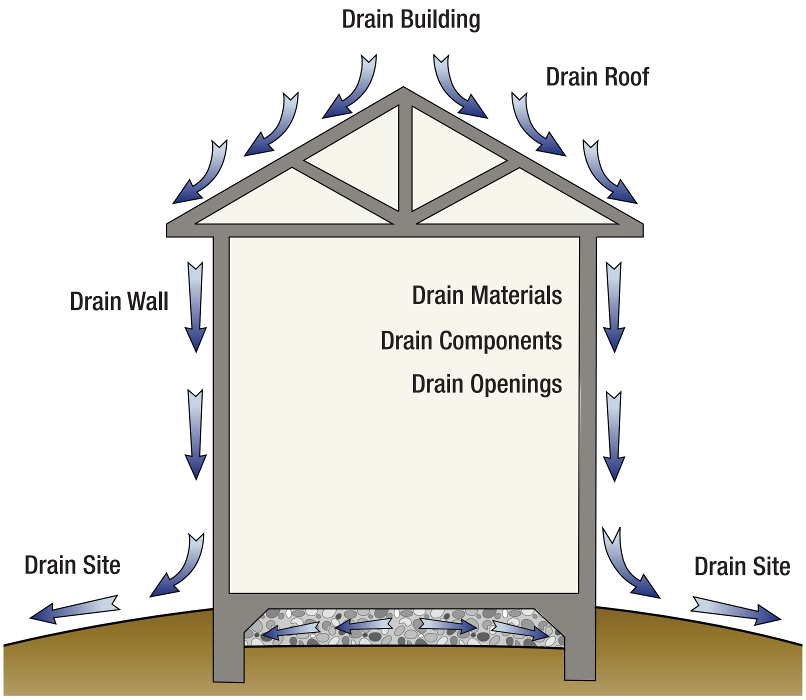
(bottom) Window flashing on outside is overlapped to provide a continuous drainage plane.

Windows

One critical point of concern is water leakage around windows. The *EEBA Water Management Guide* (Lstiburek 2006) offers examples of many window flashing applications. See Chapter 13 for detailed examples of window flashing for homes with housewrap and plywood or OSB sheathing. Window and door flashing details should be designed to match specific wall assemblies and claddings. Flashing systems should be designed in accordance with ASTM standard E2112-07, Standard Practice for Installation of Exterior Windows, Doors, and Skylights (ASTM 2007).

Flashing, gaskets, and caulk are used to air seal around penetrations in the building envelope under brick, stucco, and lap siding exteriors.

Drain all water away from the structure



(Figure adapted from Building Science Coropration)

Controlling Water Vapor in Walls

No Interior Vapor Barriers

Walls must be able to dry to at least one surface, the inside or the outside, or to both surfaces. To allow for drying to the interior, no vapor barrier (such as polyethylene plastic sheeting, foil or kraft-faced batt insulation, or reflective radiant-barrier foil insulation) should be installed on the interior side of walls in the mixed-dry and hot-dry climates. Do not specify impermeable coverings, such as vinyl wallpaper, on interior walls.

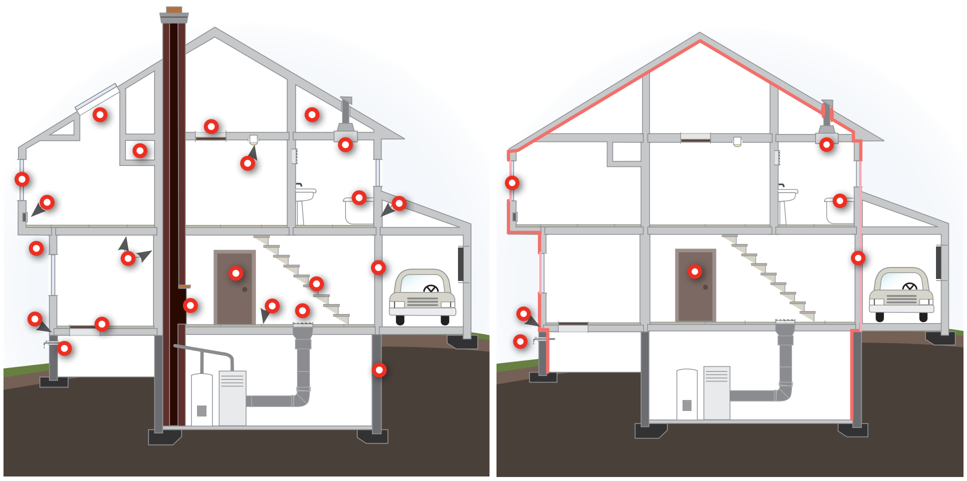
Drainage Spaces

As described above under "Drainage Planes," drainage gaps have been shown to keep some materials from contaminating housewraps. However, an airspace behind brick and masonry cladding is also important for controlling water vapor. Cladding must have a drainage space behind it of 1 inch for brick, 3/4 inch for stucco, and 1/16 inch for siding. Bricks and other masonry absorb water in the form of precipitation and irrigation. Solar energy will then drive this moisture in the form of vapor into the wall assembly. The gap allows the vapor to dissipate before entering wall cavities.

Sealing

Tightly seal wall assemblies to avoid vapor movement into walls through infiltration. Indicate on plans the methods, materials, and locations where sealing is needed to form the house air pressure barrier. Specify the approach to be taken to meet vapor barrier code requirements.

Air sealing is needed throughout the house to ensure an airtight shell. The house on the left uses conventional approaches. The house on the right uses external rigid foam sheathing, which provides a continuous air barrier so less air sealing steps are required. Foam sheathing can also serve as a drainage plane, vapor barrier, and thermal barrier. *(Detailed drawings are in Chapter 13.)*



Controlling Air Infiltration in Wall Assemblies

A comprehensive air sealing strategy starts with the house plans:

- Indicate on plans the location of the conditioned space by outlining the building envelope.
- Show the location of complex details like chases, stairwells, dropped ceilings, fireplace penetrations, balconies, and knee walls, so that they can easily be identified as being inside or outside the conditioned space.
- Show where insulation and draft stopping should be installed.
- Specify interior gypsum board as the interior air infiltration barrier. The gypsum board must be taped and sealed at all joints.
- Specify that all penetrations for wiring, pipes, etc. are to be sealed.

One method for air sealing the envelope is to use taped and caulked exterior rigid foam insulating sheathing. This exterior air-barrier system can also help control wind washing, keeping air from entering the wall from the exterior. While not always required to meet the 40% energy-efficiency reduction goal, exterior rigid insulation can simplify air sealing.

For occupant health and safety, pay close attention to sealing shared walls and ceilings between attached garages and living spaces. The garage should be completely sealed from the conditioned areas of the house. This is important from both an energy perspective, because it can be a major source of heat gain and heat loss, and from a health perspective, due to pollutants from car exhaust and stored materials. When the garage is attached to the house, the gaps created by joists spanning both conditioned space and the garage must be blocked off and sealed.

Creating air barriers to close gaps between the garage and the conditioned space can become increasingly difficult as the joists become more irregular at their cross section. This is particularly true for I-joists and web-trusses. A simple solution is to plan ahead and align the end of the joists with the wall adjoining the conditioned space to allow for end blocking.

Housewrap, Building Paper, or Felt – Your Choices for Wrapping it Up

Building Paper is a kraft paper sheet impregnated with asphalt to increase its strength and resistance to water penetration. It is primarily employed as a drainage layer. It is graded according to a test of the amount of time required for a water-sensitive chemical to change color when a boat-shaped sample is floated on water. Common grades include 10, 20, 30, and 60 minutes. The larger the number, the more resistant the paper is to water.

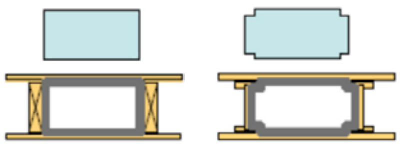
Building Felts have been in use for over a hundred years. Originally made from rags, today's felts are made of recycled paper products and sawdust. The base felt is impregnated with asphalt. Ratings for felt harken back to the traditional weight of the material before the oil crisis of the 1970s. At that time 100 square feet of the material (1 square) weighed about 15 pounds. Modern #15 felt can weigh from 7.5 to 12.5 pounds per square depending on the manufacturer.

Housewrap typically refers to specially designed plastic sheet materials. Housewrap comes in a variety of materials and can be perforated or non-perforated. If joints and connections are sealed, housewraps can serve as air retarders to reduce air leakage. Housewraps are highly resistant to tearing, unlike building paper. Non-perforated wraps tend to have higher liquid water resistance because the holes between plastic fibers are very small. *(Adapted from Straube 2001)*

Gaps between garage and conditioned space are properly sealed by carefully cutting and then caulking wood sections to fit between trusses. (*Photo source: EPA 2008 "Thermal Bypass Checklist"*)

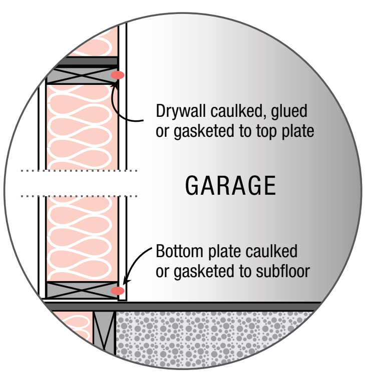
Filler blocking is a simpler shape with dimensional lumber

Filler blocking is a harder shape to cut with engineered lumber

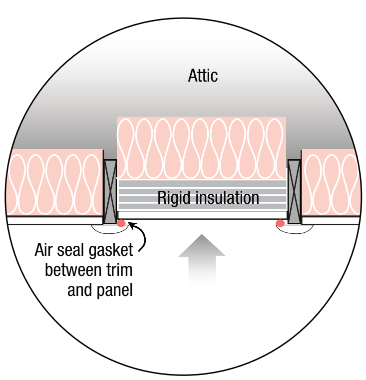


Wood or rigid foam filler blocking is needed to close off the gaps between floor joists to form an air break between conditioned and unconditioned spaces.

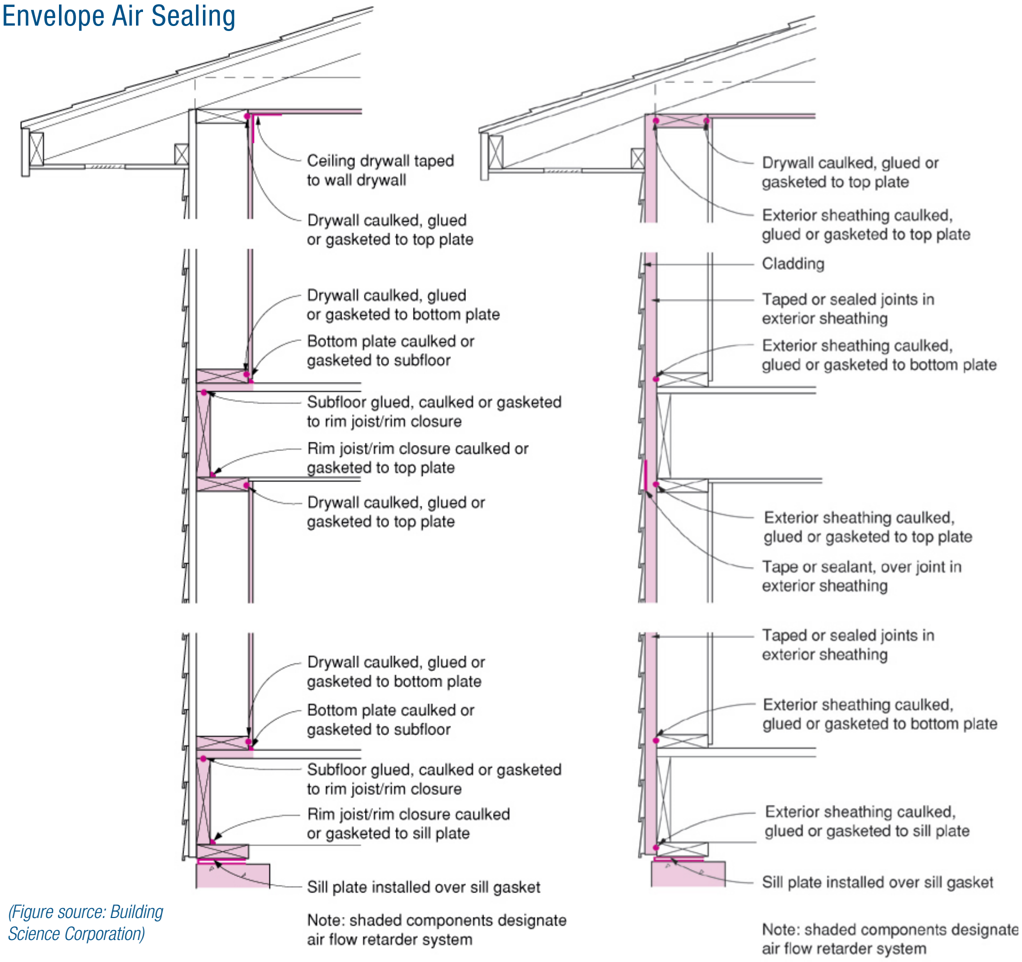
Garage common wall air sealing



Attic access panel air sealing



Envelope Air Sealing



(Figure source: Building Science Corporation)

Controlling Heat Flow in Wall Assemblies

The control of heat flow in the building is primarily managed by the type, thickness, and location of insulation. Window selection and design are also important.

- Use 2x6 advanced frame walls including 2x6 24-inch on-center studs to cut lumber costs and provide more space for insulation.
- Provide framing diagrams and details to spell out advanced framing techniques and the placement of all framing members.
- Specify that cavity walls separating conditioned and unconditioned spaces be insulated with high-density insulation batts spray-applied fibrous insulation, or low-density spray-applied foam.
- Use third-party inspectors or HERS raters to inspect insulation installation before dry walling.
- Specify that spray foam be used to insulate and seal rim joists at areas between floors or where the wall connects to the floor.
- Specify taped rigid foam insulating sheathing be used in addition to cavity insulation. This sheathing is also used to control moisture and air infiltration, to create an air barrier at the rim joist, and to eliminate the thermal bridging at the studs (not required to meet 40%).
- Specify energy-efficient windows that control solar energy gains and help reduce heating and cooling loads. Minimum U-values of 0.3 and SHGC values of 0.3 or lower are recommended.
- Specify ENERGY STAR labeled doors.
- Design roofs and overhangs to shade and protect windows, doors, and walls.

Roof Assemblies

Controlling Liquid Water in Roof Assemblies

Roof and wall assemblies must contain surfaces that will drain water in a continuous manner down and off the building. Water must have a path that will take it from its point of impact, around any elements such as chimneys, windows, doors, and seams, all the way to the exterior ground, sloping away from the house:

- Specify that valleys and roof edges are to be properly flashed.
- Size gutters and downspouts to accommodate anticipated storms. Show gutter sizes on elevations and specify sizes in construction documents.
- Provide roof drainage to carry water at least 3 feet beyond the building.
- In areas with potentially high winds and heavy rains, install 4-inch to 6-inch "peel and seal" self-adhering water-proofing strips over joints in roof decking before installing the roof underlayment and cover.

Install flashing at roof valleys and edges and install rain gutters to guide water off roof and away from house. Make sure the downspouts are connected and extend to at least 3 feet from the house. *(Photo source: EPA, photo by Terry Brennan)*

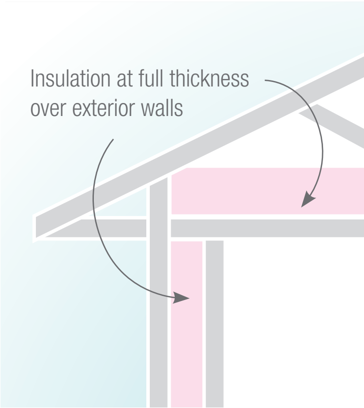
Controlling Water Vapor in Roof Assemblies

In the hot-dry and mixed-dry climates, roof/attic ventilation is preferable to installing an interior vapor barrier in the ceiling.

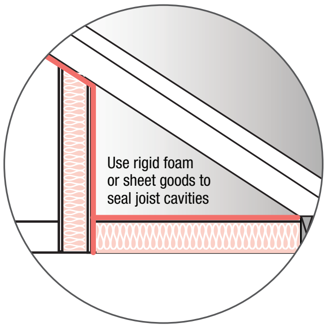
Controlling Air Flow in Roof/Attic Assemblies

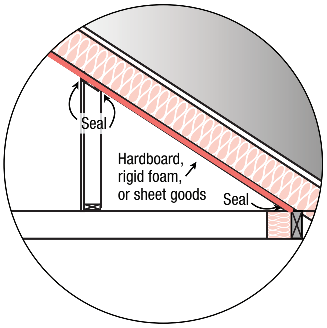
Air sealing of the roof uses techniques similar to those used for the walls, although roof air sealing may be made more challenging by irregularities in the roof shape.

- Provide details of the intersection between walls and the roof. This area may involve an attic, cathedral ceiling, or knee walls. Specify that this area is to be sealed. Tight sealing of this intersection may require spray foam.
- Specify that ceiling gypsum board is to function as an air barrier. Dropped ceiling areas are draftstopped, ceiling light fixtures are selected to be airtight, and all penetrations through plates are air sealed.
- Specify sealed and insulated attic access hatches or doors.
- Specify a cover for the whole house fan.
- Specify that all penetrations through the ceiling and the roof are to be sealed (see electrical best practices).



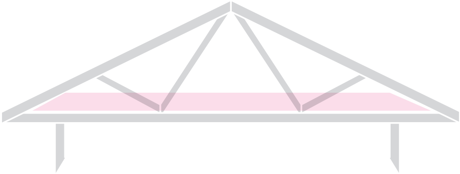
Raised heel or energy trusses allow even the corners of the attic to be well insulated; this helps to prevent ice dams in winter and keeps rooms cooler in summer.



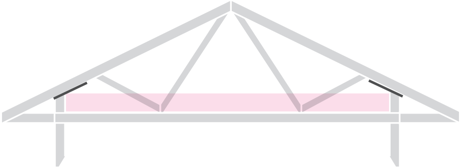


(left) Air seal the intersections of the kneewalls and roof with sheet goods and caulk or spray foam.

Baffles allow ventilation while keeping wind from blowing insulation back from the edges of an attic, when ceiling insulation is added.



Traditional roof trusses pinch insulation where the roof meets the walls



Raised heel trusses allow space for the full depth of insulation. Dark lines are baffles which allow ventilation of roof while keeping wind from blowing back insulation.

Controlling Heat Flow in Roof Assemblies

Maintaining the ceiling insulation level throughout the entire plane of the ceiling and over the top of the perimeter walls is key to controlling heat flow through the attic:

- Indicate on construction documents that blown-in insulation is to be installed on the top surface of ceiling gypsum board.
- Specify and show on elevations that raised heel energy trusses are required to maintain the thickness of the ceiling insulation directly above the top plates of the exterior wall framing.
- Specify and show on elevations that baffles are to be installed to prevent wind washing of thermal insulation and to prevent insulation from blocking ventilation in vented roof assemblies.

For More Information on Moisture, Air, and Heat Flow Control in Walls and Roofs

ASTM. 2007. *Standard Practice for Installation of Exterior Windows, Doors, and Skylights*. www.astm.org/Standards/E2112.htm

Buildernews Magazine, May 2004, "Housewrap Felt or Paper: Comparing specs on weather barriers," www.buildernewsmag.com/index.php?option=com_content&view=article&id=1168%3AHousewrap+Felt+or+Paper%3A&Itemid=107

Building Science Corporation. *Homeowner Information Resources*. www.buildingscienceconsulting.com/resources/homeowner.htm

DOE. "Weather-Resistive Barriers." Technology Fact Sheet, www.toolbase.org/PDF/DesignGuides/weatherresistantbarriers.pdf

DOE. "Vapor Barriers and Vapor Diffusion Retarders." Energy Savers Fact Sheet, www.energysavers.gov/your_home/insulation_airsealing/index.efm/mytopic=11810

ENERGY STAR. 2008. *Thermal Bypass Checklist Guide* www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/TBC_Guide_062507.pdf, pg. 13

HGTVpro.com. "Improved Stucco Systems." www.hgtvpro.com/hpro/bp_exterior_finishes/article/0,,hpro_20149_4243887,00.html

IBACOS. 2002. "Moisture Issues in Homes with Brick Veneer" www.eere.energy.gov/buildings/building_america/pdfs/db/36397.pdf

ICC. 2006. ***International Energy Conservation Code***, Section 402.4 "Air Leakage," International Code Council (ICC), Falls Church, VA. "All ducts, air handlers, filter boxes, and building cavities used as ducts shall be sealed." Available for purchase at www.iccsafe.org/dyn/prod/3810S06.html.

Lstiburek, Joseph. 2004. *Builders Guides*. Guides to mixed humid, hot-dry, mixed-dry, and cold climates for purchase at www.eeba.org/bookstore.

Lstiburek, Joseph. 2006. *EEBA Water Management Guide*, available for purchase at www.eeba.org/bookstore/prod-Water_Management_Guide-9.aspx

Lstiburek, Joseph. 2006. Understanding Drainage Planes, Building Science Digest 105, 2006-10-24, Building Science Corporation, www.buildingscience.com/documents/digests/bsd-105-understanding-drainage-planes/

Lstiburek, Joseph. 2008. Problems with Housewraps, Research Report 0106, Building Science Corporation, Building Science Press copyright 2008, www.buildingscience.com/documents/digests/bsd-013-rain-control-in-buildings

Lstiburek, Joseph. 2009. "Insight: The Perfect Wall," Building Science Insight 001: last updated 2009/05/21, Building Science Corporation, www.buildingscience.com/documents/insights/bsi-001-the-perfect-wall

Lstiburek, Joseph. 2001. Brick, Stucco, Housewrap and Building Papers, RR-0105, Building Science.com, article available at www.buildingscience.com/documents/reports/rr-0105-brick-stucco-housewrap-and-building-paper/

NAHBRC. *Moisture Protection of Wood Sheathing*, National Association of Home Builders Research Center www.toolbase.org.PDF/DesignGuides/MoistureProtectionWoodSheathing.pdf

Straube, John. 2001. "Wrapping it Up," *Canadian Architect*. May, 2001. www.cdnarchitect.com/issues/ISarticle.asp?aid=1000115982

University of Illinois Extension Office. "Five Steps to a Healthier Garage." http://web.extension.uiuc.edu/will/factsheets/family116.html

Windows and Doors

Windows are a prominent feature of any wall. Choosing highly efficient windows will add expense to your project but will provide tremendous value in comfort, durability, and energy savings. High-performance windows add so much to energy efficiency that smaller cooling and heating equipment can often be specified, which may recapture much of the upfront cost of the windows. A voluntary rating system developed by the National Fenestration Rating Council (NFRC) provides performance information for about half the windows sold. The NFRC label contains ratings for the following features. You can find more information about the NFRC on the Web at www.nfrc.org.

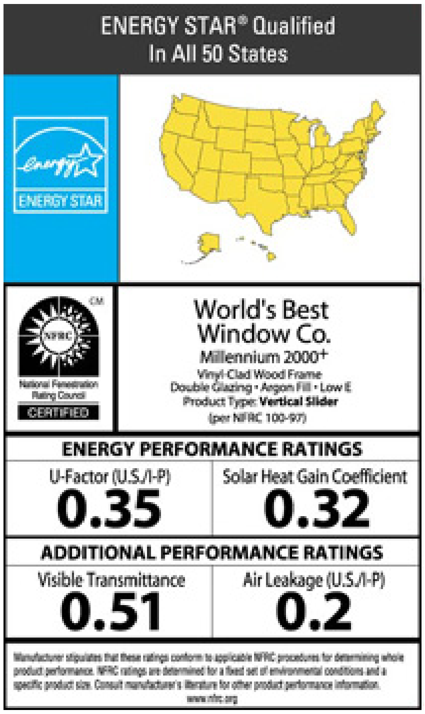
- U-factors take into account the entire window assembly. The U-factor is a measure of heat transfer – the lower the U-factor, the better the window performs at stopping heat flow. U-factors are the inverse of R-values which measure a material's insulation effectiveness. U-factor values for windows generally fall between 0.20 and 1.2.

- SHGC is the solar heat gain coefficient, which measures how well the window blocks heat caused by sunlight – the lower the SHGC rating, the less solar heat the window transmits. This rating is expressed as a fraction between 0 and 1.

- Visible transmittance (VT) measures how much light comes through a window. VT is expressed as a number between 0 and 1 – the bigger the number, the more clear the glass.

- Air leakage through a window assembly is included on most manufacturers' labels, but is not required. The AL rating is expressed as the equivalent cubic feet of air passing through a square foot of window area (cfm/sq.ft.) – the lower the AL, the less the window leaks. A typical rating is 0.2.

- Another optional rating is Condensation Resistance (CR), which measures the ability of a product to resist the formation of condensation on the interior surface of that product – the higher the CR rating, the better that product is at resisting condensation formation. While this rating cannot predict condensation, it can provide a credible method of comparing the potential for condensation formation in various products. CR is expressed as a number between 1 and 100, with a higher value representing more resistance to the formation of condensation.



Example of a window label from the National Fenestration Rating Council and ENERGY STAR.

ENERGY STAR qualifies windows based on climate zones and divides the U.S. into four climate zones. For ENERGY STAR's south/central climate region, which is not identical to the climate zones of the Building America and DOE's Building Codes Program, all windows and doors qualifying for the ENERGY STAR label must have a U-factor rating of 0.40 or below and an SHGC rating of 0.40 or below; skylights must have a U-factor of 0.60

Deep overhangs and porches provide midday shade for most of the windows on this home built by Artistic Homes of Albuquerque, NM.

or below and an SHGC rating of 0.40 or less. You need not use ENERGY STAR-labeled windows to qualify a total house for an ENERGY STAR label.

The Efficient Windows Collaborative operates a website that can help designers and consumers choose windows. The website includes a tool that allows users to analyze energy costs and savings for windows with different ratings. Visit the website at www.efficientwindows.org/index.cfm.

The website also has fact sheets with comparisons for each state. These fact sheets can be used as marketing tools. Also described on the website is a book entitled *Residential Windows: A Guide to New Technologies and Energy Performance* (Carmody et al. 2000), which offers a look at the state of the art in window technology including energy performance, the basic mechanisms of heat transfer, new products and rating systems, the effects of window frame material and installation, and guidance when purchasing windows.

ENERGY STAR Qualified Windows, Doors and Skylights Eligibility Criteria
(Version 4.0 5/14/2007)

Windows & Doors

Climate Zone	U-Factor[1]	SHGC[2]	
Northern	≤ 0.35	Any	
North/Central	≤ 0.40	≤ 0.55	
South/Central	≤ 0.40	≤ 0.40	Prescriptive
	≤ 0.41	≤ 0.36	Equivalent Performance *(Excluding CA)*
	≤ 0.42	≤ 0.31	
	≤ 0.43	≤ 0.24	
Southern	≤ 0.65	≤ 0.40	Prescriptive
	≤ 0.66	≤ 0.39	Equivalent Performance
	≤ 0.67		
	≤ 0.68	≤ 0.38	
	≤ 0.69	≤ 0.37	
	≤ 0.70		
	≤ 0.71	≤ 0.36	
	≤ 0.72	≤ 0.35	
	≤ 0.73		
	≤ 0.74	≤ 0.34	
	≤ 0.75	≤ 0.33	

Skylights

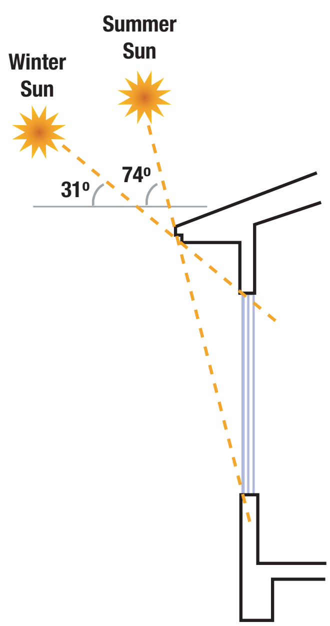
Climate Zone	U-Factor[1]: *2001 and 2004 NFRC rated at 20°[3]*	U-Factor[1]: *RES97 rated at 90°[4]*	SHGC[2]
Northern	≤ 0.60	≤ 0.45	Any
North/Central	≤ 0.60	≤ 0.45	≤ 0.40
South/Central	≤ 0.60	≤ 0.45	≤ 0.40
Southern	≤ 0.75	≤ 0.75	≤ 0.40

[1] *Btu/h.ft^2.°F*

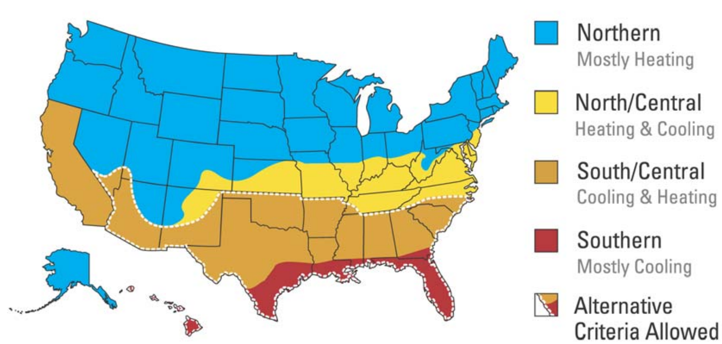
[2] *Fraction of incident solar radiation.*

[3] *U-Factor qualification criteria based on 2001 or 2004 NFRC simulation and certification procedures that rate skylights at a 20-degree angle. Although reported U-Factor is higher than RES97 rated products, energy performance at the ENERGY STAR minimum qualifying level is equivalent.*

[4] *NFRC certification using the 1997 NFRC procedures for residential windows (RES 97) that rated skylights at a 90-degree angle. Skylights rated under this procedure may be present in the marketplace until March 31, 2008. NFRC labels for products using this procedure state: "RES97 rated at 90 degrees."*



Sun angles for Albuquerque, NM. A 4-foot window would need an overhang extending 19 inches with 12 inches of wall above the window.



ENERGY STAR-labeled doors are insulated for higher R-value.

For More Information on Windows and Doors

American Architectural Manufacturers Association. "Product Certification – Search now for AAMA-Certified Products (windows and doors)." Available at www.aamanet.org/general.asp?sect=2&id=127

ASTM. ASTM E2112 - 07. *Standard Practice for Installation of Exterior Windows, Doors and Skylights*, www.astm.org/Standards/E2112.htm

Carmody, John, Stephen Selkowitz, Dariush Arasteh, and Lisa Heschong. 2000. *Residential Windows: A Guide to New Technologies and Energy Performance*. W.W. Norton & Company, Inc., New York.

ENERGY STAR Efficient Windows Collaborative
www.efficientwindows.org/energystar.cfm

ENERGY STAR window, door, and sky light product criteria
www.energystar.gov/index.cfm?c=windows_doors.pr_crit_windows

ENERGY STAR. Residential Windows, Doors, and Skylights.
www.energystar.gov/index.cfm?c=windows_doors.pr_windows

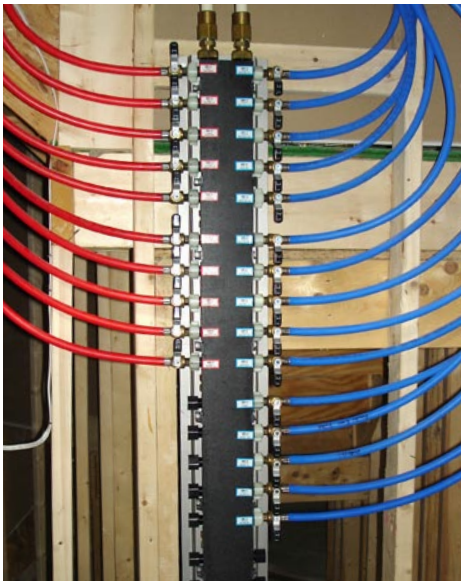
FMA/AAMA 100-07. "Standard Practice for the Installation of Windows with Flanges or Mounting Fins in Wood Frame Construction." Available from AAMA's online store at www.aamanetstore.org/pubstore/ProductResults.asp?cat=0&src=100

Insulating Glass Manufacturers Alliance.
www.igmaonline.org/content.php?doc=142

National Fenestration Rating Council.
www.nfrc.org

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 9. Mechanical, Plumbing and Electrical Systems



A centrally located manifold water distribution system saves energy by reducing hot water usage.

Homes include components and systems that must perform in combination with the building envelope. As envelope performance improves, these mechanical, plumbing, and electrical building systems are becoming ever more important as targets for improved efficiency and comfort. The pie chart shows how different building components relate to energy performance.

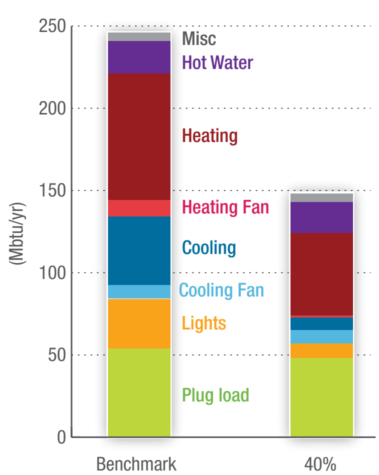
The systems described in this chapter include HVAC (heating, ventilation, and air conditioning), plumbing and water heating, lighting, and appliances.

Heating, Ventilation and Air Conditioning (HVAC)

Using Building America best practices for insulation, windows, and air sealing can improve building envelope performance to such an extent that HVAC system size can sometimes be cut in half and still meet occupant comfort needs. Builders may be surprised to find that properly sizing and designing the HVAC system increases comfort for the homeowners while providing a remarkable opportunity for dollar savings in high-performance homes.

For the best results in comfort, efficiency, and durability, HVAC and duct design must be integrated in the overall architectural design. Builders who work closely with their HVAC engineer or contractor to properly design, size, and select the HVAC equipment will save money and maximize efficiency. This single step will go a long way toward improved energy efficiency, comfort, and cost savings.

A Comparison of Energy Usage by End Use for a Home Built to Perform with 40% Energy Savings Compared to the Building America Benchmark (a home built to MEC 1993) in the Hot-Dry Climate.



Example based on a 2-story, 2,500 sq.ft. house in Sacramento, CA. Analysis by the National Renewable Energy Laboratory

CHAPTER TOPICS

2005 Typical Residential On-Site Energy Consumption End Uses in the Western United States

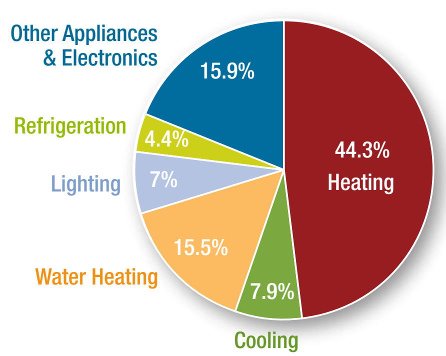
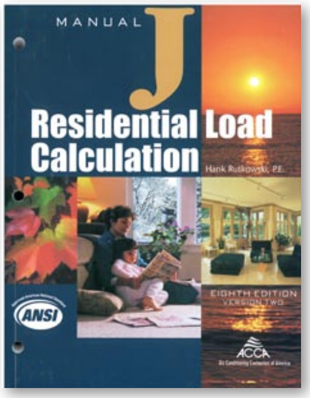


Figure source: DOE. 2008. *2008 Buildings Energy Data Book*, based on delivered energy end-uses for an average household in the west.

Heating and Cooling Equipment

A well-designed house should have an HVAC system properly sized to its demands. Equipment sizing ensures a comfortable environment and provides opportunities to partially recapture some of the expense of an efficient building envelope through equipment downsizing. Rules of thumb for equipment sizing should not be used, especially for energy-efficient housing.

The Air Conditioning Contractors of America (ACCA) has published simple but effective methods for determining loads and sizing ductwork and heating and cooling equipment.



Right sizing of HVAC equipment using *Manual J* calculations can minimize energy use and save upfront costs

- **Manual J** tells you how to calculate heating and cooling loads.
- **Manual D** tells you how to size ducts.
- **Manual S** guides you through the selection of appropriate heating and cooling equipment to meet identified loads.
- **Manual T** gives you the basics of air distribution for small buildings.
- **Manual RS** focuses on comfort, air quality, and efficiency.

For more information or to purchase these documents on the Web, go to www.acca.org.

Cooling system efficiency is especially important in hot, cooling-load-dominated climates. All central air conditioners must meet the 2006 federal (NAECA) standard of 13 SEER. Air-conditioner energy use can be reduced further by properly sizing the system, using efficient duct layouts, sealing ducts, and incorporating high-performance, low-emissivity windows and architectural window shading in the design.

In drier climates where summer evening temperatures drop by 30°F or more from daytime highs, systems that use mechanical ventilation to bring in cool nighttime air have been shown to reduce cooling energy use by up to 35%.

Mild heating loads in hot-dry/mixed-dry climates mean that high-efficiency (condensing) furnaces are not required to achieve the 40% efficiency improvement target. However, declining costs make 90+ AFUE furnaces an increasingly good value. Induced draft, direct-vent furnaces are desirable because they can be located in conditioned space, minimizing heat loss. Direct vent furnaces draw combustion air directly from outdoors rather than from the surrounding (unconditioned) space.

Heat pumps are preferable to electric resistance heating in these climates. A heat pump with a heating season performance factor (HSPF) of 7.7, the current federal standard, will reduce the electric consumption during heating by more than 50% relative to electric resistance heating.

ENERGY STAR-qualified heat pumps, air conditioners, and furnaces should be considered. Qualified heat pumps are about 8% more efficient than standard equipment, ENERGY STAR central air conditioners are 14% more efficient, and ENERGY STAR condensing furnaces are up to 15% more efficient. The Consortium for Energy Efficiency (CEE) and

Efficiency Measures for Air Conditioners, Heat Pumps, and Furnaces

Seasonal Energy Efficiency Ratio (SEER) is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air-conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period.

Heating Season Performance Factor (HSPF) is a measure of a heat pump's energy efficiency over one heating season. It represents the total heating output of a heat pump (including supplementary electric heat) during the normal heating season (in Btu) as compared to the total electricity consumed (in Watt-hours) during the same period.

Annual Fuel Utilization Efficiency (AFUE) measures the amount of fuel converted to heat at the furnace outlet in proportion to the amount of fuel entering the furnace. This is commonly expressed as a percentage. A furnace with an AFUE of 90 could be said to be 90% efficient.

Energy Efficiency Rating (EER) a rating of a central air conditioner's steady-state efficiency at 80°F indoors and 95°F outdoors, measured once the air conditioner is up and running.

Use MERV 8 air filters in the air handler for cleaner indoor air.

the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) have developed an online database that can be used to find qualifying ENERGY STAR heat pumps and air conditioners. The database is accessible at www.ceehvacdirectory.org.

For good indoor air quality, the HVAC return air stream should be filtered with a 4-inch standard filter or a new Minimum Efficiency Reporting Values (MERV) 8 normal-thickness filter. Outdoor ventilation air should also pass through this filter, if possible. Filters should be easily accessible for cleaning or replacement, and the filter slot should be designed so that there is no air bypass around the filter when the HVAC system is operating.

Evaporative coolers, commonly called "swamp coolers," are popular in the southwest. They have a low first cost, use about one-third of the electricity of conventional air conditioners, and do not use refrigerants, such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), that can harm the ozone layer. There are two types of evaporative coolers: direct and indirect (also called two-stage). In a direct evaporative cooler, a blower forces air through a permeable, water-soaked pad. As the air passes through the pad, it is filtered, cooled, and humidified. An indirect evaporative cooler uses a two-stage process of direct and indirect evaporative cooling and provides cooling with less humidity added to the inside air (approximately 50% to 70% relative humidity versus 80% with direct evaporative cooling). Both systems force large amounts of air through the home. Windows or vents must be open when an evaporative cooling system is operating. The systems use 3.5 to 10.5 gallons of water per hour of run time. Direct evaporative cooling systems cost about $700 to $1,000 installed; indirect evaporative cooling systems can cost $2,500 or more uninstalled or $4,000 to $6,000 installed.


ACCA
AIR CONDITIONING CONTRACTORS OF AMERICA

ACCA Standard 5

HVAC Quality Installation Specification

Residential and Commercial Heating, Ventilating, and Air Conditioning (HVAC) Applications

ANSI

Space-conditioning systems should meet the ACCA Quality Installation Specification

For more Information About Heating and Cooling Equipment

Air Conditioning Contractors of America. 2007. *ACCA Standard 5 HVAC Quality Installation Specification*, ANSI/ACCA 5 QI-2007, Air Conditioning Contractors of America, 2800 Shirlington Road, Suite 300, Arlington, VA. www.acca.org

Air Conditioning Contractors of America. *Manual J: Residential Load Calculation*, Eighth Edition. ACCA, Arlington, VA. www.acca.org

Air Conditioning Contractors of America. *Manual S: Residential Equipment Selection*. ACCA, Arlington, VA. www.acca.org.

ASHRAE Standard 52.2-2007, "Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size," available for purchase from ASHRAE's bookstore www.ashrae.org

Camfil Farr Company. "MERV-Filter Efficiency Simplified," www.filterair.info/articles/article.cfm/ArticleID/7AF95A61-EAF8-4C90-BFA98EE04B0DD02B

Consortium for Advanced Residential Buildings. Steven Winter Associates, Inc (CARB-SWA). *Designing Forced-Air HVAC Systems*. www.carb-swa.com/Resources

Consortium for Energy Efficiency (CEE) and the Air-Conditioning, Heating, and Refrigeration Institute (AHRI). website with database of qualifying ENERGY STAR heat pumps and air conditioners at www.ceehvacdirectory.org

Consortium for Energy Efficiency. *Residential HVAC: CEE-AHRI HVAC Directory*. www.cee1.org/resid/rs-ac/rs-ac-main.php3

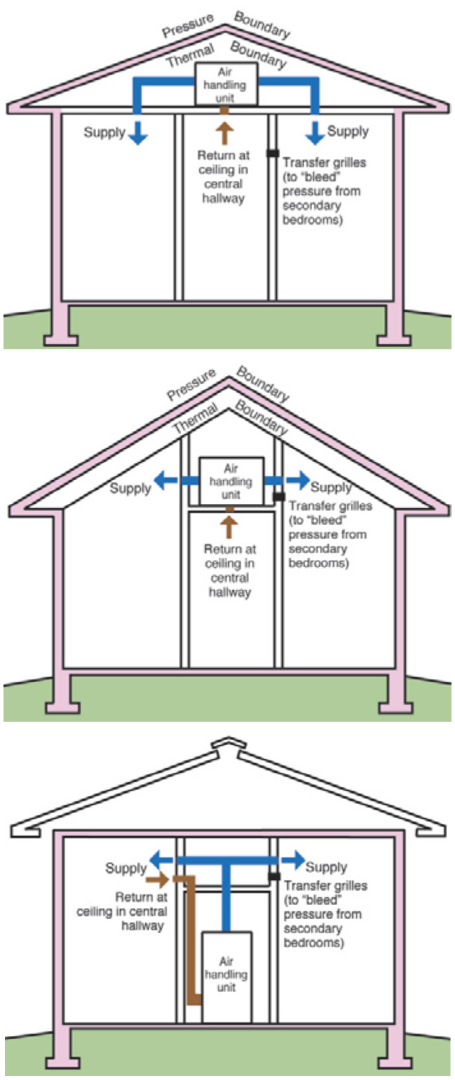
Furnace Filter Care. "Understanding MERV Ratings," www.furnacefiltercare.com/merv-ratings.php

NAHB Research Center. 2009. "Evaporative Coolers," Toolbase Services www.toolbase.org/Technology-Inventory/HVAC/evaporative-coolers.

The Building Industry Institute. *Procedures for HVAC System Installation*. www.thebii.org/hvac.pdf

U.S. Department of Energy (DOE) Building Energy Codes Resource Center. "How to Size HVAC Systems Correctly," http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article/137

Duct Run Configurations

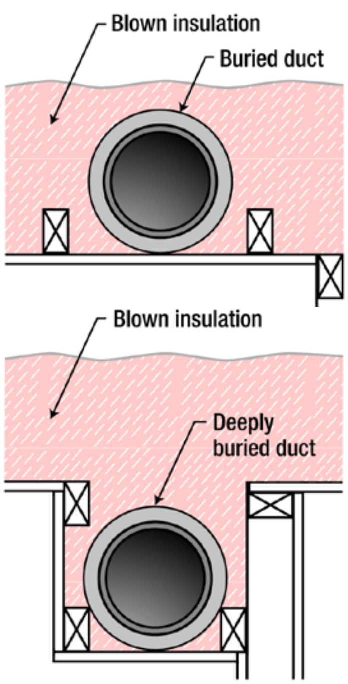


(Figure source: Building Science Corporation)

(top) One technique for placing ducts in conditioned space is to run a duct chase in a dropped ceiling down the main hallway of the house with registers off the sides for each room. This technique allows for compact duct design.

(above left) This finished house shows registers going directly from a main duct chase in the dropped hallway ceiling.

(above right) This air handler closet is carved out of the garage space but is isolated with thermal and air barriers.



Ducts Buried In Insulation
Based on Building America research, California's Title 24 includes provisions for buried and deeply buried ducts in attics.

U.S. Department of Energy (DOE). "Right-Size Heating and Cooling Equipment," U.S. Department of Energy Technology Fact Sheet, www.toolbase.org/Design-Construction-Guides/HVAC/right-size-hvac-equipment

U.S. Department of Energy (DOE). 2008. *2008 Buildings Energy Databook*. http://buildingsdatabook.eren.doe.gov/

Ducts and Air Handlers

Duct System Design and Layout

Duct systems should be designed using ACCA *Manual D*. Ducts and air handlers perform best when placed within the conditioned space.

The best practice is to locate the ducts in conditioned space so that any leakage that does occur will send air to or draw air from conditioned space. For example, ducts may be run through open webbed floor trusses in a two-story home or through a dropped hallway ceiling in a one-story home. Keeping ducts and air handlers inside conditioned space typically impacts architectural design and should be considered early in the design process. Duct chases or dropped soffits may require thinking through the sequence of how trade contractors will do the installation. For example, framers may need to install the ceiling and side wall gypsum board around the chase, then frame the chase sides and base. The gypsum board may be needed to provide a seal from the attic above and the wall cavities on the sides. Once the chase is built, and especially after the ducts are installed, these ceiling and wall surfaces may become inaccessible. After the initial gypsum board is installed and the chase is framed in, the HVAC contractor can then install the actual sealed duct work. Sheet-rockers can finish off the exposed surfaces.

Research conducted by the Building America CARB team has demonstrated that in attics in dry climates, ducts may be buried in deep insulation. Burying ducts is accepted as part of California's Title 24 building code. In more humid climates this strategy may not work since condensation could occur at the duct exterior surface.

Strategies for duct installation include the following:

- Place ducts within framing systems, such as an open-web floor-truss system.
- Design dropped soffits, tray ceilings, and lowered ceilings to locate duct chases in conditioned space in "service" rooms like baths, hallways, and closets.
- Locate ducts and air handlers within an insulated "cathedralized" attic (i.e., an attic where insulation is applied along the roof line instead of on the ceiling deck). Make sure the attic is carefully air sealed to the outside.
- Develop chase walls to accommodate duct risers.
- Keep duct runs as short as possible.
- Design closets inside the conditioned space for locating the air handler.
- Use a main duct line running through a dropped-ceiling chase in the hallway with vents to rooms off the hall. This keeps ducts in conditioned space and minimizes duct length for more even and efficient air distribution.
- Show duct sizes and layouts on floor plans and elevations.
- Design sealed mechanical closets in garages for locating air handlers.

One of the most potentially hazardous indoor air quality problems arises when return ducts are run through garage spaces where Carbon Monoxide (CO) and pollutants could be drawn from automobile exhausts or hazardous chemicals into the duct system and redistributed throughout the house. Locating the HVAC unit in the garage is not recommended in the 40% improved houses, but it is not always possible to relocate the air-handling unit. For air handlers that must be located in the garage, the recommended solution is to enclose the air handler in an insulated, air-sealed closet. Any return-air ductwork and the air handler should be thoroughly sealed with UL 181-approved mastic, with a target leakage between the duct system and the garage of 0 CFM @25Pa. This will help eliminate the possibility of bringing garage air into the supply or return system.

Mastic provides the most reliable duct sealing method. Ducts should be located in conditioned space. *(Photo source: BAIHP)*

Duct Sealing and Insulating

Leaky duct systems cause energy losses but they can also result in indoor-outdoor pressure imbalances that create significant air leakage through the building envelope. For the 40% improvement house, extensive duct sealing is typically required. When ducts are located in conditioned space, duct leakage should be less than 10% of the conditioned floor area when measured at 25 Pascals using duct pressurization methods. If ducts are outside conditioned space, leakage should be less than 3%. A typical 40% Building America house has a system sized to deliver approximately 0.5 cfm/ft^2. California Title 24 requires a maximum leakage of 6% of system air flow. Five percent leakage per ft^2 is 10% of system airflow. Thus, the recommended air leakage maximum is 3% of floor area.

Seal all ductwork seams and connections to air handlers with UL181-approved water-based mastic and seal drywall connections with caulk or foam sealant. Sealing ductwork is very important. Leaky ductwork in an unconditioned attic or crawlspace not only leaks energy but it can also draw unhealthy air into the air distribution system. Sealing ducts with mastic is desirable even for ducts located in conditioned spaces. Properly sealed ducts make sure air gets to the rooms intended, rather than leaking into a plenum space. It also minimizes the chances of creating pressure differentials from space to space that would induce unwanted airflow through the envelope. The process of sealing each joint reduces the chances of unconnected ductwork, a surprisingly common mistake.

Mastic provides the most reliable duct sealing method for new construction. All ductwork, including the air handler compartment (which typically has many leaky joints), should be mastic sealed.

DOE research has found that some tapes perform adequately for sealing ducts, particularly fiberglass duct board (see sidebar). However, good performing tapes may be difficult to identify and traditional duct tape (cloth-backed rubber adhesive tapes) should never be used to seal ducts, even if it meets UL ratings. Tapes have low tensile strength and should not be used to mechanically support ducts.

If the ducts are placed in unconditioned spaces, 10% to 30% of the energy used to cool the air can be lost to conduction through the duct surfaces due to the extreme summer temperatures in these spaces. Supply ducts should be insulated to R-8 minimum and return ducts to R-6 minimum. In dry climates the ducts can be covered with loose-fill insulation.

Standards for Duct Sealants

Underwriter Laboratories, Inc. (UL) publishes several standards that relate to duct sealants, the most important of which is UL 181. It deals with ducts in general, with UL 181A covering field-assembled duct-board and UL 181B covering flex duct systems. Each standard includes test procedures for sealants. Duct tapes and packing tapes that pass UL 181B are labeled “UL 181B-FX.” Mastics can pass 181A or B and are labeled “UL 181A-M” or “UL 181B-M.” Foil tapes are designated with a P. Most tapes that are labeled 181B-FX are duct tapes. UL 181A and 181B appear to do a good job of testing for safety, tensile strength, and initial adhesion. However, they may not do a good job of rating how well sealants seal typical duct leaks or how well they stay sealed under normal conditions.

California Title 24 residential building standards require that duct sealants meet UL 181, UL 181A, UL 181B, or UL 723 (for aerosol sealants). The California Energy Commission has approved a cloth-backed duct tape with a special butyl adhesive (CEC 2005). Metal ducts are to be sealed with UL 181 mastic. For duct board, UL 181 tapes are accepted. For flex duct, a combination of UL 181 mastic and strap ties should be used.

Adapted from Sherman and Walker 1998.

(top) Installing jump ducts from room to room is one way to balance pressures. *(Photo source: IBACOS)*

(bottom) Transfer grilles help balance air pressure between rooms, which helps to minimize drafts and comfort complaints.

For More Information About Duct Layout and Sealing

Air Conditioning Contractors of America (ACCA). *Manual D: Residential Duct Systems*. ACCA, Arlington, VA. www.acca.org

Air Conditioning Contractors of America. *Manual T. Air Distribution Basics for Residential and Small Commercial Buildings*. ACCA, Arlington, VA. www.acca.org

Better Duct Systems for Home Heating and Cooling, NREL/BR-550-30506; DOE/GO-102004-1606. Available from Building America at www.buildingamerica.gov

California Energy Commission. 2005. *2005 Building Energy Efficiency Standards: Residential Compliance Manual.* CEC-400-2005-005-CMF. Sacramento, CA. www.energy.ca.gov/title24/2005standards/residential_manual.html#4Q

D. Griffiths, M. Zuluaga, D. Springer, and R. Aldrich. 2004. "Insulation Buried Attic Ducts – Analysis and Field Evaluation Findings." *American Council for Energy-Efficient Economy (ACEEE). 2004 ACEEE Summer Study on Energy Efficiency in Buildings.* Pacific Grove, CA. August 23, 2004.

Designing and Building Interior Duct Systems, FSEC-PF-365-01. Available from the Florida Solar Energy Center at http://securedb.fsec.ucf.edu/pub/pub_show_detail?v_pub_id=4013

HGTVPro.com. "How to Seal Ductwork," available at www.hgtvpro.com/hpro/bp_mechanical/article/0,,HPRO_20151_4583390,00.html

International Code Council (ICC). 2009 International Energy Conservation Code, Section 403.2.2 "Sealing," International Code Council (ICC), Falls Church, VA. Available at www.iccsafe.org/dyn/prod/3800S09.html

Oikos Green Building Source. "Mastic Gives Ducts the Treatment," available at www.oikos.com/library/ducts/index.html

Sherman, M, and I. Walker. 1998. Can Duct Tape Take the Heat? *Home Energy*, Berkeley, California. http://homeenergy.org/archive/hem.dis.anl.gov/eehem/98/980710.html

Walker, I.; M. Sherman; M. Modera; and J. Siegel. 1998. Leakage Diagnostics, *Sealant Longevity, Sizing and Technology Transfer in Residential Thermal Distribution Systems.* Lawrence Berkeley National Laboratory, Berkeley, CA. http://epb.lbl.gov/Publications/phasevifinal.pdf

Register Placement

In cooling-dominated climates, it has been typical to locate supply registers in the ceiling. This works well for cooling, but may present problems during heating periods. High sidewall and ceiling register placements have been used successfully in Building America projects. To attain optimal performance and comfort, it is critical to properly select registers based on throw characteristics and the volume of air being delivered to the room. This becomes especially critical in energy-efficient homes where downsizing typically results in lower airflow. It may require the use of registers with manually operable vanes to fine-tune airflow for optimal comfort.

High-inside sidewall applications have been used where the register is directed at the wall of dominant heat loss or gain (usually the wall with windows or glass doors) and the register is no more than 12 to 13 feet away. Ceiling diffusers with curved blades to help direct the airflow along the ceiling can be used where the wall opposite the dominant load exceeds 13 feet.

Research is currently underway in the Building America Program to better understand the issues of air distribution in high-performance houses and to develop recommendations for supply and return apertures.

Pressure Balancing

Pressure imbalances can pull humid and unfiltered air through the building envelope when the HVAC system is operating, wasting energy and potentially causing moisture problems. Imbalanced airflows can also cause drafts and room-to-room or floor-to-floor temperature differences, leading to comfort complaints.

One key factor in eliminating room-to-room and indoor-to-outdoor pressure imbalances is the adequacy of the return air path to the air handler. In homes with individual-room ducted returns, this is generally not a problem. Individual-room ducted return systems are historically typical in colder climates, but are losing favor because of added costs. From a cost-effectiveness standpoint, a well-designed central return system with individual room pressure relief is considered the best approach.

A well-designed return system must incorporate adequate relief from each room where entry doors may be closed. Return air recommendations include the use of ceiling "jump ducts" or transfer grilles located in the walls. Door undercuts are generally not considered to be desirable because they are often too small and/or are blocked by the installation of carpeting. They can be used for smaller rooms provided the velocity is kept below about 600 cfm. One important consideration in the installation of "jump ducts" or transfer grilles is to maintain sound separation between spaces. Sound transmission can be controlled by the use of flex duct, duct lining with sound-absorbent material, a slightly circuitous path, or some combination of these strategies.

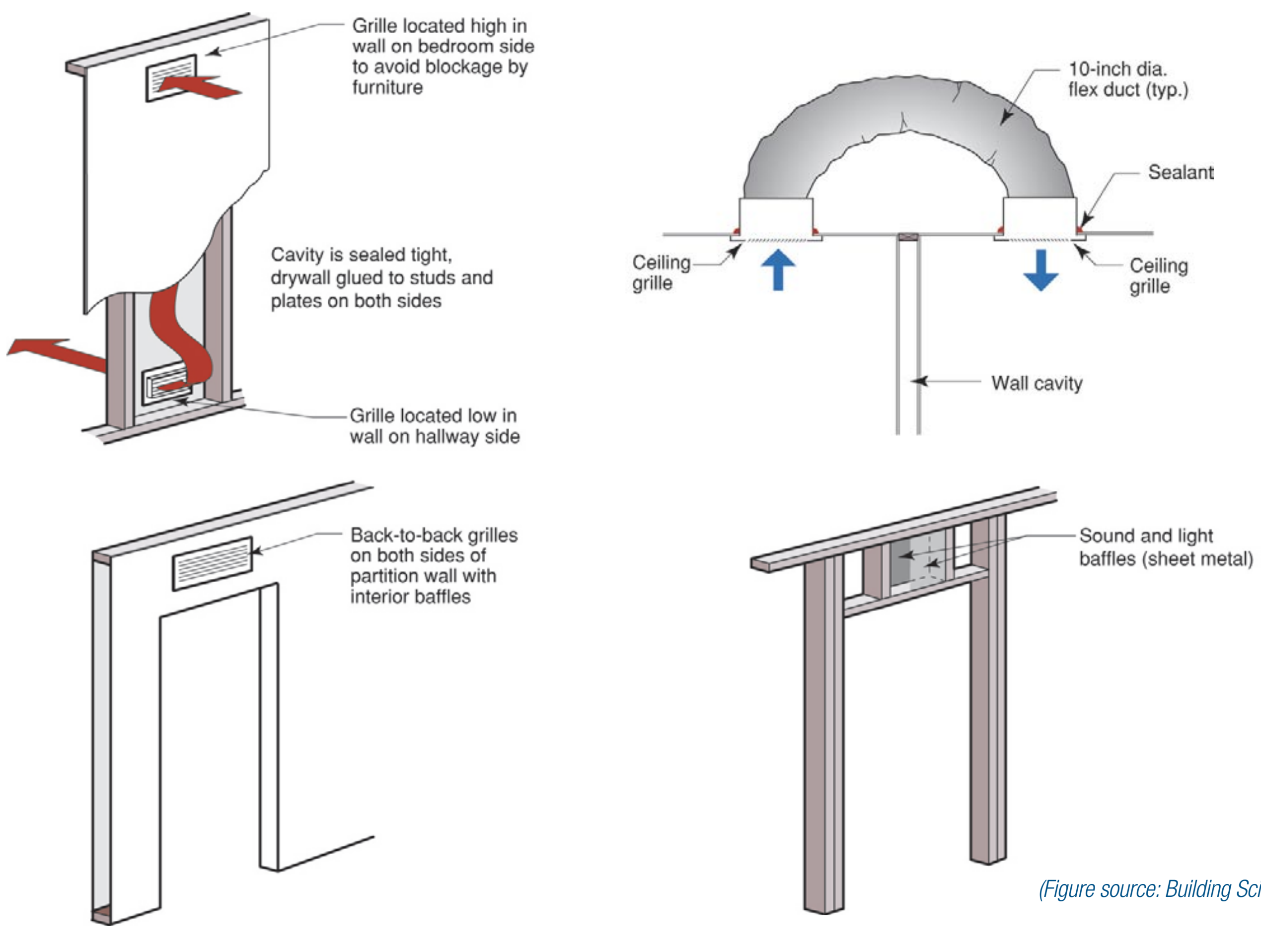
A sone is a cumulative sound rating. Two sones is twice as loud as one sone. Exhaust fans with a sone rating of 1.5 or less are considered very quiet. Ventilation experts recommend quiet fans because they believe that people will leave them on because they are not intrusive.

For More Information on Pressure Balancing in Homes

Associated Air Balance Council. *AABC National Standards for Total System Balance.* 2002.
www.aabchq.com/resources/national.aspx

National Environmental Balancing Bureau, (NEBB). *Section 15990 - Testing, Adjusting, and Balancing.*
www.nebb.org/tabspec.htm

Example of Jump Ducts and Grills



(Figure source: Building Science Corporation)

In 2003, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) established a new standard for indoor ventilation in residences. The standard is *ASHRAE 62.2, Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings* (ASHRAE 2003). The following information is adapted from the forward that is published with the Standard:

The three primary requirements involve whole-house ventilation, local exhaust, and source control. Whole house ventilation is intended to dilute the unavoidable contaminant emissions from people, materials, and background processes. Local exhaust is intended to remove contaminants from specific rooms, such as kitchens and bathrooms, where pollutant sources are produced. And source control measures are included to deal with other anticipated sources. The standard's secondary requirements focus on properties of specific items, such as sound and flow ratings for fans and labeling requirements. The standard is principally about mechanical ventilation, but its purpose is to provide acceptable indoor air quality.

ASHRAE Standard 62.2 requires a continuous ventilation rate of 1cfm per 100 sq ft of building area plus 7.5 cfm x (# bedrooms +1). An intermittent fan can meet this requirement if the airflow rate is adjusted upward based on specific ventilation effectiveness requirements published in the standard.

The states of California, Washington, Minnesota, and Vermont now require mechanical ventilation in dwellings. New guidelines from the American Lung Association and ENERGY STAR include mechanical ventilation requirements.

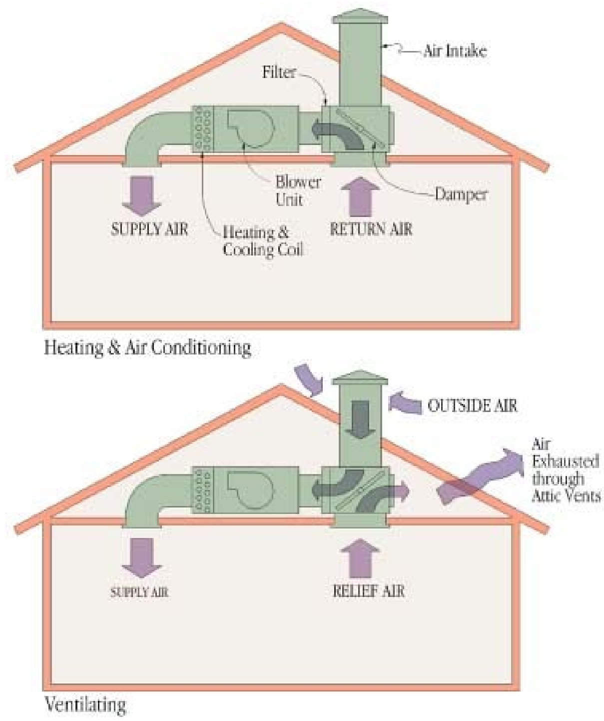
Air Distribution Fans

Air conditioning, heating, and ventilation systems often share one fan to move air, so the efficiency of the furnace or heat pump indoor fan motor can have a large impact on year-round energy use. Nearly all furnace manufacturers offer "variable-speed" brushless permanent magnet (BPM) direct current motors. They have higher efficiency or high speeds and, unlike permanent split-capacitor motors, BPM motors retain their high efficiency at reduced fan speeds. Although BPM motors have more than a $200 price premium, they are a recommended means of lowering HVAC energy use, and are required for two-stage heating and cooling systems. Some types also maintain a constant air flow as filters become dirty or registers are closed.

Ventilation

Building America recommends that all new homes be equipped with whole-house mechanical ventilation that complies with ASHRAE 62.2. Mechanical ventilation systems for indoor air quality include exhaust-only fans, systems that supply outside air, and systems that do both.

Most of the Building America teams have designed and field-tested ventilation systems that bring outside air to the intake side of a home's central air handler. A central fan-integrated supply ventilation system involves exterior air intakes, ductwork running to the return air side of the HVAC system, dampers to allow control of the air intake, and electronic controls to ensure that the HVAC fan operates frequently enough to draw in adequate outside air and to time the operation of a motorized damper. Advantages to this system are that the fresh air volume can be adjusted to meet ASHRAE 62.2 requirements, outside air is filtered, and fresh air is delivered to every space (Russell, Sherman, and Rudd 2006).



SmartVent is an automatic night ventilation cooling system with continuous fresh air ventilation developed by Davis Energy Group. Grupe installed SmartVent in 144 Building America homes at Carsten Crossings in Rocklin, California. A variable-speed fan version called NightBreeze is also commercially available.

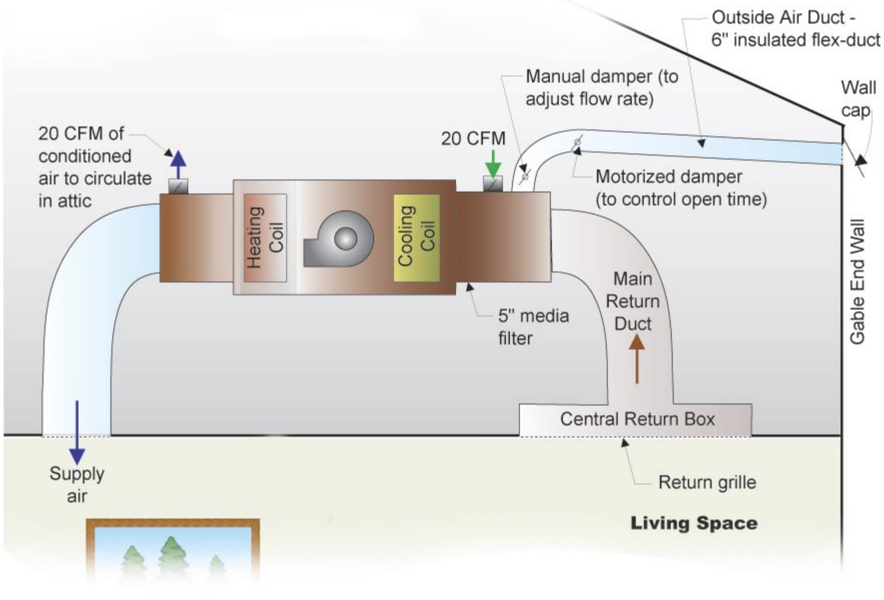
Air conditioning energy use can be significantly reduced by ventilating homes with cool night air. Ventilation cooling is practical in many hot-dry climate locations where temperature swings of 30 degrees or more between day and night and daytime highs of 90°F are common. The simplest form is opening windows at night, but security concerns may prohibit obtaining sufficient window area to provide effective ventilation. Whole house fans can be provided, but still require operation of windows and some diligence on the part of the homeowner. Automated systems that use the heating-cooling system fan and an outside air intake-relief damper eliminate the need for opening windows and provide filtered outside air. Some also include the ability to provide year-round ventilation air for indoor air quality.

This builder points to a mechanized damper on a fresh air intake to the HVAC air handler. The damper can be set by a timer (shown above) to open allowing fresh air to be pulled into the air handler by the fan, also operated by the timer. This draws fresh air into the house at regular intervals.

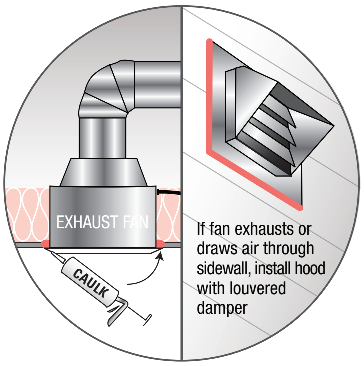
Continuously operating an exhaust fan located in a bathroom or central area of the house provides a lower cost solution. High-quality, quiet, efficient fans that have separate speeds for ventilation and exhaust are typically used for this application. Because exhaust fans draw air from leaks in the building envelope, air is not filtered, will not be evenly distributed, and comes from unknown sources. A better solution than an isolated exhaust fan is to tie all bathroom exhaust ducts together and route them through a single, continuously operating, high-efficacy axial fan that is vented to the exterior.

Exhaust fans help to improve indoor air quality by removing air contaminants near their source, such as moisture from a shower. However, be cautious about using exhaust-only ventilation systems. Exhaust systems, including bath fans, kitchen range fans, and clothes dryers, draw the air out of a home, creating a negative pressure in the home. In an inefficient, leaky home, outside air is pulled in through cracks around doors and windows. In a high-performance home, those air leaks have been sealed up so a fresh air intake must be added to the home to supply fresh air. Failing to provide an outside air intake will cause a negative pressure in the home. In a home with negative pressure, standard combustion (fuel-burning) equipment can backdraft dangerous gases (including carbon monoxide) into the house. Such negative pressure can also draw in hot outside air, air pollutants, and pollens. For this reason, some building codes limit conditions in newly constructed homes under which exhaust equipment can be used without providing for an equal amount of fresh air either through passive inlets or by powered intake.

Supply ventilation integrated into the return side of an HVAC system



Source: Building Science Corporation



Provide bathroom and kitchen exhaust fans. Duct them to the outside and caulk ducts at the dry wall for an air-tight seal. Use low sone fans for quiet operation.

For More Information on Ventilation Systems

2009 International Energy Conservation Code, Section 403.5, "Mechanical Ventilation," International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3810S09.html

2009 International Energy Conservation Code, Section 403.6, "Equipment Sizing," International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3810S09.html

2009 International Residential Code, Section M1502.1 "Clothes Dryer Exhaust – General," International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3110S09.html

2006 International Residential Code, International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3110S061.html

Air Conditioning Contractors of America. *Manual T. Air Distribution Basics for Residential and Small Commercial Buildings.* ACCA, Arlington, VA. www.acca.org

American Society of Heating, Refrigerating, and Air Conditioning Engineers. 2003. ASHRAE Standard 62.2-2007, *Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings.* ASHRAE, Atlanta, GA. http://webstore.ansi.org/default.aspx

ASHRAE Standard 62.2-2007 *Ventilation for Acceptable Indoor Air Quality in Low-Rise Residential Buildings* can be previewed at www.ashrae.org/technology/page/548

Building Energy Codes Resource Center "Whole-House Mechanical Ventilation – Code Notes," U.S. Department of Energy, http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article/1467

ENERGY STAR Thermal Bypass Checklist Guide, 2008, available at www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/TBC_Guide_062507.pdf, pg. 13

ENERGY STAR. "ENERGY STAR-Approved Ventilation Fans," available at www.energystar.gov/ia/products/prod_lists/vent_fan_prod_list.pdf

ENERGY STAR. "Ventilation Fans Purchasing and Procurement Language," www.energystar.gov/index.cfm?c=vent_fans.pr_proc_vent_fans

ENERGY STAR. *Ventilating Fans Key Product Criteria.* Available at www.energystar.gov/index.cfm?c=vent_fans.pr_crit_vent_fans.

Florida Solar Energy Center. 2007. "Indoor Air Quality," available at www.fsec.ucf.edu/en/consumer/buildings/homes/airqual.htm

Home Energy Magazine. 1999. "Oversized Kitchen Fans – An Exhausting Problem" in Home Energy Magazine Online, January/February 1999. www.homeenergy.org/archive/hem.dis.anl.gov/eehem/99/990113.html

HVI. 2006. "Fresh Ideas in Residential Ventilation." Home Ventilating Institute. Wauconda, IL. www.hvi.org/resourcelibrary/HomeVentGuideArticles.html

Minnesota Department of Commerce Energy Information Center. June 23, 2008. "Maintain home ventilation systems to provide healthy air supply." Available at www.state.mn.us/portal/mn/jsp/common/content/include/contentitem.jsp?contentid=536886092

NAHB Research Center. "Whole-House Mechanical Ventilation Strategies," www.toolbase.org/Technology-Inventory/HVAC/whole-house-mechanical-ventilation

Piazza, T., R.H. Lee, M. Sherman, and P. Price. 2007. *Study of Ventilation Practices and Household Characteristics in New California Homes*. CEC-500-2007-033. California Energy Commission, Sacramento, CA., www.energy.cq.gov/2007publications/CEC-500-2007-033/CEC-500-2007-033.PDF

Rudd, Armin, Joseph Lstiburek, 2001. "Clean Breathing in Production Homes." *Home Energy Magazine*, May/June, Energy Auditor & Retrofiter, Inc., Berkeley, CA. www.bestofbuildingscience.com/pdf/clean%20breathing%20in%20production%20homes%20HEM_18-3_p29-33.pdf

Rudd, Armin. 2006. *Ventilation Guide*. Building Science Press Inc., Energy & Environmental Building Association, Minneapolis, MN, available for purchase at www.eeba.org/bookstore/prod-Ventilation_Guide-10.aspx

Rudd, Armin. 1999. "Air Distribution Fan and Outside Air Damper Recycling Control," Heating Air Conditioning and Refrigeration News, 5 July 1999, pg. 45. Edited version of article available at www.buildingscience.com/documents/reports/rr-9901-air-distribution-fan-and-outside-air-damper-recycling-control

Russell, Marion, Max Sherman and Armin Rudd, 2007. "Review of Residential Ventilation Technologies." HVAC&R Research, Vol. 13, No. 2, p. 325-348, March. ASHRAE. http://findarticles.com/p/articles/mi_m5PRD/is_2_13/ai_n25007553

Sustainable Buildings Industry Council (SBIC). 2003. *Green Building Guidelines: Meeting the Demand for Low-Energy, Resource-Efficient Homes.* U.S. DOE. Washington, D.C. document available at www.sbicouncil.org/storeindex.cfm

Lawrence Berkeley National Laboratory. Thermal Energy Distribution Website at http://ducts.lbl.gov

University of Illinois Extension Service. "Five Steps to a Healthier Garage". http://web.extension.uiuc.edu/will/factsheets/family116.html

U.S. Department of Energy (DOE). 2002. "Whole-House Ventilation Systems," Technology Fact Sheet, December 2002. www.toolbase.org/pdf/techinv/wholehouseventilation_techspec.pdf

U.S. Environmental Protection Agency. 2007. *The Inside Story: A Guide to Indoor Air Quality*, EPA 402-K-93-007, available at www.epa.gov/iaq/pubs/insidest.html

Occupant Health and Safety

Builders can use a variety of construction practices and technologies to decrease the risk of poor indoor air quality, including careful selection and installation of moisture control systems, heating, ventilating, and air-conditioning (HVAC) systems, combustion-venting systems, and building materials. Several factors affect indoor air quality. In its Indoor airPLUS program, the U.S. EPA recommends the following for these known factors: 1) moisture control including improved control of condensation and better roof, wall and foundation drainage; 2) radon control including testing and radon abatement techniques; 3) pest management, including caulking, sealing, and screening at entry points; 4) HVAC, including properly engineered system, sealed ducts, whole-house and spot ventilation; 5) combustion venting including sealed combustion heating equipment, installation of carbon monoxide detectors, and sealing and ventilation of attached garages; 6) selection of low-chemical content materials; proper protection of materials during construction, and house ventilation prior to move in (www.epa.gov/indoorairplus).

The following safety and health features should be included in house designs:

- Use only sealed combustion or power-vented appliances in the conditioned space. Specifically, any furnace inside conditioned space shall be a sealed-combustion 90%+ (AFUE of 90 or greater) unit. Any water heater inside conditioned space shall be sealed combustion (direct vented) or power vented.

- Avoid designs that incorporate passive combustion air supply openings or do not have outdoor supply air ducts directly connected to the appliance.

- Direct vent to the outside gas cooking ranges and all exhaust heads.

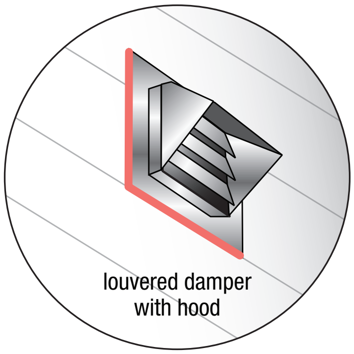
- Use sealed-combustion gas fireplaces to eliminate the threat of harmful combustion gases entering the house. All fireplaces should be sealed combustion units and should be properly vented to the outside. If not properly vented and sealed, the fireplace can produce harmful combustion pollutants that may be emitted into the home, such as carbon monoxide, nitrogen dioxide, and sulfur dioxide.

- Vent bathrooms, kitchens, toilets, and laundry rooms directly outdoors. According to the 2009 IECC, Section 403.5 "Mechanical ventilation," outdoor air intakes and exhausts should be equipped with automatic or gravity dampers that close when the ventilation system is not in operation. Use energy-efficient and quiet fans (see the section on ventilation).

- Vent clothes dryers and central vacuum cleaners directly outdoors. Smooth rigid metal ducts with louvered vents and straight runs provide the most efficient ducting systems. Check code (2009 IRC, Sec. M1502.4.1) and manufacturer's specifications for limits on duct length. Insulate ducts to avoid condensation, flash and caulk penetrations; avoid sags in ducts. Vinyl, nylon and foil ducts do not meet code.

(top) Some cabinet makers are now specializing in low-VOC cabinetry to meet growing consumer demand.

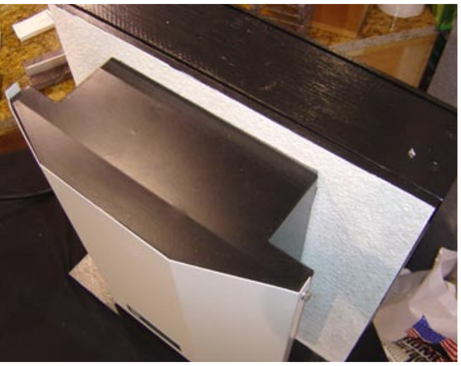
(bottom) Several low VOC adhesives are now available.



Dryer vent exhausts must have a gravity or other backdraft damper. A single hinged door with a 2½-inch effective opening is not as effective as a louvered damper.

A mechanical damper on the fresh air intake lets fresh air into the air handler box when needed to provide fresh supply air for the HVAC system.

- Avoid installing atmospheric (standard efficiency) gas heaters and water heaters in conditioned space including laundry rooms. These devices are recognizable by the high and low combustion air inlets in the combustion area and the "hat" or "skirt" around the bottom of the flue (where it meets the furnace or water heater.) These devices depend on stack effect to establish exhaust draft, but the stack effect can be easily overcome by dryers, exhaust fans, or supply duct leakage (which depressurizes the house), causing back drafting of exhaust gases.
- Provide filtration systems for forced air systems that provide a minimum atmospheric dust spot efficiency of 30% or MERV of 8 or higher. MERV (Minimum Efficiency Reporting Value) is a measure of an air filter's efficiency at removing particles.
- Maintain indoor humidity in the range of 30% to 60% by controlled mechanical ventilation, mechanical cooling, or dehumidification.
- Install carbon monoxide detectors (hard-wired units) (at one per every approximately 1,000 square feet) in any house containing combustion appliances and/or an attached garage, and even in those houses with no combustion appliances in case one should be installed at a future date. Builders should provide homeowners with guidance on what to do if the CO detector alarm sounds, for example an action plan that advises occupants that a potentially life-threatening condition has occurred, to open windows and doors to allow CO to escape, and to go outside until the CO alarm goes off.
- Maximize hard surface areas (tile, vinyl, hardwood) to better manage dust for health purposes. For slab-on-grade houses, this also reduces cooling loads.
- Provide occupants with information on safety and health related to the operations and maintenance of the systems that provide control over space conditioning, hot water, and lighting.
- Isolate attached garages from conditioned spaces. Common walls and ceilings between attached garages and living spaces should be visually inspected to ensure they are air-sealed before insulation is installed. All connecting doors between living spaces and attached garages should include an automatic closer, and they should be installed with gasket material or be made substantially air-tight with weather stripping.
- Include an exhaust fan in attached garages, with a minimum installed capacity of 70 cfm, rated for continuous operation, and installed to vent directly outdoors. If automatic fan controls are installed, they should activate the fan whenever the garage is occupied and for at least 1 hour after the garage has been vacated.
- Use low-VOC (volatile organic compound) paints, finishes, varnishes, and adhesives whenever possible.



This exhaust fan and electronic controls are designed to ventilate—and could be used to create a slightly negative pressure in—the garage. Ventilation carries pollutants to the outside; negative pressure helps to stop garage air from migrating into attached houses.

Additional Information on Healthy Homes and Combustion Safety

American Lung Association. 2008. "Health House: Builder Guidelines." ALA, Saint Paul, MN. www.healthhouse.org/build/2008HHbuilderguidelines.pdf

American Lung Association. Health House Tipsheet on Backdrafting, ALA, Saint Paul, MN. www.healthhouse.org/tipsheets/TS_backdrafting.pdf

ASTM D6670 – 01. 2007. "Standard for Full-Scale Chamber Determination of Volatile Organic Emissions from Indoor Materials/Products," www.astm.org/Standards/D6670.htm

Building Performance Institute, Inc., "Combustion Safety Test Procedure for Vented Appliances," 4/07. www.bpi.org/documents/Gold_Sheet.pdf

California Air Resource Board (CARB). "Airborne Toxic Control Measure (ATCM) to Reduce Formaldehyde Emissions from Composite Wood Products" Fact Sheet, www.arb.ca.gov/toxics/compwood/factsheet.pdf

California Air Resource Board (CARB). "Regulation for Reducing Volatile Organic Compound Emissions from Consumer Products," available online at www.arb.ca.gov/consprod/regs/cp.pdf

Canadian Standards Association CSA 6.19-01. Residential Carbon Monoxide Alarming Devices. www.shopcsa.ca/onlinestore/GetCatalogDrillDown.asp?Parent=571

Canadian Standards Association. "Carbon Monoxide Alarms," www.csa-international.org/consumers/consumer_tips?default.asp?load=carbon_monoxide&language=english

Center for ReSource Conservation. Before you buy …Cabinets. Article available at www.greenerbuilding.org/buying_advice.php?cid=4

Consumer Product Safety Commission (CPSC). What You Should Know About Combustion Appliances and Indoor Air Pollution (CPSC Document #452), www.cpsc.gov/cpscpub/pubs/452.html

ENERGY STAR. 2007. ENERGY STAR Indoor Air Package Specifications, Version 2. U.S. Environmental Protection Agency. www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/IAP_Specification_041907.pdf

Greenguard Environmental Institute. www.greenguard.org

International Code Council, Inc., "UL 2034 History – CO Alarms," May 4, 2005. www.iccsafe.org/cs/cc/ctc/CO/CO_UL2034History.pdf

International Residential Code (IRC). 2009. Section M1502.4.1, "Material and Size," International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3110S09.html

KCMA Environmental Stewardship Program 01-06. www.greencabinetsource.org/index.cfm?fuseaction=Defining.Welcome

National Association of Home Builders Research Center. "Low- or No-VOC Paints, Finishes and Adhesives," www.toolbase.org/Home-Building-Topics/Indoor-Air-Quality/low-voc-paints

LEED for Homes. USGBC, January 2008. www.greenhomeguide.org/documents/leed_for_homes_rating_system.pdf

National Green Building Standard 901.10, August 10, 2007, pg. 70. www.nahbgreen.org/Guidelines/ansistandard.aspx

NFPA 720: Standard for the Installation of Carbon Monoxide (CO) Warning Equipment in Dwelling Units. www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=720&Cookie%5Ftest=1

Raub, J. A., M. Mathieunolf, N. B. Hampson, and S. R. Thom. 2000. "Carbon Monoxide Poisoning—a Public Health Perspective." *Toxicology* (145):1-14. www.ncbi.nlm.nih.gov/pubmed/10771127

South Coast Air Quality Management District. Rule 1168 – Adhesive and Sealant Application. www.arb.ca.gov/DRDB/SC/CURHTML/R1168.pdf

The American Lung Association. Health House tipsheet on carbon monoxide www.healthhouse.org/tipsheets/TS_CarbonMonoxide.pdf

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Top Ten Things that homeowners can do to provide good indoor air quality. www.contractorconnect.net/GoodAir.html

UL 2034 Standard for Single and Multiple Station Carbon Monoxide Alarms, Edition 2, October 29, 1996. www.alliedsalescompany.com/ul/2034.pdf

U.S. Department of Energy. "The House as a System: Combustion Safety," www.eere.energy.gov/buildings/building_america/pdfs/db/31046.pdf

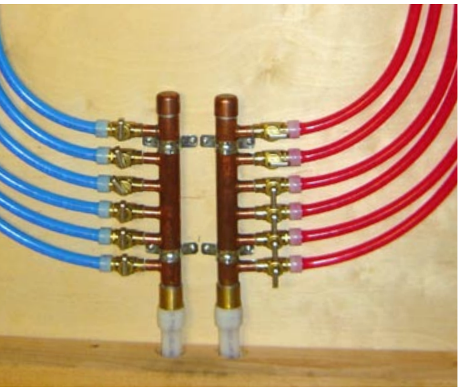
U.S. Department of Energy. 2000. "Combustion Equipment Safety," DOE Fact Sheet, May 2000. DOE/GO 10099-784. www.earthcrafthouse.com/documents/factsheets/CES-Combustion-Safety%2000-784.pdf

U.S. Environmental Protection Agency. 2009. Indoor airPLUS Construction Specifications www.epa.gov/indoorairplus

U.S. Environmental Protection Agency. "Indoor Air Quality Carbon Monoxide Fact Sheet" www.epa.gov/iaq/co.html.

U.S. Environmental Protection Agency. "Wood Coating Case Studies by Company." www.epa.gov/ttn/atw/wood/low/casebyco.html

This Building America home used low-VOC paints and finishes (shown in lower photo) to meet local green building guidelines.



In an NAHB Research Center study, the central manifold hot water distribution system provided hot water to the fixtures more quickly than traditional trunk and branch and remote manifold distribution methods.

Plumbing and Water Heating

Residential hot water energy use accounts for approximately 19% of the residential energy consumed in the United States, according to the Energy Information Administration. In new, high-performance homes, hot water energy accounts for a higher percentage, typically 21% to 32%. Hot water systems don't use more energy than they used to but they take a relatively larger share of the energy use in homes because in tighter houses less energy is required to heat and cool the homes than in older homes built to less stringent standards.

There are several measures builders can take to reduce the amount of energy needed for water heating:

- Consolidate bathrooms and other hot water-consuming activities into the same area(s) of the house.
- Consider centralizing the location of the water heater to minimize piping trunk lengths.
- Locate plumbing pipes in the attic and cover with insulation in single-story, slab-on-grade homes and locate the pipes in interstitial space between floors for multi-story homes.
- Do not oversize piping. Use code-permitted minimums. Bigger isn't better.
- Insulate hot water supply lines to R-4 and ensure tanks have at least R-12.
- Install high-efficiency electric or gas water heaters.
- Consider alternative technologies like on-demand gas or electric water heaters, solar thermal water heaters, water heating heat pumps, and ground source heat pumps for water heating.
- Do not use continuous recirculation pumps.

Hot Water Distribution

Essentially there are four types of hot water distribution systems:

- the traditional "trunk and branch" with a large main line feeding smaller pipes that then flow directly to fixtures or split to serve multiple fixtures
- the central manifold (homerun) where the water heater feeds a manifold with dedicated lines running to each household fixture
- the remote manifold system that includes trunk lines that run to remote manifolds that serve clusters of fixtures, such as in one or more bathrooms or a kitchen.
- recirculation systems, which utilize a pump and controls to circulate hot water in close proximity to the use points. Note, recirculation systems seldom save energy and must be carefully designed to avoid wasting energy.

The NAHB Research Center tested the three water distribution systems—trunk and branch, central manifold, and remote manifold. Each of the systems was made with PEX pipe, a flexible plastic tubing. The tests showed that all three hot water distribution systems will supply sufficient flow and pressure. The central manifold system provided the quickest hot water to the fixtures and the most stable pressure when multiple fixtures are being used. When just one fixture is being used, the trunk and branch system provided a slightly higher pressure.

PEX piping systems are becoming standard practice in home building. PEX installation can save labor and materials and can be cost competitive with rigid pipe systems. The NAHBRC points out that because PEX piping will not corrode and resists scale buildup, maintenance costs may be lower than for rigid piping. Fewer leaks are possible because fewer connections are required.

PEX tubing should not connect directly to a hot water tank or solar water heater where the temperature of the water could exceed 200°F. PEX tubing should not be used in installations subject to continual ultraviolet light exposure.

Hot Water Circulation Pumps and Controls

Do not use continuous recirculation systems for hot water. These systems keep hot water continuously flowing through pipes and result in substantial heat loss. Circulation pumps also can defeat the contributions made by solar thermal water heating systems. The flow-through solar collectors should always be kept separate from any hot water recirculation systems.

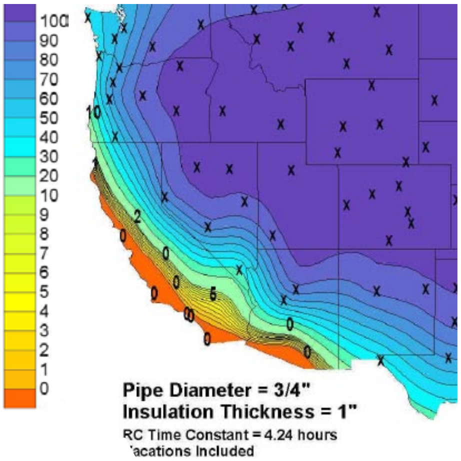
If recirculation systems are used, install a push-button type on-demand recirculator, which will minimize the energy penalty associated with recirculation systems, and insulate the pipe to R-2. An on-demand system circulates the water only when hot water is needed. The on-demand circulating pump briefly moves water out of the hot water pipe and back to the domestic hot water heater down the cold water pipe until hot water is sensed at the faucet. This system helps eliminate wasted water down the drain and is best suited for fixtures located far from the water heater. On-demand recirculators save water, a potentially important feature in the arid hot-dry and mixed-dry climates. However, these systems do not save energy except in comparison to continuous recirculation systems.

Water Heaters

At the heart of a domestic hot water system is the heater itself. Several mature technologies are available, including solar thermal systems which are especially well suited to the hot-dry, mixed-dry climates. Performance rating information for conventional storage water heaters, electric heat pumps, and instantaneous water heaters is available from the Gas Appliance Manufacturers Association (www.ahrinet.org). GAMA's members include appliance manufacturers that use all fuel types. Performance rating information for solar thermal collectors and systems is available from the Solar Rating and Certification Corporation (www.solar-rating.org). Five types of ENERGY STAR-qualified water heaters also are now available: high-efficiency gas storage, gas condensing, whole-home gas tankless, solar, and heat pump. (For a list, see www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters.)

Conventional storage water heaters offer a ready reservoir (storage tank) of hot water. The lowest-priced storage water heater may be the most expensive to operate and maintain over its lifetime. While an oversized unit may be alluring, it carries a higher purchase price and increased energy costs due to higher standby energy losses. Information on properly sizing a water heater is available on the GAMA website. Storage heaters work best with steady, continuous use patterns.

The minimum efficiency target for gas combustion storage heaters is 0.60 or higher. With the tight house construction of the 40% improvement level, these heaters should be either power vented, which forcibly discharges the products of combustion and draws combustion air from the house, direct vented with dedicated outside air for combustion, or sealed combustion units that draw combustion air from outdoors and fan discharge combustion gases outdoors.



Integrated Collector Storage solar water heating systems are well suited to areas with little threat of freezing such as most of the California coast and southern Arizona. Other types of solar thermal water heaters are available including flat-plate collectors in indirect systems that use antifreeze; these systems work well in areas where freezing temperatures are possible. (*Figure source: Jay Burch of NREL)*

Electric storage heaters are generally the most expensive to operate unless rates are very low. Builders should specify the most efficient unit possible and consider the use of solar thermal systems, a propane-fired instantaneous water heater, or a heat pump water heater.

Tankless water heaters provide hot water only as it is needed. They have no tank and so do not have the standby energy losses associated with storage water heaters. Typically, tankless water heaters provide hot water at a rate of 2 to 5 gallons (7.6–15.2 liters) per minute. If the demand for hot water does not exceed the heater's ability to produce it, tankless water heaters do not run out of hot water. Gas-fired tankless water heaters produce higher flow rates than electric on-demand heaters. Because of their instantaneous nature, electric versions can create high peak loads for electric utilities. In areas where utilities charge more for electricity at peak times, these systems could be especially expensive for consumers.

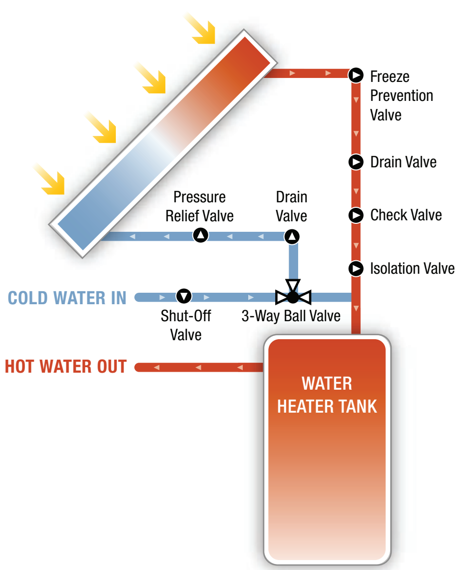
Gas-fired tankless water heaters have been tried in many Building America homes. They are readily available and are a mature technology. In addition to energy savings, other benefits include small size and longer life expectancy. One disadvantage of these units is the time needed for a cold unit to reach operating temperature. This brief warm-up time results in a slight delay in hot water delivery (10 to 20 seconds) and associated water waste.

Multiple installations in a single home should generally be avoided. Multiple installations add to costs and may require an upsized main line if other natural gas appliances, such as a furnace, dryer, or cooking stove, are in operation.

Air source heat pump water heaters use electric compressors and pumps to move heat from one place to another rather than generating heat directly. Therefore, they can be two to three times more energy efficient than conventional electric resistance water heaters. Heat pump water heaters work like a refrigerator, but move heat from its environment to the water. Air source heat pump water heaters are being researched in Building America homes, but generally are not yet mature for production building.

If a ground-source heat pump is chosen for space heating and cooling, it is possible to use it to generate hot water. These systems use the same type of technology as air source heat pump water heaters, but can move heat in either direction between a conditioned space and the ground. These systems can be effective, but the pricing varies dramatically by region. They are complex and require a skilled installer. In an area where no natural gas is available, this system may be a good option. Ground-source heat pumps can be effective in all climate zones.

Ground-source heat pumps add a desuperheater to the heat pump. This is an energy saving device that, during the cooling cycle, recycles some of the waste heat from the house to heat domestic water.



Integrated Collector Storage (ICS) systems are the least expensive solar thermal water heaters.

Solar thermal water heaters use the sun's heat to provide hot water. These systems usually include one or two collectors that typically sit on a house's roof and resemble skylights. Four types of collectors work well for heating water:

- Glazed flat-plate collectors are the most common and can be used in any climate with proper design.
- Evacuated tube collectors use thermos-like evacuated glass tubes. Some also use heat pipes with a special fluid that vaporizes at high temperatures. These collectors tend to be more expensive than other collectors but operate efficiently at high temperatures and can be used in very cold climates with proper design.

- Integrated collector storage systems combine a collector with a storage tank. These systems are one of the lowest cost but should only be used where there is no chance of freezing. Parts of the hot-dry and mixed-dry climates meet these criteria along the coast of California.

- Unglazed flat plate collectors are simple systems that consist of plastic surfaces incorporating channels for water to flow through. Some manufacturers are offering unglazed collectors for domestic hot water. Their traditional use has been for pool and spa heating. Every swimming pool with a solar exposure in the hot-dry, mixed-dry climates should be equipped with a solar pool heater, if extended pool use is desired.

Two emerging technologies are tankless coil and indirect water heaters, which are part of a combined domestic water and space conditioning system. Designs for these types of systems tend to be limited to custom homes that include radiant heating.

Additional Information on Plumbing

DOE. 2007. *Volume 6 - Building America Best Practices Series – High Performance Home Technologies: Solar Thermal & Photovoltaic Systems*. Washington, D.C. www.buildingamerica.gov

DOE. 2007. *A Consumer's Guide to Energy Efficiency and Renewable Energy*. DOE's Energy Efficiency and Renewable Energy website in the water heating section www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12770

ENERGY STAR. *High Efficiency Water Heaters Provide Hot Water for Less*. U.S. Environmental Protection Agency, Washington, D.C. www.energystar.gov/ia/new_homes/features/WaterHtrs_062906.pdf

Gas Appliance Manufacturers Association (GAMA). 2007. *Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment*. GAMA, Arlington, VA. www.gamanet.org

International Residential Code (IRC). 2009. Section 403.4, "Circulating Hot Water Systems," International Code Council (ICC), Falls Church, VA. Available for purchase at www.iccsafe.org/dyn/prod/3110S09.html

National Association of Home Builders Research Center (NAHBRC). Undated. *Toolbase Technotes*. Cross-Linked Polyethylene PEX in Residential Plumbing Systems. www.toolbase.org/PDF/DesignGuides/TechNote_Pex.pdf

Solar Rating and Certification Corporation website at www.solar-rating.org.

Wiehagen J. and J.L. Sikora. 2003. *Performance Comparison of Residential Hot Water Systems*. NREL/SR-550-32922. National Renewable Energy Laboratory. Golden, CO. www.buildingamerica.gov

High-Performance Lighting

Lighting accounts for an estimated 20% of energy use in the typical American home. The typical incandescent lamp wastes 90% of the energy it uses, producing heat rather than light. High-performance lighting provides excellent visual quality that is also very energy efficient. It is principally based on the use of new and improved fluorescent lighting technology.

Compact fluorescent lamps (CFLs), light-bulb sized versions of standard fluorescent lamps, use 70%-75% less energy than their incandescent equivalents, and they have brightness and color rendition comparable to incandescent lights. They cost more, but last 10 to 13 times longer than incandescents, making them cost effective if used at least 2-3 hours per day. A wide variety of sizes and shapes are available in varying color temperatures including the warm tones characteristic of incandescent lamps. Compact fluorescent lamps come in both pin-based models and screw-based models that fit most standard fixtures found in homes today.

Energy-efficient ENERGY STAR rated lamps now come in many attractive fixture styles, like these CFL-based lamps by Progress Lighting. *(Photo source: Progress Lighting)*

LED fixtures are becoming more efficient and affordable and are now available in several applications for homes like the under-cabinet, in-cabinet, and spot lighting shown here.

These CFL-based lights designed by Maxlite won grand prize in the 2008 Lighting for Tomorrow design competition co-sponsored by DOE. *(Photo source: Maxlite)*

In 2005 California's Title 24 building energy standards imposed mandatory lighting requirements for permanently installed lamps. These were updated in 2008 with the revised standards becoming effective August 1, 2009 (CEC 2008). The requirements stipulate the use of pin-based lamps (as opposed to the more standard Edison-type screw-in base). Almost all fluorescent lamps equipped with electronic ballasts qualify as high-efficacy light sources. Incandescent lamps (including screw-in incandescent lamps like regular 'A' style or reflector style lamps, quartz halogen lamps, or low-voltage lamps like halogen MR lamps) do not meet the definition. The new requirements are summarized as follows:

- **Kitchens.** At least half the installed wattage of lamps in kitchens shall be high efficacy – fixtures with low-efficacy lamps must be switched separately. Internal cabinet lighting cannot exceed 20 watts per linear foot of cabinets.
- **Lighting in Bathrooms, Garages, Laundry Rooms and Utility Rooms.** All lamps shall either be high efficacy or shall be controlled by a manual-on occupant sensor.
- **Other Rooms**. All lamps shall either be high efficacy or shall be controlled by an occupant sensor or dimmer. Closets that are less than 70 square feet are exempt from this requirement.
- **Outdoor Lighting**. All lamps mounted to the building or to other buildings on the same lot shall be high efficacy or shall be controlled by a photocontrol/motion sensor combination. Mercury vapor lamps do not usually meet the requirements; metal halide or CFLs are good replacements.

ENERGY STAR first established criteria for CFL lamps in 2007, and hundreds of models of CFL bulbs and fixtures are now ENERGY STAR labeled. Specify ENERGY STAR-qualified CFL lights and fixtures wherever possible, especially with fixtures expected to be on more than 2 hours per day.

Fixtures that are recessed into insulated ceilings (downlights) are required by building codes to be rated for insulation contact ("IC-rated") so that insulation can be placed over them. The housing of the fixture should be airtight to prevent conditioned air from escaping into the ceiling cavity or attic, and unconditioned air from infiltrating from the ceiling or attic into the conditioned space. IC-rated downlight fixtures are available for CFL lamps.

Light emitting diode (LED) lights are emerging in the marketplace. These lights are becoming more efficient, being developed for numerous applications, and dropping in cost. DOE tracks and tests LED products as they enter the market.

ENERGY STAR issued criteria for solid-state lighting (LED) fixtures in September 2007 with an effective date of September 2008. To earn the ENERGY STAR label, LED products have to offer a three-year warranty and meet stringent performance requirements for color rendering, luminaire efficiency, and light output over the life of the lamp, which is specified as 25,000 hours for indoor, residential products.

Example of Recessed Downlight Performance Using Different Lighting Sources

	INCANDESCENT*	FLUORESCENT*		LED**
	65W R-30 Halogen	13W triple tube Spiral CFL	15W R-30 CFL	LR6 LED downlight by Cree
Delivered light output (lumens), initial	678	466	653	639
Luminaire wattage (nominal W)	65	10	13	11
Luminaire efficacy (lm/W)	11	46	49	57
Price (average prices as of Aug 2009)	$3	$8	$5	$99
Life Span	2,500 hrs	12,000 hrs	6,000 hrs	50,000 hrs

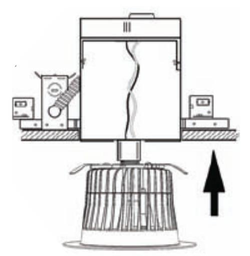
*Based on photometric and lamp lumen rating data for commonly available products. Actual downlight performance depends on reflectors, trims, lamp positioning, and other factors. Assumptions available from PNNL.
** LED tested through DOE CALiPER program.

To encourage and promote the development of more high-quality, attractive LED and CFL lamps and fixtures, DOE has partnered with lighting organizations to host three lighting competitions. DOE teamed with the American Lighting Association (ALA) and the Consortium for Energy Efficiency (CEE) on the Lighting for Tomorrow competition (www.lightingfortomorrow.com), which promotes fluorescent and LED fixtures. DOE, the Illuminating Engineering Society of North America, and the International Association of Lighting Designers co-sponsor the Next Generation Luminaires design competition (www.ngldc.org), which recognizes excellence in the design of energy-efficient LED commercial lighting luminaires. DOE conducts the L-Prize (www.lightingprize.org) to promote super-efficient solid-state lighting products to replace today's most common light bulbs. Visit the competition websites to see competition winners, including some of the most energy-efficient, eye-catching designs on the market.

Residential lighting controls represent a significant opportunity for energy savings. Lighting controls generally refers to technologies that turn off (or turn down) lighting systems when they are not needed. Examples include occupancy sensors, vacancy sensors, photo sensors, dimmers, and timers.

Installation

- Designed to easily install in standard 6" downlight housings from Cree and other manufacturers.
- Quick install system utilizes a unique retention feature. Simply attach socket to LR6. Move light to ready position and slide into housing. Rotate module 1/4 turn to the right to lock in place.
- Reference www.CreeLEDLighting.com for a list of compatible housings



This LED fixture, the LR6 LED downlight by Cree LED Lighting Solutions, Inc, fits into a standard recessed can fixture and provides comparable light output to CFL and incandescent bulbs, at lower wattage and much longer life.

For More Information on Lighting

California Energy Commission. 2009. *California's Energy Efficiency Standards for Residential and Nonresidential Buildings: Title 24*. Sacramento, CA. www.energy.ca.gov/title24/

California Lighting Technology Center. www.cltc.ucdavis.edu

DOE, ALA, and CEE. 2009. "Lighting for Tomorrow Competition." U.S. Department of Energy, the American Lighting Association (ALA), and the Consortium for Energy Efficiency www.lightingfortomorrow.com

DOE, IES, IALD. 2009. "Next Generation Luminaires Design Competition," U.S. Department of Energy, the Illuminating Engineering Society of North America, and the International Association of Lighting Designers, www.ngldc.org

A refrigerator labeled with both the ENERGY STAR label and the EnergyGuide label.

DOE. 2009. “L-Prize,” U.S. Department of Energy www.lightingprize.org

DOE. 2007. Lighting for Tomorrow: Solid State Lighting Competition 2007. www.lightingfortomorrow.com

ENERGY STAR. 2007. Light Bulbs and Fixtures website. www.energystar.gov

IBACOS. High-Performance Lighting Guide website www.ibacos.com

U.S. Department of Energy. Solid-State Lighting (SSL) website www.ssl.energy.gov

Appliances

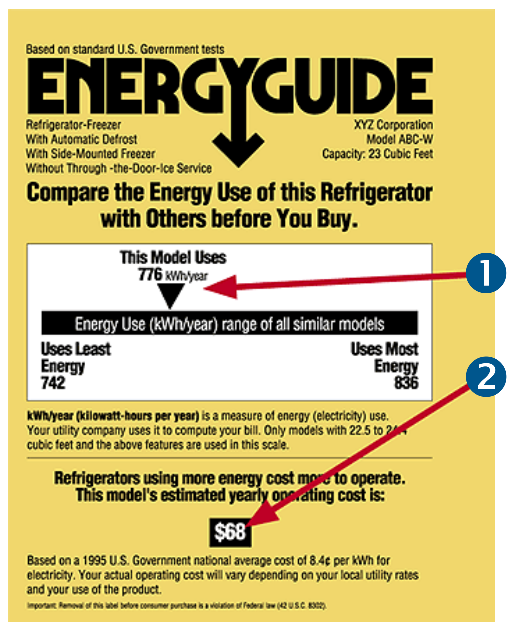
When it comes to shopping for and comparing energy-efficient appliances and home electronics, look for the EnergyGuide and ENERGY STAR labels. Building America recommends using best-in-class products for appliances that are not currently rated by ENERGY STAR.

EnergyGuide Label

The Federal Trade Commission requires EnergyGuide labels on most home appliances (except for stove ranges and ovens), but not home electronics, such as computers, televisions, and home audio equipment. EnergyGuide labels provide an estimate of the product’s energy consumption or energy efficiency. They also show the highest and lowest energy consumption or efficiency estimates of similar appliance models.

1. Estimated energy consumption on a scale showing a range for similar models
2. Estimated yearly operating cost based on the national average cost of electricity.

The EnergyGuide label helps consumers compare the energy efficiency of appliances



ENERGY STAR Label

ENERGY STAR labels appear on appliances and home electronics that meet strict energy efficiency criteria established by the U.S. Department of Energy and U.S. Environmental Protection Agency. The ENERGY STAR labeling program includes most home electronics and appliances except for water heaters, stove ranges, and ovens.

On-Peak vs. Off-Peak Controls

While not directly saving energy, shifting energy consumption to off-peak times can save consumers money and benefit the electric utility. In areas with time-of-use rates, consumers are charged less for electricity used during off-peak times. Electric utilities benefit by reducing the need for purchasing or generating expensive on-peak power.

Whirlpool's energy management system for stand-alone Time-of-Use (TOU) appliances offers an example of how consumers can delay the operation of the dishwasher, washing machine, and dryer until times (for example night time) when energy prices are lowest (off-peak rate). An LED indicator light lets the consumer know if the rate is currently on- or off-peak. To delay until off-peak, the consumer can press a button and another indicator light displays that this appliance will start at a later time.

ENERGY STAR dishwashers and clothes washers save both energy and water. Whirlpool offers time-of-use controls on these appliances so that they will delay the start to run at off-peak hours for utility bill savings.

Additional Information on ENERGY STAR and EnergyGuide Labeling

California Energy Commission Consumer Energy Center "EnergyGuide,"
www.consumerenergycenter.org/home/appliances/energyguide.html

ENERGY STAR.
www.energystar.gov

ENERGY STAR Windows.
www.efficientwindows.org/energystar.cfm

SRP. "Energy Guide Labels help you compare,"
www.srpnet.com/energy/energyguide.aspx

The U.S. Department of Energy "Best Practices" Builders Guides
www.eere.energy.gov/buildings/building_america/

Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 10. Durability and Energy Efficiency Checklist

For a home to be both comfortable and energy efficient, it must be sealed from the unwanted movement of moisture, air, and heat. Health, safety, and pest issues must also be addressed. This checklist summarizes the measures presented in Chapters 6, 7, 8, and 9.

Designers, use this checklist as a reminder to investigate these features throughout the design process. Develop specifications and drawings to ensure that selected features are included in construction documents.

This list can aid site supervisors by providing a master list of recommended home features. Use this list to develop customized on-site pre-job and post-job inspection checklists for each trade contractor.

CHAPTER TOPICS

Foundation Assemblies

Monolithic slab-grade beam assemblies are the predominant foundation system in the hot-dry and mixed-dry climates and are the focus of this discussion.

CONTROLLING MOISTURE IN FOUNDATIONS

- ☐ Maintain a surface grade of at least 5% for at least 10 feet around and away from the entire structure.
- ☐ Drain driveways, garage slabs, patios, stoops, and walkways away from the structure.
- ☐ Place a 6-mil polyethylene sheeting directly beneath the slab. Wrap the sheeting continuously around the slab as well as footings up to grade.
- ☐ Specify that footings poured independent of slabs or foundation walls are to be treated with a bituminous damp-proof coating, masonry capillary-break paint, or a layer of 6-mil polyethylene plastic to isolate the footing from the remainder of the assembly.

Continued...

- ☐ Do not place a sand layer between the vapor retarder and the concrete slab. Handle differential drying and cracking with a low water-to-concrete ratio and wetted burlap covering during initial curing.
- ☐ Place a 4-inch-deep, ¾-inch gravel bed directly beneath the polyethylene sheeting to act as a capillary break and drainage pad.
- ☐ Apply a capillary break between the foundation and wall and between the foundation and soil.
- ☐ Install damp proofing on the above-grade, exposed portion of the foundation with latex paint or another sealant.

CONTROLLING AIR INFILTRATION IN SLAB FOUNDATIONS

- ☐ Specify and install a seal gasket between the foundation and the bottom plate of the exterior framed wall to control air infiltration. This gasket also serves as a capillary break.

CONTROLLING HEAT FLOW IN FOUNDATIONS

- ☐ Do insulate slabs in the mixed-dry climate at the perimeter with at least one inch of borate-treated foam board insulation. Do not need to insulate slabs in the hot-dry climate except for extremely hot areas because of the low overall heating load.

OTHER FOUNDATION ISSUES

Pest Control

- ☐ Use local code and Termite Infestation Probability (TIP) maps to determine environmentally appropriate termite treatments, bait systems, and treated building materials for assemblies that are near soil or have ground contact.
- ☐ Provide roof drainage to carry water at least 3 feet beyond the building.
- ☐ Apply decorative ground cover no more than 2 inches deep within 18 inches of the foundation.
- ☐ Keep plantings at least 18 inches from the foundation with supporting irrigation directed away from the finished structure.
- ☐ Specify and install an environmentally appropriate soil treatment and a material treatment (treated wood, termite blocks) for wood materials near grade.

Radon Control

- ☐ Use a layer of gravel under slab to provide a path for radon and other soil gas to escape to the atmosphere rather than being drawn into the house.
- ☐ Use a vapor retarder to block soil gas entry into the house.
- ☐ See EPA website: www.epa.gov/iaq/whereyoulive.html for information about local variations in radon levels.
- ☐ Use a radon reduction system if your homes are built in Zone 1 (high radon potential).
- ☐ Include in your plans and details a sub-slab-to-roof vent system to handle high radon levels.

Wall Assemblies

CONTROLLING LIQUID WATER IN WALL ASSEMBLIES

- ☐ Install flashing at all intersections of the wall with roofs and other building elements.
- ☐ Properly flash and seal windows and doors and other penetrations through the wall.
- ☐ Specify and show in elevations building paper, housewrap, or taped insulating sheathing (rigid foam insulation) behind the exterior cladding to serve as a drainage plane.
- ☐ In walls with brick facades, provide an airspace between the brick and the drainage plane.
- ☐ For the drainage plane behind stucco cladding, include insulating sheathing, two layers of building paper or housewrap, and a layer of building paper to avoid chemically contaminating the housewrap.
- ☐ If building paper is used as a drainage plane in areas prone to severe storms, use two layers to increase resistance to leakage at fasteners and to allow for more flexible installation.
- ☐ Overlap building paper seams shingle style to shed water and properly lap at window flashing (over the flashing above the windows and to the side, and under the flashing beneath the window).
- ☐ Overlap housewrap seams shingle style and tape seams. Properly lap at window flashing (over the flashing above the windows and to the side, and under the flashing beneath the window).
- ☐ Run housewrap top and bottom edges past top and bottom plates by at least one inch and seal at the edges.
- ☐ Use overhangs to keep water away from walls and penetrations and to provide shade.

CONTROLLING WATER VAPOR IN WALL ASSEMBLIES

- ☐ Back prime wood and fiber cement cladding to avoid water saturation and migration.
- ☐ Do not install vapor barrier (e.g., polyethylene sheeting, foil-faced batt insulation, reflective radiant-barrier foil insulation) on the interior side of walls in air conditioned structures. Wall assemblies should be able to dry to at least one side and in many cases both sides of the assembly.
- ☐ Do not use impermeable coverings, such as vinyl wallpaper, on exterior walls.
- ☐ Indicate on plans the methods, materials, and locations where sealing is needed to form the house air pressure barrier. Specify the approach to be taken to meet vapor barrier code requirements.

CONTROLLING AIR INFILTRATION IN WALL ASSEMBLIES

- ☐ Properly install wall insulation to ensure cavity is completely free of voids.
- ☐ Use interior gypsum board as the interior air infiltration barrier. Tape and seal gypsum board at all joints and caulk or glue at the intersections of the wall with the floor and the ceiling.

Continued...

- ☐ Create an exterior air infiltration barrier using taped and sealed exterior rigid foam insulating sheathing to control wind washing and to keep air from entering the wall from the exterior. Note: Exterior rigid insulation is not required to meet the 40% energy-efficiency reduction goal.
- ☐ Use the ENERGY STAR Thermal Bypass Checklist.
- ☐ Install insulation and draftstopping between bathtubs, dropped ceilings, dropped soffits, and stairwells on exterior walls.
- ☐ Seal all penetrations (exterior lights, phone lines, speakers, cables, etc…) with caulk, gaskets, or other sealants.
- ☐ For occupant health and safety, verify sealing at all shared walls and ceilings between attached garages and living spaces.
- ☐ For homes with attached garages, block and seal any gaps created by joists spanning both conditioned space and the garage.

CONTROLLING HEAT FLOW IN WALL ASSEMBLIES

- ☐ Use 2x6 advanced framing techniques and specify framing details in plans.
- ☐ Insulate wall cavities that separate conditioned and unconditioned spaces with high-density, unfaced fiberglass batts, spray-applied cellulose, or spray-applied foam.
- ☐ Use spray foam to insulate and seal rim joists at areas between floors or where the wall connects to the floor (and where the wall connects to the roof in non-vented attics).
- ☐ Install taped rigid foam insulating sheathing (in addition to cavity insulation) on the exterior side of the wall to control moisture and air infiltration, eliminating double vapor barriers.
- ☐ Install efficient windows with minimum u-values of 0.3 and SHGC values of 0.4 or lower to control solar energy gains and help reduce heating and cooling loads.
- ☐ Use ENERGY STAR labeled doors.
- ☐ Use roof overhangs to provide shade and protect windows, doors, and walls.

Roof Assemblies

CONTROLLING LIQUID WATER IN ROOF ASSEMBLIES

- ☐ In areas with potentially high winds and heavy rains, apply 4-inch to 6-inch “peel and seal” self-adhering waterproofing strips over joints in roof decking before installing the roof underlayment and cover.
- ☐ Install roofing materials shingle-fashion to provide a continuous drainage plane over the entire surface of the roof.
- ☐ Properly flash roof valleys and edges including kick-out flashing at the edges.
- ☐ Size gutters and downspouts to accommodate anticipated storms. Roof drainage should carry water at least 3 feet from the building.

CONTROLLING WATER VAPOR IN ROOF ASSEMBLIES

- ☐ Install roof/attic ventilation in vented attics.
- ☐ Do not use any kind of interior vapor barrier material in the ceiling (e.g. polyethylene sheeting).

CONTROLLING AIR FLOW IN ROOF ASSEMBLIES

- ☐ Insulate and seal at the intersection between walls and roof, including attics, cathedral ceilings, and knee walls. Use blown-in foam for tight sealing of wall-roof intersection in non-vented attics.
- ☐ Tape and seal all ceiling gypsum board seams so that the gypsum board functions as an air barrier. Caulk, glue, or tape all intersections with walls and other components (soffets, fans, registers, light fixtures).
- ☐ Use draft stopping in dropped ceiling areas.
- ☐ Use ceiling light fixtures that are rated for ceiling contact (CT) and airtight (AT); install with proper trim and caulk cracks around light fixtures.
- ☐ Air seal all penetrations through plates.
- ☐ Weatherstrip and insulate attic access hatches or doors.
- ☐ Seal all penetrations through the ceiling and the roof including holes for ventilation fans, lights, wires, and plumbing.

CONTROLLING HEAT FLOW IN ROOF ASSEMBLIES

- ☐ Consider a non-vented attic.
- ☐ Install blown-in insulation at the appropriate depth on the top surface of ceiling gypsum board. Maintain the ceiling insulation level throughout the entire plane of the ceiling and over the top of the perimeter walls. A depth gauge should be visible from the attic hatch.
- ☐ Use raised energy trusses to maintain the thickness of ceiling insulation directly above the top plates of the exterior wall framing.
- ☐ In vented attics, install baffles to prevent blocking of soffit vents and wind washing (when thermal insulation is blown back from edges of attic by wind blowing through the soffit vents).

Whole-House Air Leakage

- ☐ Have building envelope tested for air leakage by a HERS rater. Air leakage should measure less than:
  - ☐ 2.5-in.^{2} per 100 ft^2 of envelope area (Canadian General Standards Board (CGSB), calculated at a 10 Pa pressure differential), or
  - ☐ 1.25-in.^{2} per 100 ft^2 of envelope area (American Society for Testing and Materials (ASTM), calculated at a 4 Pa pressure differential), or
  - ☐ 0.25 CFM/ft^2 of envelope area when tested at a 50 Pa pressure differential.
  - ☐ 3.0 SLA (specific leakage area, per California Title 24)

Mechanical Systems

HEATING AND COOLING EQUIPMENT

- ☐ Size heating and cooling equipment using ACCA Manual J.
- ☐ Specify central air conditioners at a minimum 13 SEER (10 EER) for cooling, and specify heat pumps at a minimum of 7.7 HSPF for heating.
- ☐ Install ENERGY STAR-qualified equipment.
- ☐ Install sealed combustion gas furnaces.
- ☐ Install furnaces in conditioned space.
- ☐ Install HVAC equipment equipped with brushless, permanent magnet, direct-current motors.
- ☐ Isolate HVAC system and ducts from areas with potential pollutants including garage spaces.
- ☐ Have refrigerant charge on air conditioner or heat pump verified in writing by installer to be within design specifications, using the superheat method for non-Thermostatic Expansion Valve (TXV) systems or the subcooling method for TXV systems.
- ☐ Filter HVAC return air through a 4-inch standard filter or a new Minimum Efficiency Reporting Values (MERV) 8 normal-thickness filter. Make the filter easy to access for cleaning or replacement and design the filter slot so there is no air bypass around the filter when the HVAC system is operating. The maximum air velocity through the filter should not exceed 400 fpm.
- ☐ Keep pressurization balanced from room to room by providing individual room ducted returns for each room or by providing jump ducts or transfer grilles located in the walls of each room. Use flex duct and staggered grille locations or ducts lined with sound absorbent material to minimize sound transfer through jump ducts.

DUCTS

- ☐ Specify location, size, and type of ducts and registers on construction plans. Include heating and cooling ducts, passive return air ducts or transfers, location of the mechanical ventilation air inlet, and the locations of all exhaust outlets. Indicate the location of dedicated chases for ductwork.
- ☐ Place ducts and air handlers in conditioned space when possible. It is also acceptable for attic ducts to be buried in insulation as described in the California Title 24 code.
- ☐ Size ducts using ACCA Manual D.
- ☐ Use ducts made of galvanized sheet metal, duct board, or flex duct.
- ☐ Keep duct runs as short as possible. Consider using a central duct chase in a dropped hallway ceiling with registers located along it providing air directly to rooms along hallway.

Continued...

- ☐ Provide a continuous vapor barrier on insulated ducts running outside conditioned spaces, by use of proper duct sealing techniques (e.g., mastic).
- ☐ Use these duct sealing materials
  - ☐ For metal ducts: UL 181 mastic
  - ☐ For duct board: UL 181 tapes
  - ☐ For flex duct: a combination of UL 181 mastic and strap ties.
- ☐ Verify duct air leakage with a duct pressure test. The leakage should be no more than 5% of the total air handling unit air flow (at high speed) when tested at 25 Pa pressure.
- ☐ Seal drywall connections to ducts with caulk or foam sealant.
- ☐ Insulate ducts in unconditioned spaces. Insulate supply ducts to R-8 minimum and return ducts to R-4 minimum.
- ☐ Insulate ducts in conditioned space to R-8 for supply and R-4 for return ducts to avoid condensation formation.
- ☐ Equip each bedroom with a separate return duct, transfer grille, or jump duct.
- ☐ Don't use "pan" ducts in spaces between joists and in stud cavities as supply or return air ducts.
- ☐ Don't locate ducts in exterior walls.
- ☐ Seal any return-air ductwork or air handler located in the garage with UL 181-approved mastic.
- ☐ Don't put air handler in garage unless it is in a sealed closet.

VENTILATION

- ☐ Install whole-house mechanical ventilation compliant with ASHRAE Standard 62.2.
- ☐ Provide a fresh-air intake ducted to the return air side of the air handler to provide fresh air and air pressure balancing for homes ventilated primarily with exhaust-only kitchen and bath fans.
- ☐ Filter ventilation air through a 4-inch standard filter or a new Minimum Efficiency Reporting Values (MERV) 8 normal-thickness filter. Make the filter easy to access for cleaning or replacement and design the filter slot so there is no air bypass around the filter when the HVAC system is operating.
- ☐ Install ENERGY STAR-qualified low-sone exhaust fans in bathrooms and kitchens. Sone ratings should not exceed 1.5.
- ☐ Seal bathroom and kitchen fans to drywall with caulk or gaskets.
- ☐ Equip outdoor air intakes and exhausts with automatic or gravity dampers that close when the ventilation system is not in operation.
- ☐ Consider installing a night ventilation cooling system in appropriate subclimates.

PLUMBING

- ☐ Locate bathrooms and other hot water-consuming activities near each other in house layout.
- ☐ Centrally locate water heater to minimize piping trunk lengths.
- ☐ Bury plumbing in attic insulation for single-story, slab-on-grade homes and in interstitial space between floors for multi-story homes.
- ☐ Install code-permitted or manufacturer-approved minimum size lines.
- ☐ Insulate hot water supply lines to R-4.
- ☐ Insulate tanks to at least R-12.
- ☐ Use a central manifold (homerun) water distribution system.
- ☐ Use PEX (high-density polyethylene) piping. Do not specify PEX pipes connected directly to water heaters or solar collectors.
- ☐ Do not install continuous recirculation pumping systems on hot water lines. Use on-demand switch if recirculation controls are desired to minimize the energy penalty of a circulation system.
- ☐ Use gas-fired instantaneous power vented or direct vented water heaters inside conditioned space.
- ☐ Consider alternative technologies like on-demand gas or electric water heaters, solar thermal water heaters, and ground source heat pumps for water heating. If using solar-thermal water heating, integrated collector storage systems are the least expensive and work well in areas with a low threat of freezing temperatures. Other systems are available for areas that experience freezing.
- ☐ Use unglazed solar pool water heaters on all spas and swimming pools in the hot-dry and mixed-dry climates, and use two-speed pumps and controls to reduce energy.

ELECTRICAL

- ☐ Use ENERGY STAR-qualified compact fluorescent lights (CFLs) in all fixtures expected to be on more than 2 hours per day.
- ☐ In California, follow these lighting requirements which were updated in 2008 and become effective August 1, 2009. All CFLs are pin-based CFLs.
    - ☐ Kitchens: At least half the installed wattage of luminaires in kitchens shall be high efficacy and the ones that are not must be switched separately.
    - ☐ Bathrooms, garages, laundry rooms, and utility rooms: All luminaires shall either be high efficacy or shall be controlled by a manual-on occupant sensor.
    - ☐ Other rooms: All luminaires shall either be high efficacy or shall be controlled by an occupant sensor or dimmer. Closets that are less than 70 ft^2 are exempt from this requirements.
    - ☐ Outdoor Lighting: All luminaires mounted to the building or to another building on the same lot shall be high-efficacy luminaires or shall be controlled by a photocontrol/motion sensor combination.

Continued...

- ☐ Use recessed ceiling lights that are ICAT rated (approved for insulation contact and air tight).
- ☐ Use occupant sensors, photocells, and motion sensors to automate lighting operation.
- ☐ Use air-sealed electrical boxes in all exterior walls and ceilings adjacent to unconditioned attics.
- ☐ Use ENERGY STAR-qualified appliances.

OCCUPANT HEALTH AND SAFETY

- ☐ Use only sealed combustion or power-vented combustion appliances in conditioned space.
- ☐ Direct vent gas cooking ranges to the outside.
- ☐ Do not use combustion appliances that rely on passive combustion air supply openings or outdoor supply air ducts that are not directly connected to the appliance.
- ☐ Use sealed-combustion gas fireplaces to eliminate the threat of harmful combustion gases enterring the house.
- ☐ Use filtration systems for forced air systems that provide a minimum atmospheric dust spot efficiency of 30% or MERV (Minimum Efficiency Reporting Value) of 8 or higher.
- ☐ Maintain indoor humidity in the range of 30% to 60% by controlled mechanical ventilation, mechanical cooling, or dehumidification.
- ☐ Install carbon monoxide detectors (hard-wired units) (one approximately every 1,000 square feet) in any house containing combustion appliances and/or an attached garage.
- ☐ Maximize hard surface areas (tile, vinyl, hardwood) to enable homeowners to better manage dust for health purposes. For slab-on-grade houses, this also reduces cooling loads.
- ☐ Provide occupants with information on the safe, healthy, operation and maintenance of the building systems that provide control over space conditioning, hot water, and lighting.
- ☐ Ventilate attached garages with a 100 cfm (ducted) or 80 cfm (un-ducted) exhaust fan, venting to outdoors and designed for continuous operation. Or, install automatic fan controls that activate the fan whenever the garage is occupied and for at least 1 hour after the garage is vacated.
- ☐ Completely seal the garage from the conditioned areas of the house to keep car exhaust and chemical fumes from entering home.
- ☐ Use low-VOC paints, finishes, varnishes, and adhesives whenever possible.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 11. Construction and Contract Documents

CHAPTER TOPICS

Good plans, showing features such as duct sizing and layout, framing details, and flashing specifications are critical to building high-performance homes. Plans are important to show where building elements are to be located and how those elements tie together with other building components. But construction documents should be more than a set of plans and accompanying specifications needed to get building permits and planning approval. Scopes of work are needed to communicate expectations with trades contractors. Job-ready and job-complete checklists are needed to ensure that each trade contractor is handing off a work environment that is ready for the next trade, and that jobs are completed as specified.

Improved construction documents facilitate communication between construction managers, site supervisors, and subcontractors. These documents should make clear what subcontractors should be doing with what materials, and what they should not be doing. Get the construction documents right and decisions will be made by designers, engineers, and managers, *not on the fly* in the field. Using construction and contract documents as tools for communication and site supervision makes these tools part of a quality management program as described in Chapters 3 and 12.

Plans and Specifications

Plans and specifications are the most familiar parts of construction documents. Elevations, floor plans, and details show codes officials that projects meet code minimums. Construction managers and field crews often refer to plans in the building process. Plans and materials schedules are important for ordering materials.

Plans and specifications can do more than show minimum code compliance. Detailing in plans how building components fit together takes the guesswork out of field installation. Designers think through how buildings should come together at the front end of the construction process, rather than forcing site supervisors and installers to repeatedly (and possibly incorrectly) make these calls in the field. Documentation should address the following examples of building features related to energy efficiency:

- Provide framing diagrams and details to spell out advanced framing techniques and the placement of all framing members. This topic is discussed in Chapter 7.
- Show duct sizes and layouts on floor plans and elevations, as discussed in Chapters 9 and 10. Specify and indicate on plans the methods, materials, and locations where sealing is needed to form the house air pressure barrier as discussed in Chapters 6, 7, and 8. Specify the approach to be taken to meet vapor barrier code requirements.
- Specify and indicate on plans the methods, materials, and locations where rain screens and barriers will be installed. Examples may include housewrap, sealing materials, flashing systems, gutter systems, and grading requirements as discussed in Chapters 6, 7, and 8.
- Provide plans and details for all specialized building features, such as sealed and conditioned attics, sealed and conditioned crawlspaces, sealed and insulated air handler closets in garages, and radon control measures.

Scopes of Work

A scope of work is a description of the specific work that builders expect trade contractors to perform. Every contract, including those executed with only a nod and a handshake, incorporates a scope of work. Builders and consumers should get what they pay for. In some cases, this may mean the builder needs to spend more to get an improved product. However, without a clear understanding of the task that can be conveyed to the trade contractors, and especially to the installer, the expectations for what a task entails can be all over the map.

Most builders' scopes of work have evolved over time and meet the basic legal and production tests necessary for the day-to-day new home construction operation. As materials change and techniques evolve, scopes of work must change to keep up. Front offices should give construction managers, trade contractors, and designers plenty of opportunity to review and update scopes of work. These reviews can happen any time, but are especially important before big trade contracts are initiated, and just after projects are completed.

Construction details, contract specifications, and written assignments of responsibility can greatly simplify the ordering of materials. Duct installers, for example, will know exactly what type of duct material will be used and the required quantities. With this knowledge, most likely confirmed with site visits, they may be able to prefabricate many of their assemblies back at the shop, rather than in the field. These pre-assembled pieces tend to be of higher quality thanks to the proximity of tools and materials and better working conditions in the shop.

This is not to say that field installers don't have good ideas. They often do have great ideas; for this reason construction managers need to continue to improve the guidance provided in construction documents. Get your ideas and your installer's ideas into the construction documents, and make revisions when new ideas surface.

Scopes of work should take into account sequences of work that are unfamiliar to trade contractors. If designs incorporate materials or approaches that are new to a market, emphasize this approach in plans and in scopes of work. One example of a new building approach could be putting duct chases in dropped ceilings. A "Field Guide for Installers" describes this process in Chapter 13.

Building America is in the process of developing high-performance scopes of work intended to serve as models for builders and trade contractors. These models will include unique requirements for design, specification, installation, inspection, and testing that will facilitate the construction of high-performance homes. High-performance scopes of work differ from conventional scopes of work in that they include

- industry-recommended best practice for design and specification
- coordination and integration between trade contractors, and between contractors and the designers or engineers, when required
- performance testing whenever possible, tied to successful job completion.

The high-performance statements of work include sections directed to office functions, related to legal requirements, penalty clauses, payment provisions, and schedules; and sections related to field installation, which are described in more detail in the following sections.

Field Scope of Work

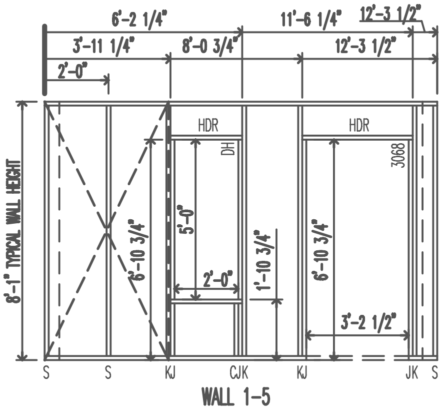
The field scope of work section explains to the trade contractor what measures must be installed, how each should be installed, which materials and equipment are acceptable, and the tolerances or performance requirements that the contractor must meet or exceed. As much as possible, this document includes pictorial representations of installation instructions for clarity.

Job-Ready and Job-Complete Checklists

Job-Ready and *Job-Complete Checklists* are two parts of high-performance scopes of work that are especially important for establishing expectations and managing trade contractors. When checklists are used, less detailed field supervision of subcontractors is required, fewer return visits are needed, scheduling is easier and work process flows more smoothly, production times are shorter, and ultimately there are fewer callbacks from homebuyers.

The *Job-Ready Checklist*, to be completed jointly by the site supervisor and trade contractor, includes all items that must be installed or prepared on the jobsite—by other trade contractors—before work can begin. Items in the *Job-Ready Checklist* are not directly under the control of the trade contractor getting ready to work, but they directly affect his or her ability to successfully and efficiently complete the job. The *Job-Ready Checklist* should be part of the scope of work because it highlights the ways in which one trade contractor's work is connected to another's and encourages trade contractors to think of their individual work as part of a larger whole.

The *Job-Complete Checklist* is the mechanism by which the trade contractor certifies that the work has been completed to the high standard expected and for the site supervisor to agree that the work was completed satisfactorily. To verify that the high performance features of the home were constructed correctly according to the scope of work, performance testing



Provide framing diagrams to spell out advanced framing techniques.

is often part of a *Job-Complete Checklist*. The *Job-Complete Checklist* holds both the builder and the trade contractor responsible for proper implementation and appropriate inspection of the scope of work. Properly defined and implemented, the *Job-Complete Checklist* functions both as a part of the *Job-Ready Checklist* for subsequent trade contractors and as a field authorization of payment for the completed work.

Trade Contract Provision Summary

Establishing clear contract documents helps to establish clear expectations with trade contractors. Ensure that trade contracts include the following provisions adapted from the NAHBRC Toolbase:

- Trade contractors are contractually obligated to ensure that workers fully understand field specifications and builder quality assurance processes using pre-job and post-job checklists.
- A competent crew leader will be in charge of all crews and able to communicate with the builder's site supervisor.
- Trades must self inspect each phase of work, using the pre-job and post-job checklists, before reporting the work complete to the site supervisor.
- All work must be completed in accordance with field specifications, applicable building codes, and industry standards.
- Trades must identify recurring errors in their work and train crews as needed to reduce similar errors. Training approaches are described in Chapter 12, including Hot Spot training, a graphics-based intervention that illustrates the right and wrong ways to do a task.
- Trades will confirm in writing that all materials and equipment were installed according to field specifications and manufacturer's instructions. One approach to this requirement would be to use post-job checklists. Copies of both field specifications and the manufacturer's instructions should be available on the job site.

Additional Information on Developing Quality Management Programs

NAHBRC. 2000. *Quality Assurance System for Wood Framing Contractors: National Quality Housing*. U.S. Department of Housing and Urban Development. www.pathnet.org/si.asp?id=478

NAHBRC. 2006. "Quality Matters: Six Ways to Improve Trade Contracts." *ToolBase News*, Summer 2006: Volume 11, Issue 3. www.toolbase.org/Newsletters/News/tbn-summer2006#5

NAHBRC. 2008. "Building Management." www.toolbase.org/ToolbaseResources/level 3.aspx?BucketID=5&categoryID=24

IBACOS. *High Performance Scopes of Work*, Prepared for the U.S. Department of Energy. www.ibacos.com/pubs/High_Performance_Scopes.doc

Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

Builders Challenge Guide to Achieving 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 12.
Site Supervision and Construction

The construction process brings together piles of materials, seeming armies of trades subcontractors, and site supervisors—all the ingredients to turn ideas into homes. Getting it right requires having the proper plans, contracts, permits, and materials, in combination with properly trained and competent installers, scheduled at the right time.

This chapter focuses on the people who work out in the field building houses. Key topics that can help smooth the construction process include

- using construction and contract documents
- training
- scheduling work
- inspections and testing.

Building high-performance homes with a 40% improvement in energy efficiency has more to do with quality installation than exotic new equipment or unfamiliar features. Efficiency happens through the careful selection of high-performance equipment and materials and consistent, quality installations. In short, achieving energy efficiency is greatly aided, and may only be possible, by a commitment to quality assurance.

CHAPTER TOPICS

Use Construction and Contract Documents to Describe What You Want

Clearly stating what is wanted is a critical step in acquiring a desired objective. Much of what quality management is about involves tools to help communicate to subcontractors what the expectations are for a task or project. Site supervisors help to communicate expectations with every interaction involving subcontractors and company installers. A powerful way to communicate expectations is for your company to explicitly include them in contractual construction documents. Construction documents are described in Chapter 11.

Construction documents may include plans, scopes of work, and checklists. In order for these documents to be accurate and effective, they need the input of site supervisors and quality inspectors. Site supervisors should review construction documents before they are

Need information about something new?

The U.S. Department of Housing and Urban Development Pathnet website (www.pathnet.org) contains descriptions, installation instructions, case studies and videos on buildings systems and new technologies. Visit www.pathnet.org/sp.asp?id=10787 to view PATH TV. PATH stands for the Partnership for Advanced Housing Technology.

Cooling the HotSpots

Identify quality issues through job inspections, builder feedback, and comprehensive quality reviews. Include the problems that show up on your punch lists time and again.

Add HotSpot checkpoints to the inspection form where improvement is needed.

In weekly production meetings HotSpot inspection forms are distributed and discussed. Site supervisors are trained on procedures to prevent those problems. The training uses one-page diagrams that address specific problem areas.

In toolbox talks, site supervisors and contractor supervisors use the diagrams to train crews.

Site supervisors monitor the use of the new processes and the quality of installations. HotSpot inspection forms are used by supervisors on every job. Results provide feedback on the effectiveness of the improvements.

Celebrate success. When HotSpots are no longer an issue, remove them from the HotSpot list and put them in a reminder section. In time, items may leave the inspection form altogether.

Adapted from the ToolBase News, Summer 2005: Volume 10, Issue 3 (September 2005), available at www.toolbase.org/Newsletters/NewsDetail.aspx?ContentDetailID=1308#5, and the ToolBase Resources Website at www.toolbase.org/Best-Practices/Business-Management/Hot-Spot-Inspections. This website includes examples of HotSpot inspection forms.

folded into contracts and should continue to provide recommendations and comments as construction documents are put into practice to make them as effective as possible.

The popular management term for ongoing feedback and dialogue is "continuous improvement," a term coined by W. Edwards Deming. The point here is that when workers in the field find ways to improve designs or construction processes, that information needs to be communicated back to designers and managers so that documentation can capture those improvements. Although individual improvements may seem small, getting them into construction documents helps them add up to superior buildings in the field.

Train Installers

Contract and construction documents should describe designs, specify materials, and illustrate how buildings fit together. However, these documents do not typically show subcontractors and staff how to do the work. Training can come in many forms, including hands-on instruction, manufacturers' instructions, installation guides, web-based videos, and classroom training.

At the beginning of a job, schedule a meeting with all of your subcontractors present to review required interactions, particularly for novel energy features. This will help identify training needs.

Meet with your subcontractors. Whether it is over a conference table or a tailgate, whether the discussion is led by you, a consultant, or an installation crew supervisor, tell contractors what you want and show them how to do it. Training need not involve days off the worksite sitting in big lecture halls. Hands-on training is the most common approach and can happen constantly. Chapter 13 contains resources to help train your subcontractors and staff.

Manufacturers provide installation instructions with most products. Manufacturers also make available Material Safety Data Sheets. Go through the instructions with installers and make copies of all these documents available for installers to check as needed.

HotSpot Inspections and Training

Systematically checking work is an important aspect of quality construction. As part of the National Housing Quality Program, the NAHB Research Center and a group of framing contractors and builders developed the idea of HotSpot Inspections and HotSpot Training. A "HotSpot" is a recurring issue that requires some form of remediation in order to get a site ready for the next trade or a home ready for move-in by a buyer.

The idea is to focus inspections and training on the construction processes that are failing. HotSpot checkpoints are constantly adjusted. As new problems are added and solved, problems are removed from scrutiny. The NAHB Resource Center describes a quality improvement process using HotSpot Inspections and Training based on an inspection form.

Training is a key part of the HotSpot process. In order to correct and discontinue the actions that cause an identified hot spot, the field training process has to be simple, specifically focused, and relevant to the regular activities performed at a jobsite. HotSpot training for a builder's key trade contractors should be seamlessly integrated into normal daily production activities on the jobsite. HotSpot training materials should also be brief and highly visual, to minimize language barriers on jobsites and increase the likelihood that a HotSpot issue will not be repeated. The use of a single sheet of paper for HotSpot training with "correct" and "incorrect" photos or other graphics can be very effective.

Sample HotSpot Form

HOTSPOT INSPECTIONS

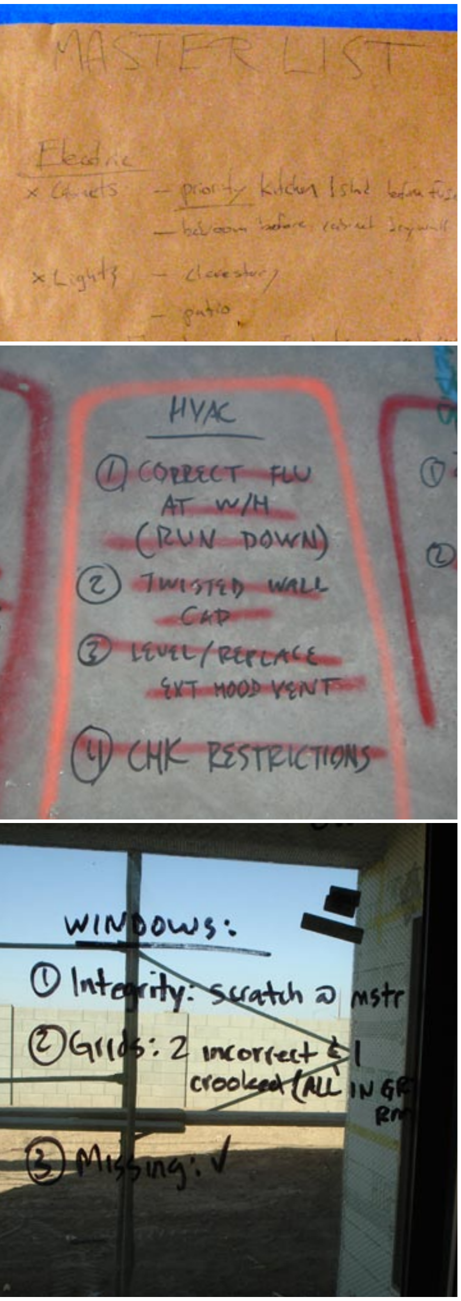
Job Inspection Record-Schuck and Sons Construction

Date:	Release #:	Sequence #:	Production #:	Unit #:	Lot #:

Inspector/Date:

Key Requirements (for review)	HotSpots (must be verified)
Layout: ➢ Accurate foundation dimensions ➢ Square foundation ➢ Flat foundation ➢ Safe site conditions	Supervisor: _______________ ❑ Back to front max deviation: __________ ❑ Side max deviation: ____________ ❑ Square deviation: ___________ ❑ Flat max deviation: ___________
Exterior walls: ➢ Window size, level, and plumb ➢ Temporary power ➢ Header sizes ➢ Shear properly nailed ➢ Strap location and nailed properly ➢ Walls plumb ➢ Window margins even, level sill, & plumb trimmers ➢ Glass block opening size, plumb & level ➢ Backing for interior wall connections ➢ Swept out house	Foreman:_______________ ❑ Studs flush with inside of bottom plates ❑ Tower walls & patio columns strapped & srp4 on studs and fire stopped ❑ Proper number of trimmer & king studs at openings
Interior walls: ➢ Temporary power ➢ Walls plumb ➢ Skylights framed in and straight & plumb ➢ Wrapped openings plumb, sides straight, header level, and bottoms square ➢ Nitches level & plumb ➢ Drops lined & tied up ➢ Interior shear walls frames and tied ➢ Fire stop ➢ Ceiling backing ➢ Swept out house	Foreman:_______________ ❑ Small bottom plates secured by glue ❑ Closet openings plumb, level & double studs at opening [insert] ❑ Garage door backing 99" sides, 119" center ❑ Pony wall level top, plumb ends
Trusses: ➢ Temporary power ➢ Hang backing installed ➢ Sway bracing installed with gable ties ➢ Gable vents ➢ Swept out house	Foreman:_______________ ❑ Nailing of H-1's and H-2.5's
Roof foreman:________________ ➢ Temporary power ➢ Overhangs proper length ➢ Face straight ➢ Pigeonhole size ➢ Nailing per layout marking ➢ Skylight opening with plumb trusses and curbs built ➢ OSB gapped on roof ➢ Fireplace stack built & installed (where necessary) ➢ Swept out house	❑ OSB nailed where over-framing occurs

Field Guides for Installers are included in the next chapter. These tips are not specific to any one manufacturer or product, but they offer general guidance on installation and may discuss issues that may not be covered by the manufacturers. These issues include proper placement of materials, general installation techniques, material incompatibilities, the order that particular materials should be installed in relation to other materials, and suggestions for which trades should do the installation.



Make your expectations clear with on-site meetings and visible inspection checklists.

DOE Building Energy Codes Resources

Code Notes provide references to specific sections in the codes to reassure code officials that efficiency measures are in full compliance. Topics are added to the Code Notes over time. Code Notes can be downloaded from DOE's Building Energy Codes Resource Center at www.energycodes.gov/support/code_notes.stm

Installers are not the only people who may need training. In some cases it is necessary to educate code officials. Code officials may be unfamiliar with some of the recommended construction techniques. It is well worth your while to raise these issues with codes officials before construction begins so that you're not surprised by a red tag later.

DOE's Building Codes Program has developed a series of Code Notes that describe several energy-efficient construction practices in language directed specifically at code officials.

For information on specific building systems, see Chapters 5 through 9 of this document. Other sources include:

Building Energy Codes Resource Center – http://resourcecenter.pnl.gov/

Building America – www.buildingamerica.gov

Energy and Environmental Building Association – www.eeba.org

Building Science Corporation – www.buildingscience.com.seminars.com

National Association of Home Builders Research Center – www.nahbrc.org

Southface Energy Institute – www.southface.org

IBACOS – www.ibacos.com

Other sources may include regional universities or Cooperative Extension Service programs, homebuilder associations, utilities, and codes programs. For example, Louisiana State University published a book on building homes in Louisiana (Reichel et al. 2002). More specialized training is available at the above sources, plus trade organizations, such as:

Air Conditioning Contractors Association – offers technician certification
www.acca.org

American Architectural Manufacturers Association – offers window installation master certification
www.installationmastersusa.com

The web provides a free and easy method to train crews. The California Energy Commission offers on its website a series of brief videos, lasting only a few minutes each, that cover many installation processes. Visit www.energyvideos.com for access to dozens of videos.

Scheduling

Building an energy-efficient home requires careful attention to scheduling. Several of the new construction techniques may require changing the order of subcontractors; some require (or benefit from) a shifting of responsibilities from one sub to another; and some new activities will need to be added into the schedule. Here are examples of some of the more important schedule considerations:

- Schedule HVAC rough-in before plumbing and electrical. It is far more important for the ductwork to have un-constricted access and pathways than it is for wires or pipes. However, be sure needs for other systems, such as drain pitch, are coordinated.
- If using a conditioned attic, schedule insulating under the roof deck before HVAC rough-in. The insulators must be able to do their job without tromping on the carefully placed ductwork.

- Be sure to schedule caulking of electrical and plumbing penentrations before the drywall is completed and affter the lines have been installed.
- Don't forget to schedule for pipe insulation under the slab.
- Be sure to schedule pre-drywall insulation inspections, flashing inspections, and envelope and duct pressure tests. Inspect at key points to ensure that insulation and envelope sealing take place before areas become inaccessible. Inspections are much more likely to happen if scheduled, and subcontractors may be a bit more conscientious if they know their work will be evaluated.
- If ducts are installed in conditioned space, drywall must be installed behind duct chases and soffits before they are framed.

Some situations that may require a shifting of responsibilities include the following:

- If using advanced framing techniques that include two-stud corners and floating drywall corners, someone must attach drywall clips. The framer is a more likely candidate than the drywall installer for framing modifications.
- Some caulking work needs to be done by the HVAC subcontractor. In particular, the main supply and return trunks that lead through the walls need to be caulked by the person connecting them to the equipment. Don't let the drywall finisher do this with mud—it is neither a good sealant nor durable enough. Also, all duct terminations, including jump ducts, must be sealed when registers are installed.
- Some post-finish caulking can be avoided by having the electrician use pre-fabricated air-tight electrical boxes.
- If installations of windows and drainage planes are done by different subs, the window installer must be careful to leave flashing unattached at the bottom so that the first row of building paper may be tucked under it (see Chapter 13 for an installer's guide to window flashing, housewrap, and sealants).
- If you are using insulated headers, the framer will need to install insulation inside any double headers (using sandwiched foam insulation). Open headers may be left for the insulation contractor. Pre-fabricated, insulated headers are another alternative.
- Draft stops must be installed behind bathtubs and stairwells on exterior framed walls as well as attic knee walls. The framer or insulator should do this, but be sure that insulation is installed before the draft-stop material goes on.

Efficient scheduling of subcontractors can bring huge rewards in reduced costs and improved quality.

Inspections and Tests

Conduct systematic inspections during the course of construction. A checklist for designers in Chapter 10 contains many of the provisions that site supervisors should look for and work to include. General walk-throughs and inspections are especially good at critical times during construction before the next step makes it impossible to detect a problem or make a repair.

Especially when energy-efficient systems-designed housing is new to your subcontractors, you should conduct multiple inspections to ensure that the subcontractors have understood

Pulte Homes pushed production building to a new level at its Sun Lakes development in Banning, California, taking homes from start to finish in 55 days – twice typical local construction builder output. All of the homes were built to meet the Environments for Living™ platinum level for energy efficiency.

Pulte achieved these remarkable construction times by preassembling some building components, offering a limited number of options, and implementing an innovative construction method of sequentially building five houses at a time on each side of the street. This process kept trade contractors consistently employed and promoted an unusually high amount of cooperation on site.

"In all my years in the construction business I have not seen such remarkable cooperation among subs and management. Every visit to the site I'm approached by everybody from the installers to management anxiously asking how we're doing and how we can improve."

Bill Irvine, of BCI Testing, a Building America field testing partner on the Pulte Sun Lakes Project

(top) Duct blaster testing confirms that ducts are well sealed *(Source: NREL)*

(bottom) Before the drywalling starts, you should conduct a pre-drywall inspection to test ducts and make sure insulation is properly installed.

"You can expect what you inspect."

Dr. W. Edwards Deming, the originator of total quality management

"Monitoring progress is the only way you are going to change behavior."

Nat Hodgson, Vice President of Construction, Pulte Homes Las Vegas Division

what is required of them and how to implement it. After the process has become more routine, you might get by with spot inspections.

One key inspection should occur prior to installation of drywall. The pre-drywall inspection allows you to ensure that insulation and draftstopping have been properly installed before they get permanently enclosed. This is also the best time to conduct a pressure test on the ductwork. The duct pressure test should be conducted with the HVAC contractor present, at least for his or her first several energy-efficient homes. If the ductwork fails to meet the pressure criteria, a smoke test will reveal the worst leaks. It is crucial that this happen while the ductwork is still visible and the HVAC contractor is present to see what the problem areas are.

The HVAC contractor should also test the system to ensure that thermostats and zone dampers are operating correctly and that bypass dampers are properly adjusted.

Duct testing services can be most easily obtained through a certified HERS rater. The rater can also conduct whole-house pressure tests and assist with training. And the HERS rating itself can be a valuable marketing tool for an energy-efficient house. To identify a certified rater in your area, check the registry at the Residential Energy Services Network (RESNET) website: www.natresnet.org.

Another important inspection comes after completion of the home, including all interior and exterior finishes. This pre-occupancy inspection should check for proper sealing of electrical and plumbing (fixtures and drywall penetrations), HVAC registers, and the HVAC closet. A whole-house air leakage test (aka "blower-door" test) is crucial. Again, your HERS provider is the easiest resource for this service, and this is when he or she would be rating the home anyway. You or your HERS rater should verify that any specified energy-efficient lighting and appliances were installed. Also, if your HVAC contractor has not done it, a final check of the AC or heat pump refrigerant charge is crucial. Studies have shown that incorrect refrigerant levels can lower efficiency by 5% to 20%. (*Heating and Cooling Sizing and Installation* www.energystar.gov/index.cfm?c=heat.cool.pr_properly_sized).

General inspections are helpful at spotting problems, but not necessarily helpful at solving them. One approach that can help you avoid problems is to use pre-job and post-job checklists. Building America teams have worked with builders and experts in the area of quality assurance to develop sample checklists and statements of work that can help in working with subcontractors. Examples of pre- and post-job checklists are available in Chapter 11.

To make these checklists a tool that helps save time and improve quality, a key step is to encourage trades contractors to complete the checklists themselves before and after they start work on a house. The prejob checklists will help ensure that the proper materials are available and the structure has been adequately prepared for their task. The post-job checklist helps to ensure that work meets necessary standards before the site supervisor needs to render an opinion. Self-evaluation makes the checklists an important part of routine work flow. Work with trade contractors and manufacturers to prepare inspection checklists that are specific to your house features, climate, and materials.

Earlier in this chapter HotSpot training and checklists were described. Using these checklists requires active identification of the causes of the problems, understanding the solutions, and communicating those points to work crews. HotSpot checklists and training and pre-job/post-job checklists can tie together many aspects of quality assurance and site management.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Chapter 13.
Field Guide for Installers

On the following pages you will find step-by-step, easy-to-follow illustrated instructions for implementing key energy efficiency technologies.

These guides are designed to be easily duplicated and distributed. Hand them to your subcontractors when you meet with them at the jobsite, to help them understand what you expect.

- Advanced Framing
- Slab Foundation System Moisture and Air Leakage Control
- Housewrap
- Window Flashing
- Interior Air Sealing
- Exterior Air Sealing with Insulating Sheathing Panels
- Air Sealing - Glossary
- Fiberglass Insulation
- Duct Location
- Air Handler & Duct Sealing
- Radiant Barriers

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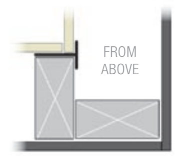
Advanced Framing

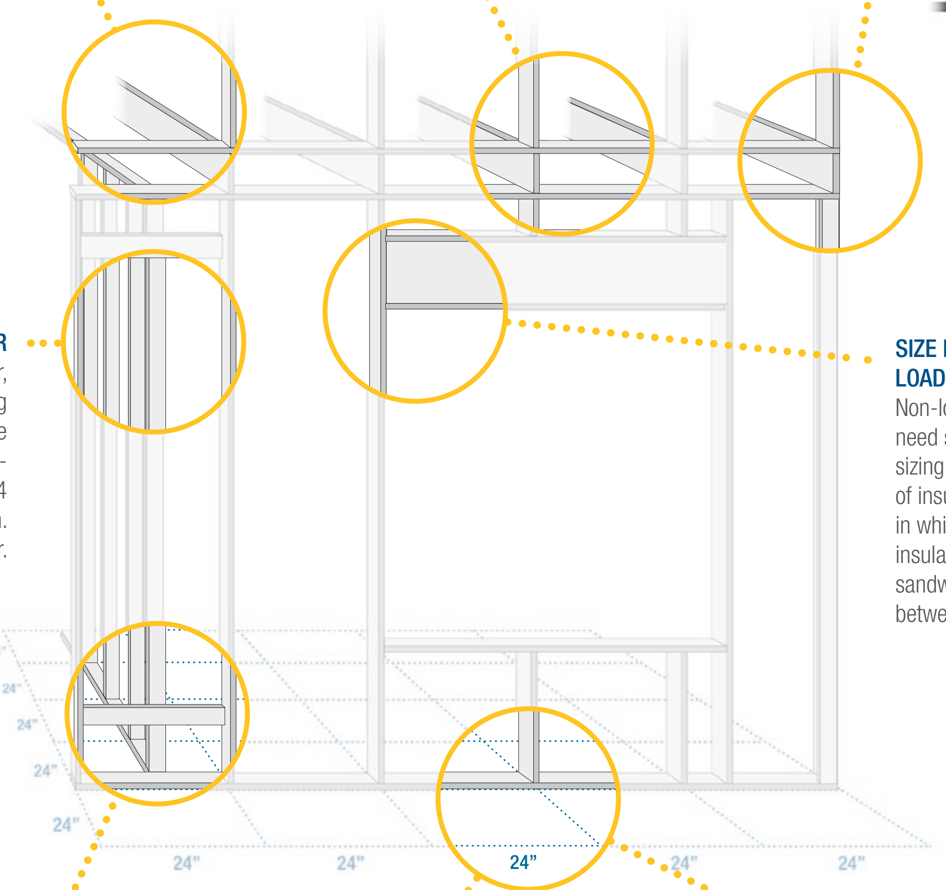
The following tips show examples of framing techniques that can create more open space to hold insulation while reducing framing cost and waste. The following page shows a typical framing plan which should be included in construction documents.

ELIMINATE REDUNDANT FLOOR JOISTS: Double floor joists aren't needed below non-load-bearing partitions. Partitions parallel to overhead floor or roof framing can be attached to 2x3 or 2x4 blocking. Nailing directly to the sub-floor provides adequate support.

ALIGN FRAMING MEMBERS AND USE A SINGLE TOP PLATE: Plate sections are cleated together using flat plate connectors. For multistory homes, this may increase the stud size on lower floors to 2x6.

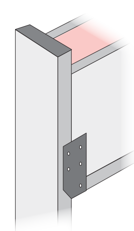
USE TWO-STUD CORNERS: Rather than using a third stud as a nailing edge for interior gypsum board, use drywall clips, a 1x nailer strip, or a recycled plastic nailing strip. Using drywall clips also reduces drywall cracking and nail popping.





USE 2X3s FOR PARTITIONS: Interior, non-load-bearing partition walls can be framed with 2x3s at 24-in. on center or 2x4 "flat studs" at 16-in. on center.

SIZE HEADERS FOR ACTUAL LOADING CONDITIONS: Non-load-bearing walls do not need structural headers. Proper sizing may allow for the use of insulated headers in which foam insulation is sandwiched between lumber.

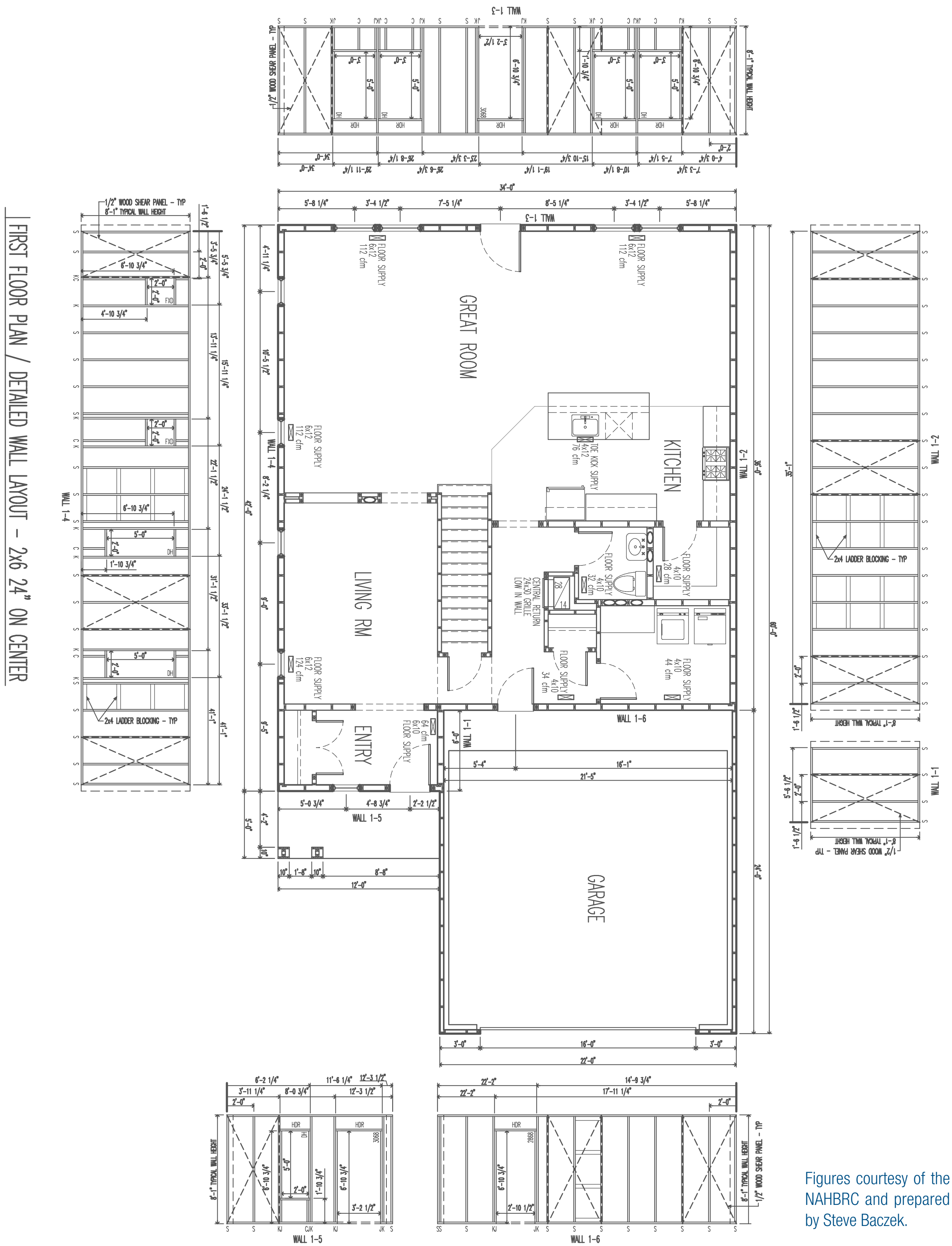


LADDER-BLOCK EXTERIOR WALL INTERSECTIONS: Partitions can be nailed either directly to a single exterior wall stud or to flat blocks inserted between studs.

TWO-FOOT MODULE DESIGN: Starting with the foundation, the house footprint should be based on 2-foot increments. Layouts should be based on this 2-foot grid to minimize material waste.

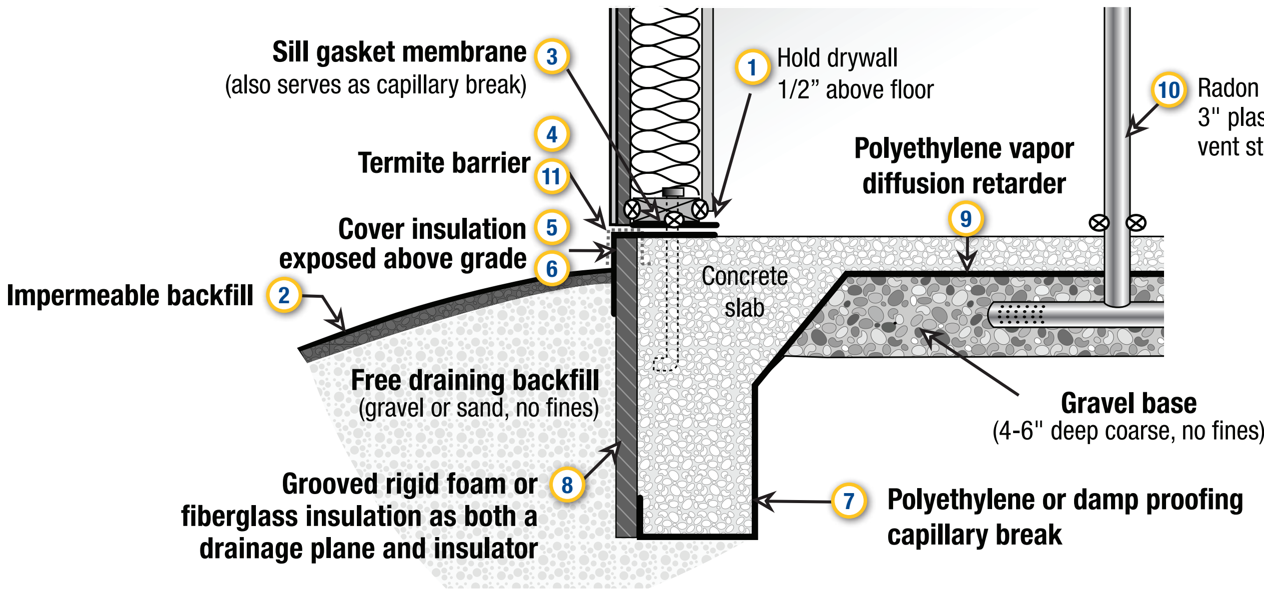
FRAME 24-IN. ON CENTER: 24-in. on center studs are structurally adequate for most residential applications. Even when the stud size must be increased from 2x4 to 2x6, 24-in. spacing can significantly reduce framing lumber needed.

An example of a detailed wall framing layout. Use detailed layouts like this to make sure studs align from first floor to second floor to roof.



Figures courtesy of the NAHBRC and prepared by Steve Baczek.

Slab Foundation System Moisture and Air Leakage Control

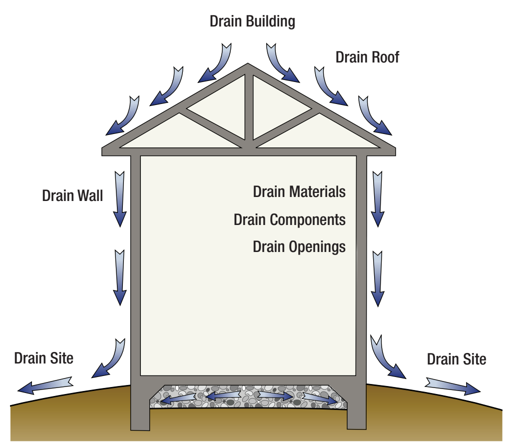


1. Keep all untreated wood materials away from contact with earth and concrete.
2. Slope dirt, driveway, patios, etc., away from the house and ensure that no irrigation strikes near the foundation.
3. Use a sill gasket for air sealing and capillary break from foundation.
4. Install a protective shield such as metal flashing, plastic L bracket, or a membrane (such as EPDM flexible roofing material*) to block capillary water wicking into the wall from the foundation. The protective shield may also serve as a termite shield.
5. Damp proof the exposed portion of the foundation with latex paint or other sealants.
6. Exterior foundation wall insulation requires a protective coating at above-grade applications. Examples of protective coverings for exterior, above-grade insulation include flashing, fiber-cement board, parging (stucco type material), treated plywood, or membrane material (EPDM* flexible roofing).
7. Install bituminous damp proofing, masonry capillary-break paint, or a polyethylene sheet under the footing to block capillary water wicking into the foundation side wall.
8. Place a continuous drainage plane over the damp proofing or exterior insulation on foundation walls to channel water and relieve hydrostatic pressure below grade. Drainage plane materials include washed gravel, sand, special mats, high-density fiberglass insulation, dimpled sheets, and grooved rigid insulation.
9. Install a capillary break and vapor retarder under the entire slab consisting of at least a 6-mil polyethylene sheet or continuous rigid foam insulation approved for below-grade applications, on top of 4 to 6 inches of coarse gravel. Do not put a sand layer over polyethylene sheet and under concrete. Prevent cracking with low water-to-concrete ratio and wetted burlap covering during initial curing.
10. Install radon control measures (check local requirements and EPA recommendations).
11. Note that some code jurisdictions may require a gap between exterior insulation and wood foundation elements to provide a termite inspection area.

**EPDM stands for Ethylene Propylene Diene Monomer.*

OPTIMAL DRAINAGE PATTERNS

Design the house structure with overhangs, gutters, drainage planes, and flashing to shed rainwater and conduct it away from the house. In wet locations, slabs require a foundation drain where the slab (or floor) is located below grade. Install a foundation drain (perforated pipe) alongside the footing (not above it). The drain should rest in a bed of coarse gravel (no fines) that slopes away from the foundation and is covered with filter fabric in wet environments.



(Figure source: Lstiburek, J.W. 2003. p.4)

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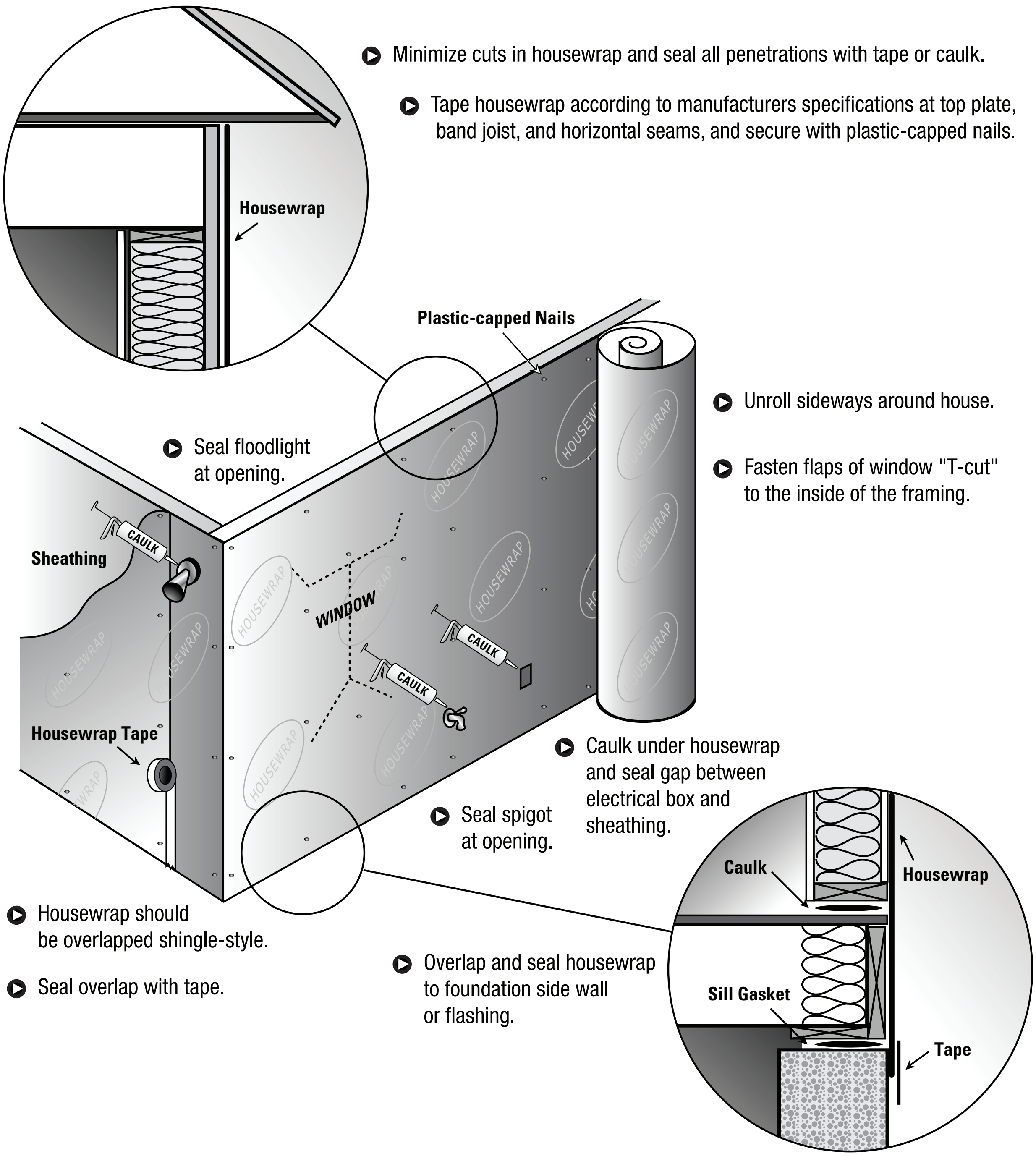
Housewrap

Example of housewrap strategies



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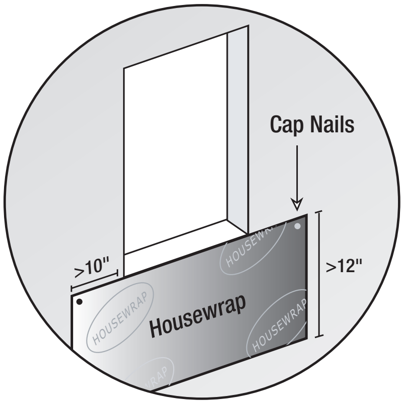
Window Flashing

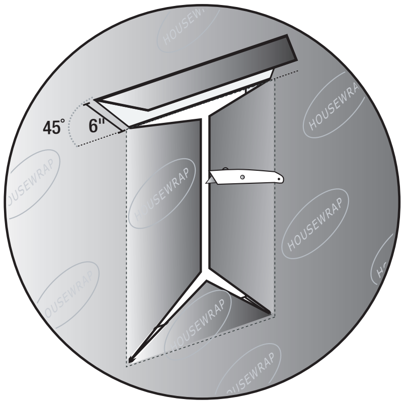
Window flashing details for home with housewrap and plywood or OSB wall sheathing

STEP 1- IF HOUSEWRAP HAS NOT YET BEEN INSTALLED



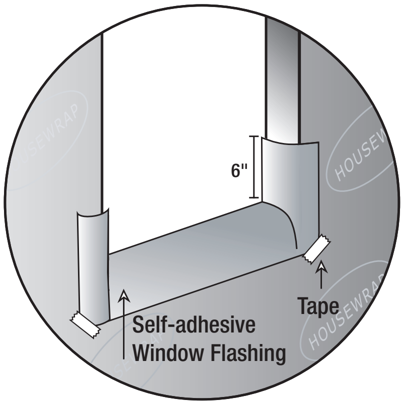
- Apply at least a 12-inch flap, or apron, of building paper or housewrap just below the window sill.
- If the window sill is close to the sill plate, the apron can extend all the way to the sill plate.
- The apron should extend at least 10 inches past the sides of the window opening, or to the first stud in open wall construction.
- Attach only the apron's top edge with cap nails.

STEP 1- IF HOUSEWRAP HAS BEEN INSTALLED



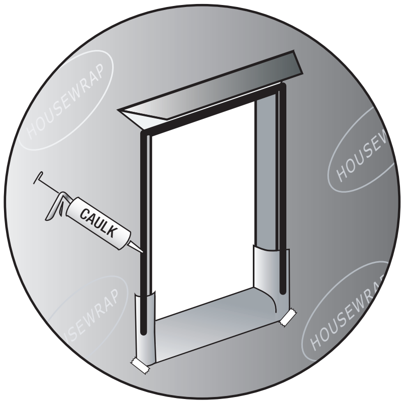
- Cut the housewrap covering the rough opening in the shape of a modified "Y."
- Fold the side and bottom flaps into the window opening and secure.
- Above the window opening, cut a head flap and flip up to expose sheathing, and loosely tape in place out of the way.

STEP 2 - SILL FLASHING



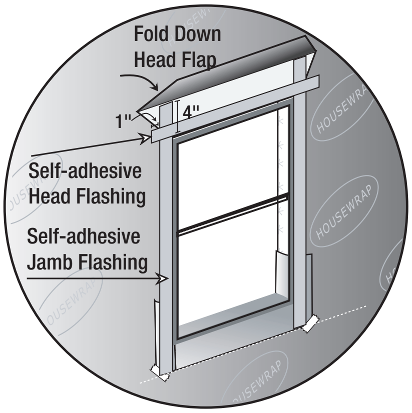
- Install self-adhesive flashing to the sill, ensuring that flashing extends up jambs at least 6 inches.
- One commercial product comes with two removable strips over the adhesive. Remove the first strip to expose half the adhesive and apply this area to the sill. Begin pressing in the middle of the sill and work towards the sides. Remove the second strip to expose the adhesive that will be used to apply the flashing below the window to the outside wall.
- Tape down the bottom corners of the flashing.

STEP 3 - JAMB CAULKING



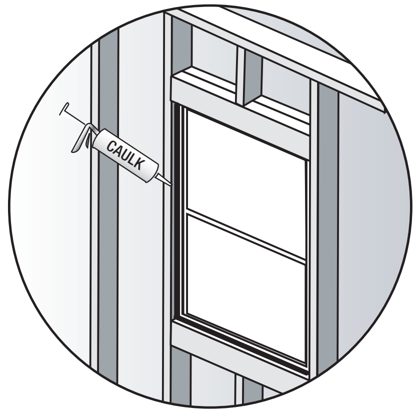
- Caulk the outside edges of the head and side jambs.
- Do not caulk across the sill.
- Install the window using corrosion-resistant nails and following manufacturer's specifications.

STEP 4 - JAMB AND HEAD FLASHING



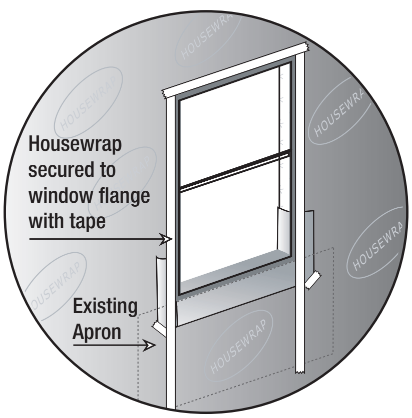
- Install self-adhesive jamb flashing extending 4 inches above the top of the head flange and even with the bottom of the sill flashing.
- Install self-adhesive head flashing extending 1 inch beyond the jamb flashing.
- If housewrap has been installed, be sure that the head flap, when it is folded down, will cover the top of the flashing.

STEP 5 - SEAL ROUGH OPENING GAP



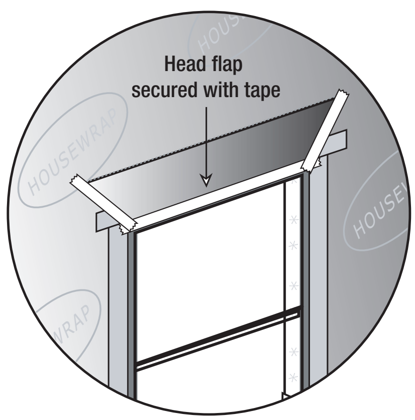
- On the interior side of the window, seal gap between the window and the rough opening with appropriate sealant.

STEP 6 - IF APRON WAS INSTALLED



- If an apron was installed under the window, slip the housewrap or building paper under the apron.
- Tape the edges where the housewrap meets the window flange if housewrap is installed after flashing.
- If building paper is used, embed the edges in a bead of sealant where the paper meets the window flange.

STEP 6 - IF HEAD FLAP WAS CREATED

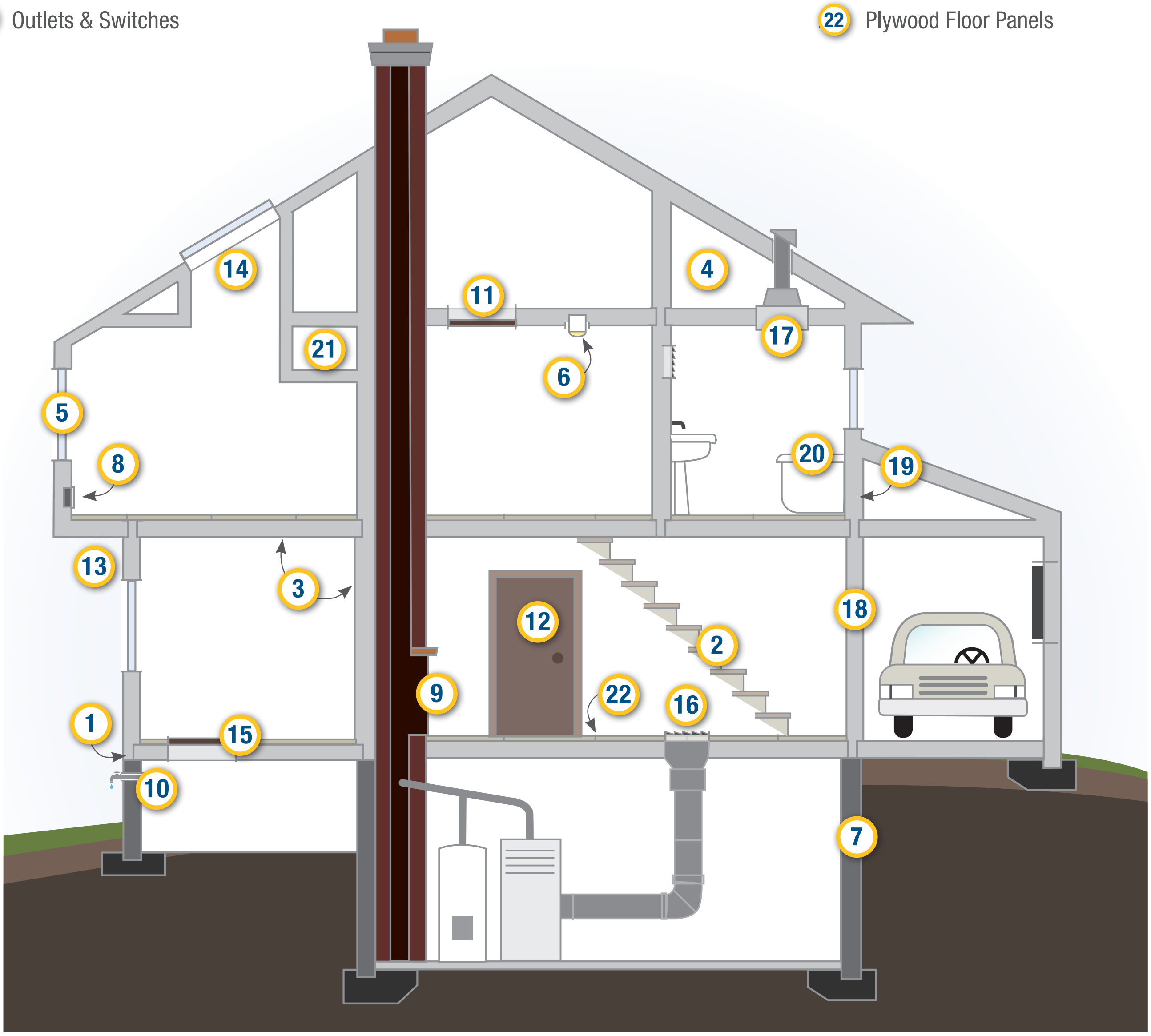


- If headflap was created, fold it over the head flashing and tape across the top window flange and the 45° angle seams.

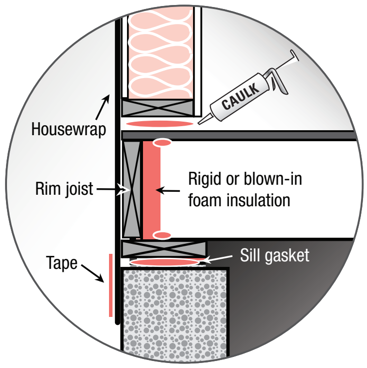
Interior Air Sealing

Conventional construction (and typical retrofits) requires tracking down and sealing multiple penetrations that ultimately lead to or through the exterior shell

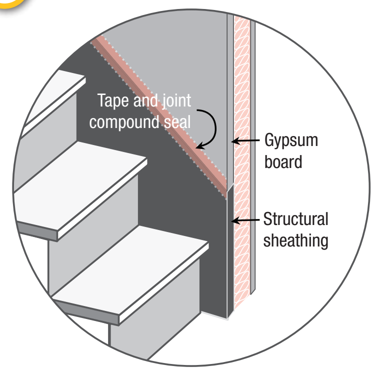
1. Sill Plate & Rim Joist
2. Stairs
3. Wall & Ceiling Drywall
4. Kneewalls
5. Windows
6. ICAT Can Light
7. Electric Circuit Box
8. Outlets & Switches
9. Fireplace
10. Plumbing Penetrations
11. Attic Access
12. Doors
13. Cantilever
14. Skylight
15. Crawlspace Access
16. Registers
17. Exhaust Fan
18. Garage Common Wall
19. Wall Adjoining Cavity
20. Tub
21. Interior Soffit
22. Plywood Floor Panels



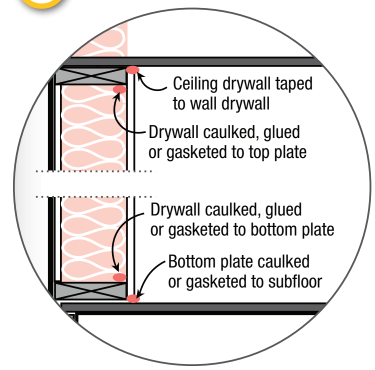
1 Sill Plate & Rim Joist



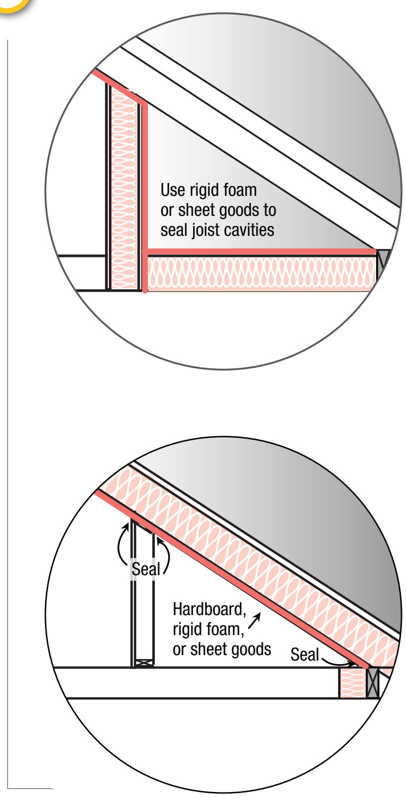
2 Stairs



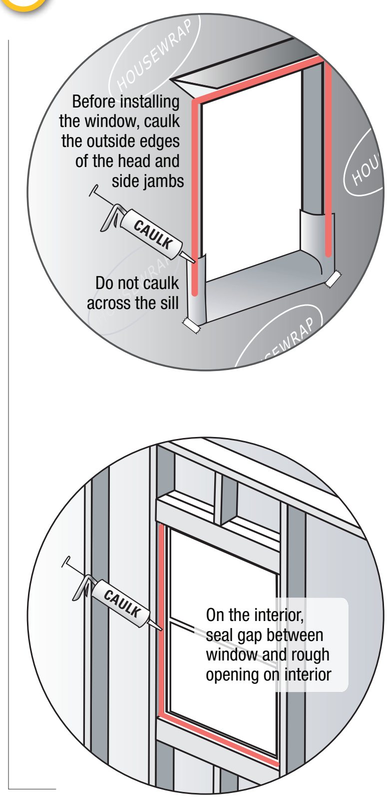
3 Wall & Ceiling Drywall



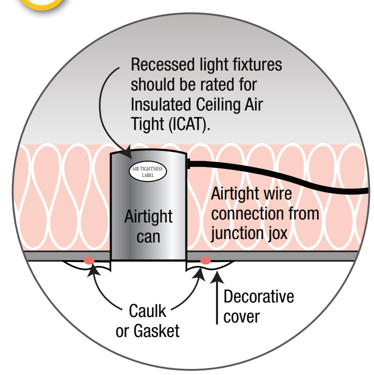
4 Kneewalls



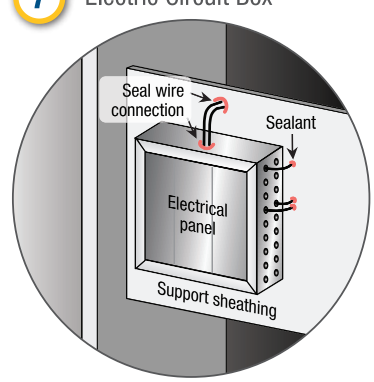
5 Windows



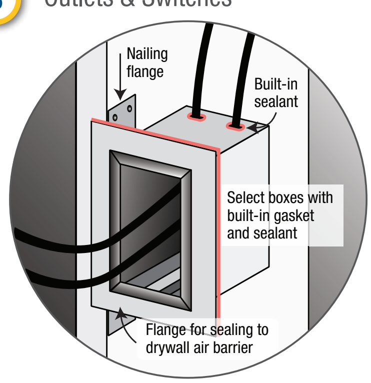
6 ICAT Can Light



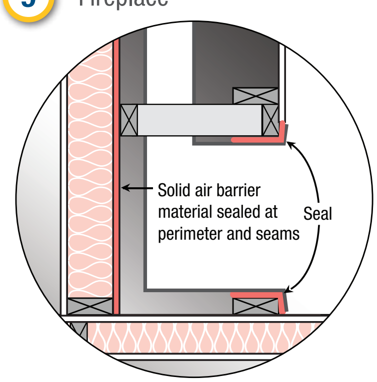
7 Electric Circuit Box



8 Outlets & Switches

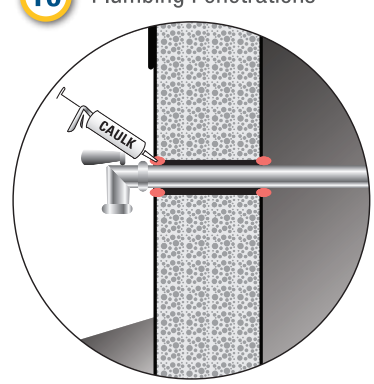


9 Fireplace

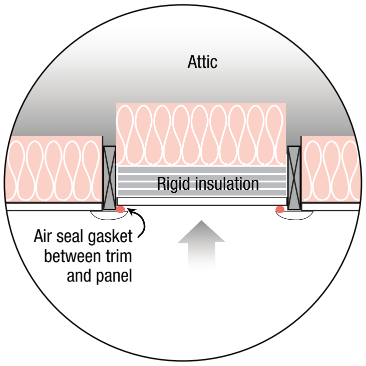


Direct vent fireplace eliminates the chimney;
but seal fireplace alcove

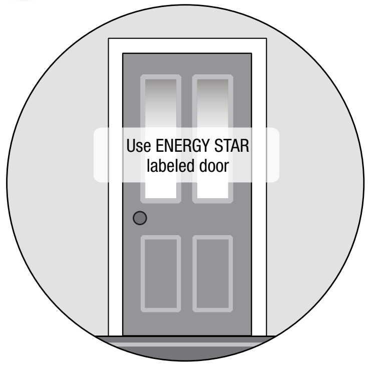
10 Plumbing Penetrations



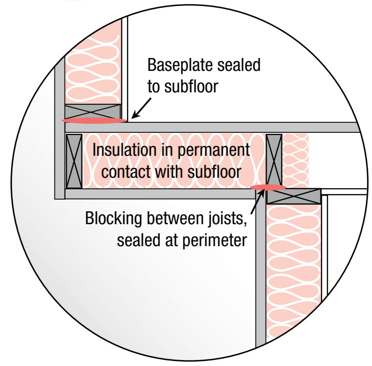
11 Attic Access



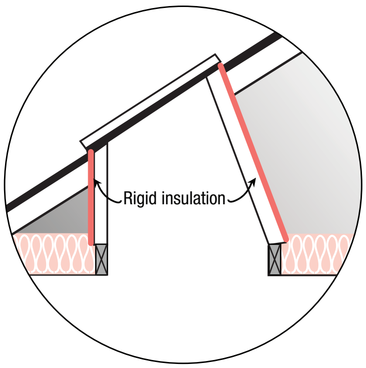
12 Doors



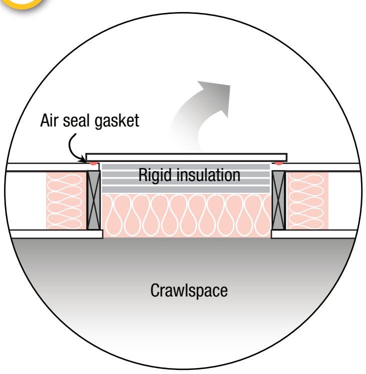
13 Cantilever



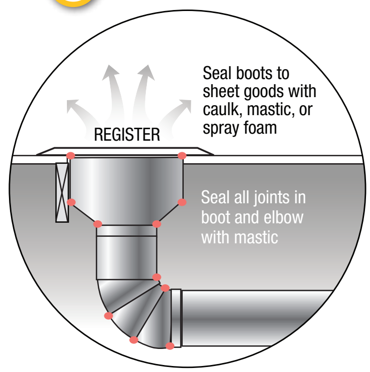
14 Skylight



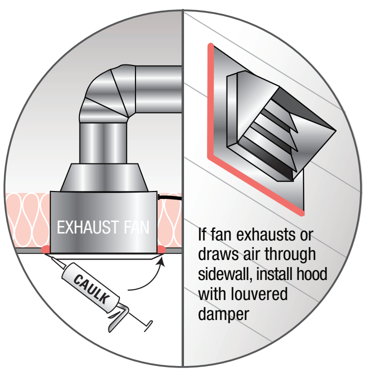
15 Crawlspace Access



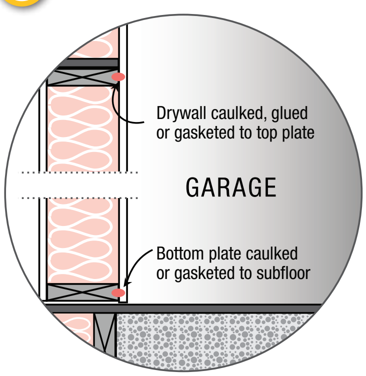
16 Registers



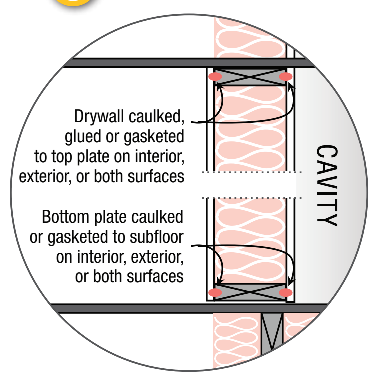
17 Exhaust Fan



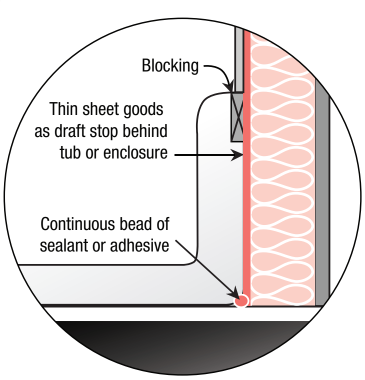
18 Garage Common Wall



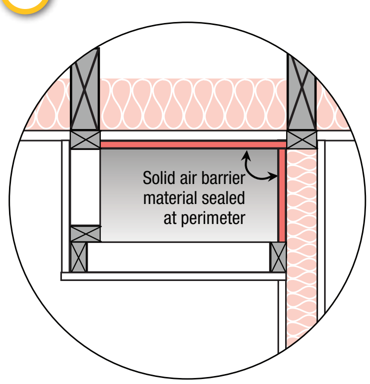
19 Wall Adjoining Cavity



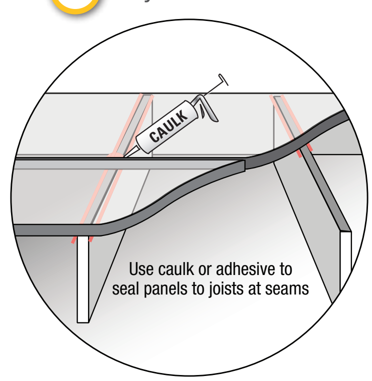
20 Tub



21 Interior Soffit



22 Plywood Floor Panels



Interior Air Sealing Assignments

INTERIOR MEASURES	FRAMER	INSULATION	ELECTRICIAN	DRYWALLER	PLUMBER	WINDOW & DOOR INSTALLER	HVAC MECHANIC
1. Sill Plate and Rim Joist • Caulk and place gasket between sill plate and foundation wall. • Tape edges and seams of housewrap.	■						
2. Stairs • Tape and joint compound to seal along edge of stairs	■						
3. Wall and Ceiling Drywall • Tape ceiling drywall to wall drywall. • Caulk, glue, or gasket drywall to top plate and to bottom plate. • Caulk or gasket bottom plate to subfloor.				■			
4. Kneewalls • Use rigid foam or sheet goods to seal joist cavities		■		■			
5. Windows • Caulk outside edges of head and side jambs before installing windows.						■	
6. ICAT Can Light • Caulk or gasket around can under decorative trim. • Use airtight wire connection. • Use ICAT rated fixture.			■				
7. Electric Circuit Box • Seal wire connections to box.			■				
8. Outlets & Switches • Install boxes with built-in gasket and sealant.			■				
9. Fireplace • Install solid air barrier around fireplace and seal at seams.	■	■					
10. Plumbing • Caulk all plumbing penetrations through framing.					■		
11. Attic Access • Air seal gasket between trim and panel.		■					
12. Doors • Use ENERGY STAR labeled doors.						■	

Continued on following page

Interior Air Sealing Assignments, *Continued*

INTERIOR MEASURES	FRAMER	INSULATION	ELECTRICIAN	DRYWALLER	PLUMBER	WINDOW & DOOR INSTALLER	HVAC MECHANIC
13. Cantilever • Seal baseplate to subfloor. • Install blocking between joists and seal at perimeter.	■	■					
14. Skylight • Install rigid insulation around skylight box.		■					
15. Crawlspace Access • Install gasket along edges.		■					
16. Registers • Seal boot to sheet goods with caulk, mastic, or spray foam. • Seal all joints in boot and elbow with mastic.							■
17. Exhaust Fan • Caulk around fan and vent or other back draft damper.							■
18. Garage Common Wall • Caulk, glue, or gasket drywall to top plate and to subfloor.				■			
19. Wall Adjoining Cavity • Caulk, glue, or gasket drywall to top plate and to subfloor on interior, exterior, or both surfaces.	■						
20. Tub • Install blocking and thin sheet goods as draft stop behind tub or shower. • Apply continuous bead of sealant or adhesive behind tub or enclosure where wall meets floor.		■			■		
21. Interior Soffit • Seal solid air barrier material at perimeter.	■						
22. Plywood Floor Panels • Caulk panels to joists at seams.	■						

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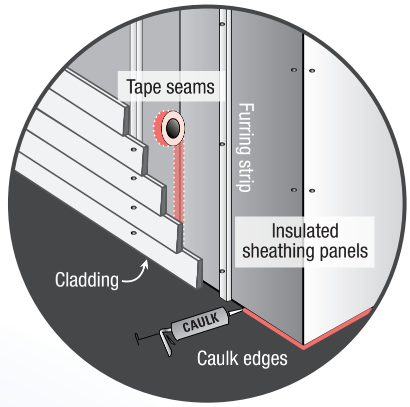
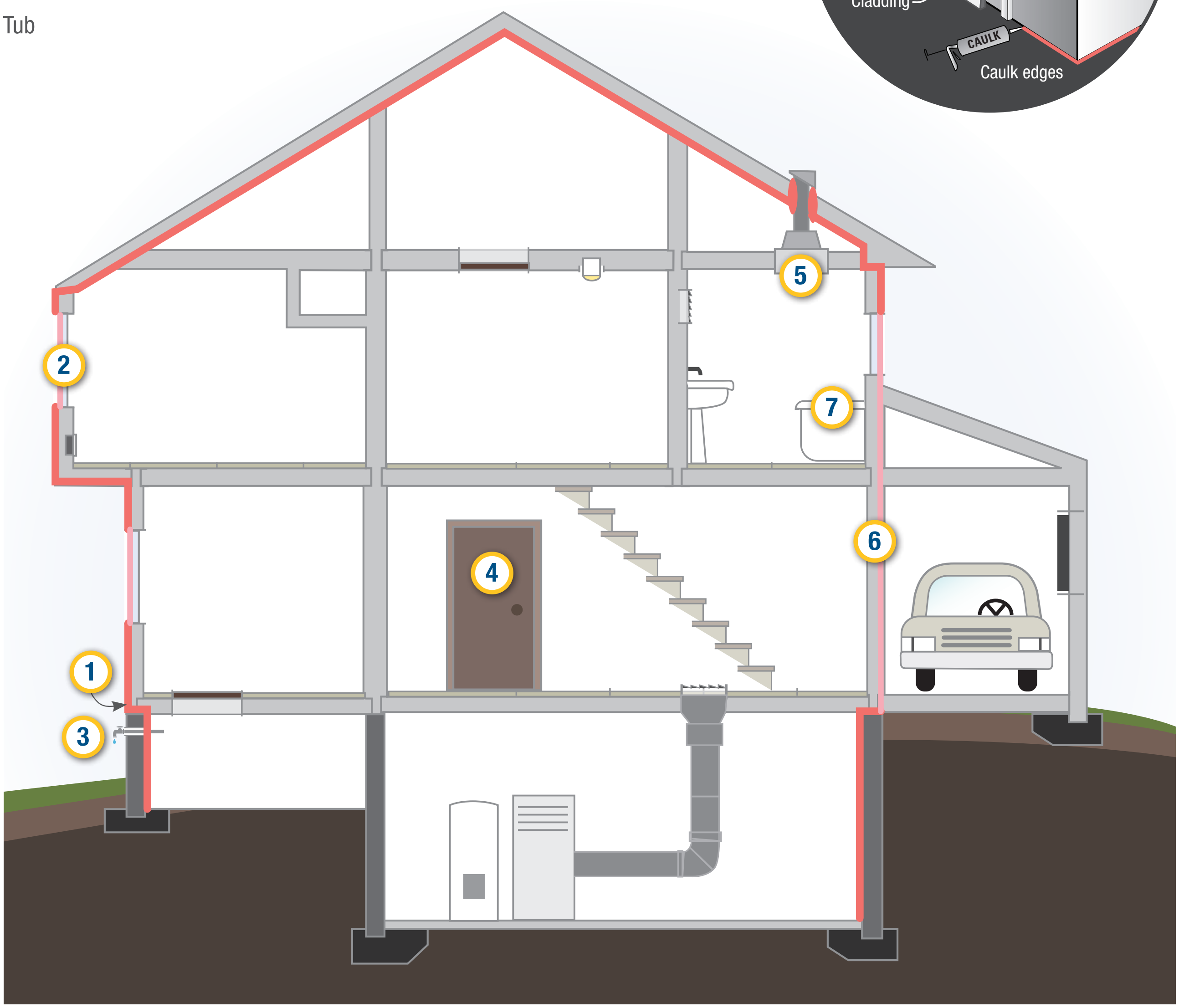
Exterior Air Sealing with Insulating Sheathing Panels

This figure shows an approach to construction used in some Building America homes. Exterior insulating sheathing provides an air barrier for walls. The non-vented attic is sealed and insulated under the roof. Particular attention is paid to the intersection of foundations, walls, and the roof. Sealed combustion furnaces and water heaters do not require a vertical chimney. Insulating sheathing requires structural elements.

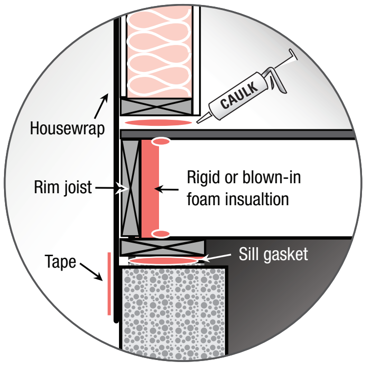
1. Sillplate & Rim Joist
2. Windows
3. Plumbing Penetrations
4. Doors
5. Exhaust Fan
6. Garage Common Wall
7. Tub

Insulating Sheathing Detail

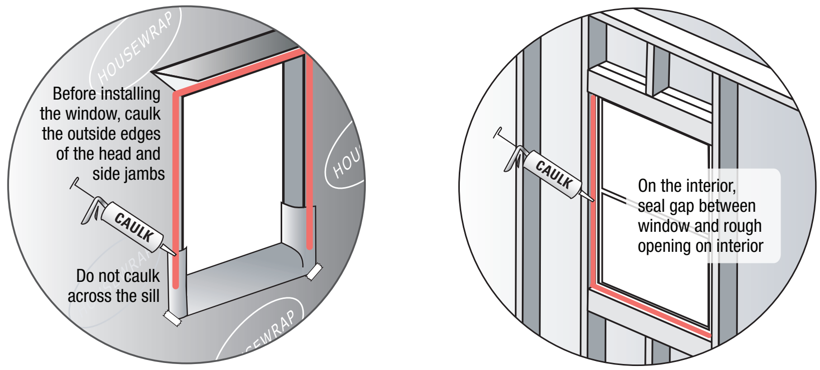




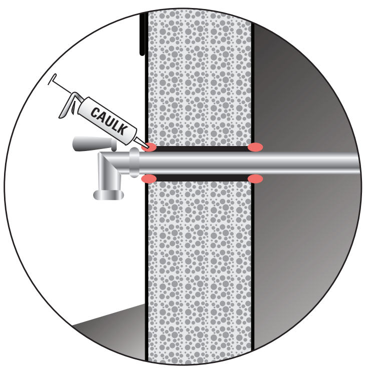
1 Sill Plate & Rim Joist



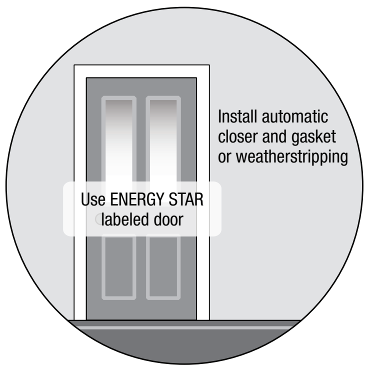
2 Windows



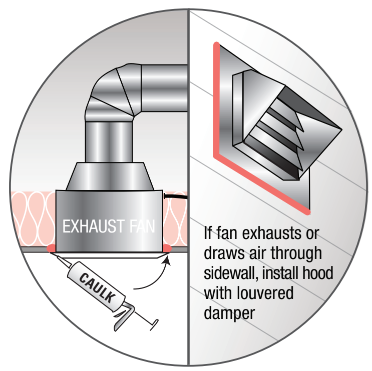
3 Plumbing Penetrations



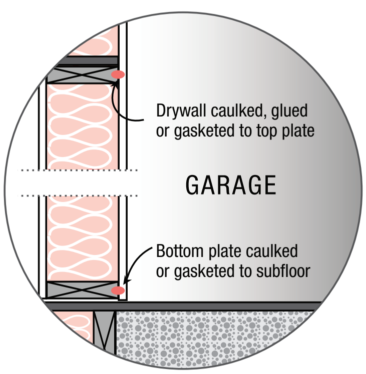
4 Doors



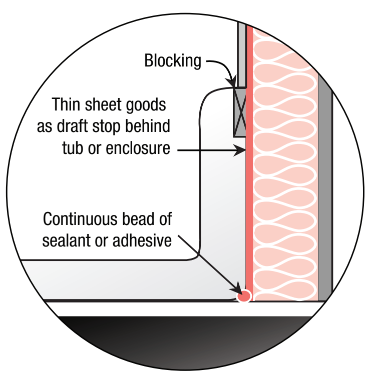
5 Exhaust Fan



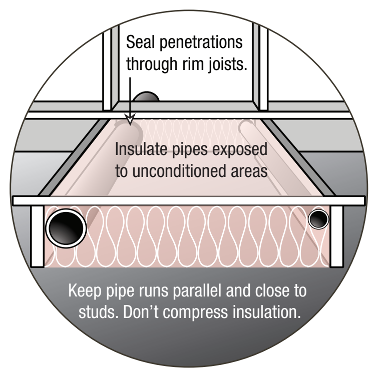
6 Garage Common Wall



7 Tub



Plumbing Floor Penetrations



Keep pipes out of exterior walls and
seal penetrations through floor.

Sample Exterior Air Sealing Assignments

EXTERIOR MEASURES	FRAMER	INSULATER	ELECTRICIAN	DRYWALLER	PLUMBER	WINDOW & DOOR INSTALLER	HVAC MECHANIC
1. Sill Plate and Rim Joist • Caulk and place gasket between sill plate and foundation wall. • Tape edges and seams of housewrap. • Caulk subfloor to bottom plate.	■	■					
2. Windows • Tape and joint compound seal	■	■					
3. Walls, Ceilings, Floors • Seal ceiling to wall drywall. • Caulk, glue, or gasket drywall to bottom plate. • Seal all envelope penetrations	■			■			
4. Doors • Use ENERGY STAR labeled doors.						■	
5. Exhaust Fan • Caulk around exhaust fan. Install louvered vent hood.							■
6. Garage Common Wall • Caulk, glue, or gasket drywall to top plate. • Caulk or gasket bottom plate to subfloor. • Seal joist cavities above and below wall.	■			■			
7. Tub • Install blocking and thin sheet goods as draft stop behind tub or shower. • Apply continuous bead of sealant or adhesive behind tub or enclosure where wall meets floor.					■		
8. Plumbing Penetrations • Keep pipes out of exterior walls. • Seal penetrations through floor and at rim joists. • Keep pipe runs parallel and close to studs. Don't compress insulation. • Insulate pipes exposed to unconditioned areas.					■		
9. Electrical Penetrations • Seal penetrations through roof, walls, and floors. • Do not compress insulation. • Seal conduit that provides air passage to exterior. • Install gasketed electrical boxes and fixtures.			■				

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Air Sealing Glossary

CAULK

Seals gaps of less than 1/2 inch. Select grade (interior, exterior, high temperature) based on application.

EXPANDING SPRAY FOAM

Fills large cracks and small holes. Expanding foams are messy but useful for filling large holes or cracks. The material expands two to three times in volume after application. It degrades in sunlight and users should be careful not to get the foam on their skin. DO NOT USE near flammable applications (e.g., flue vents). DO NOT USE on windows and doors. It comes in one-part cans that require no mixing or, for larger jobs, in two-part systems which involves mixing the sealant on site.

LOW-EXPANDING/ NON-EXPANDING SPRAY FOAM

These latex-based spray foams come in one-part spray cans. They expand very little or not at all and will not pinch jambs or void window treatments.

BACKER ROD

Closed-cell foam or rope caulk. Press into crack or gap with screwdriver or putty knife. Often used with caulk around window and door rough openings.

GASKETS

Apply under the bottom plate before an exterior wall is raised or use to seal drywall to framing instead of caulk or adhesive.

HOUSEWRAP

Installed over exterior sheathing. Must be sealed with housewrap tape or caulk to act as an air retarder. Resists water, but is NOT a vapor barrier.

SHEET GOODS

(Plywood, Drywall, Rigid Foam Insulation) These materials form an air retarder. Air leaks only at unsealed seams or penetrations.

SHEET METAL

Used with high-temperature caulk for sealing high-temperature components, such as flues, chimneys, and framing.

POLYETHYLENE PLASTIC

This inexpensive material for air sealing also stops vapor diffusion. All edges and penetrations must be completely sealed for an effective air retarder. Poly is fragile and proper placement is climate specific.

WEATHERSTRIPPING

Used to seal moveable components, such as doors, windows, and attic accesses.

MASTIC

A thick paste that can be used on all duct materials that provides a permanent seal. Seals air handlers and all duct connections and joints. UL-181-approved water-based mastic is best.

UL-181 OR FOIL-FACED TAPE

Tapes approved for ducts and air handlers. Temporarily seals the air handler.

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Fiberglass Insulation

Installing fiberglass batt insulation

ALWAYS:

- ☐ Avoid gaps, tight turns, and compression
- ☐ Cut insulation to fit snugly in non-standard spaces.
- ☐ Slit batts to fit around wiring and plumbing.
- ☐ Notch out around electrical boxes and use scraps to fill in behind.
  - Install long runs first – then use scraps to fill in smaller spaces and gaps.
  - Use unfaced batts in hot and humid climates.
  - Even if blown-in insulation is to be generally applied, use fiberglass batts to insulate areas that will be inaccessible to the blown-in insulation, such as behind bath enclosures.

WALLS:

- ☐ Friction-fit the batts in place until covered by drywall or sheathing.
- ☐ Insulate before installing stairs and tubs and other features that will block access.

KNEE WALLS:

- ☐ Seal knee wall to create a continuous air barrier. Insulate and air seal the rafter space along the sloping ceiling of the knee wall attic space or insulate and air seal the roofline, wall, and floor.
- ☐ Rafters should receive R-19 or R-30 insulation.
- ☐ Cover rafters with a sealed air barrier (such as drywall or foam board).
- ☐ Caulk the barrier to the top plate of the wall below the attic space and to the top plate of the knee wall itself.
- ☐ Seal all other cracks and holes.

CEILINGS:

- ☐ Insulate and seal the attic access door
- ☐ Install insulation over ICAT-rated recessed cans.
- ☐ Verify ventilation pathways.
- ☐ Install insulation baffles.

BAND JOISTS:

- ☐ Place insulation in the cavities between joists and subfloor.
- ☐ Caulk bottom plate to subfloor.
- ☐ Caulk band joist to subfloor and plates and insulate.
- ☐ Caulk bottom plate to subfloor.

UNDER FLOOR INSULATION:

- ☐ Metal stays, lathe, or stainless steal wire support insulation in joist cavities.
- ☐ In new construction it is preferred that crawlspace walls are insulated. If underfloor insulation is to be used, it can be held in place with metal staves, lathe, stainless steel wire, or twine.
- ☐ If truss systems are used under floors, an approach better than batt insulation is to install netting or rigid insulation to the underside of the floor trusses and fill the joist cavity with blown-in insulation.

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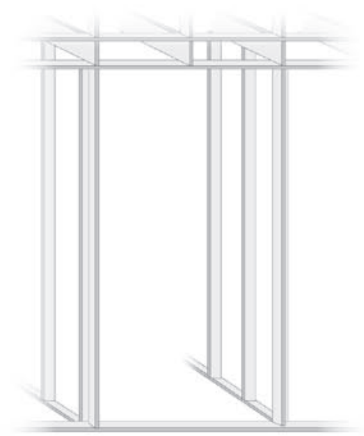
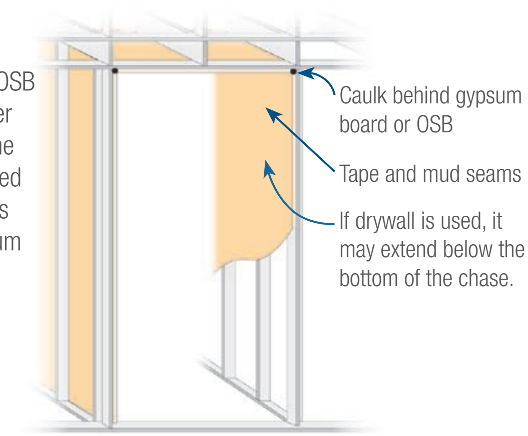
Duct Location

Ducts can be placed in a dropped ceiling or in open web trusses between floors to keep them in conditioned space.

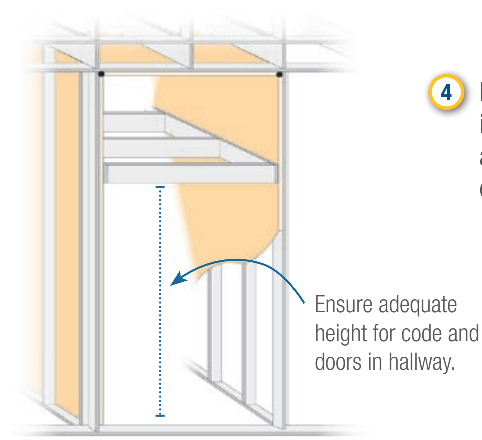
1 Start with a framed hallway.



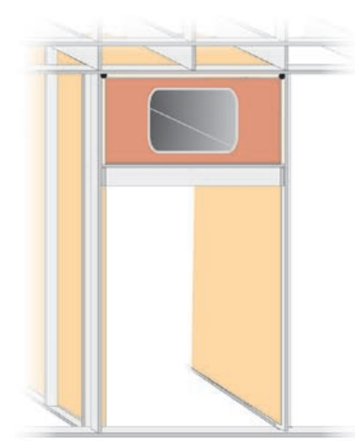
2 Install drywall or OSB or other air barrier extending past the area to be included in chase. Framers may install gypsum board.



3 Framers furr down space for duct chase.



4 HVAC contractor installs sealed and insulated ducts in chase.



5 Drywallers finish exposed surfaces with sealed, caulked, taped, and mudded drywall and seal connection of duct boot to drywall.

6 Install register and finish.

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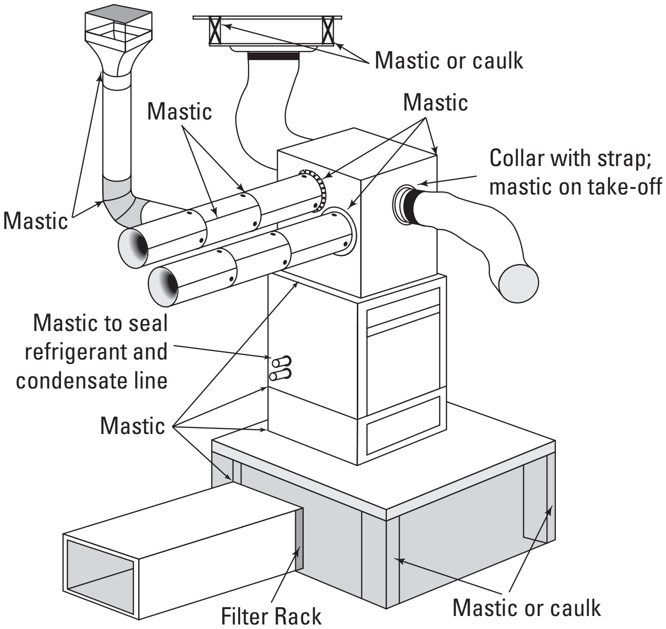
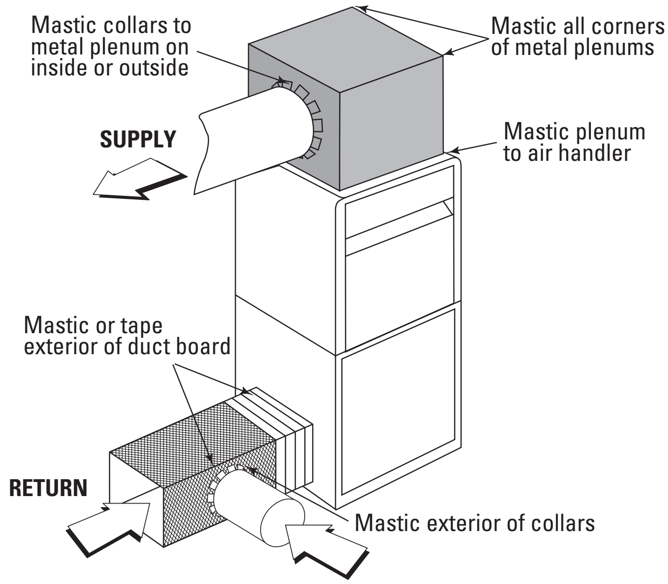
Air Handler and Duct Sealing

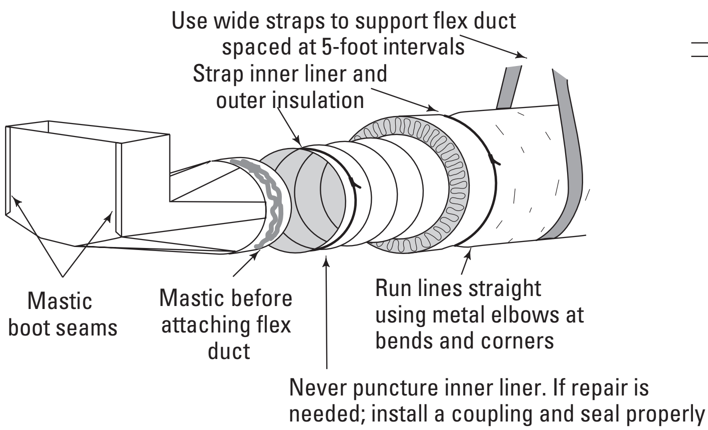
AIR HANDLER



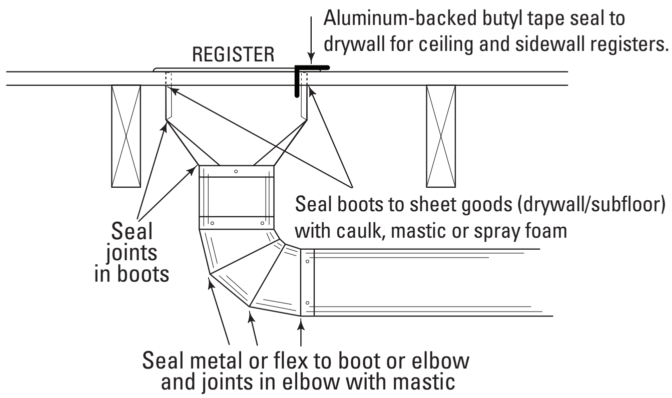
SUPPLY AND RETURN PLENUMS



FLEX DUCT



BOOTS



Mastic is a gooey adhesive that is applied wet. It fills gaps and dries to a soft solid. Mastics may or may not contain reinforcing fibers, and they may be used with reinforcing mesh tape.

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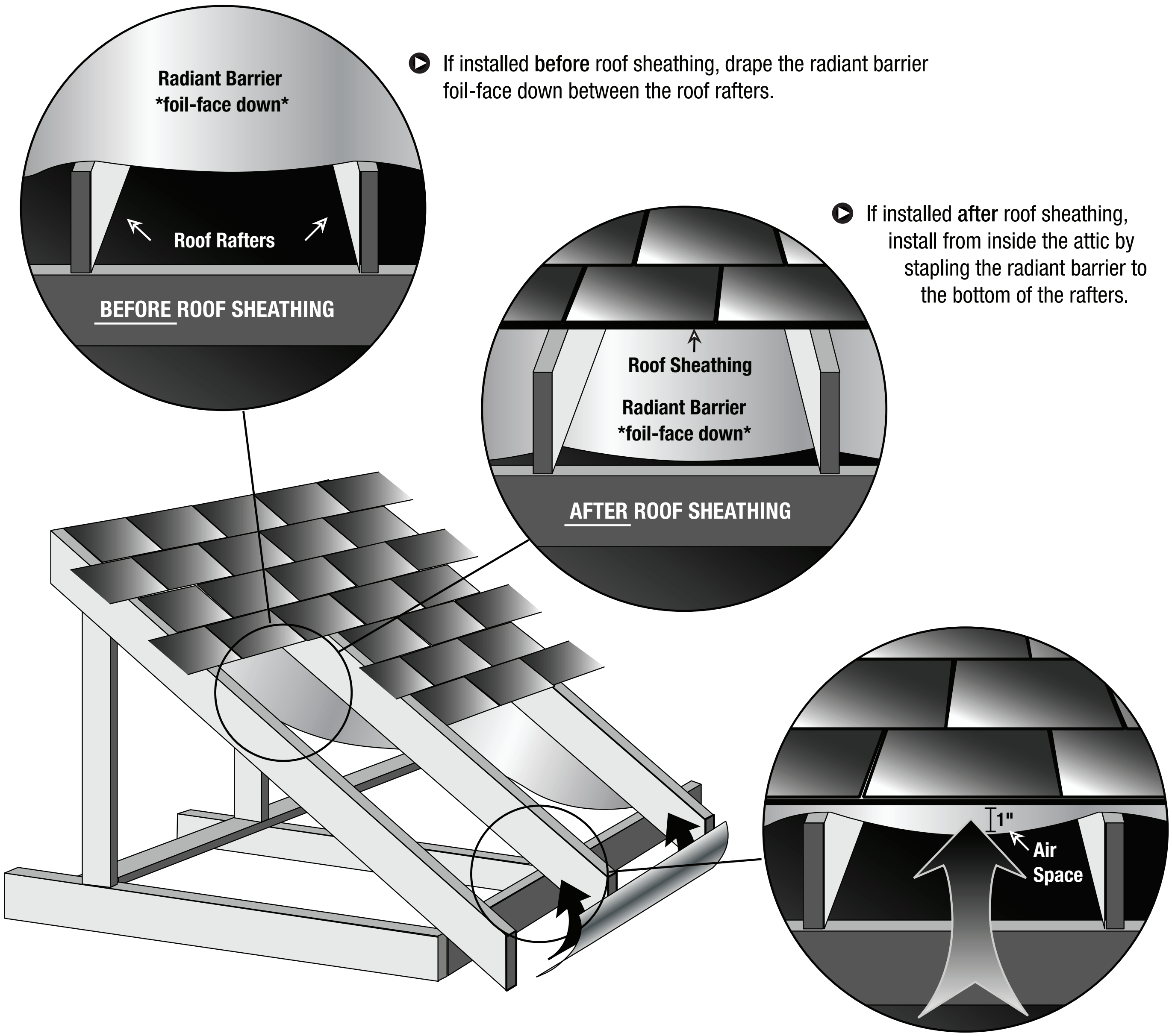
Radiant Barriers

Radiant Barriers are appropriate for hot climates

(They are prescriptively required in California.)



- If installed **before** roof sheathing, drape the radiant barrier foil-face down between the roof rafters.
- If installed **after** roof sheathing, install from inside the attic by stapling the radiant barrier to the bottom of the rafters.
- NOTE: Some roof sheathing products have a radiant barrier preinstalled; in this case, ensure the shiny side faces the attic. This is the most cost-effective radiant barrier installation strategy.
- Allow the material to droop between attachment points to make at least a 1-inch air space between the radiant barrier and the bottom of the roof. Ridge venting would allow hot air to escape.

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Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Case Studies

Several builders are building energy-efficient homes in the hot-dry/mixed-dry climates. The following case studies showcase six of these builders. The energy-efficient measures they incorporate in their homes are summarized in the table below.

Table 1. Summary of Energy-Efficient Measures Incorporated in Case Study Homes in the Hot-Dry/Mixed-Dry Climates

MEASURE	Artistic Homes Albuquerque NM	CDC Realty Tucson AZ	Grupe Homes Stockton CA	John Wesley Miller Tucson AZ	Pulte Del Webb Las Vegas NV	Treasure Homes Sacramento CA
HERS	0-50	40% over BA Benchmark	50% savings over CA Title 24	HERS 0	HERS 60	50%
Walls	Advanced framing 2x6 24” o.c., 3-stud corners, open headers	2x6, 16” o.c., R-19 blown cellulose	2x4 stud	Concrete block w 3-coat stucco finish and steel-framing inside	OVE framing	2x4, 16” o.c., R-13 +1” rigid polystyrene exterior insulation
Attic insulation	R-50	R-38 blown cellulose, along underside of rof deck	R49 blown cellulose	R-38 foam plus 1.5” rigid foam polyisocyanurate wrapped in foil laid above rafters for R55	Blown cellulose	R38
Radiant Barrier	no	no	yes	yes	no	yes
Wall insulation	R-21 blown insulation R5 rigid foam exterior	R-19 blown cellulose plus R5 rigid foam exterior	R-5 rigid foam exterior, Soy-based foam or blown cellulose in cavity	Exterior 1.5” rigid foam polyisocyanurate	Blown cellulose	R-13 plus 1 inch foam EPS
Foundation	Slab on grade with R-10 rigid foam insulation under grade	Slab on grade	Slab on grade	Slab on grade	Slab on grade	Slab on grade
Ducts	In conditioned space, in dropped hall ceiling	In conditioned space, in dropped hall ceiling	In attic buried in blown cellulose	In conditioned space in dropped ceiling	In insulated attic	Buried in blown in attic insulation

MEASURE	Artistic Homes Albuquerque NM	CDC Realty Tucson AZ	Grupe Homes Stockton CA	John Wesley Miller Tucson AZ	Pulte Del Webb Las Vegas NV	Treasure Homes Sacramento CA
Air Handler	In sealed utility closet	In conditioned attic	In unconditioned attic	In conditioned space	In conditioned attic	In unconditioned attic
Air Sealing	Gaskets, foam sealing, caulking	Gaskets, foam sealing, caulking	Rigid foam wrapped walls	All envelope penetrations	Sealed top and bottom plate, mastic sealed ducts	Rigid foam wrapped walls
HVAC	15 SEER AC, 9.0 HSPF air source heat pump	14 SEER AC, 7.5 HSPF air source heat pump	90 AFUE variable speed gas furnace	SEER 17.6 Air source heat pump	SEER 15 HVAC	SEER 13, 0.90 AFUE furnace
Pressure balancing	Jump ducts, fresh air intake on AHU	Flex duct supply and return to every room	Dual-zone equlizer	Transfer grills	Jump ducts	Zoned heating and cooling, SmartVent
Windows	Dual-pane, low-e, Fibrex frame	Dual-pane, low-e, vinyl frame	Energy efficient	Dual-pane, low-e,	Dual-pane, low-emissivity, vinyl frame	Dual pane, low-e
Water Heating	Solar thermal	Solar thermal, with tankless heater	Tankless gas; Homerun manifold plumbing	Solar thermal, with tankless water heater backup, and parallel piping	Some tankless	Tankless water heater
Ventilation	ERV	Fresh air intake to air handler, whole house fan with heat recovery	FreshVent continuous ventilation and programmable night cooling	Bath and kitchen fans vent outside	Filtered outside air intake, bath and kitchen fans vented outside	SmartVent automatic filtration
Green	Low-VOCs, job-site recycling	low-VOC paint, passive solar design	On-site recycling, used local materials	Xeriscaping, water-saving devices	Low-flow toilets, low-VOC paints, smart irrigation, formaldehyde-free cabinets	Non-toxic insect and mold deterrants, dual-flush toilets
Lighting and Appliances	ENERGY STAR	ENERGY STAR	ENERGY STAR	ENERGY STAR	ENERGY STAR	ENERGY STAR
Solar	Roof top PV 4.2-7.0 kWh Solar thermal water heating	Solar thermal ICS	2.4 kW PV	5.7 kW PV Solar hot water collector	none	2.4 kW PV
Comissioning	3rd party HERS rater duct and blower door test every house	3rd party blower door test	3rd party HERS rater duct and blower door test every house	Duct and whole house testing	3rd party duct blaster, insulation inspection, blower door test every house	Duct testing

Building America U.S. Department of Energy Research Toward Zero Energy Homes

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Case Study: Artistic Homes

ALBUQUERQUE, NM

Artistic Homes, a New Mexico production builder, completed this true net zero energy home in summer 2008. The home qualifies for the U.S. Department of Energy Builders Challenge and LEED platinum level, and is the first in the nation to meet the ENERGY STAR Indoor Air Quality certifications.

Artistic Homes of Albuquerque, New Mexico, is the first home builder in the United States to offer true net zero energy construction to the average home buyer on every home it builds. The New Mexico production builder signed a contract for its first true net zero energy upgrade package December 20, 2008. The price tag for the 2,157-square-foot upgraded home, which qualifies for U.S. Department of Energy Builders Challenge, LEED platinum, and ENERGY STAR Indoor Air Quality certifications, is just over $294,000.

Since joining DOE's Building America program a decade ago, Artistic Homes has continually sought to refine and improve its home building craft. In September 2008 Artistic became one of the first builders in the country to build a true net zero home. The 1,666-square-foot home completed in Rio Rancho, New Mexico, will produce and conserve more energy than it uses throughout the year for heating, cooling, and plug load. The home's tight construction ensures that, even without the 5.3-kilowatt solar photovoltaic power system and solar thermal water heating system, the home would still achieve a HERS index score of less than 60.

In November 2008 Artistic committed to building all of its homes to meet the Builders Challenge criteria. While Builders Challenge requires a HERS index score of 70 or lower, starting in 2008, Artistic committed to building all of its homes to a HERS score of 60 or lower and LEED silver level or better. The production builder has built more than 5,300 high-performance homes since 1998 and hopes to build 500 to 800 houses per year in the years ahead.

"We build all over New Mexico, from the southwest, which gets very hot, to the Four Corners area in the north with its extreme cold. We have a wide spectrum of climate conditions so we have to really apply our building science knowledge to get LEED silver or better and HERS 60 or below," said Tom Wade, co-owner of Artistic Homes. "We've worked with Building America for 10 years," said Wade, adding the DOE program helped encourage Artistic's cultural shift toward a greater emphasis on building science. "We continually look at what we are doing to see how we can improve our product. Everything we do is geared toward improving energy efficiency, indoor air quality, and affordability."

BUILDER PROFILE

Builder's Name:
Artistic Homes

Where:
Albuquerque, NM

Founded:
1986

Employees:
13, not counting subs

Square footage:
1,305-2,905 sq. ft.

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For more information
1-877-EERE-INF (1-877-337-3463)
buildingamerica.gov

Dollars and Sense

KEY FEATURES

- Air handler in sealed utility closet
- Ducts in conditioned space
- R-21 blown insulation in walls, R-38 blown insulation with wind baffles at soffit vents in attics
- Advanced framing techniques
- Gasketing, foam sealing, and caulking of all envelope penetration to minimize air leakage
- Fresh air inlet, positive pressure in home, and jump ducts
- 3rd party HERS rater blower door and duct blaster testing of every house
- 15 SEER AC and 9.0 HSPF electric furnace
- Heating and cooling energy usage and comfort are guaranteed
- Low-emissivity, dual pane, fibrex frame windows
- Borate treatment of studs and bottom plate
- Low and no VOC products
- Job-site recycling
- True net zero upgrade package includes:
  - Roof-mounted photo-voltaic power system (from 4.2 to 7.0 kWh depending on home's square feet)
  - Solar thermal hot water heating
  - R-50 attic insulation
  - Heat recovery ventilator for constant conditioned fresh air circulation

Artistic's price for a Builders Challenge home without the zero energy upgrade averages $222,000. Its homes range in size from 1,305 to 2,905 square feet and are geared to first-time home buyers and retirees on fixed incomes. Artistic charges about $20,000 more for a Builders Challenge home than its competitors charge for code-built homes, but found that energy efficiency is helping it to outsell competitors two to one (Figure 1).

The slowing of the market has had a positive side for Artistic. "When money was easy, people didn't care about energy efficiency. Some buyers were more interested in big foyers and vaulted ceilings, which we don't do. Now 100% of our buyers are coming to us for the energy efficiency," said Wade.

Figure 1. Number of Homes Sold in One Month (July 2009)

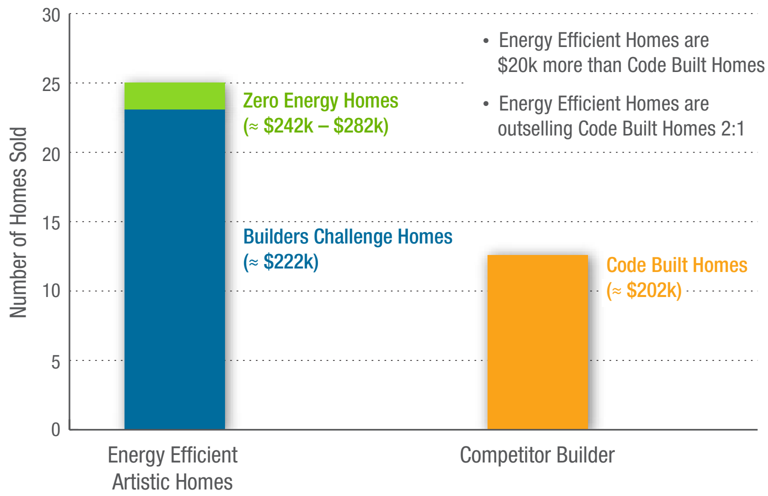


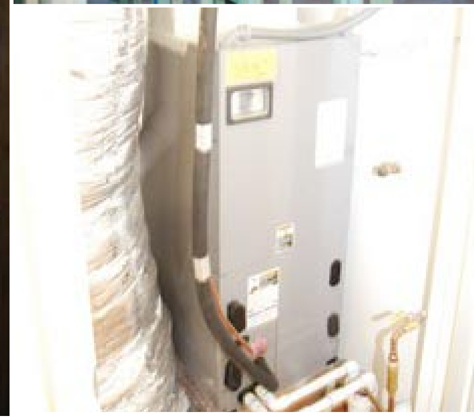
Chart compares data from three Artistic communities in Albuquerque to similar sized new communities by two competing builders [a large local builder and a national builder with a local division] who are building code-built home.

Artistic sold its very first zero energy home, a prototype built on speculation, for $240,000. The builder signed its first contract on a home with the zero energy upgrade package in December 2008 for $294,086 (which, included $19,000 in cosmetic upgrades).

Artistic sells the zero energy upgrade package for $40,000 to $60,000 depending on the size of the home and the size of the PV system. Local, state, and federal incentives combine to make the zero energy home package much more affordable. Artistic estimates that after applied incentives, homeowners could be paying less than $1,000 for the zero energy home package, and this is not including the ongoing savings homeowners will accumulate by eliminating their utility costs. In addition to the existing federal and state tax credits, the local utility company pays homeowners 13 cents per kWh for 12 years. After applying for all available incentives, homeowners will have close to 99% of the incremental cost covered.

Incentives cover 99% of the cost of a ZEH upgrade

Cost of Zero Energy Home Upgrade	$49,550.00
Incentives	
Xcel Energy - Solar Rewards Program	$15,840.00
New Mexico Sustainable Building Tax Credit	$18,698.65
Federal PV Tax Credit	$12,000.00
Federal Solar Thermal Tax Credit	$2,200.00
INCENTIVES TOTAL:	$48,738.65
Actual Cost of Zero Energy Home Upgrade	**$811.35**



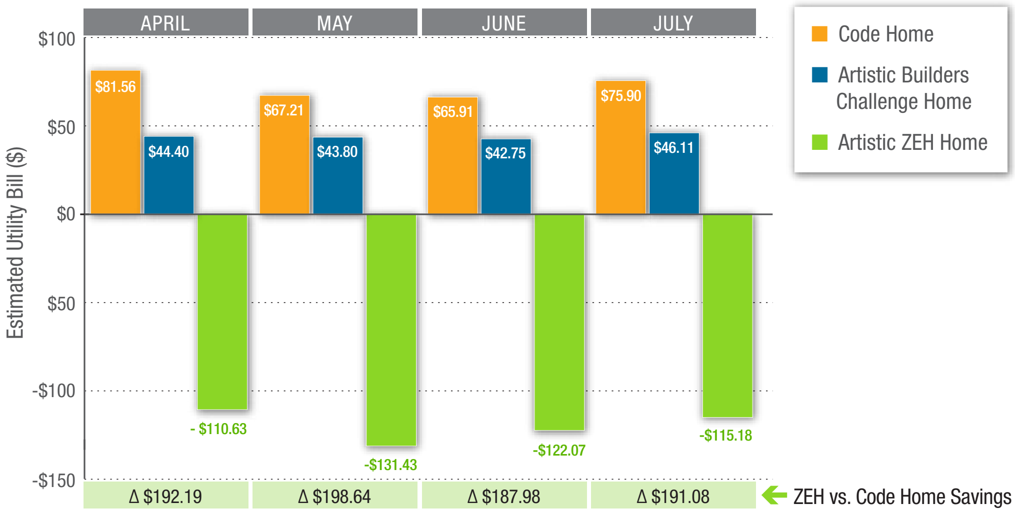
(left) Advanced framing with 2x6 24-inch on-center stud walls, 2-stud corners, and open headers, which use less lumber and provide more space for the R-21 blown insulation in the wall cavity.

(top right) Artistic increases the efficiency of its heating and cooling systems by putting ducts in conditioned space in a central chaise down the main hallway.

(bottom right) Techniques like the location of the air handler and furnace in the home's conditioned space, timed ventilation with a fresh air intake, extensive envelope air sealing, jumper ducts to balance indoor air pressure, and testing of each house for duct and whole house air leakage help to ensure a comfortable and healthy indoor air environment.

Artistic asked its first zero energy home owners for utility bill data. During the first four months the homeowners had been in the home, they received a check each month from the utility company averaging $100 per month. The chart below compares the homeowners' electric bills to those of homeowners in Artistic's Builders Challenge homes, and to owners of a code-built home. When compared to a code-built home, the zero energy home owner can expect to save about $200/month in avoided utility costs plus reimbursements.

Figure 2. Comparison of Utility Bill Data for a Code-Built Home, an Artistic Builders Challenge Home, and an Artistic Zero Energy Home



Energy Efficiency

Wade noted that Artistic doesn't need to rely on esoteric or avant-garde gadgetry to achieve its high efficiency ratings. "We use off-the-shelf products. We are a production builder so what we build has to be reproducible and maintainable."

Energy efficiency features include R-21 blown insulation in the walls, R-38 blown insulation in the ceiling with wind baffles installed at the soffits vents (R-50 in zero energy home package), and high-efficiency windows. Artistic uses slab-on-grade construction with R-10 rigid foam insulation under the slab and R-5 rigid foam vertical insulation on the edges of the slab. Advanced framing techniques include 2x6 24-inch on center walls, California (2-stud) corners, and open headers, which use less lumber and provide more space for insulation in the wall cavity. Air sealing details include gasketing the sill plate and caulking or foam sealing all wiring and piping holes to minimize air leakage. Every home is tested by an independent HERS rater for whole house and duct leakage.

The biggest energy savings probably come from locating the ducts in conditioned space. Most of the home's heating and cooling registers come directly off a main duct trunk line that runs through a dropped ceiling in the hallway. The airhandler is located inside conditioned space in a utility room.

The zero energy package includes Schüco roof-mounted solar photovoltaic panels, a roof-mounted solar thermal water heater and 80-gallon storage tank, a 15-SEER air conditioning unit, a 9.0-HSPF heat pump, and R-50 ceiling insulation. The zero energy upgrade package yields a house that is 68% to 75% more energy efficient than a home built to code. The zero energy home upgrade also includes and an energy recovery ventilator which provides steady circulation of fresh conditioned air through the home. The fresh air is cleaned by a HEPA filter and preheated or cooled by the energy recovery ventilator before sending it through the ducts. The energy recovery ventilator system helped Artistic's model zero energy home become the first home in New Mexico and one of the first in the country to meet the requirements of ENERGY STAR's new Indoor Air Quality certification.

Artistic is considering making energy recovery ventilators standard on every new Artistic home because Artistic's goal is to have every home it builds meet the ENERGY STAR Indoor Air Quality certification. Artistic also hopes to get its new homes to achieve EnergySmart Home Scale scores down to a HERS index of 40 to 48 in the upcoming year.

"The HERS index is the very best measuring stick we could use to see if we are improving. We use it for ourselves and we'd like to see other builders use it so homebuyers can compare," said Wade.

The Bottom Line

Artistic is determined that net zero will not be an idealistic dream but a realistic possibility within the grasp of the average home buyer. Artistic is now offering a zero energy package to home buyers on any home it builds, with a net zero energy guarantee for heating, cooling, and plug load. Wade hopes in 3 to 5 years Artistic will be building only zero-energy homes.

"We are constantly looking at different technologies and making changes to make the homes more energy efficient and healthy. It's part of the evolution of our internal culture; we just want to be better than we were yesterday," said Wade.

Builders Challenge Guide to Achieving 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Case Study:
CDC Realty Inc.

CENTENNIAL TERRACE | TUCSON, AZ

A Centennial Terrace home is an economical and energy-efficient choice for the first-homebuyer

Small Neighborhood, Big Savings

When Lee Rayburn decided to design and develop homes for a small subdivision called Centennial Terrace in Tucson, Arizona, he was determined to create an energy-efficient neighborhood, not just a row of houses. Rayburn had participated in the creation of Civano, a New Urbanist community located near Tucson that was pedestrian-friendly and featured energy-efficient homes. (Read more about Civano in the Building America Best Practices guide *Volume 6: Solar Technologies.*)

Impressed by the Building America systems approach he observed at Civano, Rayburn approached Building America partner Building Science Corporation (BSC) for guidance."I wanted to do the best I could as cost effectively as I could afford," said Rayburn. "This was not the bank's money—it was *my* money, so doing it right was very important to me."

Know the Market

Even before construction work began, Rayburn carefully targeted his market. While other builders in the Tucson area were focusing on large, sprawling houses, Rayburn's homes averaged a cozy 1,550 square feet and featured efficient storage—particularly appealing for young singles and empty-nesters. He also recognized that buyers were interested in healthier energy-efficient homes. Also, homebuyers loved the low energy bill guarantee that Rayburn offered through Tucson Electric Power.

Rayburn concentrated on the look and livability of the homes. "We focused on three main areas," he says, "First we wanted to keep the air circulation going with a whole-house fan and heat exchanger to ensure healthier indoor air quality. Second, we wanted to make use of as much natural light as possible. And third, we kept the ceilings as high as possible to keep the homes bright and airy—an important consideration in a smaller home." It would be up to Tom Doucette, the builder, to incorporate these design elements with energy-efficient systems. Doucette had also participated in the creation of Civano and was aware of the Building America systems approach to construction.

BUILDER PROFILE

Builder's Name:
CDC Realty Inc.

Where:
Tucson, AZ

Development:
Centennial Terrace

Size:
17-lot subdivision;
1,500 sq. ft. 1-story homes

Completed:
2006

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For more information
1-877-EERE-INF (1-877-337-3463)
buildingamerica.gov

The air handler is located inside the conditioned attic.

The 17 homes at Centennial Terrace feature R-38 blown-in cellulose along the underside of the roof decking providing conditioned space for the air handler and ducts.

KEY FEATURES

- Insulated attic with ducts and air handler in conditioned space
- Blown cellulose insulation, R-38 ceiling; R-19 walls plus R-5 rigid foam
- Double-pane, low-emissivity, spectrally selective windows;
- Overhangs to reduce solar gain
- 14 SEER A/C unit optional upgrade
- Programmable air exchange
- Tankless Water Heater, 82% Energy Efficient
- High ceilings throughout (minimum 9 feet, with 12 feet in the Great Room)
- ENERGY STAR appliances and lighting
- Solar features: Sun Earth Copperheart 40 combined collector/storage solar hot water panel, and Seisco instantaneous hot water system

Innovations

To achieve high levels of energy efficiency, a great deal of attention was paid to the building envelope. The standard unit is a simple slab-on-grade design with a flat roof, with nine-foot ceilings throughout the home and 12-foot ceilings in the great room and kitchen. A sloped section over the great room and kitchen provides the openness desired by Rayburn, while other ceiling sections hide the air handler and all of the duct work. R-38 blown-in cellulose was added to the underside of the roof deck providing a conditioned attic space for the HVAC equipment.

The space conditioning used an American Standard 12 SEER/7.5 HSPF air source heat pump (when SEER minimum was 10). Roof-top units are paired with an air handler located in the conditioned attic space above the laundry room, and insulated flex ducts supply and return air from every room. Ventilation is provided by a balanced system with both a dedicated air intake duct and a dedicated exhaust duct to bring in fresh air and exhaust stale air.

Homes Hit 40% Savings

The original home design for Centennial Terrace achieved a model energy consumption reduction of approximately 37% when compared to the Building America benchmark home (which is equivalent to a home built to the 1993 Model Energy Code). Before construction began in 2005, Rayburn contacted Building Science Corporation for design assistance to boost energy savings above 40%.

As a result of their work with Building Science Corporation, all the Centennial Terrace homes have ducts located in conditioned space between the insulated flat roof and a dropped ceiling. Blown cellulose to R-38 is applied along the attic roof line to make a conditioned space for the ducts and air handler. Walls are insulated to R-19 plus R-5 exterior rigid insulation. All of the homes are plumbed for solar thermal water heating and five of the homes include a Sun Earth Copperheart CP 40 integral collector storage solar hot water system which Rayburn offered to homebuyers at a reduced cost.

All of the homes have an instantaneous electric hot water system instead of a standard electric hot water tank. The HVAC was rated at 12 SEER/7.5 HSPF (compared to 10 SEER/6.8 HSPF which was code at the time).

To further minimize energy losses, Building Science Corporation recommended reducing the window ratio from 18% to 12.2%. Overhangs shade the east, south, and west sides of the homes to help reduce solar heat gain through the windows. The windows are upgraded to the Milgard Classic Vinyl product with a U-value of 0.38 and an SHGC of 0.30.

Building Science Corporation modeled energy savings of 41% over the Building America benchmark. Building Science Corporation also analyzed utility bill savings in terms of costs. They found that when compared to the Building America benchmark home, the CDC Realty design achieves energy savings of 41%, costs $7,400 in upfront costs, and yields annual energy savings of $123 in space heating costs, $595 in space cooling costs, and $114 in domestic hot water costs per home. This adds up to utility bill savings of $833 per year.

Ducts are located in conditioned space and mastic sealed to minimize heating and cooling losses.

The CDC Prototype Home:
Costs to Achieve 41% Savings over the Building America Benchmark

Feature	Cost of Change	Annual Energy Savings
Reduce windows 18% to 12.2%	*	$154
Overhangs	$200	$54
Upgraded vinyl, low-e windows, U=0.38, SHGC = 0.30	$1,000	$88
Attic insulation R-22 to R-38	$400	$139
Wall insulation R-12.7 to R-19 + R-5 rigid insulation	$700	$83
Air seal building envelope	$200	$41
Ducts inside conditioned space	$0	$106
Standard to instantaneous electric hot water heater	$200	$38
HVAC 10 SEER/6.8 HSPF to 12 SEER/7.5 HSPF	$700	$54
Add solar hot water	$4,000	$76
Total:	**$7,400**	**$833**

**Not quantified*

"If you view the whole house as a system…it's not only easier, you end up with a better product."

Lee Rayburn, CDC Realty

A Sun Earth Copperheart CP 40 integral collector storage solar hot water system is mounted on the roof's flat surface.

Dollars and Sense

"Sales were quick," says Rayburn. "I think because they were well-designed and addressed the way homes are used. Now that people have been living in them, they really love the energy savings as well." Energy bills at Centennial Terrace run $60-70 per month in an area that typically sees monthly bills of $300-400.

The Bottom Line

As noted by Lee Rayburn, most builders view each aspect of the house—the electrical work, the plumbing, the framework—as separate jobs, but the Building America approach views each aspect as part of the whole. "Builders don't like to make changes—each subcontractor has their own system and they tend to stick with it," says Rayburn. "However, if you view the *whole house* as a system, so that any changes take place at the same time throughout the building, it's not only easier, you end up with a better product."

Building America U.S. Department of Energy Research Toward Zero Energy Homes

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Case Study: Grupe

CARSTEN CROSSINGS | ROCKLIN, CA

Despite a very slow housing market, Grupe sold its 144 energy-efficient homes at Carsten Crossings in Rocklin, California, more than twice as quickly as its competitors.

Zero-Energy Sets Sacramento Area Builder Apart

In the volatile California housing market, near zero-energy construction has helped Stockton area home builder Grupe to stand out from the competition. The production builder's 144-home Carsten Crossings in Rocklin, CA, outsold the competition two to one in a very tough Sacramento home market. "The zero-energy features of these homes have definitely helped us close deals," said Mark Fischer, a senior vice president at Grupe.

Sacramento's new home market took a nose dive in March 2006 dropping 30% to 45% from 2005, just when the first 10 of the 144 homes at Grupe's Carsten Crossings project were completed. "We sold 23 of our first 30 homes in the first three months, even though the market in Sacramento was very slow, the slowest housing market in the country," said Fischer. Grupe's 144 homes sold in 31 months, 45 months sooner than builders with similar, but non-energy-efficient developments.

This was the first solar development for Grupe, a Stockton-based production builder producing 200 to 300 homes per year. They chose to make solar a standard feature on all 144 houses.

"We certainly like the fact that it made us unique and we felt good about offering it because we think solar is the right thing to do," said Fischer. Photovoltaics are only part of the equation. Carsten Crossings homeowners have seen utility savings of 40% to 80% per month compared to comparably sized homes built to California's Title 24, thanks to both the photovoltaics and an impressive mix of energy-efficient features that were offered as standard features by Grupe.

"Making solar a standard feature instead of an optional upgrade is the way to do it," said David Springer of Davis Energy Group, which is a partner in the U.S. Department of Energy's Building America program on the Consortium for Advanced Residential Buildings (CARB) team. "Our experience on previous projects has been that very few homeowners purchase solar photovoltaics when it is offered as an option. Grupe was able to negotiate a much better deal with their contractors by making it standard across the project," said Springer.

BUILDER PROFILE

Builder's Name:
Grupe

Where:
Stockton, CA

Development:
Carsten Crossings at Whitney Ranch in Rocklin, CA

Size:
144 homes

Square footage:
2,168-2,755 sq.ft.
(3-5 bedroom, 3 baths)

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For more information
1-877-EERE-INF (1-877-337-3463)
buildingamerica.gov

Powerlight integrated solar roof tiles blend in with surrounding roof tiles to provide 2.4 kw of clean, quiet energy.

KEY FEATURES

- 2.4 kW roof-mounted photovoltaic system
- Tankless gas-powered hot water heaters
- Energy-efficient windows
- High-efficiency, variable speed furnace 90+AFUE
- SmartVent automatic night ventilation cooling
- "FreshVent" continuous ventilation system
- Dual-zone equalizer two-zone heating and cooling system
- Energy-efficient lighting
- ENERGY STAR dishwasher
- R-49 attic insulation
- Radiant barrier sheathing in attic ceiling to reduce cooling
- 1-inch rigid foam exterior insulation
- Ducts in attic covered with blown-in cellulose insulation
- Wall insulation soy-based foam (option)
- Homerun parallel piping central manifold for plumbing
- Third-party duct and air sealing testing

Other builders have found that when solar is offered as an upgrade, buyers will often choose more immediately visible options like upgraded counter tops or flooring. A RAND Corporation study done for Building America partner ConSol in 2006 shows that the majority of buyers are interested in energy-efficient and green construction. But, as Bill Dakin of Davis Energy Group pointed out, it's much easier to actually sell solar when it's in the context of an all-solar community where it is included in the price of the home than to sell the homebuyer solar as a $15,000 to $20,000 upgrade perceived to be an extra out-of-pocket expense.

Carsten Crossings is the second largest community to meet the California Energy Commission Zero-Energy New Homes initiative criteria and one of the largest all-solar communities in Northern California.

"The Carsten Crossings project has been a positive learning experience for Grupe" said Lew Pratsch, the DOE Project Manager for Integrated Onsite Power.

Building America's Davis Energy Group has helped Grupe on several aspects of the project, including selecting energy efficiency measures, preparing bid specifications for the photovoltaic system, testing and inspections during construction, and post-construction analysis. Davis also helped develop educational materials for staff and the public.

Energy-efficient construction can be a great selling tool if sales staff know how to use it. Grupe conducted 4 hours of formal training for all its sales staff, followed by ongoing training. "If you are going to put it in, be prepared to train your whole organization on why it's a good deal, especially sales staff. They have to be able to tell potential buyers why zero-energy construction is so great," said Fischer.

To further the learning experience, Grupe turned the garage of one of its model homes into an energy efficiency and solar show room for training sales staff and educating potential buyers. They also conducted media outreach, like holding press conferences, and put together a GrupeGreen DVD.

It's worked well. "Grupe's sales staff is sold on solar; they are passionate about it," said Bill Dakin of Davis Energy Group.

To learn more about the energy savings, Davis conducted duct blaster and blower door tests of the homes to test air leakage in the ducts and whole house during and after construction. Davis Energy Group also evaluated utility billing data after the homes were occupied.

The Solar System

For its solar system, Grupe chose a product called SunTile made by PowerLight, that is similar in size and dimensions to a row of concrete roofing tiles. Rather than sitting on top of the roof like traditional solar panels, these integrated solar tiles are used in place of some of the roofing tiles, in an overlapping pattern that blends in with the surrounding roofing materials.

"What really affects the power production of the PV cells is orientation toward the sun," said Fischer. "We don't limit ourselves to putting these tiles on the backs of our houses. We put tiles on the front, back, or sides of the houses, wherever they will get the most solar gain. They blend in so well with the cement tiles that buyers have no objection to seeing them. You almost can't tell they're there."

Powerlight offered Grupe a complete turn-key package, including delivering and installing the tiles, 5 years of free post-installation performance monitoring, and a warranty covering parts, workmanship, and repairs.

"We had no difficulty working solar into the production schedule. The solar installation does not interfere with any other critical path in the construction process. It really didn't add time for installation," said Fischer. "The PV system was inspected while the city inspectors were already on site doing other inspections. That may vary by jurisdiction, but that was the case in Rocklin," said Fischer.

Powerlight is unique in offering post-installation performance monitoring, which enables Powerlight to make sure each system is producing power. Homeowners can also access the information through a user-friendly website that lets them see how much power their PV system is producing on a given day and how much greenhouse gas emissions from traditional power sources their PV system is displacing.

Energy Efficient, Innovative, Green

A super-efficient building envelope and high-performance appliances are another key to cutting energy costs.

All of the Carsten Crossings homes feature energy-efficient low-emissivity windows, energy-efficient lighting, tankless gas-powered "on-demand" hot water heaters with a parallel piping manifold, high-efficiency variable speed 90+ AFUE furnaces, "FreshVent" continuous ventilation systems, and dual-zone equalizers.

To cut cooling costs, the homes use SmartVent automatic night ventilation cooling. The system uses a thermostat-controlled damper to automatically let in cool, filtered air when outdoor temperature drops at night. "Think of it as an intelligent whole-house fan. It provides filtered outside air to a specific set point, say 65 degrees, to cool off the house at night without having to open the windows," said Dakin. A study of SmartVent's effectiveness conducted on another project by PG&E showed average daily energy savings of 22% and peak demand reduction of 42% when temperatures were 104°F or higher and average daily energy savings of 16.3% overall and 48% peak demand reduction on days when the temperatures reached 92°F.

At Carsten Crossings, the attics have R-49 blown cellulose and the heating and cooling system ducts were wrapped, sealed, and buried in the attic insulation. The attic ceilings were lined with a radiant barrier to keep out heat. The 2x4 stud walls were filled with blown-in fiberglass or soy-based foam insulation. In addition, all of the homes' exterior walls were blanketed with a 1-inch-thick layer of rigid foam for additional insulation. Duct and whole house air sealing was independently confirmed through duct blaster and blower door testing conducted by Davis Energy Group.

"By using a Building America consultant like Davis Energy Group, not only do we get third-party credibility," said Fisher, "we become incredibly educated about the things we can do to save energy while building sustainable and beautiful communities" (as quoted in the *San Francisco Chronicle* July 2, 2006).

Grupe marketed the homes as GrupeGreen. With their bundle of energy-efficiency measures, the homes met the criteria of Building America's Zero Energy Homes, the California Energy Commission's Zero Energy New Home (ZENH) Initiative, and the ENERGY STAR homes program. Grupe also participated in the LEED (Leadership in Energy and Environmental Design) Homes Green Building certification program. Compliance with the LEED Homes program required water efficiency, on-site recycling, use of local materials, and site selection that ensures open spaces, along with energy efficiency and renewable energy systems, according to Dakin.

Plumbing manifold gets hot water to its destination faster.

Grupe's Carsten Crossing Community won the gold award for moderate climate production homes in the 2007 Energy Value Housing Award competition held by the National Association of Home Builders Research Center.

Positive Cash Flow from Day One:

Grupe sales staff showed buyers how they would actually make money back on their energy-efficient home

YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Mortgage Payment				
($1,391)	($1,391)	($1,391)	($1,391)	($1,391)
Utility Savings				
$1,440	$1,483	$1,527	$1,573	$1,620
Tax Credit				
$2,000				
Tax Benefit				
$280	$277	$274	$270	$266
Net Positive Cash Flow to Buyer				
$2,329	$369	$410	$452	$495
Cumulative Cash				
$2,329	$2,698	$3,108	$3,560	$4,055

Assumptions: 100% Financed, 6.5% Interest Rate, 25% Tax Rate, 3% Energy Inflation

(top) Grupe is marketing the zero-energy homes as GrupeGreen homes. With their bundle of energy-efficiency measures, the homes meet the criteria of Building America's Zero-Energy Homes, the California Energy Commission's Zero-Energy New Home (ZENH) Initiative, the ENERGY STAR homes program, and the LEED Homes Green Building certification program.

(bottom) Using a real-time monitoring system, the solar installer can check the PV system's performance from a portable computer or Blackberry at any time.

"By using a Building America consultant like Davis Energy Group, not only do we get third-party credibility, we become incredibly educated about the things we can do to save energy while building sustainable and beautiful communities."

Mark Fischer, a senior vice president at Grupe (as quoted in the San Francisco Chronicle July 2, 2006)

"The Grupe Company has been a leader in energy efficiency," said Pratsch, who noted Grupe was among the first ENERGY STAR builders in its area and one of the first to use blown-in insulation. "We hope the Carsten Crossings solar project provides a model that other builders will follow."

Dollars and Sense

In its first foray into an all-solar development, Grupe did get a boost from the California Public Utilities Commission. In January 2006, the Commission approved a 10-year, $2.9 billion program to give homeowners or builders a $7,000 per home subsidy to add solar units to their homes. This brought Grupe's cost for adding solar down to about $18,000 for solar plus all of the energy efficiency measures.

In addition to the $7,000 subsidy, homeowners get a $2,000 federal tax credit, which goes directly to the homeowner and not to the builder or developer.

Based on first and second year utility bill data, CARB projected annual utility savings of $1440 to $1620 for the first five years. According to Springer, even based on a system cost of $18,000 to $20,000, if that cost is included in a 30-year mortgage with a 6.5% interest rate, the utility bill savings are greater than the annual incremental cost to finance the PV system. When rebates and tax benefits are rolled in, CARB calculated that homeowners come out $4055 ahead after 5 years.

An energy-efficient appraisal estimated that adding the solar and energy efficiency features would increase the value of a Grupe Carsten Crossings home by $24,300 in the first five years and by $28,185 after 10 years (in 2007$).

Because of the soft market, Grupe did not charge more for the energy-efficient homes than its competitors who were selling similar sized houses—they "gave away" the solar, but Grupe found that they did not lose the money. They got it back, and then some, through faster sales even in a slow market.

Grupe compared their sales rate to that of eight competitors with similar homes selling in 2006 and 2007. Grupe determined that the GrupeGreen features cost an additional $2,642,000 for the 144 homes. The cost to carry that extra expense on the 144 homes at Carsten Crossings was $311,000 per month for every month they weren't sold. Grupe determined a typical rate of sales among competitors was 1.9 homes sold per month. At that rate it would take 76 months to sell all the homes. If they could sell out 8.5 months sooner, i.e., in 67.5 months, they would make up the extra carrying cost. That meant selling at a rate of 2.1 homes per month. Grupe found they actually sold at a rate of 4.6 homes per month, well above their break-even rate of 2.1 homes per month and more than twice as fast as their competitors. At the faster rate, Grupe could sell all 144 homes in 31 months, 45 months sooner than the competition, for a savings of $14 million (45 months x $311,000/month).

The Bottom Line

For Grupe, solar homes make a lot of environmental sense, but they also make sense from a business stand point. "They helped Gupe outsell the competition more than 2 to 1," said Daikin.

Said Fischer. "In a few years, you will see this everywhere."

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Case Study:
John Wesley Miller Companies

ARMORY PARK DEL SOL | TUCSON, AZ

John Wesley Miller combined thick masonry walls with rigid foam sheathing insulation, R-38 attic insulation, high-performance windows, 14-SEER heat pumps, and solar photovoltaic and water heating systems for 50% energy savings over the Building America benchmark on all 97 standard units at Armory Park del Sol in Tucson.

A "Second-Generation" Net Zero-Energy Home

Solar home visionary John Wesley Miller has teamed with the U.S. Department of Energy to build two zero-energy homes at his award-winning 98-unit development in Tucson's historic Armory Park neighborhood.

Miller was one of four builders selected to work on DOE's Net Zero-Energy Homes program. Through the initiative, Miller worked with the National Association of Home Builders Research Center, the National Renewable Energy Laboratory, Devereaux and Associates Architects, and a team of suppliers and contractors to design one of the first true zero energy homes in the country in 2003. Four years later they improved on their design to build a second zero-energy home. Both homes are located in Miller's Armory Park del Sol community. Every home in the community already exceeds the 1993 Model Energy Code by 50% or more. The homes in Armory Park del Sol use about 7 kWh of electricity per square foot per year.

Two Net Zero-Energy Homes – Lessons Learned

Miller completed the first net zero-energy home at Armory Park in 2003. The 1,700-square-foot, two-story home uses 7,000 kWh of energy annually, compared with 18,000 kWh for a conventional home, and it produces nearly all the energy it uses on an annual basis. The home's solar hot water system provides almost all of the homeowner's hot water and home heating needs. Total energy costs in 2005 for the zero-energy home were about $15 per month—including all heating, cooling, lighting, and appliance use.

The second net zero-energy home was completed in 2007. This 2,168-square-foot home, which is 26% larger than the first home, is similar to the other 93 homes in the development in that it contains the same basic energy-efficiency features, such as photovoltaic panels for producing electricity, a solar thermal water heater, thermal mass masonry walls, exterior polyisocyanurate, and HVAC and ductwork located within the home's conditioned space. It also incorporates handicap accessibility and low-maintenance features to accommodate aging residents.

BUILDER PROFILE

Builder's Name:
Treasure Homes

Where:
Tucson, AZ

Development:
Armory Park del Sol

Size:
99 homes

Square Footage:
977 to 2,026 sq. ft.
(2-3 bedrooms and baths)

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For more information
1-877-EERE-INF (1-877-337-3463)
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All homes come standard with a 1.5-kW photovoltaic system and solar hot water collector. *(left photo source: NAHBRC) (right photo source: JW Miller).*

KEY FEATURES OF STANDARD HOMES

- 1.5-kW PV system on standard homes, 4.2-kW on 1st generation ZEH, 5.7 kW on 2nd generation ZEH
- Copperheart solar hot water collector with 10-year guarantee
- Seisco tankless water heater
- R-38 ceiling insulation
- Milgard dual-pane, low-E2 windows with lifetime guarantee
- 14 SEER high-efficiency heat pump
- Masonry wall superstructure with exterior foam sheathing and 3-coat stucco finish
- Copper water lines
- Universal accessibility design with 3-foot-wide doors on single-level floor plans

Miller and his team also made several changes between the "first-generation" and "second-generation" zero-energy homes, based on NAHBRC's analysis of the energy usage data and interviews with the homeowners.

- **Changed plumbing from PEX to copper.**
  Although PEX piping had been used in the first-generation home, Miller prefers to use copper piping because of its perceived durability but recognized that the parallel piping design used in the first home would minimize resource-wasting wait times for hot water.

- **Changed space heating from solar hot water heat to air source heat pump and reduced solar hot water tank size foot print by two-thirds.**
  In the first home, the solar thermal system for heating domestic water was designed to handle 100% of the domestic water heating load as well as nearly 90% of the space heating load. However, this system required a large custom tank that needed post-installation modifications to work and took up too much space inside the home. In the second-generation home, the solar thermal system was downsized for less square footage of thermal collectors on the roof and a smaller storage tank designed to meet 90% of domestic hot water needs, with an electric on-demand water heater for back up. Space heating was provided by a SEER 17.6-rated high-efficiency air source heat pump for heating and cooling.

- **Increased PV size from 4.2 kW to 5.7 kW system.**
  The solar photovoltaic system is approximately 65% larger than the first zero-energy home's PV and provides nearly all of the energy annually to operate the home, including the increased electricity demand of the electric water heater and heat pump. Although a larger photovoltaic system is more expensive than a larger solar thermal system, in this case the builder felt that the benefits of increased installation simplicity, lower maintenance, and smaller sized water tank outweighed the higher cost.

- **Switched from recessed can lights to high-efficiency lighting without recessed fixtures.** The first-generation home contains recessed "can" lights located in the ceiling. These lights resulted in high lighting costs and in penetration of the ceiling thermal boundary. The second generation home contains high-efficiency lighting with predicted savings of 50% (2,548 kWh to 1,274 kWh).

- **Added 1.5 inches of rigid foam insulation above roof frames.** This rigid polyisocyanurate foam is wrapped in aluminum foil and laid above the roof frames with R-38 insulation below for an equivalent of R-55 roof insulation. By adding insulation above the roof rafters, Miller is able to increase R-value while avoiding the higher costs associated with increasing the depths of the rafter to accommodate increased insulation thickness.

Insulation from the Elements

Interior comfort can be difficult to maintain in the extreme outdoor conditions found in Arizona. However, John Wesley Miller incorporates several best practices that protect against the temperature swings found in desert climates.

Masonry Construction

The Armory Park del Sol homes have a masonry wall superstructure consisting of conventional masonry concrete blocks. The concrete block is insulated on the exterior side with 1.5 inches of polyisocyanurate foam and covered with a 3-coat stucco finish. Interior framing consists of termite-proof steel framing. This masonry construction, notes Miller, provides a thermal mass wall to protect the indoor environment from outdoor conditions. The exterior walls cool at night; because they are so slow to transmit temperature, they emit a cool feeling to the home during the heat of the day and warmth at night. A side benefit for homebuyers is their sound-deadening properties. With the masonry walls and attention to air sealing at all envelope penetrations, Miller was able to achieve a very tight house (2.9 ACH50).

HVAC System

John Wesley Miller Companies works with a professional engineer to review house plans to assess the placement of ductwork and the proper sizing of HVAC equipment. At Armory Park del Sol, the ducts are sealed with mastic, tested for air leakage, and enclosed in soffits along the central core of the house within the conditioned enveloped of the home. Transfer grilles across doorways and a central return equalize air pressure throughout the house. This careful attention to the HVAC system and its placement further contribute to the home's energy efficiency.

Windows

Inferior windows can contribute to air leakage or heat transfer, which is why low-emissivity dual-pane windows were chosen for Armory Park del Sol homes. The spectrally selective coatings on these windows protect occupants from the heat and glare of the daytime sun, while the U-value of 0.31 indicates low heat loss during the night.

The first-generation zero-energy home contains an AC unit and an integrated solar water and space heating system. In the second-generation home, solar collectors provide water heating with backup water heating provided by a tankless gas water heater and space heat provided by an air source heat pump *(Photo source: by NAHBRC).*

Deep overhangs and porches help minimize heat gain to the interior of the home. Xeriscaping minimizes irrigation needs in the hot dry climate.

"John Wesley Miller Companies worked with the NAHB Research Center to analyze its first-generation net zero-energy home at Armory Park del Sol. Together they came up with a list of energy-, space- and cost-saving changes that simplify installation for the builder while still allowing the home to reach true net zero-energy use."

John Wesley Miller

The southwestern architecture of John Wesley Miller's Armory Park del Sol urban infill project cleverly hides the rooftop photovoltaic and solar water heating panels from passersby.

First-Generation Zero Energy

First Generation
R-38 blown attic insulation
1.5-inch rigid foam exterior wall insulation thickness
PEX parallel piping
Recessed can lights
4.2 kW PV
Solar hot water space heating
Custom-built, oversized solar hot water tank

VERSUS

Second-Generation Zero Energy

R-38 blown attic insulation plus 1-inch rigid polyisocyanurate foam sandwiched in aluminum foil for R-55 attic equivalent
2-inch rigid foam exterior wall insulation thickness
Copper modified parallel piping
High-efficiency lighting
5.7 kW PV
Air source heat pump
Standard solar hot water tank

Solar Energy Features

"In 1973, I became enthralled with solar energy" said Miller, whose solar energy credits include coming up with the concept for the original Solar Village, which evolved into the Civano planned solar community in Tucson. His passion has evolved into a homebuilding creed that puts solar energy first.

For example, each of the 99 lots within the Armory Park del Sol was carefully configured to take full advantage of the sun. The southwestern architecture—like flat roofs and parapet walls, are ideal for keeping PV and solar hot water panels hidden from view. All homes have wind-resistant, 1.0- to 1.6-kW (or better) PV systems with programmable thermostats, backed by a 25-year guarantee. The Homeowners Association (HOA) restricts the placement and maximum height of trees to avoid adverse shading conditions that could interfere with the efficiency of the PV modules.

In addition, each house was outfitted with a roof-mounted Copperheart solar hot water collector, which combines thermal collection (i.e., water heated by the sun) and storage in a single unit. It is backed up by a Seisco tankless water heater to ensure hot water on demand. Parallel piping was installed to improve hot water delivery time as well. This hot water distribution system features copper pipes that branch off of the main pipe to each hot water use point, speeding up delivery time and reducing energy losses.

Working Together

Miller has formed long-standing relationships with local subcontractors and holds frequent meetings with staff and trades to review building practices and discuss issues. This ensures that all parties are on the same page when working with new techniques or materials.

In addition to working with Building America, Miller is also involved with other national and local building organizations. The company has also formed a strong bond with Tucson Electric Power, the local utility. The utility aggressively promotes renewable energy power systems by offering rebates and other incentives. Miller is also participating in the utility's Guaranteed Home program. Tucson Electric Power offers every home in Amory Park del Sol guaranteed heating and cooling energy costs for five years. Tucson Electric Power inspects each home three times during construction to ensure that building science performance criteria are met. Miller is also involved in developing local county green building codes. Said Miller, "This is a volunteer program that gives builders incentives for doing good things instead of penalizing them. Too long we've been fighting each other. It's time to sit down at the table and work together to accomplish these common goals."

The Bottom Line

Miller believes that education is the key to helping buyers understand the long-term financial benefits of energy-efficient homes. "About 80% of our buyers looked us up on the web first. We probably have more Ph.D.s living in our little development than any other part of town. This doesn't mean you have to be a genius to appreciate the homes we build, but it shows that education and a willingness to learn about energy efficiency can drive sales," said Miller.

Local and federal incentives make high-efficiency features more palatable to price-conscious buyers. Tucson Electric Power agreed to a billing cap so heating and cooling bills are guaranteed not to exceed $1 per day for five years (depending on the size of the house). The utility also offered rebates for solar systems of $2.40 - $3.00 per installed watt, for a total rebate of $3,600 - $4,800 per house. This is in addition to federal and state tax rebates for solar and energy-efficient appliances and equipment.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Case Study: Pulte Homes and Communities of Del Webb – Las Vegas Division

The Biggest Home Builder in Las Vegas Teams with Building America

Pulte Homes Las Vegas Division may have the fastest ramp up time on record to get a home certified to the U.S. Department of Energy's Builders Challenge.

"I first heard about the Builders Challenge from David Rodgers, Deputy Assistant Secretary for Energy Efficiency, in July 2008. Within 10 days we had our first house certified," said Nat Hodgson, Vice President of Construction for the Las Vegas Division of Pulte Homes and Communities of Del Webb. Since July 2008, Pulte Las Vegas has certified more than 780 homes through Builders Challenge.

Passion and Performance

The Pulte Las Vegas division's passion for energy efficiency isn't exactly an overnight phenomenon. They have been a local leader in energy efficiency since 1997 when Hodgson teamed up with Building America's Building Science Consortium to build pilot homes in Las Vegas.

Pulte has built 100% ENERGY STAR homes in the Las Vegas valley since 1999 and builds the most ENERGY STAR-labeled homes nationwide. Pulte Homes Nevada Operations was named an ENERGY STAR partner of the year in 2004. Pulte has continually gone beyond ENERGY STAR, implementing an Environments for Living® package that incorporates building science technology throughout each home.

In January 2009, Pulte held a grand opening for Villa Trieste, a 185-unit community in northwest Las Vegas. Pulte offered solar PV, LEED certfiication, and an EFL guarantee standard on each home. The homes are designed to use 60% less energy than the Building America benchmark. DOE provided a research grant to develop the community, which features 1,400 to 1,960 sq. ft. homes starting at $200,000.

BUILDER PROFILE

Builder's Name:
Pulte Homes and Communities of Del Webb – Las Vegas Division

Founded:
Pulte founded in 1950 in Bloomfield Hills, Michigan; Las Vegas division started in 1992

Employees:
36 construction staff, not counting subs, 13,400 nationally (2006)

Homes Built:
2,200 Las Vegas division, 27,540 in U.S. in 2007 (a 35% drop from 2006)

Development:
23 developments under construction in Las Vegas valley in 2008

Size:
850-5,000 sq. ft., 2-bedroom town homes to 6-bedroom 3-bath single-family detached houses, depends on development

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Pulte is the first builder in the Las Vegas valley to accept the DOE Builders Challenge. Pulte has built more than 780 homes to the Builders Challenge criteria since July 2008.

"Most of our sales are through word of mouth. Homebuyers don't always understand the value of what they are getting until they've lived in the home a few months and start seeing their utility bills. Then they can't wait to talk about it with their friends."

Nat Hodgson, Vice President of Construction for the Las Vegas Division of Pulte Homes and Communities of Del Web

2008 JD Powers and Associates New-Home Builder Customer Satisfaction Study

Pulte Homes operations ranked highest in customer satisfaction in 11 of 26 U.S. markets, more than any other U.S. builder. Pulte Homes' market operations earned top rankings for new-home quality in seven markets, tied for the most among all builders, and earned the most top rankings for new-home design with top scores in six markets.

Pulte Homes, including its Del Webb brand, has the largest home building volume in metropolitan Las Vegas. The company built and sold 4,600 new homes in 2006 and 2,200 in 2007. They built 1,550 in 2008 and anticipated building 1,000 in 2009 according to Hodgson.

Meeting the Challenge

When Pulte decided to step up to the Builders Challenge, they found that they were already doing many of the things that would help them meet the ambitious goal of 30% energy savings over a Building America baseline home. (The baseline home is roughly equivalent to a home built to meet the 1993 Model Energy Code.)

Builders Challenge homes must score a 70 or lower on the HERS Index score; ENERGY STAR requires a HERS index score of 85 and Environments for Living requires a HERS index score of 80 or less. "When we heard about Builders Challenge we were already consistently getting HERS index scores below 70. Some homes and floor plans are down as low as 56 and 54," said Hodgson.

Pulte is so committed to energy-efficient home construction that it offers the Environments for Living package standard on every house it builds. "It's not an optional upgrade. In the late '90s when we looked into increasing our energy efficiency, we realized every homeowner needs this," said Hodgson. He went on to explain that meeting the efficiency levels they wanted to reach for Builders Challenge and Environments for Living meant really thinking about the house as a system and making changes at the design stage.

"We are so far above code that I don't think we could offer it as an option even if we wanted to. To achieve the levels of efficiency we're getting, it has to be a whole package," said Hodgson.

That systems approach starts with a Manual J calculation of cooling needs, Manual D engineered duct design, location of ducts and air handler in conditioned space, pressure balancing every room, and meticulous attention to air sealing both the envelope of the house and the ducts. Pulte chose blown cellulose instead of fiberglass batt to insulate the attic and walls because gaps where pieces of batt come together or compressions due to piping and wiring can limit the effectiveness of the batts, significantly compromising insulating values.

One thing that really sets Pulte apart from the competition is its attic insulating technique. Rather than distributing the cellulose insulation along the ceiling deck, Pulte applies it along the underside of the roof line, holding it in place with netting stapled to the roof struts, providing a conditioned attic space. “We can get temperatures over 105°F several days in a row here in the summer. Unconditioned attics can get up to 150°F. Mine stay about 80°F. It’s not rocket science to figure out that if you’re sending your ducts through the attic, you are going to have to work a lot harder to cool your living space to 78°F when you’ve got 150°F attics than when you’ve got 80°F attics,” said Hodgson.

Pulte hires an independent inspector to conduct duct blaster tests and do an extensive visual inspection of each home after the HVAC is installed but before sheetrock is put in. “The visual inspection reports come straight to me. I grade my supervisors on them and their bonuses are based on how well they do on these inspections, not how many houses they crank out,” said Hodgson.

“When we started doing conditioned attics, we thought everyone would jump on the band wagon, but they haven’t,” said Hodgson. “This kind of construction is not that hard, it’s just different. For whatever reason, our industry is about the most archaic manufacturing system in the world. Buying a home is the largest personal investment most individuals will ever make and yet the industry still relies on the most archaic means of production. We are just now starting to talk about energy use monitoring equipment in homes. Even programmable thermostats are considered unusual. Cars have had computerized monitors onboard since 1973,” said Hodgson.

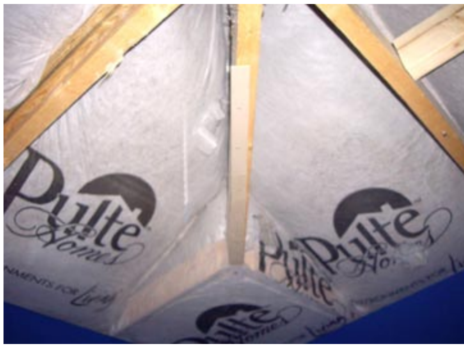
Dollars and Sense

Pulte’s Las Vegas division actively markets the high performance of its homes. Each sales office has a room Pulte calls the QCC Room (for Quality Construction Center). The room is full of three-dimensional wall displays showing side-by-side comparisons of Pulte construction and code-minimum construction.

“Right now it’s a buyer’s market,” said Hodgson. “There is a great deal of pressure to lower our sales prices, but we know we are giving buyers a better product, and our buyers tell us this. Most of our sales are through word of mouth. Homebuyers don’t always understand the value of what they are getting until they’ve lived in the home a few months and start seeing their utility bills. Then, they can’t wait to talk about it with their friends.”

Hodgson said higher energy performance and the higher quality that goes along with it have set his product apart in the Las Vegas valley, and he believes the Builders Challenge label will help drive the message home for buyers.

Hodgson appreciates the new Builders Challenge label, which prominently features the E-Scale based on the Home Energy Rating System (HERS). The E-Scale uses an index of 0 to 100 with 0 being the ultimate goal, a net zero-energy home. A code minimum house would score 100, Builders Challenge homes must score 70 or lower. “Buyers understand it because it’s like miles per gallon for a car. It’s a simple way to compare one home to another, only in this case, the lower the score, the better,” said Hodgson.



Pulte’s unique method of applying attic insulation keeps the blown cellulose right up against the roof line. This insulated attic provides conditioned space at the air handler and ducts at around 80°F instead of the 150°F temperatures found in uninsulated Las Vegas attics.

KEY FEATURES

- HERS Index score of 60
- Right sized 15 SEER HVAC
- Engineered duct design
- Ducts located in conditioned space
- Conditioned attic space with insulation applied along roof line
- Blown cellulose rather than batt wall insulation for more thorough insulation
- Pressure balancing between rooms
- Outside filtered air intake
- Vinyl-frame low-emissivity windows
- Sealing of penetrations in envelope and top and bottom plate and sealing of bottom plate
- Optimum value engineering framing
- Continuous air barrier enclosing the conditioned space
- Low-flow toilets, fluorescent lighting, and ENERGY STAR appliances in most communities
- Programmable thermostats
- Outside vented kitchen and bath fans
- *Environments for Living* package with heating and cooling bill guarantee
- Green features vary somewhat by community but include low VOC paints, “smart” irrigation systems, formaldehyde-free cabinets

Pulte markets its energy-efficient features in information rooms that show potential buyers side-by-side displays of Pulte building science technology versus code minimum techniques.

Environments for Living

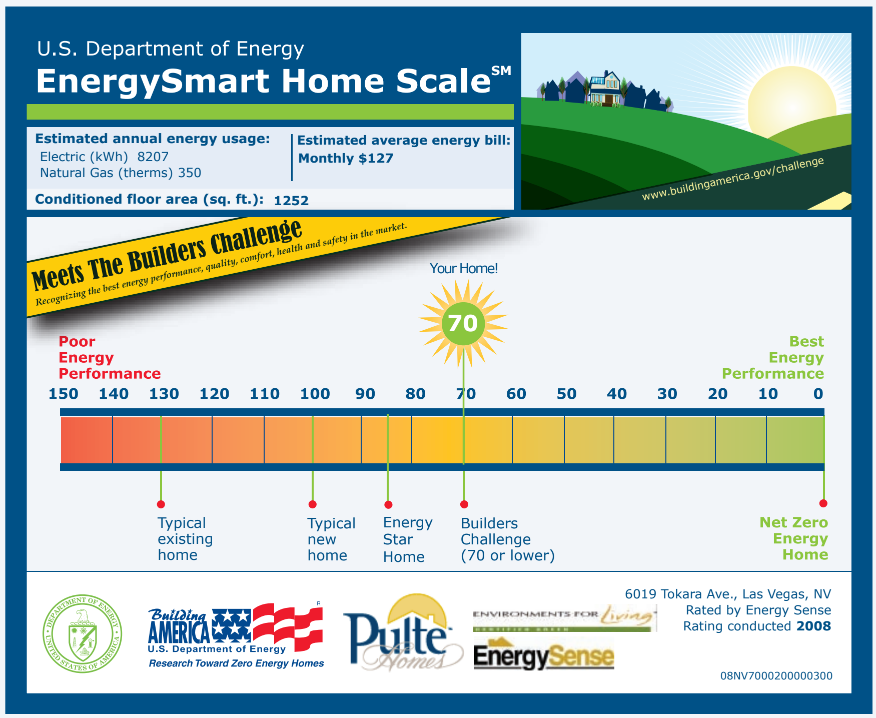
Pulte's Las Vegas Division participates in the Environments for Living Program. Started by MASCO in 2001, the program assists builders in constructing homes using sound building science principles for an end result that is comfortable, durable, and energy efficient. MASCO provides certification and marketing materials. Builders who want to get their homes certified for Environments for Living can contact MASCO at 1-866-912-7233, or via e-mail at EnvironmentsForLiving@mascohq.com to obtain a list of local Master Certified Contractors (MCCs) who can help builders fill-out the Plan Input Sheet. The input sheet and house plan(s) are sent to EFL's Plan Review Center. EFL conducts a diagnostic analysis of the plans and compares the performance of a home built to specifications to one built using the EFL program features. Costs, heating and cooling usage, and carbon emissions reduction calculations are also provided. For homes that are built to EFL recommendations, EFL guarantees heating and cooling energy usage. For gold, platinum, and diamond-level homes, EFL will also give a comfort guarantee—that the temperature at the thermostat will not vary more than 3 degrees from the center of any conditioned room in the thermostat's zone. See www.eflhome.com/index.jsp?action=fl_guarantee for details.

The Bottom Line

"I want to make all of the houses built in the U.S. more energy efficient because there is something in it for all of us. I like to be the leader, don't get me wrong, but I want to help other builders get this," said Hodgson.

"People ask me 'Why did you choose to build this way?' I say 'Why *wouldn't* you build this way?' Consumers tell us they want it. Energy costs are continuing to go up. This is the best tool we have to fight back. As an industry, we need to do this," said Hodgson.

U.S. Department of Energy Builders Challenge



DOE has posed a challenge to the homebuilding industry—to build 220,000 high-performance homes by 2012. Homes that qualify for this Builders Challenge must meet a 70 or better on the EnergySmart Home Scale (E-Scale). The E-scale allows homebuyers to understand—at a glance—how the energy performance of a particular home compares with others. Through the Builders Challenge, participating homebuilders will have an easy way to differentiate their best energy-performing homes from other products in the marketplace, and to make the benefits clear to buyers.

The figure to the right shows an E-Scale for Pulte Homes and Communities of Del Webb. The E-scale is based on the well-established Home Energy Rating System (HERS) index, developed by the Residential Energy Services Network. To learn more about the index and HERS Raters visit www.natresnet.org.

To learn more about the Builders Challenge and find tools to help market your homes, visit www.buildingamerica.gov/challenge.

Building America U.S. Department of Energy Research Toward Zero Energy Homes

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Case Study: Treasure Homes

FALLEN LEAF AT RIVERBEND | SACRAMENTO, CA

Treasure Homes' Fallen Leaf project was named a California Green Builder Community by the California Building Industry Association for its energy efficient and green building practices.

A California Building Industry Award Winner

Treasure Homes' Fallen Leaf at Riverbend, a 32-home development started in 2006, is the first solar community built in Sacramento. Homes in Fallen Leaf save their homeowners as much as 50% on their utility costs. The savings are a result of collaboration between Treasure Homes and the Sacramento Municipal Utility District (SMUD), the U.S. Department of Energy's Building America program, the National Renewable Energy Laboratory (NREL), and consultant ConSol, a Building America team lead.

As a result of this creative teamwork, Fallen Leaf was named a California Green Builder Community in 2006 by the California Building Industry Association. The project was also honored with two Awards of Merit by the Association's Gold Nugget Award program, which recognizes creative achievements in architectural design and land use.

Education is Key

In spite of this positive press and the obvious need for energy efficiency with increasing energy costs, the company initially found it difficult to convince its first-time-buyer customer base.

"I underestimated the challenge of educating people about the benefits of energy efficiency," said Jim Bayless, the president of Treasure Homes. Thankfully, he adds, since the initial opening of Fallen Leaf at Riverbend, "there has been a cultural shift in the awareness of the benefits of solar and energy-efficient homes. Now I can't turn on the TV or open the paper without hearing or reading something about energy efficiency. This has really helped us close out the community on a strong note."

BUILDER PROFILE

Builder's Name: Treasure Homes

Where: Sacramento, CA

Development: Fallen Leaf

Size: 32-lot development

Square Footage: 1,026 to 2,271 sq. ft.

Completed: 2006

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For more information
1-877-EERE-INF (1-877-337-3463)
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Solar panels can meet nearly 70% of the energy needs of a Fallen Leaf home.

KEY FEATURES

- R-13 wall +1-inch EPS foam; R-38 attic; R-30 floor above garage; R-4 buried ducts in attic
- Radiant barrier in roof
- SmartVent system automatically circulates fresh, filtered air
- Mechanically designed HVAC system with mastic-sealed ducts
- Double-pane windows with Solarban glazing: U-Factor: 0.38; SHGC: 0.29
- 13 SEER A/C unit with a thermal static expansion valve 0.90 AFUE furnace
- Tankless water heater, with a minimum factor of 0.82 and R-4 insulated pipes
- Tyvek housewrap
- ENERGY STAR appliances and fluorescent lighting
- Non-toxic insect and mold deterrants
- 2.4-kW PV solar roof panels

A Model for Education

Even with a cultural shift toward valuing energy efficiency, Jim Bayless and his team took a pro-active approach to educating potential homeowners. Treasure Homes converted the garage of a model home into an energy-efficiency room where buyers followed a path of "fallen leaves" to different displays showcasing the energy-efficient features of the homes and their financial and environmental benefits. Sales agents viewed the room as a valuable sales tool for selling the affordable 1,000- to 2,300-square-foot homes.

The homes have numerous features to highlight which, when working as a system, reduce homeowners' utility bills by 50% and more.

Energy Saving Features

To reach their total energy savings goals, the homes at Fallen Leaf contain the following features:

For the home's shell, the wall insulation is R-13 plus 1-inch EPS foam. The attic insulation is rated at R-38. Ducts are insulated at R 4.2 and buried in the attic insulation. The floor above the garage has an R-30 rating. The roof contains a radiant barrier sheathing. A Tyvek housewrap also protects the house from water and air infiltration while allowing moisture vapor to escape.

The dual-pane windows are coated with "Solarban" glazing to reduce radiant heat gain. Their U factors are 0.38 for sliding and fixed windows and patio doors.

(left) Treasure Homes marketed the exceptional energy saving features of its Fallen Leaf homes by converting the garage of the model home into an energy-efficiency information center where potential homebuyers followed a path of fallen leaves to different displays showcasing the homes' environmental benefits.

(right) The garage is separated from the conditioned space which is well insulated with R-30 unfaced fiberglass batt above the garage. The exterior walls are filled with R-13 blown insulation covered with 1 inch of EPS rigid foam exterior insulation.

A tankless water heater (with R-4 insulation on all trunk lines) produces up to 8.5 gallons of hot water per minute, which saves up to 30% in energy costs per year. A traditional water heater constantly heats water held in the storage tank, even when hot water is not needed. In addition to the energy cost savings, the tankless system takes up less space than a conventional water heater.

The state-of-the-art HVAC system is 13 SEER rated with a thermostatic expansion valve for maintaining the air conditioning capacity and a 90 AFUE furnace. The HVAC and duct design were engineered for right sizing of the heating and cooling equipment and more even distribution of conditioned air. Ducts were sealed and tested for tightness. A Smart Vent system was installed to use the HVAC ductwork to circulate fresh cool filtered outside air. The zoned heating and cooling provides comfortable indoor temperatures for the two-story homes.

The florescent energy-efficient fixtures last 10 times longer and use 75% less energy than incandescent lighting. ENERGY STAR appliances contribute to utility bill savings.

Fallen Leaf homes are outfitted with low-flow showerheads that use only 2.5 gallons per minute instead of the typical 7 gallons. Dual-flush toilets save up to 6,000 gallons a year. Efficient faucets and smaller pipes further help to save water and reduce energy usage.

Treasure Homes uses the BP Solar 2.4-kW-solar photovoltaic Integra, which mounts to the asphalt shingle roof with a two-inch profile. The system is offered with a 25-year warranty and is expected to meet nearly 70% of the energy needs of the typical household. SMUD helped defray the PV cost with a $6,000 rebate.

"The homes at Fallen Leaf are directly connected to the electric grid," said Mike Keesee the coordinator of SMUD's solar advantage program. "They will be generating free energy from the sun during the day, even if no one is home. If a homeowner uses less energy than their home [produces]…, they will have a 'zero' energy bill from SMUD." According to Keesee, homeowners can "bank" a certain amount of energy from SMUD that they can draw from during the months when they use more energy than they've produced.

"In a time when energy conservation is a huge concern for all of us, we are putting our efforts into creating homes that can truly create more energy than their residents use. Not only is that a fantastic benefit for our environment, but homeowners will also see a direct, positive benefit to their pocketbooks."

Jim Bayless, Treasure Homes President

(left) Roof and window flashing help keep rain out of walls and roof assemblies. Dual-pane, vinyl frame windows with solarban glazing help keep out unnecessary heat gain.

(right) The roof is lined with radiant barrier to reflect solar heat, minimizing the heat gain to the attic.

Performance Results

Real-use data show that the Fallen Leaf homeowner's electric bills are averaging 58% less than the average SMUD residential customer's electric bill. One home owner achieved 88% savings over the average SMUD customer. The electric bills at Fallen Leaf have ranged from a low of $9.17 to a high of $52.72 per month. Equally as important to Treasure Homes, at the first annual homeowners association meeting—a meeting traditionally full of complaints—the home owners gave testimonials of their energy savings, not their problems.

Dollars and Sense

The 2.0-kW PV system costs $16,397 to purchase and install. Other energy-efficiency measures including the Smart Vent System, higher efficiency furnace and AC, tankless water heater, pipe insulation, fluorescent lighting, and third-party inspections added $5,640 to the cost for a total additional cost of $22,037.

Local and state incentives, including SMUD's $500 hook-up fee discount, a $200 incentive per home for ENERGY STAR lighting, and a $3/watt SMUD PV buy down of $6,126, reduced the total incremental cost to the buyer to $15,211 (not counting federal incentives).

Building America partner ConSol calculated that energy-efficiency improvements not including solar will reduce annual utility bills by $766 per year, while the increased cost of the energy-efficiency improvements will increase the annual mortgage cost by $395 (not counting solar) for a positive annual net cash flow to the consumer of $371. When solar is added into the equation, the energy savings increased an additional $233 per year and annual mortgage costs increased $700, for a net cash flow to the consumer of -$299.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Appendix I.
Homebuyer's Checklist

Homebuyers, take this with you when you go house shopping to make sure you get an energy-efficient home.

MEASURE	Building America Recommendations	Builder #1	Builder #2	Builder #3
HEATING AND COOLING EQUIPMENT				
ENERGY STAR qualified air conditioning of **SEER*** **13 or greater**	Yes			
ENERGY STAR qualified heat pump	Yes			
ENERGY STAR qualified boiler	Yes			
ENERGY STAR qualified furnace of **AFUE*** **90**	Yes			
ENERGY STAR qualified programmable thermostat	Yes			
Ductwork sealed with mastic (no duct tape)	Yes			
5% or less duct leakage found with pressure test 10% allowed if all ducts are located in the conditioned space.	Yes			
Duct Insulation: **R-4** in conditioned space, **R-8** in attic, **R-6** in crawlspace	Yes			
House plans show duct layouts	Yes			
Ducts located in conditioned space as much as possible	Yes			
Ducts sized according to industry standards in **Manual D**	Yes			
Heating and cooling equipment sized according to industry standards in **Manual J**	Yes			
House pressure balanced with jump ducts or transfer grills	Yes			
HVAC* equipment and duct work inspected and tested after installation	Yes			
Filter with MERV rating of 8 or higher installed on the central air handler	Yes			
Air handler isolated from garage by a thermal barrier (insulation) and air barrier (e.g., drywall sealed at seams)	Yes			

MEASURE	Building America Recommendations	Builder #1	Builder #2	Builder #3
INSULATION *(take a look at a house under construction before sheetrock is installed)*				
Insulation installed behind tubs, landings, and other hard to reach places	Yes			
Insulation fills entire cavities – no voids or compressed batts – Attic insulation level without gaps and covers entire attic floor	Yes			
Where fiberglass batt insulation is used it is high-density	Yes			
Rim joists are insulated	Yes			
Rigid foam insulation applied under exterior siding or stucco	Yes			
WINDOWS *(take a look at a house under construction before exterior siding is installed)*				
ENERGY STAR qualified windows, doors, and skylights	Yes			
Windows flashed to help repel water	Yes			
Windows rated to 0.40 U-factor and 0.40 SHGC	Yes			
MOISTURE MANAGEMENT *(take a look at a house under construction before exterior siding is installed)*				
Ground slopes away from house	Yes			
Housewrap or building paper covers exterior sheathing in wood framed houses or rigid foam exterior insulation taped at seams and caulked at edges	Yes			
Roof flashing in valleys, where walls and roofs intersect, and at other places where water may enter the house – the more complex the roof, the more flashing you should see	Yes			
Air gap between stucco, brick, or masonry cladding and housewrap	Yes			
Overhangs for shade and to direct water away from walls	Yes			
Plantings 18 to 36 inches away from the foundation	Yes			
AIR BARRIERS				
Follow ENERGY STAR Thermal Bypass Checklist	Yes			
All penetrations through exterior walls sealed	Yes			
Careful sealing of sheetrock or exterior sheathing	Yes			
Canned lights rated as airtight and for insulated ceiling (ICAT)	Yes			
Electrical boxes on exterior walls caulked or gasketed	Yes			
Holes into attic sealed	Yes			
Attic hatch weather-stripped and insulated	Yes			
Air leakage determined with house depressurization test	Yes			
Wall-roof intersection carefully sealed to avoid ice dams	Yes			
Draft stops installed behind tubs, showers, stairs, and fireplaces	Yes			
Garage completely sealed from conditioned areas of house	Yes			
Careful sealing around bathtubs, landings, fireplaces, kneewalls, cantilevered floors, etc.	Yes			
Sill plates gasketed or sealed	Yes			

MEASURE	Building America Recommendations	Builder #1	Builder #2	Builder #3
SLAB FOUNDATION MEASURES				
Radon control measures installed	Yes			
4 to 6 inch gravel base under slab and basement floors	Yes			
Polyethylene (plastic) vapor barrier between gravel and slab	Yes			
Conditioned crawlspace	Yes			
Exterior wall insulation	Yes			
Termite flashing added at sill plate	Yes			
PLUMBING				
No pipes in exterior walls	Yes			
Pipe insulation	Yes			
VENTILATION				
Whole house mechanical ventilation installed	Yes			
Spot ventilation installed in kitchen and bathrooms	Yes			
Clothes dryers are vented to the outside	Yes			
Gas-fired furnaces or water heaters sealed combustion, direct vented, or power vented (could also have a separate section on combustion safety)	Yes			
Carbon monoxide detector installed in homes with a combustion appliance or attached garage (there is also a recommended criteria that a CO alarm be installed in any home, not just those with combustion appliances and attached garages)	Yes			
Attached garages are ventilated (only a recommendation)	Yes			
FRAMING				
Use Optimum Value Engineering (also called Advanced Framing); recommend: - 2x6 24 in. oc instead of 2x4 18 in. oc studs - Align framing members from floor joists to wall studs to rafters - Use single top plates and single headers where possible - Use two-stud corners and drywall clips instead of 3-stud corners	Yes			
OTHER				
Low VOC interior coatings	Yes			
Low VOC adhesives	Yes			
Low emission cabinets	Yes			
CFL lighting	Yes			
OTHER FEATURES FOR COMPARISON				

**SEER: Seasonal Energy Efficiency Ratio | *AFUE: Annual Fuel Utilization Efficiency | *HVAC: heating, ventilation, and air conditioning*

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Appendix II.
Energy & Housing Glossary

Accreditation

The process of certifying a Home Energy Rating System (HERS) as being compliant with the national industry standard operating procedures for Home Energy Rating System.

AFUE Annual Fuel Utilization Efficiency (AFUE)

Measures the amount of fuel converted to space heat in proportion to the amount of fuel entering the furnace. This is commonly expressed as a percentage. A furnace with an AFUE of 90 could be said to be 90% efficient. AFUE includes any input energy required by the pilot light but does not include any electrical energy for fans or pumps.

Air Barrier

Any material that restricts air flow. In wall assemblies, the exterior air barrier is often a combination of sheathing and either building paper, housewrap or board insulation. The interior air barrier is typically gypsum board.

Air Flow Retarder

Sealants used to keep outside air and inside air out of the building envelope. Four common approaches to retarding air flow include careful sealing using the following building components: drywall and framing, plastic sheets (should not to be used in hot and humid climates) between drywall and framing, exterior sheathing, and building paper. Air flow retarders define the pressure boundary in a house that separates indoor and outdoor air.

Building Envelope

The outer shell, or the elements of a building, such as walls, floors, and ceilings, that enclose conditioned space. See also *Pressure Boundary* and *Thermal Boundary*.

Btu (British Thermal Unit)

A standard unit for measuring energy. One Btu is the amount of energy required to raise the temperature of one pound of water by one degree Fahrenheit from 59 to 60. An Inches-Pounds unit.

CABO (Council of American Building Officials)

A national organization of building code officials and interested parties, which, through a national consensus process, developed, adopted and promulgated the national Model Energy Code (MEC). CABO has recently become CABO International and has taken on the administrative responsibility for the development of a uniform international building code through an International Code Council (ICC).

Capacity

The rate at which a piece of equipment works. Cooling capacity is the amount of heat a cooling system can remove from the air. For air conditioners total capacity is the sum of latent capacity, the ability to remove moisture from the air, and the sensible capacity, the ability to reduce dry-bulb temperature. Heating system capacity indicates how much heat a system can provide. Heating and cooling capacities are rated in Btu per hour.

Chase

An enclosure designed to hold ducts, plumbing, electric, telephone, cable, or other linear components. A chase designed for ducts should be in conditioned space and include air flow retarders and thermal barriers between it and unconditioned spaces such as attics.

Construction Documents

The drawings (plans) and written specifications that describe construction requirements for a building.

COP (Coefficient of Performance)

A measure of efficiency typically applied to heat pumps. The COP for heat pumps is the ratio, at a given point in time, of net heat output to total energy input expressed in consistent units and under designated conditions. Heat pumps result in a COP greater than 1 because the system delivers or removes more heat energy than it consumes. Other specific definitions of COP exist for refrigeration equipment. See HSPF for a description of a unit for seasonal efficiency.

Debt-to-Income Ratio

The ratio, expressed as a percentage, which results when a borrower's total monthly payment obligations on long-term debt are divided by their gross monthly income. This is one of two ratios (housing expense-to-income ratio being the other) used by the mortgage industry to determine if a prospective borrower qualifies (meets the underwriting guidelines) for a specific home mortgage. Fannie Mae, Freddie Mac and FHA underwriting guidelines set an upper limit of 36% on this value for conventional loans but increase ("stretch") the ratio by 2% for qualifying energy efficient houses.

Dry-Bulb Temperature

The temperature of air indicated on an ordinary thermometer, it does not account for the affects of humidity.

ECM (Energy Conservation Measure)

An individual building component or product that directly impacts energy use in a building.

EEM (Energy Efficient Mortgage)

Specifically, a home mortgage for which the borrower's qualifying debt-to-income and housing expense-to income ratios have been increased ("stretched") by 2% because the home meets or exceeds CABO's 1992 version of the Model Energy Code (MEC). This so-called "stretch" mortgage is nationally underwritten by Fannie Mae, Freddie Mac and the Federal Housing Administration (FHA). This term is often used generically to refer to any home mortgage for which the underwriting guidelines have been relaxed specifically for energy efficiency features, or for which any form of financing incentive is given for energy efficiency.

EER (Energy Efficiency Ratio)

A measurement of the instantaneous energy efficiency of cooling equipment, normally used only for electric air conditioning. EER is the ratio of net cooling capacity in Btu per hour to the total rate of electric input in watts, under designated conditions. The resulting EER value has units of Btu per watt-hour.

EF (Energy Factor)

A standardized measurement of the annual energy efficiency of water heating systems. It is the annual hot water energy delivered to a standard hot water load divided by the total annual purchased hot water energy input in consistent units. The resultant EF value is a percentage. EF is determined by a standardized U.S. Department of Energy (DOE) procedure.

Energy (Use)

The quantity of onsite electricity, gas or other fuel required by the building equipment to satisfy the building heating, cooling, hot water, or other loads or any other service requirements (lighting, refrigeration, cooking, etc.)

Energy Audit

A site inventory and descriptive record of features impacting the energy use in a building. This includes, but is not limited to all building component descriptions (locations, areas, orientations, construction attributes and energy transfer characteristics); all energy using equipment and appliance descriptions (use, make, model, capacity, efficiency and fuel type) and all energy features.

ENERGY STAR® Home

A home, certified by the U.S. Environmental Protection Agency (EPA), that is at least 30% more energy efficient than the minimum national standard for home energy efficiency as specified by the 1992 MEC, or as defined for specific states or regions. ENERGY STAR is a registered trademark of the EPA.

Envelope

See *Building Envelope*

Fannie Mae (FNMA - Federal National Mortgage Association)

A private, tax-paying corporation chartered by the U.S. Congress to provide financial products and services that increase the availability of housing for low-, moderate-, and middle-income Americans.

FHA (Federal Housing Administration)

A division of the U.S. Department of Housing and Urban Development (HUD). FHA's main activity is the insurance of residential mortgage loans made by private lenders.

Freddie Mac (FHLMC - Federal Home Loan Mortgage Corporation)

A stockholder-owned organization, chartered by the U.S. Congress to increase the supply of mortgage funds. Freddie Mac purchases conventional mortgages from insured depository institutions and HUD-approved mortgage bankers.

Grade Beam

A foundation wall that is poured at or just below the grade of the earth, most often associated with the deepened perimeter concrete section in slab-on-grade foundations.

HERS (Home Energy Rating System)

A standardized system for rating the energy-efficiency of residential buildings.

HERS Energy-Efficient Reference Home (EERH)

The EERH is a geometric "twin" to a home being evaluated for a HERS rating and according to a newly revised system, is configured to be minimally compliant with the 2004 International Energy Conservation Code.

HERS Provider

An individual or organization responsible for the operation and management of a Home Energy Rating System (HERS).

HERS Rater

An individual certified to perform residential building energy efficiency ratings in the class for which the rater is certified.

HERS Score

A value between 0 and 100 indicating the relative energy efficiency of a given home as compared with the HERS Energy-Efficient Reference Home as specified by the HERS Council Guidelines. The greater the score, the more efficient the home. A home with zero energy use for the rated energy uses (heating, cooling and hot water only) scores 100 and the HERS Reference Home scores 80. Every one point increase in the HERS score amounts to a 5% increase in energy efficiency.

Housing Expense-to-Income Ratio

The ratio, expressed as a percentage, which results when a borrower's total monthly housing expenses (P.I.T.I.) are divided by their gross monthly income. This is one of two ratios (debt-to-income ratio being the other) used by the mortgage industry to determine if a prospective borrower qualifies (meets the underwriting guidelines) for a specific home mortgage. Fannie Mae, Freddie Mac and FHA underwriting guidelines set an upper limit of 28% on this value for conventional loans but increase ("stretch") the ratio by 2% for qualifying Energy Efficient Mortgages (EEM).

Housewrap

Any of several spun-fiber polyolefin rolled sheet goods for wrapping the exterior of the building envelope.

HSPF (Heating Season Performance Factor)

A measurement of the seasonal efficiency of an electric heat pump using a standard heating load and outdoor climate profile over a standard heating season. It represents the total seasonal heating output in Btu divided by the total seasonal electric power input in watt-hours (Wh). Thus, the resultant value for HSPF has units of Btu/Wh.

Infrared Imaging

Heat sensing camera which helps reveal thermal bypass conditions by exposing hot and cold surface temperatures revealing unintended thermal flow, air flow, and moisture flow. Darker colors indicate cool temperatures, while lighter colors indicate warmer temperatures.

Insulated Concrete Forms (ICFs)

Factory-built wall system blocks that are made from extruded polystyrene insulation. Steel reinforcing rods are added and concrete is poured into the voids, creating a very air-tight, well insulated and sturdy wall as the insulation is inherently aligned with the exterior and interior air barriers.

Insulation Contact, Air-Tight (ICAT) Lighting Fixture

Rating for recessed lights that can have direct contact with insulation and constructed with air-tight assemblies to reduce thermal losses.

Jump Duct

A flexible, short, U-shaped duct (typically 10-inch diameter) that connects a room to a common space as a pressure balancing mechanism. Jump ducts serve the same function as transfer grilles.

Load

The quantity of heat that must be added to or removed from the building (or the hot water tank) to satisfy specific levels of service, such as maintaining space temperature or hot water temperature at a specified thermostat setting (see also the definitions of energy and thermostat).

Low-E

Refers to a coating for high-performance windows, the “E” stands for emissivity or re-radiated heat flow. The thin metallic oxide coating increases the U-value of the window by reducing heat flow from a warm(er) air space to a cold(er) glazing surface. Low-E coatings allow short-wavelength solar radiation through windows, but reflect back longer wavelengths of heat.

MEC (Model Energy Code)

A “model” national standard for residential energy efficiency. The MEC was developed through a national consensus process by the Council of American Building Officials (CABO) and is the accepted national minimum efficiency standard for residential construction. Since MEC is a model code, it does not have the “force of law” until it is adopted by a local code authority. The MEC is used as the national standard for determining Energy Efficient Mortgage (EEM) qualification, and it serves as the national “reference point” used by Home Energy Rating Systems (HERS) in the determination of energy ratings for homes.

Mechanical Ventilation

The active process of supplying or removing air to or from an indoor space by powered equipment such as motor-driven fans and blowers, but not by devices such as wind-driven turbine ventilators and mechanically operated windows.

Optimal Value Engineering (OVE)

A strategy for reducing thermal bridging by minimizing wall framing needed for structural support. Common techniques include 2x6 framing with 24” on-center spacing, single top plates where trusses align with wall framing below, properly sized headers, two-stud corners, lattice strips at exterior/interior wall intersections, and the elimination of excessive fire blocking and window framing. This results in much more open framing for insulation to improve energy efficiency and comfort.

Performance Test

An on-site measurement of the energy performance of a building energy feature or an energy using device conducted in accordance with pre-defined testing and measurement protocols and analysis and computation methods. Such protocols and methods may be defined by national consensus standards like those of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and the American Society for Test and Measurement (ASTM).

P.I.T.I.

An abbreviation which stands for principal, interest, taxes, and insurance. These generally represent a borrower’s total monthly payment obligations on a home loan. The taxes and insurance portion are often paid monthly to an impound or escrow account and may be adjusted annually to reflect changes in the cost of each.

Pressure Boundary

The point in a building at which inside air and outside air are separated. If a building were a balloon, the rubber skin would form the pressure boundary. Where inside and outside air freely mingle there is no pressure boundary.

Pressurization Test

A procedure in which a fan is used to place a house, duct system, or other container, under positive or negative air pressure in order to calculate air leakage.

RESNET (Residential Energy Services Network)

The national association of energy rating providers.

Rated Home

A specific residence that is evaluated by an energy rating.

R-Value

Measures a material’s ability to slow down or resist the transfer of heat energy, also called thermal resistance. The greater the R-value, the better the resistance, the better the insulation. The effective R-value of an insulation material will be reduced by gaps, voids, compression or misalignment. R-values are the reciprocal of U-values. See U-values for more information.

Sealed Combustion

Sealed combustion means that a combustion appliance, such as a furnace, water heater, or fireplace, acquires all air for combustion though a dedicated sealed passage from the outside; combustion occurs in a sealed combustion chamber, and all combustion products are vented to the outside through a separate dedicated sealed vent.

SEER (Seasonal Energy Efficiency Ratio)

A measurement similar to HSPF except that it measures the seasonal cooling efficiency of an electric air conditioner or heat pump using a standard cooling load and outdoor climate profile over a standard cooling season. It represents the total seasonal cooling output in Btu divided by the total seasonal electric input in watt hours (Wh). The SEER value are units of Btu/Wh.

Semi-Permeable

The term vapor semi-permeable describes a material with a water vapor permeance between 1 and 10 Perms. Water vapor can pass through a semi-permeable material but at a slow rate.

Shading Coefficient (SC)

The ratio of the total solar heat admittance through a given glazing product relative to the solar heat admittance of double-strength, clear glass at normal solar incidence (i.e., perpendicular to the glazing surface).

Site Energy

The energy consumed at a building location or other end–use site

Solar Heat Gain Coefficient (SHGC)

SHGC measures how well a window blocks heat caused by sunlight. The lower the SHGC rating the less solar heat the window transmits. This rating is expressed as a fraction between 0 and 1. The number is the ratio of a window's solar heat admittance compared to the total solar heat available on the exterior window surface at normal solar incidence (i.e., perpendicular to the glazing surface).

Sone

A sound rating. Fans rated 1.5 sones and below are considered very quiet.

Source Energy

All the energy used in delivering energy to a site, including power generation and transmission and distribution losses, to perform a specific function, such as space conditioning, lighting, or water heating. Approximately three watts (or 10.239 British thermal units) of energy is consumed to deliver one watt of usable electricity.

Structural Insulated Panels (SIPs)

Factory-built insulated wall assemblies that ensure full alignment of insulation with integrated air barriers. Composed of insulated foam board glued to both an internal and external layer of sheathing (typically OSB or plywood). Many SIP panels are manufactured with precut window and door openings.

Supply ducts

The ducts in a forced air heating or cooling system that supply heated or cooled air from the or air conditioner to conditioned spaces.

Thermal Boundary

The border between conditioned and unconditioned space where insulation should be placed.

Thermal Bridging

Accelerated thermal flow that occurs when materials that are poor insulators displace insulation.

Thermostat

A control device that measures the temperature of the air in a home or the water in a hot water tank and activates heating or cooling equipment to cause the air or water temperature to remain at a pre-specified value, normally called the set point temperature.

Ton(s) of Refrigeration

Units used to characterize the cooling capacity of air conditioning equipment. One ton equals 12,000 Btu/h.

U-Value

Measures the rate at which heat flows or conducts through a building assembly (wall, floor, ceiling, etc.). The smaller the u-value the more energy efficient an assembly and the slower the heat transfer. Window performance labels include U-values (calling them U factors) to help in comparing across window products.

Ventilation

The controlled movement of air into and out of a house.

W (watt)

One of two (Btu/h is the other) standard units of measure for the rate at which energy is consumed by equipment or the rate at which energy moves from one location to another. It is also the standard unit of measure for electrical power.

Wet-Bulb Temperature

A measure of combined heat and humidity. At the same temperature, air with less relative humidity has a lower wet-bulb temperature. See *Dry-Bulb Temperature*.

Wind Baffle

An object that serves as an air barrier for the purpose of blocking wind washing at attic eaves.

Wind-Washing

Air movement due to increased pressure differences that occur at the outside corners and roof eaves of buildings. Wind-washing can have significant impact on thermal and moisture movement and hence thermal and moisture performance of exterior wall assemblies.

Xeriscaping

Landscaping that minimizes outdoor water use while maintaining soil integrity and building aesthetics. Typically includes emphasis on native plantings, mulching, and no or limited drip/subsurface irrigation.

Zero Energy House

Any house that over time, averages out to net zero energy consumption. A zero energy home may supply more energy than it needs during peak demand, typically using one or more solar energy strategies, energy storage and/or net metering.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Appendix III.
Code Notes

A meeting with the building department before construction is well advised. Should your code official need information in support of the new techniques you may use in an energy-efficient home, this appendix contains websites and a sample document that may be helpful. A set of draft code notes are available on DOE's Building Energy Codes Resource Center website. These draft documents are written for code officials and provide a description of energy-efficiency techniques, citations to relevant codes, and guidance for plan reviews and field inspections.

Here is a list of available code notes that can help re-assure your local code official that the proposed techniques are both safe and in compliance with the model codes. The code notes are available at www.energycodes.gov/support/code_notes.stm.

- Single Top Plate
- No Headers in Nonbearing Walls
- Header Hangers in Bearing Walls
- Open Spaces as Return-Air Options
- Details for Mechanically Vented Crawl Spaces
- Ventilation Requirements for Condensing Clothes Dryers
- Drywall Clips
- Rigid Board Insulation Installed as Draft Stop in Attic Kneewall
- Whole-House Mechanical Ventilation
- Residential Heating and Cooling Load Calculation Requirements
- Conditioned Attics.

We have included one of these Code Notes as a sample in this document, the Code Note for *Rigid Board Insulation Installed as Draft Stop in Attic Kneewall*. You will find it on the pages that follow.

Rigid Board Insulation Installed as Draft Stop in Attic Kneewall - Code Notes (DRAFT)

Framing kneewall

Rigid board insulation (foam plastic) is an effective draft stop and also increases the R-value of the attic kneewall if installed on the attic side of the kneewall, replacing the need for separate draft stop and insulation products. The IRC requires foam plastic insulation to be protected against ignition by using fiberglass batt insulation, gypsum board or other products that meet the flame and smoke density requirements. Foam plastic products rated for flame and smoke density can be installed without such a protective covering.

Insulating attic kneewalls between a conditioned space with vaulted ceilings and the attic is important to reduce energy loss through the wall, especially in the summer months. To be effective, the insulation installed in the kneewalls must be supported so that it stays in contact with the gypsum board, and protected against air moving through the insulation.

photo by Britt-Makela Group

Kneewall sheathing insulation to increase R-value to equal the outside wall.

Foam plastic insulation can be installed on the attic side of the attic kneewall (see Figure) to both act as a draft stop between the conditioned house and the unconditioned attic and to increase the insulation R-value of the attic kneewall. Installing such an insulating backing in the kneewall supports the fiberglass batt insulation between framing members, replaces an air barrier, and adds insulating value to the attic kneewall.

Plan Review

1. Verify that plastic insulation called out on the construction detail meets the ASTM E 84 requirements for flame spread and smoke development. Require manufacturer literature or an ICC Evaluation Service report.
2. Verify that the insulation R-value of the foam plastic insulation called out on the building plans meets or exceeds the R-value requirements called for on the energy code compliance documentation (only if credit has been taken for the foam plastic insulation).

Field Inspection

1. Verify that the foam plastic insulation installed in the field is consistent with that called out on the building plans.
2. Verify that the insulation R-value specified on the insulation meets or exceeds the R value called out on the plans or documentation.
3. Verify that that sealant has been installed around the edges of the insulation and that any holes or penetrations in the foam plastic insulation are sealed.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Appendix IV.

Counties in the Hot-Dry and Mixed-Dry Climates

This section contains a list of all the counties, by state, that are within the hot-dry and mixed-dry climates. You can find a master list for the entire country at www.eere.energy.gov/buildings/building_america/pdfs/climate_regions_us_county_rev02.pdf

HOT-DRY CLIMATE

MIXED-DRY CLIMATE

ARIZONA

Cochise	Hot-Dry
Gila	Mixed-Dry
Graham	Hot-Dry
Greenlee	Hot-Dry
La Paz	Hot-Dry
Maricopa	Hot-Dry
Mohave	Hot-Dry
Pima	Hot-Dry
Pinal	Hot-Dry
Santa Cruz	Hot-Dry
Yavapai	Mixed-Dry
Yuma	Hot-Dry
Cochise	Hot-Dry
Gila	Mixed-Dry
Graham	Hot-Dry
Greenlee	Hot-Dry
La Paz	Hot-Dry
Maricopa	Hot-Dry
Mohave	Hot-Dry
Pima	Hot-Dry
Pinal	Hot-Dry
Santa Cruz	Hot-Dry
Yavapai	Mixed-Dry
Yuma	Hot-Dry

CALIFORNIA

Amador	Mixed-Dry
Butte	Hot-Dry
Calaveras	Mixed-Dry
Colusa	Hot-Dry
Contra Costa	Hot-Dry
El Dorado	Mixed-Dry
Fresno	Hot-Dry
Glenn	Hot-Dry
Imperial	Hot-Dry
Inyo	Mixed-Dry
Kern	Hot-Dry
Kings	Hot-Dry
Lake	Mixed-Dry
Los Angeles	Hot-Dry
Madera	Hot-Dry
Mariposa	Mixed-Dry
Merced	Hot-Dry
Orange	Hot-Dry
Placer	Hot-Dry
Riverside	Hot-Dry
Sacramento	Hot-Dry
San Bernardino	Hot-Dry
San Diego	Hot-Dry
San Joaquin	Hot-Dry
Shasta	Hot-Dry
Solano	Hot-Dry
Stanislaus	Hot-Dry
Sutter	Hot-Dry
Tehama	Hot-Dry
Trinity	Mixed-Dry
Tulare	Hot-Dry
Tuolumne	Mixed-Dry
Yolo	Hot-Dry
Yuba	Hot-Dry

COLORADO

Baca	Mixed-Dry
Las Animas	Mixed-Dry
Otero	Mixed-Dry

NEW MEXICO

Bernalillo	Mixed-Dry
Chaves	Hot-Dry
Curry	Mixed-Dry
DeBaca	Mixed-Dry
Dona Ana	Hot-Dry
Eddy	Hot-Dry
Grant	Mixed-Dry

- Guadalupe
- Hidalgo
- Lea
- Lincoln
- Luna
- Otero
- Quay
- Roosevelt
- Sierra
- Socorro
- Union
- Valencia

NEVADA

- Clark

OKLAHOMA

- Beaver
- Cimarron
- Texas

TEXAS

- Andrews
- Armstrong
- Bailey
- Baylor
- Borden
- Brewster
- Briscoe
- Callahan
- Carson
- Castro
- Childress
- Cochran
- Coke
- Coleman
- Collingsworth
- Concho
- Cottle
- Crane
- Crockett
- Crosby
- Culberson
- Dallam
- Dawson
- Deaf Smith
- Dickens
- Donley
- Ector
- El Paso
- Fisher
- Floyd
- Foard
- Gaines
- Garza
- Glasscock
- Gray
- Hale
- Hall
- Hansford
- Hardeman
- Hartley
- Haskell
- Hockley
- Hutchinson
- Hemphill
- Howard
- Hudspeth
- Irion
- Jeff Davis
- Jones
- Kent
- Kerr
- Kimble
- King
- Knox
- Lamb
- Lipscomb
- Loving
- Lubbock
- Lynn
- Martin
- Mason
- McCulloch
- Menard
- Midland
- Mitchell
- Moore
- Motley
- Nolan
- Ochiltree
- Oldham
- Parmer
- Pecos
- Potter
- Presidio
- Randall
- Reagan
- Reeves
- Roberts
- Runnels
- Schleicher
- Scurry
- Shackelford
- Sherman
- Sterling
- Stonewall
- Sutton
- Swisher
- Taylor
- Terrell
- Terry
- Throckmorton
- Tom Green
- Upton
- Ward
- Wheeler
- Wilbarger
- Winkler
- Yoakum

UTAH

- Washington

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

Research and Development of Buildings

Our nation's buildings consume more energy than any other sector of the U.S. economy, including transportation and industry. Fortunately, the opportunities to reduce building energy use—and the associated environmental impacts—are significant.

DOE's Building Technologies Program works to improve the energy efficiency of our nation's buildings through innovative new technologies and better building practices. The program focuses on two key areas:

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  Research and development of the next generation of energy-efficient components, materials, and equipment
- **Technology Integration**
  Integration of new technologies with innovative building methods to optimize building performance and savings

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