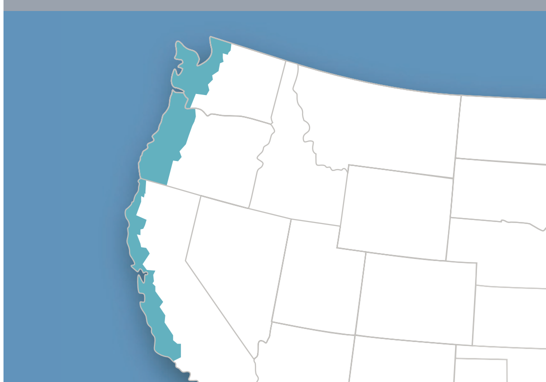
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

VOLUME 11. BUILDING AMERICA BEST PRACTICES SERIES



MARINE CLIMATE

BUILDERS CHALLENGE GUIDE TO

40% Whole-House Energy Savings in the Marine Climate

PREPARED BY

Pacific Northwest National Laboratory
& Oak Ridge National Laboratory

September 2010

Building America U.S. Department of Energy

September 2010 • PNNL-19517, Rev. 1

BUILDING AMERICA BEST PRACTICES SERIES

VOLUME 11.

Builders Challenge Guide to 40% Whole-House Energy Savings in the Marine Climate

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September 2010

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www.buildingamerica.gov

Preface

This best practices guide is the eleventh 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 marine climate can build homes that have whole-house energy savings of 40% over the Building America benchmark with no added overall costs for consumers.

The best practices described in this document 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 innovative, energy-efficient construction practices. Building America builders have found they can build homes that meet these aggressive energy-efficiency goals at no net increased costs to the homeowners. To recognize builders who are producing the most efficient, sustainable, and comfortable homes on the market, DOE created the Builders Challenge. Homes that qualify for the Builders Challenge must achieve a 70 or lower on the EnergySmart Home Scale (E-Scale), which is described in this document.

This document represents a step up from our first marine best practices document (*Volume 5. Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Marine Climate*), which aimed at achieving energy-efficiency savings of 15% above the benchmark. Building America has continued to develop systematic building strategies that meet more challenging efficiency goals over time.

Currently, Building America homes achieve energy savings of 40% greater than the Building America benchmark home (a home built to mid-1990s building practices roughly equivalent to the 1993 Model Energy Code). 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 a 3-year 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)

Acknowledgments

The U.S. Department of Energy's Building America Program comprises public-private partnerships that conduct systems research to improve overall housing performance, increase housing durability and comfort, reduce energy use, and increase energy security for America's homeowners. Program activities focus on finding solutions for both new and existing homes, as well as integrating clean onsite energy systems that will allow the homebuilding industry to provide homes that produce more energy than they use. In addition to the DOE management and staff, the Building America Program includes several consortia, four national laboratories, and hundreds of builders, research organizations, manufacturers, and service providers. Building America works closely with the U.S. Department of Housing and Urban Development's Partnership for Advancing Technology in Housing (PATH) program, co-manages the ENERGY STAR Program along with the U.S. Environmental Protection Agency, and works with other federal agencies to coordinate research findings and disseminate information. These partners make the program a successful source of knowledge and innovation for industry practitioners and government policy makers. Together, these cooperating agencies have provided reviews and shared insightful comments, as well as making the authors aware of their technical libraries.

The U.S. DOE Building America Program funded the development of this series of handbooks. DOE also funded the Building America consortia and national laboratories to conduct the research that forms the basis for these best practices. The consortia listed to the right were Building America's research teams through FY2010. The consortia have taken on the hard work of applied research, field testing, training builders, and transforming results into building practices. Numerous drawings, descriptions, photos, and case studies originated with these research partners.

Hundreds of builders across the country have chosen to work with Building America and its partners on research projects to further our understanding of building science. These builders deserve thankful recognition for contributing to the success of the Building America Program and the Best Practices Series. Four builders from the marine climate are showcased in case studies in this document: New Tradition Homes of Vancouver, Washington; Quadrant Homes of Bellevue, Washington; Schneider Homes, Inc. of Burien, Washington; and Tom Walsh & Co. of Portland, Oregon. Examples from these and other marine climate builders are used throughout the document to illustrate construction best practices.

2010 Building America Research Teams

These Building America research teams partner with all segments of the building industry to conduct research and demonstration projects that develop, analyze, and test strategies and technologies for improving building performance and energy efficiency. Building America teams who participated in the preparation of this document included

BIRA
Building Industry Research Alliance

Building Industry Research Alliance
www.bira.ws led by ConSol

bsc

Building Science Consortium
led by Building Science Corporation
www.buildingscienceconsulting.com

CARB
Consortium for Advanced Residential Buildings

Consortium for Advanced Residential Buildings (CARB)
www.carb-swa.com/index.html led by Steven Winter Associates, Inc. (SWA)

Building America U.S. Department of Energy Research Toward Zero Energy Homes
Industrialized Housing Partnership
www.baihp.org
Florida Solar Energy Center

Building America Industrialized Housing Partnership (BAIHP)
www.baihp.org led by the Florida Solar Energy Center of the University of Central Florida

IBACOS

Integrated Building and Construction Solutions (IBACOS)
www.ibacos.com

NAHB RESEARCH CENTER

National Association of Home Builders Research Center (NAHBRC)
www.nahbrc.com

Several national laboratories participated in this project. Pacific Northwest National Laboratory and Oak Ridge National Laboratory led the writing and production of this document. The National Renewable Energy Laboratory made its library of Building America documents available to the authors, reviewed this guide, and posted it to the Web. Scientists at Lawrence Berkeley National Laboratory reviewed the document as well.

The authors and DOE wish to thank the many contributors who have made this project a success. We would especially like to thank graphic artist Christina Van Vleck who designed this document and prepared many of its illustrations.

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Chapter 1.
Welcome

"It is remarkable what you can accomplish when you simply ask the question: 'Is there anything that we can do better?'"

Ben Walsh, construction manager of the Tom Walsh & Co. New Columbia Project and current owner of Green One Construction Services

Constructing energy-efficient, durable, and comfortable homes makes economic sense—for the builder, the consumer, the real estate professional, and the environment. In a time of significant challenges for the real estate community, Building America builders have made an important discovery—their homes are selling while their competitors' homes are not. They are making some other exciting discoveries as well. They are having fewer callbacks and complaints. Instead, buyers are calling to thank them for lower utility bills. Builders of all sizes are discovering the benefits of teaming with Building America. In fact, nine of the nation's ten largest builders in 2009 were Building America partners.

Discover what hundreds of builders across the country have already found out—it isn't difficult to build energy-efficient homes that are more healthy, durable, and comfortable to live in, while cutting energy bills nearly in half. Building America will help show you how.

This guide can help you apply Building America research to your own projects to achieve energy savings of 40% over the Building America benchmark (a home built to the 1993 Model Energy Code). Using these whole-house building principles, your homes will meet and exceed the new 2009 International Energy Conservation Code (2009 IECC) and the 2009 International Residential Code (2009 IRC). Whether you're a multi-state builder with managers, sales

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Case Studies:
- **New Tradition Homes**, Vancouver WA
- **Quandrant**, Bellevue WA
- **Schneider Homes**, Burien WA
- **Tom Walsh & Co**, Portland OR

Appendices:
I. **Homebuyer's Checklist**
II. **Counties in the Marine Climate**
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(top) Reworking their processes with changes like improving air sealing and moving ducts into conditioned space were enough to help Portland builder Ben Walsh qualify 20 homes for DOE's Builders Challenge and the federal tax credit.

(bottom) Building America helped Schneider Homes of Burien, Washington, achieve energy savings of 50% and qualify 28 homes for the federal tax credit.

staff, designers, site superintendents, and installers on your staff, or a small builder wearing many of these hats yourself, this guide can help you understand and apply the latest building science to differentiate yourself in a struggling new-construction market and to meet the new tougher energy codes.

Break open this guide and you'll find the following:

Chapters 2 through 4 provide the data to make the case to upper management, yourself, and your shareholders for the value of energy-efficient construction, including research on consumer preferences, competitive advantage, and incentives. Here you'll also find business management tools, sales training tips, and marketing strategies.

Chapters 5 and 6 explain the whole-house approach to building science and special considerations for building in the marine climate.

Chapters 7 through 10 provide energy-efficiency construction recommendations to architects and engineers based on Building America research, with guidance on best practices for meeting and exceeding code in regard to moisture management, insulation, and air sealing of home foundations, walls, and roofs. Guidance is also provided on windows, and HVAC, plumbing, and electrical systems. Chapter 10 provides a useful checklist of all of these recommendations.

Chapters 11 and 12 cover important site documentation for the site supervisor and how-to field guides on specific energy-efficiency measures for installers.

Throughout these chapters, real-life examples are highlighted from exceptional builders in the marine climate. Case studies at the back of the report tell how four builders achieved significant energy savings using Building America practices.

Finally, appendices provide a homebuyers' checklist, counties in the marine climate, a DOE–sponsored resource for meeting codes, a glossary, and acronym list.

The 2009 IECC and 2009 IRC mandate a significant increase in energy efficiency in new home construction. Changes in the 2009 IECC and 2009 IRC represent an approximate 15% improvement in energy efficiency over the 2006 IECC. This guide will help builders meet and exceed these new requirements.

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).

For More Information

You can learn more about Building America and download additional copies of this document, other best practices, case studies, and research reports at www.buildingamerica.gov.

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). Builders who use Building America principles are among the most successful in the United States today.

> "Strong, sustainable building practices can help builders differentiate themselves in a competitive marketplace, while still keeping focused on the bottom line."
>
> Jeff Jacobs, then of Centex Homes, currently President of Building Advisory, LLC

Builders and Building America

Building America has worked with production builders since 1995 to improve the energy efficiency, durability, comfort, environmental performance, and quality of new homes. Building America and its partners have conducted building science field research with builders throughout the country to test techniques, materials, and processes in real-world situations. As of August 2010, the program has contributed directly to the energy-efficient construction of more than 42,200 homes, and builders and vendors that have worked with Building America have influenced over a million new homes.

Nine of the nation's ten largest builders are Building America partners. Twenty-three of Building America's 350+ builder partners made *Builder Magazine*'s Builder 100 list of the top 100 builders of 2009 (based on home sale closings). While new home starts in 2009 dropped to their lowest on record since 1959, twelve of Building America's partners moved up in the Builder 100 rankings.

Qualifying for programs such as DOE's Builders Challenge and ENERGY STAR provides an easy way to show consumers that your company's homes are a cut above the competition.

CHAPTER TOPICS

2.1 Builders and Building America

2.2 The Business Case for Energy Efficiency

Building America builders ranked highest in 20 of the 25 new home markets surveyed in J.D. Power's 2009 survey of homebuyer satisfaction. These builders include some of the best known names in the business: Pulte and its Del Webb brand, Centex, David Weekley Homes, Shea Homes, Standard Pacific Homes, Pardee Homes, and K. Hovnanian. These builders bundle energy efficiency with other attributes valued by their customers, such as affordability, comfort, and quality construction. Pulte ranked highest in new home quality in 12 of the 25 U.S. home markets surveyed by J.D. Powers in 2009.

Learn more about Building America at www.buildingamerica.gov.

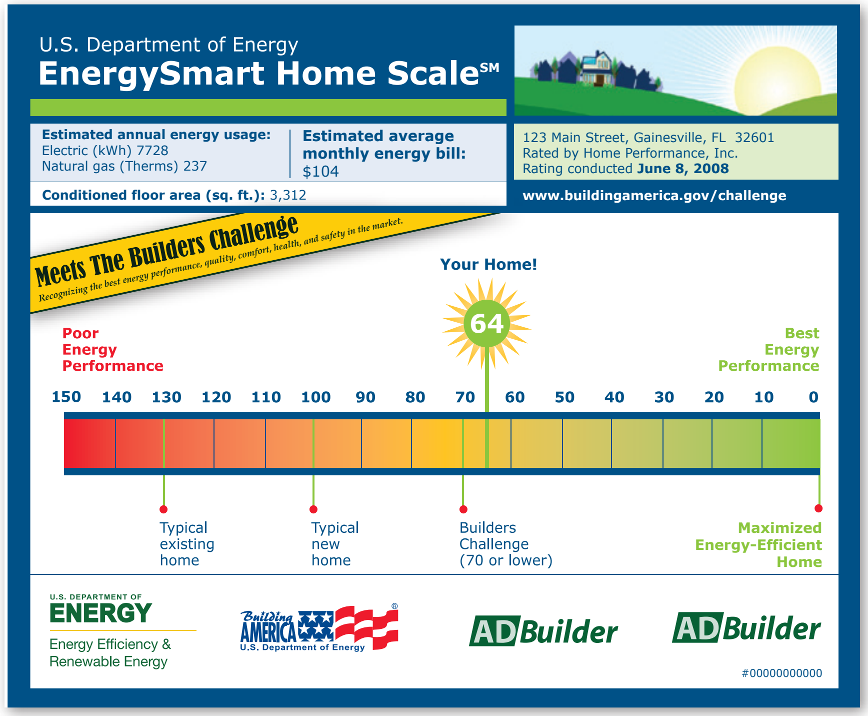
"We were doing a lot of things wrong—not on purpose, we simply didn't know any better. Building America taught us how to build the right way. Artistic now offers an energy use and comfort guarantee on every home it sells."

Jerry Wade, President of Artistic Homes, Albuquerque, New Mexico

Energy Use & Comfort Artistic Homes Guaranteed

Builders Challenge

The Builders Challenge label prominently features the E-Scale, which shows a Home Energy Rating System (HERS) score. A house built to the 2006 IECC would score 100; a home that uses no more energy than it can produce with onsite generation such as solar panels would have a HERS score of 0. Builders Challenge homes must score 70 or lower.



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.

The business case for high-performance, energy-efficient construction is straightforward and is based on the following points:

1. Consumers prefer energy-efficient homes.
2. Builders can use energy efficiency and other high-performance features to gain competitive advantage. Consumer preference and competitive advantage lead to more and faster sales.
3. Building America homes can meet energy-efficiency goals at no net increased costs to homeowners when added costs are balanced with utility savings.
4. New state and federal building codes are now a driving force in energy-efficient construction.

Consumer Preferences

McGraw Hill Construction (2009) reports that "green building has grown in spite of the market downturn. Green seems to be one area of construction insulated by the downturn, and we expect green building will continue to grow over the next five years despite negative market conditions to be a $96–$140 billion market." In 2005, the size of the green homebuilding market was $3 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 market demand for green construction is up and green construction can help differentiate builders and stabilize their business in a struggling market. McGraw Hill found word-of-mouth referrals are the most likely way that consumers learn about green home builders (McGraw Hill Construction 2009).

Surveys show that consumers want energy efficiency and they are willing to pay for it:

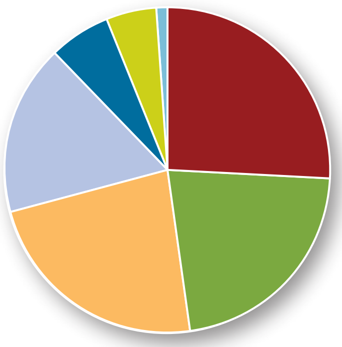
- 87% said a greener, more-energy-efficient home is a priority in a *Better Homes and Gardens Magazine* survey (Patterson 2010).
- 94% of builders report that their buyers want more energy-efficient new homes; 55% said buyers specifically want EnergyStar®-rated homes (NAHB 2009).
- Most builders (69%) indicated that some of their buyers are willing to pay extra for green amenities; 9% indicated that most were. 25% of builders said buyers want homes with more recycled materials and less materials overall (NAHB 2009).
- 91% preferred an energy-efficient home with lower utility bills to a cheaper home (sales price 2% to 3% lower) without the energy-efficient features (Rice 2009).
- Homebuyers are willing to pay on average $6,000 more for their new home to save $1,000 annually on energy costs (Rice 2009).
- 86% of Americans would choose one home over another based on its energy efficiency. Yet 78% of the homeowners polled said no one talked to them about energy efficiency during the buying process (*National Builder News*, April 9, 2007).
- Energy improvements topped the list of how homeowners would spend an extra $5,000 on their new homes. (NAHBRC 2007).
- 90% of new homebuyers are willing to spend more for energy efficiency—up to $17,000 more (McGraw Hill 2007).
- 84% listed energy efficiency as the most important factor in their appliance purchases (Maynard 2009).

Building America Partners on *Builder Magazine* Top 100 List 2009

Ranking	Building America Partner
1	DR Horton
2	Pulte
3	Lennar
5	KB Home
6	Centex
7	K. Hovnanian
8	Habitat for Humanity Int'l
9	The Ryland Group
10	Beazer Homes USA
11	Meritage Homes Corp
12	Standard Pacific Corp
13	Taylor Morrison Homes
17	David Weekley Homes
18	Weyerhaeuser Real Estate Co
20	Shea Homes
29	William Lyon Homes
32	WCI Communities
44	Mattamy U.S. Group
63	John Wieland Homes and Neighborhoods
64	ICI Homes
67	Heartland Homes
71	Castle & Cooke
90	Ideal Homes

Nine of the nation's ten largest builders are Building America partners. Twenty-two of Building America's 350+ builder partners made *Builder Magazine's* Builder 100 list of the top 100 builders of 2009 (based on home sale closings) in a very difficult year for U.S. home builders. According to *Builder Magazine*, single-family home starts fell to 444,000, dropping below one million units for only the second time since 1945. New single-family home sales represented fewer than 8% of all homes sold, about half of their historical portion. New homes competed with almost 3.3 million existing homes on the market at the end of 2009, many of them foreclosures (as reported by John Caulfield in the May 4, 2010, issue). Despite the difficulties Building America partners made a strong showing with 9 in the top 10, up from 8 in 2008, and 23 in the top 100, up from 19 last year. Twelve Building America partners moved up in the ranks, including four builders who didn't make the cut last year.

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 home built by Building America builder Premier Homes, Roseville, California. as quoted in a Rand Corporation report, 2006.

"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, National Association of Home Builders (NAHB) vice president of research, *National Builder News* April 16, 2007

Competitive Advantage

Competitive advantage is critical, especially in a down market when buyers are few and their choices abound for new and existing homes.

Building America builder Grupe Homes of Stockton, California, found that it could sell homes twice as fast as its competitors in a depressed Sacramento, California, housing market, when it focused on energy-efficient construction and integrated photovoltaic systems. Grupe was the first California builder to certify a home to Builders Challenge; it received a HERS rating of 47.

In addition, 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 (Daikin et al. 2008).

One builder in Seattle found a commitment to energy efficiency helped secure funding in a down market. When established builder Martha Rose Construction finally secured funding for its newest project, Fish Singer Place, an energy-efficient four-house project in north Seattle, in September 2009, the loan officer told her that being a green builder had "everything to do with" why the bank gave her the money. Rose said educating bankers on the homes' sustainable features made the difference. "The strongest part of the market is hard-core green housing, so bankers were interested in Fish Singer Place's green credibility," said Rose (as quoted in the *Seattle Daily Journal of Commerce* January 4, 2010).

Cost Neutral Energy Savings

Building America case studies prove that energy-efficient construction does not have to cost more for homebuyers. Tradeoffs in building material choices, streamlining of processes and tax incentives and rebates can minimize cost increases for builders.

Case Studies Prove Homebuyers Profit

In 2007 and 2008, Building America researchers worked with four builders in the marine climate to build more than 360 homes that met or exceeded 40% energy savings. In each of those projects, homeowners' utility bill savings were high enough to yield a net profit each year, after subtracting increased mortgage costs. All of the builders kept first costs at less than $4,000 per home while implementing energy-efficiency features. Table 2.1 shows the energy savings calculated for each builder's home, the incremental increase in the annual mortgage to cover the costs of including the energy-efficiency features versus the cost of a mortgage for a typical house, and the net cash flow to the homebuyer. In every case the homebuyer came out ahead, with net gains ranging from $700 to $830 per year. Table 2.2 details one builder's choices in energy-efficient features. With some measures, the energy-efficient choice was less expensive than standard practice. These examples show some homebuyers can realize a better return on investment from energy efficiency improvements than investing in stocks and bonds.

Table 2.1. Marine Climate Case Study Costs and Savings.

Every Building America Project yielded net annual gains for homeowners after deducting increased mortgage costs from annual utility bill savings.

Builder	Cost Increase for Energy Improvements	Added Annual Mortgage Cost for Energy Efficiency	Annual Utility Bill Savings vs. Benchmark	Net Annual Cash Flow
New Tradition Homes	$3,635	($290.24)	$990.61	$700.37
Quadrant Homes	$2,000	($159.67)	$951.02	$791.35
Schneider Family Homes	$3,921	($313.08)	$1,143.68	$830.60
Tom Walsh & Co.	$2,398	($191.45)	$943.60	$752.15

Utility bill savings relative to the Building America benchmark were calculated by BIRA using BEopt 0.8.6 (a software developed by NREL for identifying optimal building design). Savings are based on current utility rates in each community, including electric and natural gas rates. Incremental annual mortgage costs are derived from first cost estimates from the builders. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. The Building America benchmark is a home built to the 1993 Model Energy Code.

Table 2.2. How Much Does it Cost to Reach 40% Energy Savings?

One Example in the Marine Climate

The example shown here is for a typical 2-story, 1880-ft^2 home built by Tom Walsh & Co. in the New Columbia development in Portland, Oregon. The costs in the table below were provided by the builder. In this case, moving the ducts into conditioned space saved the builder money. Although a small amount of additional materials was needed for the dropped soffit for the ducts, the framer did not charge additional labor and Tom Walsh & Co. saved money because they were able to use 35% less ductwork. Some builders have also seen significant savings by reducing the HVAC equipment size. When the building envelope is tighter, builders can rely on the Air Condtioning Contractors of America's (ACCA) Manual J for correct sizing of the equipment instead of oversizing width "rule-of-thumb" measurements. Note that this example does not reflect any benefit to the builder from tax rebates or energy-efficiency program incentives.

Energy-Efficiency Feature	Added Cost, per Home, Over Builder's Conventional Practice
Upgrade to 94% AFUE furnace	$880
Improved duct sealing, envelope sealing and duct and whole-house leakage testing	$880
Increase to R-49 blown cellulose attic insulation	$352
Upgrade to ENERGY STAR appliances	$264
Upgrade to 62% EF water heater	$165
Upgrade to 100% CFL lighting	$132
Move ducts into conditioned space (saved money over standard practices because used 35% less ducting)	-$275
Total	**$2,398**
Annual cost (when incorporated into a 30-yr loan at 7% interest)	$191.45
Annual Utility Bill Savings	$943.60
Net Annual Cash Flow to Homeowner	**$752.15**
Conclusion: These energy-efficiency improvements are actually money makers for the owner of this home.	

Costs were provided by the builder, Tom Walsh & Co.
AFUE = annual fuel utilization efficiency, CFL = compact fluorescent lamp, EF=energy factor

Seattle builder Martha Rose has made a name for herself as a green builder with projects like Homestead, shown here, a Building America project completed in 2007.

"We are in a city and a region that pays a lot of attention to environmental issues and health issues; so, for us it was huge to be able to walk buyers through the processes we used to ensure that we built the healthiest, most energy-efficient homes at the dollar point we achieved."

Chris Bonner, real estate broker of homes at the New Columbia development in Portland, Oregon, built by Tom Walsh & Company, a Building America builder.

"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

Federal, State, and Local Incentives and Tax Credits

Incentives can help offset costs as builders transition to more energy-efficient construction materials. A wide range of incentives and tax credit opportunities are available at the federal, state, and local level. In addition to financial incentives for energy-efficient homes, some local governments offer streamlined permitting processes for green and energy-efficient projects.

For information on what is available to you, visit the Database of State Incentives for Renewables and Efficiency (DSIRE), at www.dsireusa.org. DSIRE is a comprehensive source of information on state, local, utility, and federal incentives, tax credits, and policies that promote renewable energy and energy efficiency. Established in 1995 and funded by the U.S. Department of Energy, DSIRE is an ongoing project of the North Carolina Solar Center and the Interstate Renewable Energy Council.

Here is a list of some of the larger federal, state, and regional incentive programs available to marine climate builders at the time of publication.

NORTHWEST ENERGY STAR INCENTIVES - To set a higher bar than their already stringent state building codes, Washington and Oregon established the Northwest ENERGY STAR requirements, which are stricter than the national ENERGY STAR requirements. www.northwestenergystar.com/partner-resources/incentives/.

OREGON ENERGY TRUST INCENTIVES - Builders who build within participating utility territories in Oregon and southwest Washington can sign up as "trade allies" to receive incentives for building energy-efficient homes. www.energytrust.org

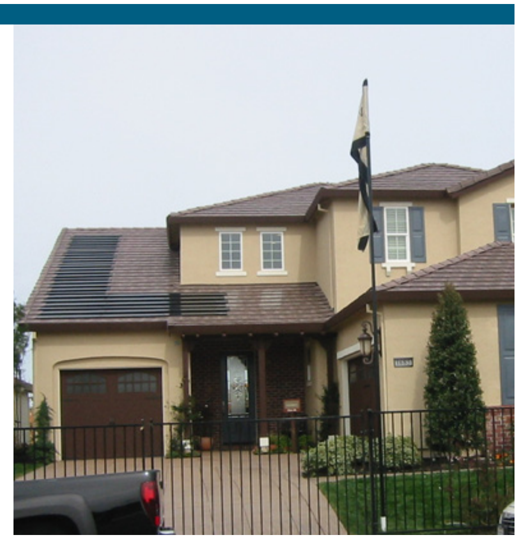
BUILT GREEN OF WASHINGTON STATE - Built Green is a non-profit, residential building program of the Master Builders Association of King and Snohomish Counties, that provides funding for remodeling, single-family, town home, and community development projects to help offset the cost of certifying and designing innovative green projects. Incentives of $2,500 to $15,000 are competitively awarded. www.builtgreen.net/incentive.html

EARTH ADVANTAGE - Earth Advantage, Inc. is a utility-based energy conservation program of Portland General Electric. It does not offer independent incentives to builders; however, it does certify homes for ENERGY STAR and LEED for Homes programs, as well as for its own residential, commercial, communities, and remodeling programs. www.earthadvantage.org

THE CALIFORNIA ENERGY COMMISSION - The California Energy Commission provides market support to existing, new, and emerging renewable technologies; incentives for small wind and fuel cell electricity systems; and incentives for solar electricity systems in new home construction (CEC 2009). www.energy.ca.gov/commission

PACIFIC GAS AND ELECTRIC COMPANY (PG&E) IN CALIFORNIA - Builders of single-family homes within PG&E's service area can apply for financial incentives for maximizing the energy efficiency of their new homes. http://pge.com/mybusiness/energysavingsrebates/incentivesbyindustry/newconstruction/

SOUTHERN CALIFORNIA EDISON (SCE) - Builders of single-family homes within the SCE service area can apply for financial incentives for maximizing the energy efficiency of their new homes. www.sce.com/b-rs/rebates-savings



Buyers flocked to Centex's energy-efficient homes at Windemere in San Ramon, California.

"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

"With the economy the way it is and the number of existing houses on the market, the only builders in Clark County doing new construction and selling are builders like New Tradition who are building really energy-efficient homes."

Chris Taylor, installation manager for Area Heating and Cooling, the HVAC contractor for New Tradition Homes, a Building America builder in Vancouver, Washington.

For More Information on the Business Side of Building

2009 IECC. 2009. *International Energy Conservation Code*, International Code Council (ICC), Washington, DC. . www.iccsafe.org/Store/Pages

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J.D. Power and Associates. 2009. "2009 New-Home Builder Customer Satisfaction Study." www.jdpower.com/homes/articles/2009-Homebuilder-Customer-Satisfaction-Study

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McGraw Hill Construction. 2009. 2009 Green Outlook: Trends Driving Change. http://construction.com/market_research/reports/GreenOutlook.asp.

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NAHBRC. 2007. B*uilding 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.

New Tradition Homes of Vancouver, Washington, partners with Building America and local programs like Earth Advantage to build and sell energy-efficient homes.

"The interest in sustainable building has been overwhelming, and an interesting indicator for the new construction economy."

Adrian Willanger, as quoted in the *Seattle Daily Journal of Commerce* January 4, 2010

"As the home market continues to tighten and Americans focus on energy efficiency, health, and greening their lifestyle, builders who are improving their homes today will be in a position to enjoy greater market success tomorrow."

Ryan Kerr, of Building America research partner ConSol, as reported in *Home Energy Magazine* May/June 2008

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Codes as Drivers

New building codes are now a driving force in energy-efficient construction. All three marine climate states are, or recently have, undertaken building energy code revisions. (See www.energycodes.gov for more information on code changes.) Below is a brief status of the International Energy Conservation Code (IECC) and each state's energy code (as of May 2010).

The 2009 International Energy Conservation

The 2009 International Energy Conservation Code (IECC) is the most recently published national energy code (published in December 2008) and is getting a boost in adoption from the American Recovery and Reinvestment Act (ARRA) of 2009. States seeking funding for building programs through the Act must show that they have adopted a building energy code (or codes) for residential buildings that meets or exceeds the 2009 IECC. (Note that provisions of the 2012 IECC are scheduled to be finalized in November 2010.)

State Codes

WASHINGTON STATE

The Washington State Energy Code (WSEC) is a state-developed code that is equivalent to or more stringent than the 2009 IECC for most homes. Washington is on a three-year code review/change cycle. The State Building Code Council revised the Washington State Energy Code in November 2009 and it became effective on July 1, 2010.

OREGON STATE

The Oregon Residential Specialty Code (ORSC) is a state-developed code for 1- and 2-family residential dwellings that is more stringent than the 2006 IECC.

In 2006, Oregon Governor Ted Kulongoski mandated a 15% increase in energy performance for new residential construction by 2015. In response to this, the Oregon Building Codes Division (BCD) and the Oregon Department of Energy cooperatively submitted an energy code change proposal. This proposal was enacted in March 2008 and became effective July 1, 2008. To achieve this 15% efficiency improvement, the building envelope requirements were upgraded, additional measures were added to prescriptive standards, and a structural requirement—that builders must include one of nine energy-efficiency options—was added. Two of the eligible options builders may choose to include are solar photovoltaic and solar water heating systems. Many of the measures were drawn from the 2004 Northwest ENERGY STAR specifications.

CALIFORNIA STATE

California Title 24, Part 6, is a state-developed code that is more stringent than the 2009 IECC. California is on a three-year code change cycle. The Commission adopted the new 2008 Standards on April 23, 2008. These standards, known as the California Building Standards Code, which is Title 24 of the California Code of Regulations (often referred to as Title 24), became effective January 1, 2010.

STATE CODES SUMMARY

The 2009 IECC has one prescriptive package for the marine climate. California has three prescriptive compliance approaches (Component Packages C, D and E). Component Package D is the basis for the performance calculation methods and is the component referenced compared to Washington, Oregon, and the 2009 IECC. California identifies 16 climate zones; climate zones 1–5 are similar to the 2009 IECC marine designation. Washington's prescriptive packages are based on two climate zones and Oregon's "state-specific" prescriptive compliance package is based on one climate zone.

"Energy efficiency is something that we jumped on right away; the company believes it is a huge benefit for our customers to provide increased comfort and economic savings through lower energy costs."

Johanna Coleman, Schneider Homes assistant vice president. Schneider Homes built 28 homes near Seattle to the federal tax credit level in 2008. All of its homes meet the more rigorous requirements of the Northwest ENERGY STAR program.

For More Information on Codes

2009 IECC. 2009. *International Energy Conservation Code*, International Code Council (ICC), Washington, DC. www.iccsafe.org/Store/Pages

2009 IRC. 2009. *International Residential Code - One and Two-Family Dwellings*, International Code Council (ICC), Washington, DC. ww.iccsafe.org/Store/Pages

Building Energy Codes Program. U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, www.energycodes.gov

Chapter 3.

Business Management Tools

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

Building science, integrated design, and quality management help deliver more energy-efficient, durable, and green buildings. Choosing the right materials and properly sizing equipment can help manage builder risk and increase the value of new homes. For builders who want to build high-performance homes and achieve a healthy bottom line, sound business systems are a critical part of the picture.

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

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

Each of these four practices has value on its own, but they work best when applied as part of an overall management system suited to an individual business. For businesses to prosper, return on investment must also be an important criterion.

"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 California

CHAPTER TOPICS

3.1 Quality Management

3.5 Integrated Design

3.10 Value Engineering

3.11 Managing Innovation with Prototypes

Quality Management

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

- **QUALITY MANAGEMENT:** a process for achieving maximum customer satisfaction at the lowest overall cost to the organization while continuing to improve the building process. A quality management system documents the structure, responsibilities, and

Factors in New Tradition Home's quality management program include an in-house building science team, a corporate commitment to energy efficiency, ongoing training of staff, participation in federal and regional energy-efficiency programs, a dedicated air sealing contractor, third-party performance testing, in-house marketing research, and an ongoing, interactive relationship with an HVAC contractor interested in high quality.

procedures required to achieve your company's goals. 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.

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

Many companies formalize their quality management processes and practices. 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. The important point is to plan for quality.

Building America's IBACOS research team has developed comprehensive quality management guidelines for builders. The recommendations encompass all facets of the builder's organization including leadership, strategic planning, customer satisfaction, performance management, jobsite responsibilities, safety, workforce development, quality construction processes, and trade contractor and supplier partnerships. The recommendations can be found in Appendix D of the report, *Achieving 30% Whole-House Energy Savings Level in Marine Climates*, prepared by Building America's research teams (Dec. 2006) and available at http://apps1.eere.energy.gov/ buildings/publications/pdfs/ building_america/39743.pdf.

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.

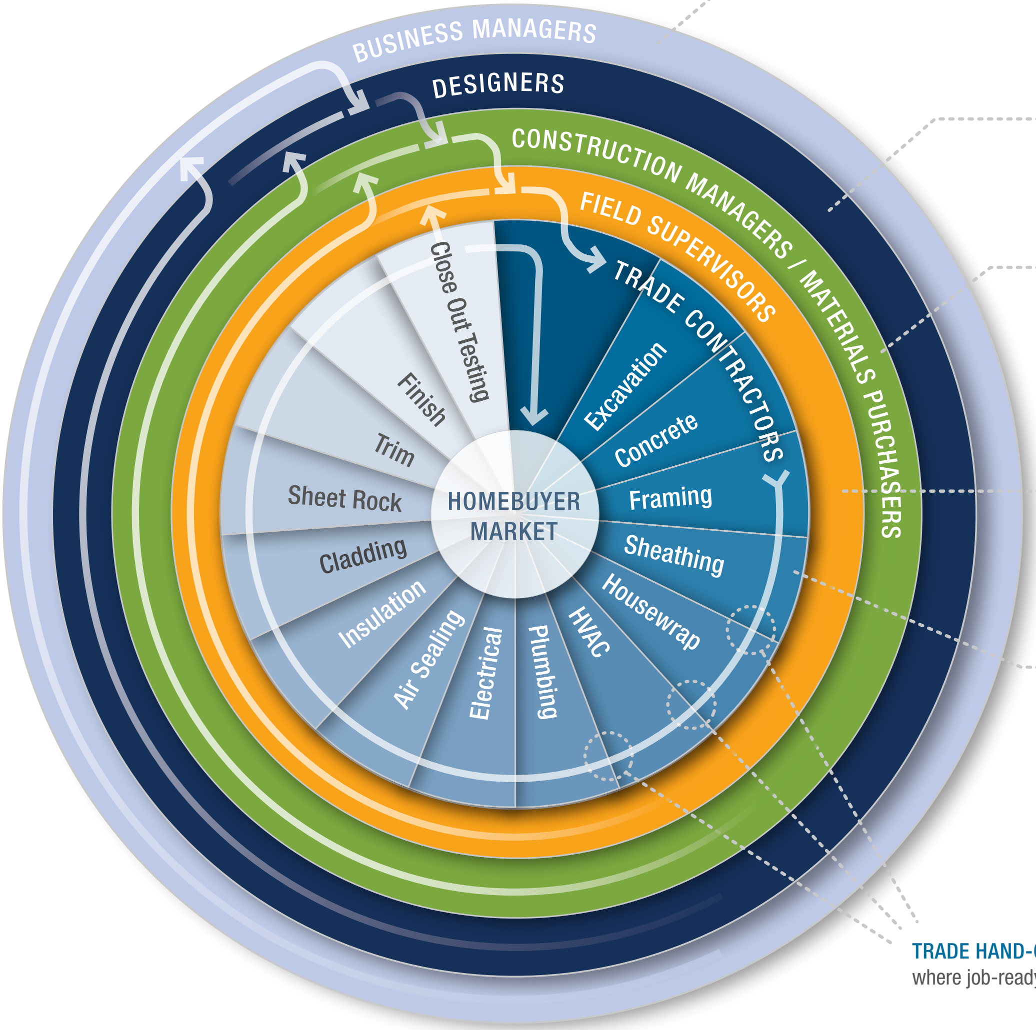
"The beauty of Quadrant Homes is their consistency. When I go into a house, and I see it from the heating side, I know that it is going to be built the way my plans show it to be built. The trusses and studs are where I expect them to be so when I go out there to do my installation, I don't have surprises."

Wade Craig, Bob's Heating and Air Conditioning, manager, Quadrant's HVAC contractor

Plans and Specifications

Plans and specifications are essential quality management tools for conveying consistent information. Plans will show elevations, floor plans, and details needed to confirm that projects meet code minimums. Plans and specifications should clearly identify all details related to energy efficiency, such as duct layout, advanced framing techniques, moisture management techniques, and air sealing details.

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 customers 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 codes. Perform final inspection to ensure work is performed according to your own standards and those of the builder. Confirm 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. It conveys to the contractors a clear understanding of the task and expectations of how it will be completed. Scopes of work should be reviewed and updated, especially 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.

The Building America research teams have put together an extensive set of scopes of work that builders can include with the contract documents they give their installation contractors. The scopes of work cover the foundation, framing, walls/drainage plane, windows, HVAC, and air sealing. They include job descriptions and pre-job

"By using a Building America consultant, not only do we get third-party credibility, 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)

and post-job checklists that can be signed off by the subcontractor and the jobsite supervisor. These scopes of work can be found in Appendix E of the report, *Achieving 30% Whole-House Energy Savings Level in Marine Climates*, prepared by Building America's research teams and available at http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/39743.pdf.

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 the work can begin. The job-ready checklist 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, on the other hand, 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 accountable—the trade contractor for proper implementation and the builder for appropriate inspection of the 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 2008).

For More Information on Quality Management

ASQ. 2008. *ISO 9001:2000 Interpretive Guide for the Design and Construction Project Team*. American Society for Quality Press, Milwaukee, WI. www.asq.org/qualitypress..

2009 International Energy Conservation Code. Section 103.2, "Information on Construction Documents." International Code Council (ICC), Washington, DC. www.iccsafe.org/Store/Pages

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ISO 9000. *Quality Management Systems*. International Organization for Standardization, 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

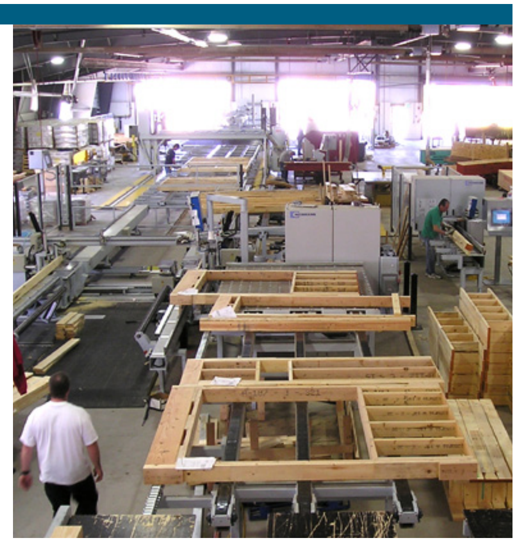
The integrated design process, including energy-efficiency modeling and appropriate HVAC system sizing, is at the heart of Building America recommendations. Integrated design is a process by which all the various building subsystems are evaluated for the local climate and their interrelationships are 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.

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 house design.

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.



Quadrant Homes, Washington State's largest home builder, has its wall panels built in a factory and assembled on site for more precise quality control, less exposure to the elements, and faster installation on site.

"A lot of builders have processes. What sets Quadrant apart is that they are very disciplined. They build on a defined schedule. Every task has a specific day that it gets completed."

Craig MacKay, president of
Woodinville Lumber, Inc.,
wall supplier to Quadrant Homes

Related Standards & Procedures

- ISO 9000, Quality Management Systems
  www.iso.org
- 2009 International Energy Conservation Code, Section 103.2 "Information on construction documents," International Code Council (ICC), Washington, DC. Available for purchase at www.iccsafe.org/Store/Pages

The HVAC contractor worked with builder Quadrant Homes of Bellevue, Washington, to change its HVAC installation process to bring ducts and furnace into conditioned space, a Building America recommendation for meeting the federal rebate target energy savings of 50%.

"Quadrant Homes refers to us as vendor partners. We have a tough economy—some of the builders come to us and say 'well, we need 10% off.' Quadrant comes to us and says, 'recognizing that you need to stay in business, we need to figure out a way to reduce costs so that we can deliver a lower priced home to our purchasers.' In partnership, we design systems, like moving the furnaces into a closet, that reduce costs for us because we are able to install the equipment quicker. So, we are able to deliver lower costs to Quadrant."

Wade Craig, a manager at Bob's Heating and Air Conditioning, HVAC contractor for Quadrant Homes

Traditional Design Processes

Typically a design process includes the following steps.

1. PROGRAMMING:

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

2. 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.

3. DESIGN DEVELOPMENT:

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

4. CONSTRUCTION DOCUMENTS:

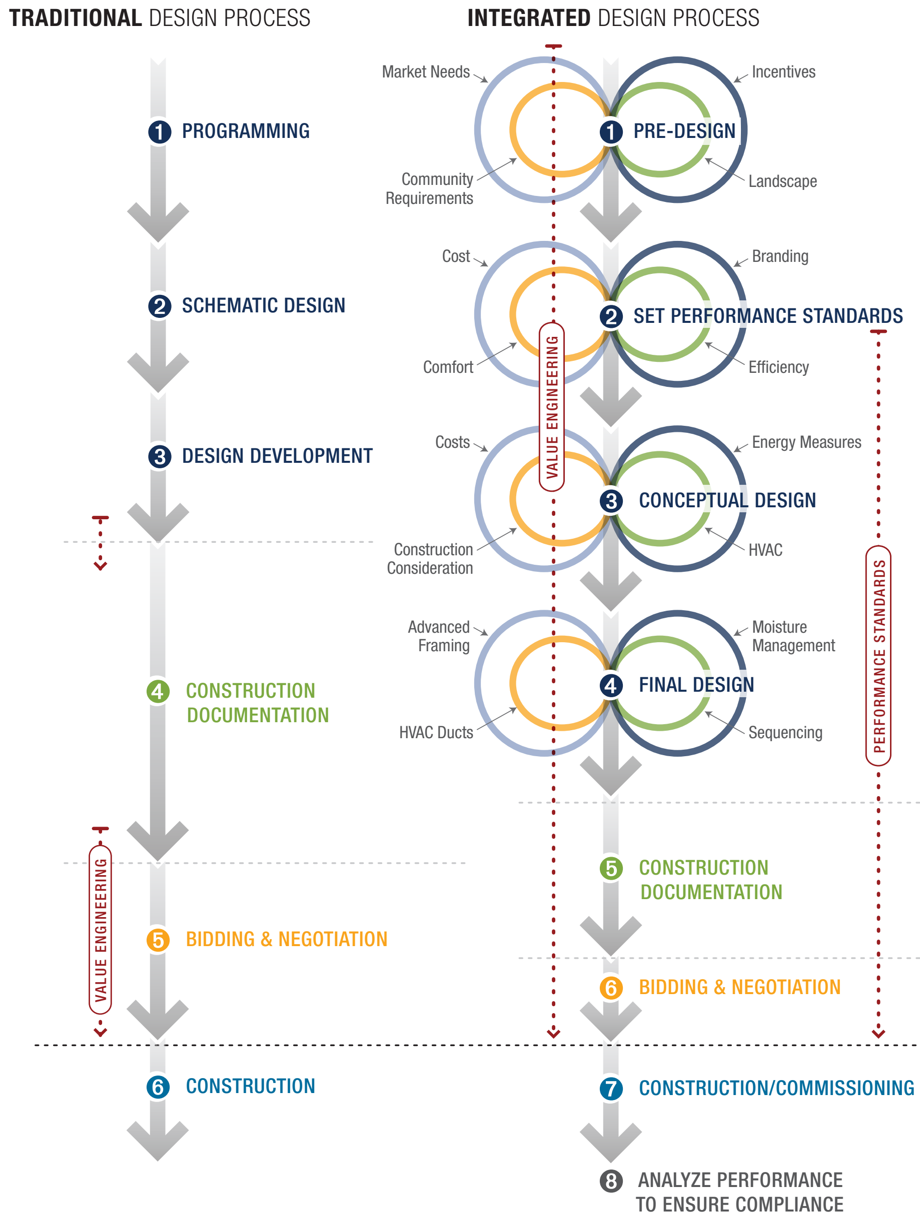
Final working drawings and specifications are ready for bidding and code approval.

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. For example, 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.

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.

Traditional Versus Integrated Design Process



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

Tom Walsh & Co. of Portland, Oregon, worked with its subcontractors to change its duct installation process, bringing ducts inside conditioned space in dropped ceilings that were designed to add architectural interest to the homes' interiors.

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

"They [Tom Walsh & Co.] were able to really improve energy efficiency, quite frankly, without spending much more money. It came down to creating opportunities for their subs to learn a new system. I remember one thing clearly that Ben Walsh told me, 'In the end, getting all that extra energy efficiency didn't really cost as much as we thought. It was really about communicating with people a new way of doing things.'"

Chris Bonner, a real estate broker with Hasson Company, who listed Tom Walsh & Co.'s 46 homes in the New Columbia development in Portland, Oregon.

Quadrant is the largest builder in Washington State. Quadrant sold 540 homes in the first half of 2009.

"The thing that is really impressive to me about Quadrant is that they are all about process. Once they decide what they are going to do, the consistency and quality control are impeccable. From the day they break ground, they have 54 working days until the house is delivered to the customer."

David Hales, Building Systems Specialist with the Washington State University Extension Energy Program

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, achieving a HERS index score to qualify for a tax credit).

CONCEPTUAL AND PRELIMINARY DESIGNS – Gain team feedback during all phases of design and construction. Use an energy specialist to test 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. You may want to consult with code officials for any nonstandard techniques or materials. 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. 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 carbon monoxide 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/Institute for Market Transformation to Sustainability (ANSI/MTS). The document codifies a specific integrated design process.

For More Information on Integrated Design

AIA. 2007. *The Integrated Project Delivery Guide*, the American Institute of Architects, www.aia.org/contractdocs/AIAS077630

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 for improving 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 7. Advanced framing can be an important design feature, but value engineering can be applied to all aspects of home design.

Quadrant has established good relationships with its vendors, like Woodinville Lumber, by treating the vendors like partners and seeking their input in the building process.

"From our perspective, what sets Quadrant apart is their desire to partner with top-quality vendors to build efficiencies and cost savings and safe work environments, as opposed to working against the vendor or forcing the vendor into a scenario that does not work for the vendor."

Craig MacKay, president of Woodinville Lumber, Inc.

What does it take to get from 30% savings to 40% savings?

BIRA evaluated a 2,000-ft^2 home built by Clarum Homes in Menlo Park, California, that was 30% more efficient than a typical code-built home. It took just three changes to get a calculated jump in whole-house energy savings to 41% over code. The home already had a 90% AFUE furnace, R-38 ceiling insulation, R-13 batt plus 1-inch rigid foam wall insulation, 50% CFL lighting, and ENERGY STAR appliances. By upgrading the furnace to 92% AFUE, increasing the batt wall insulation to R-15, and moving the ducts into conditioned space, Clarum achieved 41% energy savings, enough to qualify for DOE's Builders Challenge.

"Quadrant's code homes and ENERGY STAR homes perform better than other ENERGY STAR homes regardless of the package because their ducts are in conditioned space and they use panelized walls that have fewer seams. And, they do a good job of sealing, so they have a tighter envelope. The things they do in their production process to make a more efficient building process also result in a more energy-efficient home."

Ryan Kerr, formerly a researcher for BIRA, the Building America team that worked with Quadrant Homes of Bellevue, Washington; currently with the Gas Technology Institute in Chicago

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 callbacks which leads to more customer referrals.

Value engineering is an important part of quality management and integrated design. Production builders are in a 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 is 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 July 30, 2008 www.value-eng.org/pdf_docs/monographs/vmstd.pdf

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 which features to carry forward into standard construction. This chart shows a process for working with building scientists, such as a Building America team, a HERS rater, 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

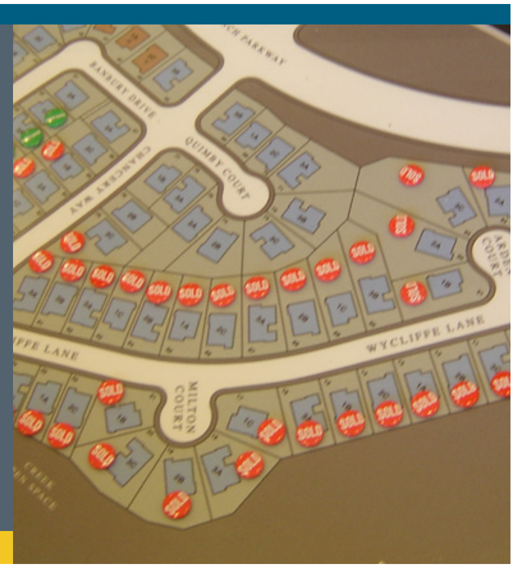
BUILDER/DEVELOPER		BUILDING SCIENCE PERSPECTIVE ENGINEER / ARCHITECT / HERS RATER / HVAC CONTRACTOR
Commits to go forward with best practices, sets goals, and expands design team to include building scientists	PHASE #1 **Decision**	Educates builder about building science and systems approach
Management tracks financial benefits Designer evaluates changes in style and materials, consults code officials for preliminary review. Site supervisors evaluate skills, subcontractors, and code issues Construction documents include detailed plans, specifications, and scopes of work	PHASE #2 **Integrated Design & Analysis**	Offers design solutions based on whole building analysis, including materials compatibility and durability, and system tradeoff modeling Determines impact of design solutions, including energy savings
Marketers create marketing program to emphasize improvements	PHASE #3 **Marketing**	Provides test results and data for marketing
Management ensures proper materials are purchased and available Site supervisors train crews, set clear expectations, and check quality Trades professionals implement best practices in their installation and construction processes Together, trades and supervisors use pre-job and post-job checklists	PHASE #4 **Construction**	Communicates design approach to supervisors and crew – helps work out installation sequences Observes construction practices, recommends improvements, and offers training
Management evaluates costs and benefits and decides on next steps	PHASE #5 **Post-Construction Evaluation**	Conducts field tests and inspections including blower door, duct pressure, and HVAC system tests
Planners integrate lessons learned in selection and siting of future communities Designer adds new features to production plans	PHASE #6 **Lessons Learned**	Offers help with upgrading production plans with solar and energy-efficient design

Quadrant Homes, located in the Puget Sound area of Washington State, used a prototype home to figure out how to meet the federal tax credit incentive for homes achieving 50% energy savings. Quinn Wyatt, Assistant Design Manager at Quadrant Homes, explains “when we learned about the federal tax credit program, we decided that it was something we really wanted to shoot for.” Quadrant worked with (Building America research partner) the Washington State University Extension Energy Program. Quadrant developed a federal tax credit-level home it marketed as an “Energy Sound” home. Quadrant built its first Energy Sound home in a 300-unit development called Kentlake Highlands near Seattle. “At that time, it was a test case. We launched our program across all of our communities from this house,” said Wyatt.

“One of the 46 homes I built is now owned by a friend I have known since I was 6 years old. The value that the 46 houses represent to their buyers...is that people’s equity has been preserved [in the collapsing housing market].”

Ben Walsh, Construction Manager for Tom Walsh & Co. New Columbia Homes

Chapter 4.
Selling Performance



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 hundreds of builders who have successfully used energy efficiency to sell houses. Consumers want the value and comfort high-performance homes offer. Builders want happy customers and the positive referrals they will give.

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

- Brand and label their products for fast and easy differentiation.
- Train their sales staff to educate consumers.
- Market the sometimes hidden energy-efficient features of the home.
- Get the business name and products in front of the public.

"Having increased energy efficiency really let us stand out from the competition."

Chris Bonner, a real estate broker who listed homes for Tom Walsh & Co. at the New Columbia development in Portland, Oregon

CHAPTER TOPICS

4.1 Branding and Labeling
4.3 Training Sales Staff
4.5 Marketing Energy Efficiency
4.6 Reaching Out to the Media

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.

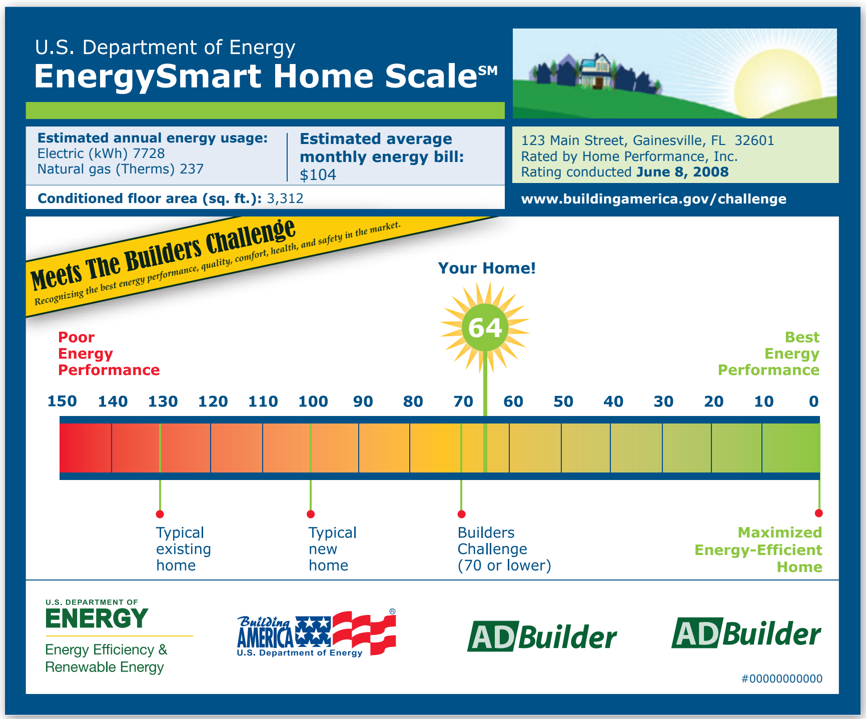
Creating recognizable brands that resonate with consumers is difficult. Large corporations that rely on consumer sales spend millions of dollars on campaigns to keep their brands fresh but familiar. This investment pays off best when products involve multiple, frequent purchases from many consumers. 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.

"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.

Brands like Builders Challenge, ENERGY STAR, and other national and regional programs offer builders a recognizable label tied to known sets of standards. Qualifying for these nationally known programs will give your energy-efficiency efforts instant credibility; they are excellent vehicles for leveraging your marketing dollars.

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.



Consumers recognize the ENERGY STAR logo as a label for products that are energy efficient and good for the environment. This 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 the 2006 IECC building code requirements. Whether or not builders choose to brand their homes as ENERGY STAR homes, many of the products that go into the home (or are on display in model homes) carry the ENERGY STAR logo.

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.

U.S. Department of Energy Builders Challenge

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

DOE's Builders Challenge program has formed national partnerships with other green building programs that provide marketing and labeling support, including the National Association of Home Builders' National Green Building Program™ (NAHB 2009) the U.S. Green Building Council's LEED for Homes program, and Masco's Environments for Living®.

Many Building America builders choose to offer their homeowners an energy-use guarantee. Some builders do this on their own; others work through Masco Home Service's Environments for Living program. Masco developed the program in 2001 with help from 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.

Training Sales Staff

Having properly trained sales staff is key to helping buyers understand and appreciate the value of energy-efficiency 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, and utility information.

Another Building America builder, Vern McKown, co-owner of Ideal Homes in Norman, Oklahoma, shared some of his tips for training at the Energy and Environmental Building Alliance (EEBA) National Conference in Denver, Colorado, in September 2009:

☑ ENSURE CULTURAL AND CORPORATE ALIGNMENT.

- Identify your company's core values and hire people who share those values.
- Ask your employees where the weak spots are and fix them.
- Ask your employees how you can help them do their jobs better.

ENERGY STAR Update

In April 2010, the U.S. Environmental Protection Agency (EPA) announced new, more rigorous guidelines for new homes that earn the ENERGY STAR label. Compared to the current ENERGY STAR guidelines, the new requirements will make qualified new homes at least 20% more efficient. These guidelines will go into effect in January 2011, although builders may choose to adopt the new requirements earlier.

For more information about ENERGY STAR qualified homes see: www.energystar.gov

Builders who meet the DOE Builders Challenge criteria also qualify for the Environments for Living platinum level.

Field train sales staff every six months to keep them up to date on energy-efficiency techniques.

"You have to educate home-buyers 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."

Bob Walter, Morrison Homes, Elk Grove, California

☑ GIVE SALES STAFF SIMPLE MESSAGES TO CONVEY, FOR EXAMPLE:

- Here's how we are different—show infrared camera photos.
- Blown-in insulation fills in nooks and crannies better than batt.
- Our duct leakage is 5%, the average is 27%.
- Our windows are high performance—less heat in, less energy loss out.
- Utilities are guaranteed.

☑ GET SALES STAFF TO WALK BUYERS THROUGH THE HOME.

- Identify four key exterior features and nine key interior features.
- Use mystery shoppers to find out what your sales folks are actually telling shoppers.
- Keep it simple—"We tell sales folks, if you aren't sure of the specifics just say 'we're better' and stop there."

☑ SET UP A CUSTOMER INFORMATION CENTER IN THE MODEL HOME'S GARAGE.

- Use side-by-side displays on walls, demo walls showing wall and window features, touch screen videos, and poster board displays.

☑ TRAIN SALES STAFF.

- Field training of every sales person every six months, no matter how long they've been with the company.
- New hire sales training boot camp.

☑ KEEP YOUR WEBSITE ACTIVE.

We respond to web inquiries within five minutes.

- When the typical customer looks at the website, they look at the location, street scene, elevation, and floor plan.
- Ideal trains its sales staff to interrupt that typical thought process, to emphasize that "we are different and we are better," by pointing out energy savings and quality.

☑ FIND A NICHE.

- "We have a competitor 1.5 miles away who is a national builder. They sell at 78 cents/ft^2, we sell at \$1.12/ft^2, we have a different market niche," said McKown.
- All of Ideal's homes are Builders Challenge homes.

☑ DO YOUR OWN RESEARCH.

- Do exit interviews with customers, buyers, and lookers.
- Drill down for specifics in problem areas.
- Have every trade fill out job-ready and job-complete forms.
- Do NAHB quality certification audits of the whole company on a regular basis.

Marketing Energy Efficiency

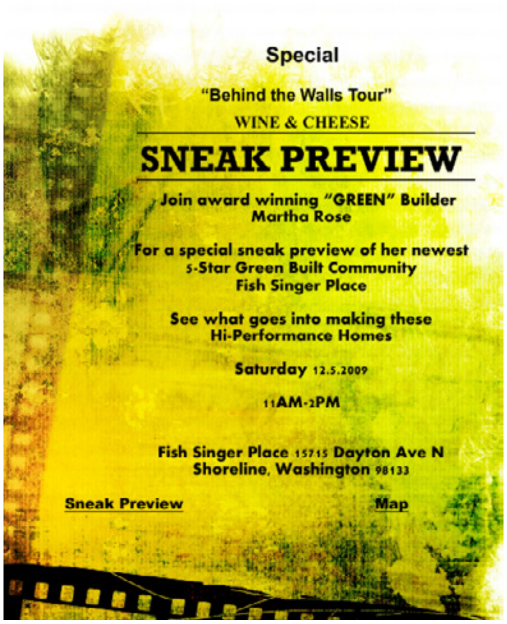
A challenge for builders of energy-efficient homes is showing consumers the energy efficiency they are purchasing. Most energy-efficiency improvements are hidden away in walls and attics invisible to buying eyes. Making energy improvements “real” to the consumer is a multi-faceted, ongoing process that can include any of the following (NAHBRC 2010):

- Emphasize cost, comfort, health, and environmental benefits.
- Educate customers and sales professionals. Use duct blaster, blower door, and HERS scores to show differences.
- Use walk-throughs and model homes with display cutaways of energy features such as insulated attics and wall sections to help buyers and sales staff understand the energy-efficient construction process.
- Turn the model home’s garage into an energy information center.
- Organize tours for homebuyers, school groups, media, and realtors. Use slides, sample products, and energy bills as aids.
- 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. Another builder has the buyer meet with the building site supervisor after the sale is made for one more chance to sign up for energy-efficiency upgrades.
- Provide take-home brochures that explain energy-saving features. Develop your own brochures or give away Building America and ENERGY STAR brochures, reprints of magazine articles, vendor and trade association brochures. 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).
- Use paid advertising with a simple slogan. 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.
- Use the Internet—websites, YouTube videos, Facebook, Twitter, etc.
- Seek out free publicity, send out press releases, hold media events.
- Offer energy-efficiency guarantees.
- Make buyers aware of energy-efficient mortgages.
- Package energy-efficiency features through a national or regional program or your company’s own energy-efficiency “brand.”

(top) Show potential buyers your energy-efficient features with cut-aways and side-by-side displays.

(bottom) Use signage to spell out your message.

Building America builders have won 93 Energy Value Housing Awards (EVHA) from the National Association of Home Builders Research Center. 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.



Martha Rose, a Seattle area custom builder, used "sneak preview" fliers reminiscent of film screening fliers to promote a "Behind the Walls" tour of her newest, energy-efficient project, Fish Singer Place, north of Seattle. In the first half of 2010 she hosted nearly 1,000 visitors in tours for community colleges, building programs, realtors, media, and the public. Rose, a Building America partner, also hosted green building workshops and lectures to educate the public and draw visitors to her projects.

Building America team lead Con Sol partnered with Clarum Homes of Palo Alto, California, to develop its energy-efficient and solar-powered Enviro-Home package, which reduces homeowner energy bills by up to 90%.
(Figure source: Clarum Homes)

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.

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

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&articleid=375&qu=consumer+survey

NAHB. 2009. ICC 700-2008 *National Green Building Standard*, the National Association of Home Builders and the International Codes Council, http://store.builderbooks.com/cgi-bin/builderbooks/874?id=kh25n99N&mv_pc=43

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

NAHBRC. 2010. Energy Value Housing Award Program. National Association of Home Builders Research Center www.nahbrc.org/EVHA

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

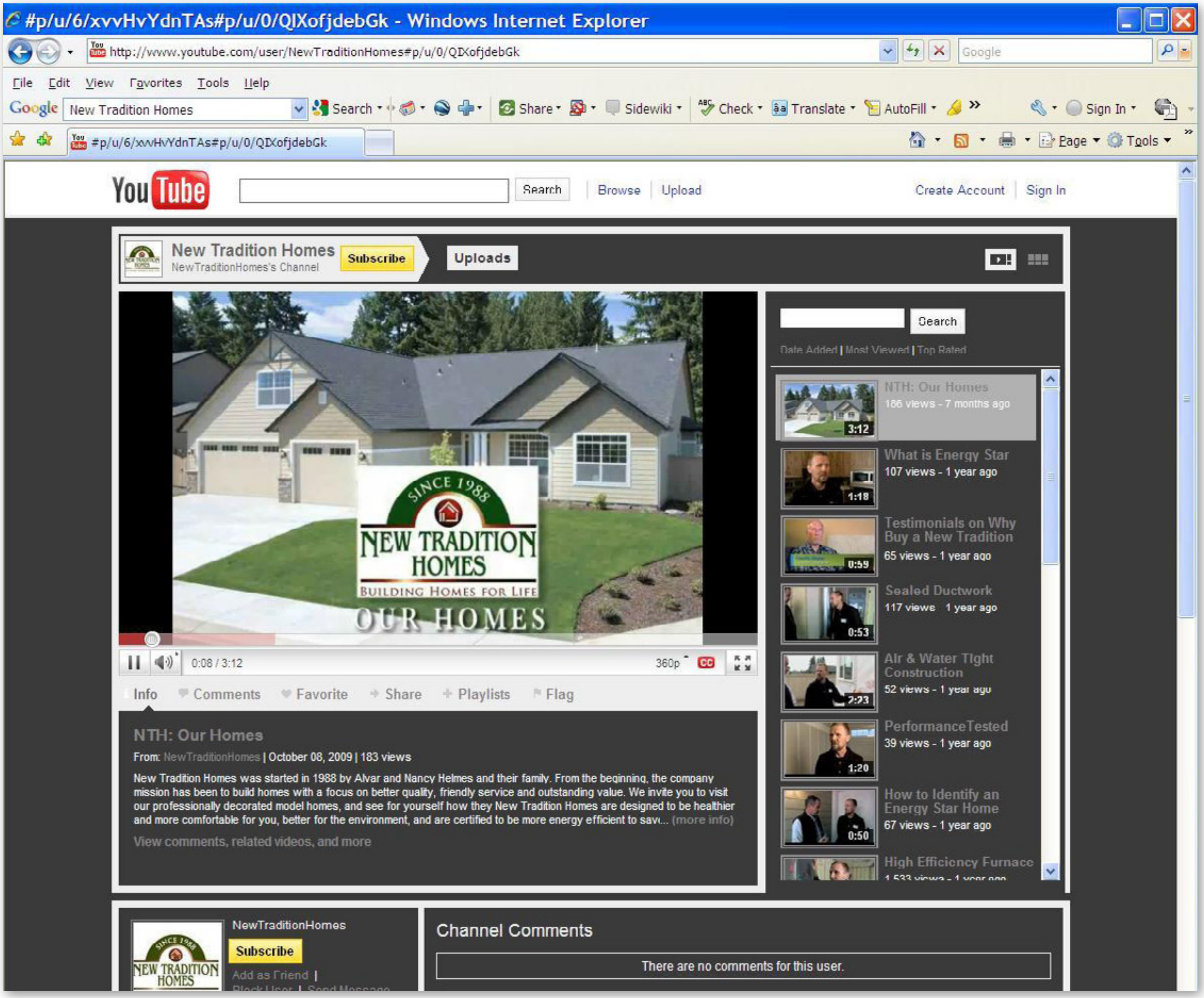
U.S. Environmental Protection Agency. EPA WaterSense water-saving labeling program: New Homes. www.epa.gov/watersense/pp/new_homes.htm

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

New Tradition Homes of Vancouver, Washington, uses signs at the curb and "dare to compare" displays in its model homes to tout the energy efficiency of its homes.

Quadrant, a Weyerhaeuser real estate company based in Bellevue, is Washington State's biggest homebuilder, with 873 home starts in 2008 and an average of three sales per day in the first six months of 2009. Quadrant Homes has a 96% customer referral rate.

Quadrant offers buyers "custom" production homes with over 300 house plans and 10,000 features options to choose from. Quadrant successfully markets its energy-efficient options as the only features that pay you back. Quadrant Homes has been recognized by the U.S. Environmental Protection Agency (EPA) with a 2009 ENERGY STAR® Leadership-in-Housing Award.



New Tradition Homes has its own channel on YouTube with over a dozen video clips advertising its energy-efficiency features. www.youtube.com/user/NewTraditionHomes

Chapter 5.

The Marine Climate

The marine climate covers a narrow band paralleling the West Coast from the Canadian border south to the county boundary separating Ventura and Los Angeles counties in California. In some stretches, this band is only one county deep inland from the Pacific Ocean. The marine climate was designated in recognition of the mild temperatures and moist conditions found along the coast. However, the marine climate borders on the cold climate in the north and the hot-dry climate in the south and the more extreme conditions of these neighbors are found in some inland areas. Homes in the marine climate are faced with high levels of moisture, often in the form of rain, fog, or snow.

In addition to describing the marine climate, this chapter also provides information on constructing for the extreme weather conditions that sometimes occur in the marine climate including heavy precipitation, high winds, flooding, earthquakes, and forest fires. Siting and design considerations with respect to solar gain are also included. See Chapters 6 and 8 for information on moisture management techniques for roofs, walls, and foundations.

"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

5.1 Climate Description

5.2 Weather

5.8 Considering Solar Gain in Siting and Design

Climate Description

The marine climate is defined as a region that meets all of the following criteria:

- a mean temperature of the coldest month between 27˚F (-3˚C) and 65˚F (18˚C)
- a warmest month of mean less than 72˚F (22˚C)
- at least 4 months with mean temperatures more than 50˚F (10˚C)
- a dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year.

For More Information on Climate Description

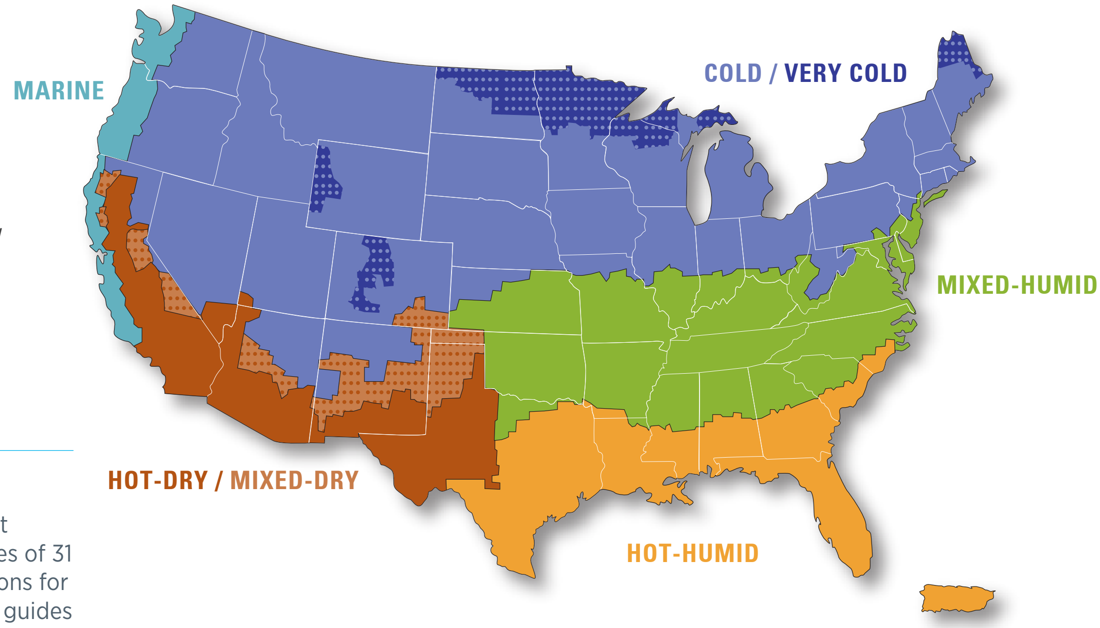
Briggs, RS; RG Lucas; and ZT Taylor. 2003. "Climate Classification for Building Energy Codes and Standards: Part 2 - Zone Definitions, Maps and Comparisons," *Technical and Symposium Papers, ASHRAE Winter Meeting*, Chicago, IL, January 2003

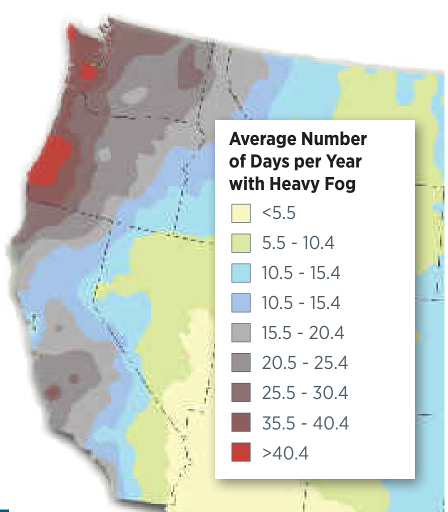
PNNL. 2008. *Vol. 7: Guide to Determining Climate Regions by County*. PNNL-17211, Building America Best Practices Series, Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory, www.buildingamerica.gov

FEMA Fact Sheets

The Federal Emergency Management Agency (FEMA) has produced a series of 31 fact sheets providing recommendations for building homes in coastal areas. The guides cover siting recommendations; moisture barrier systems; housewrap, masonry, roof sheathing and other building materials; door and window installation; roof and deck to wall flashing; tile and asphalt roofing techniques for high wind areas; foundations; and construction techniques in flood-prone areas. See www.fema.gov/library/viewRecord.do?id=1570.

Building America U.S. Climate Regions





Fog

Average number of days per year with heavy fog *(Source: City University of New York www.geography.hunter.cuny.edu/~tbw/wc.notes/5.cond.precip/clouds/fog_map.htm)*

Weather

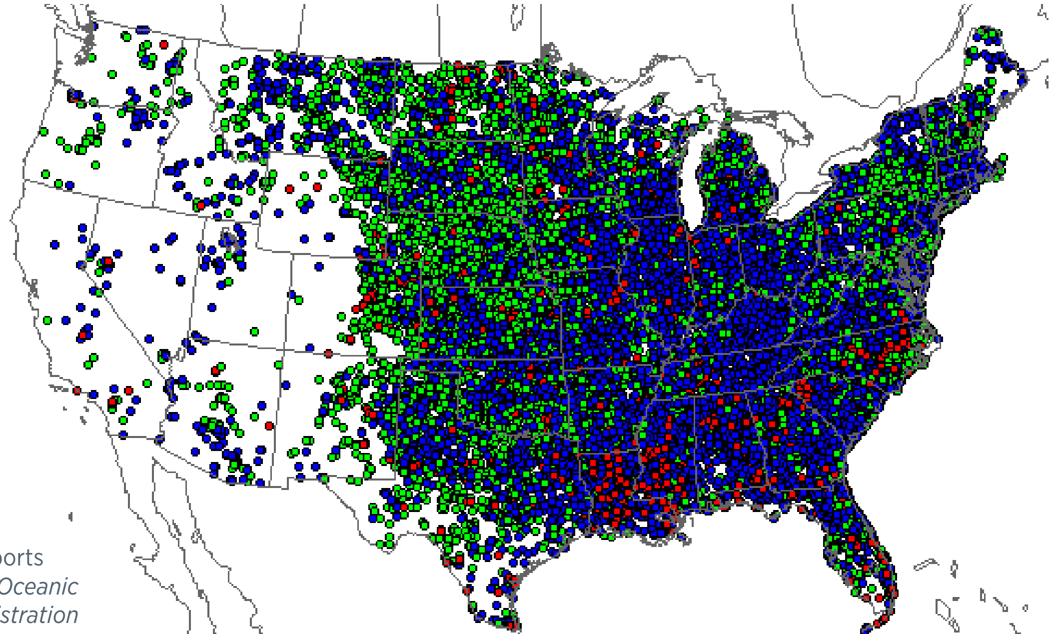
The marine climate is at low risk for hurricanes, tornadoes, and severe thunderstorms. However, the region is vulnerable to frequent precipitation, high winds, seismic events, and forest fires.

Precipitation

Rain falls frequently in the Pacific Northwest. Sometimes it comes as wind-driven sheets, often a fine drizzle, and sometimes a drenching downpour, but rain-imbued weather patterns in the Northwest can settle into the landscape and last weeks, and sometimes months, at a time.

Precipitation in the marine climate varies from an average of 10 to 35 inches annually along the California coast south of San Francisco, to 30 to 50 inches annually north of San Francisco and along the Oregon and Washington coast with localized areas experiencing up to 200 inches annually. While the marine climate's population centers receive an average amount of annual rainfall compared to other U.S. cities, they are among the rainiest in terms of days of rainfall per year, with Portland, Seattle, Tacoma, and Olympia averaging 150 to 160 rainy days annually.

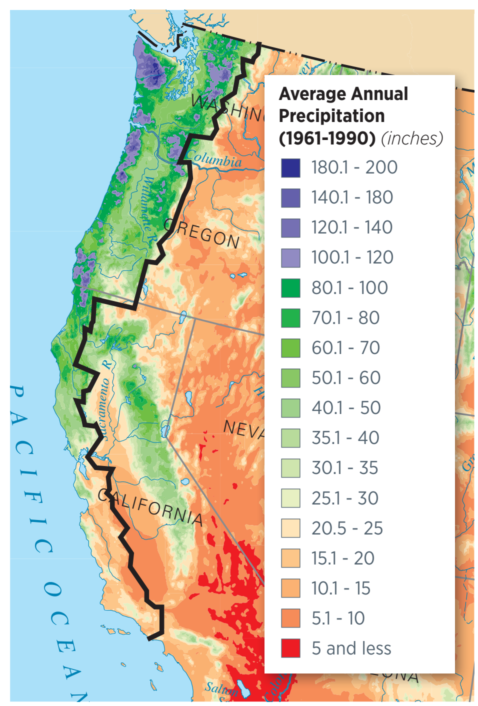
Severe Storm Reports 2008



U.S. Severe Weather Reports 2008. *(Source: National Oceanic and Atmospheric Administration [NOAA] Storm Prediction Center)*

In the northwest, much of this precipitation falls in the form of mist, drizzle, and light showers, which occur fairly constantly from October through June, while July through September are characterized by hot, sunny, and dry days. In coastal California and coastal Oregon, a considerable amount of moisture occurs as fog. Spring rain and thawing can cause flooding and mudslides both in the mountains and in lower elevations. Builders should take stability of the site into account when building on sloped areas.

Examples of substantial moisture-related building failures can be found in Seattle, Portland, Vancouver, B.C., and other marine climate cities. Researchers from Oak Ridge National Laboratory (ORNL) found that 20% of Seattle multifamily structures built between 1984 and 1998 are suffering premature building enclosure failures due to moisture intrusion (Karagiozis 2002a). Moisture management techniques applicable to this climate are described in Chapter 8 of this guide.

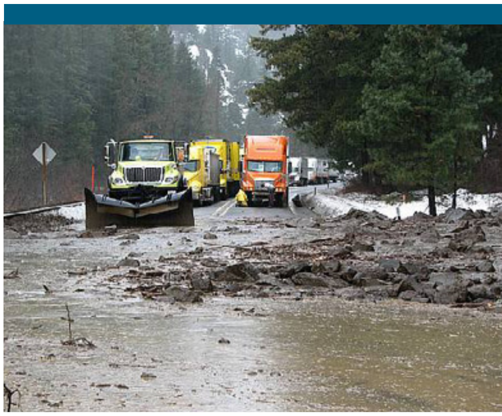


Annual Precipitation

The marine climate includes some of the wettest micro-climates in the United States with localized areas experiencing up to 200 inches of precipitation annually. *(Source: U.S. Department of the Interior, U.S. Geological Survey, Nationalatlas.gov)*

For More Information on Precipitation

Karagiozis, A. 2002. *Seattle Building Enclosure Hygrothermal Performance Study: Phase I*, Oak Ridge National Laboratory publication No. ORNL/TM-2002/ 89, September www.ornl.gov/~webworks/cppr/y2001/rpt/113799.pdf.



(top) Mudslides and flooding are common local events in the Northwest in spring time due to ground saturation from rain and snow melt. *(Photo source: Washington State Dept. of Transportation)*

(middle) Walsh Construction installed pervious pavers in alleys. Overflow during high rain events runs into 30-ft-deep drywells located under the streets.

(bottom) In the marine climate, new roofs are not immune to moss, which can spread quickly under favorable conditions like constant shade and low roof pitch.

Flooding

Flooding is a concern along the coast and inland waterways of the marine climate region. Builders should check state building codes and contact the local community floodplain administrator for information on local floodplain management regulations. Location-specific Flood Insurance Rate Maps (FIRMs) can be obtained at www.fema.gov/hazard\map\firm.shtm

Stormwater Management

Stormwater management is a significant issue in many marine climate cities. The city of Portland, Oregon, recommends controlling stormwater onsite by planting new trees; retaining existing trees; constructing swales, drywells, soakage trenches, planter boxes, vegetated infiltration basins, and flow-through planters; and using pervious pavement and turf block.

Walsh Construction Company won awards for its environmentally friendly stormwater management system at New Columbia, an 82-acre urban renovation site that is home to 854 single-family and multifamily housing units in Portland, Oregon. Walsh combined topography, vegetation, and soil features to naturally infiltrate rain water into the groundwater aquifer below the site. The stormwater management system uses 80% less underground piping than a comparable traditional development and retains 98% of the storm water on the site. Stormwater is naturally filtered through 101 pocket swales and 31 flow-through planter boxes. Overflow from large storm events runs into forty 30-foot-deep drywells located beneath the streets.

For More Information on Storm Water Management

City of Portland. 2010. Stormwater Solutions Handbook, Bureau of Environmental Services, www.portlandonline.com/bes/index.cfm?c=43110

Moss

In moist climates such as the marine climate, unwanted moss and other plant life can grow on roofs—especially on surfaces facing north. Moss and algae growth can stain and damage most roofing types. To inhibit moss and mold growth, roofs must have sunlight and airflow allowing them to dry properly. Options for inhibiting moss growth in heavily treed areas include using metal roofs, installing metallic zinc or copper strips along the roof just beneath the peak, or using copper-treated asphalt shingles. The better option from an environmental (and cost) standpoint is to allow adequate air and light to reach the roof by trimming trees so that branches do not overhang the roof.

For More Information on Moss

City of Portland. "Safe Roof Moss Control," Portland Bureau of Environmental Services, City of Portland, www.portlandonline.com/BES/index.cfm?c=50367

High Winds

Although all of the marine climate is in wind zone 1 (the lowest risk zone) on FEMA's scale of four U.S. wind zones, areas of the coastal northwest are designated special wind regions and have been known to experience high wind events. FEMA, the NAHBRC, and the U.S. Department of Housing and Urban Development (HUD) have put together guidelines for constructing asphalt and tile roofs in high-wind coastal areas www.fema.gov/library/viewRecord.do?id=1570. The Institute for Business and Home Safety provides structural details and guidance and a list of building materials acceptable for high-wind areas at www.disastersafety.org.

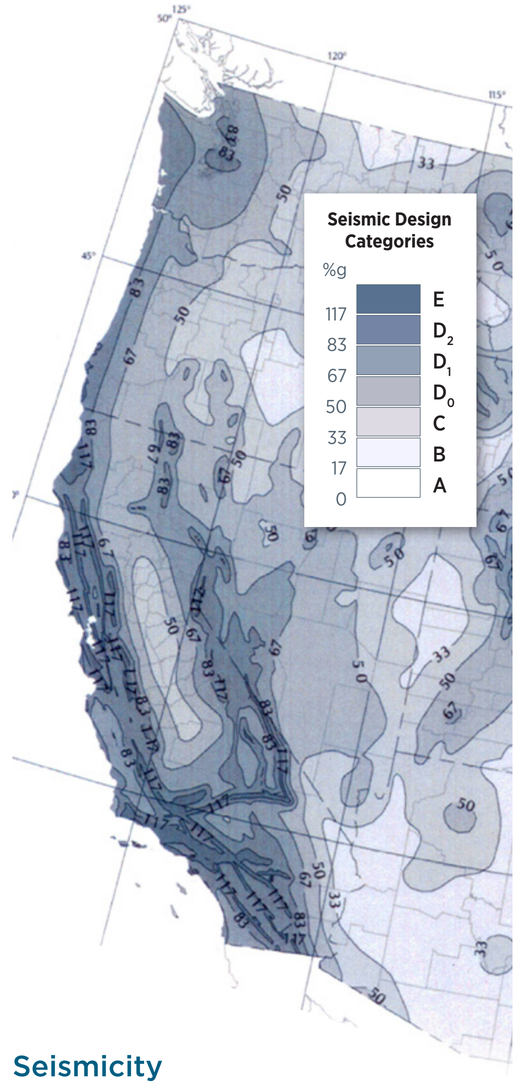
New requirements in the 2009 International Residential Code (IRC) address some of these high wind concerns with increased wall bracing requirements for homes built in high wind and high seismic areas. The new code increases the amount of wall bracing needed to resist wind loads for three-story homes, homes with large open plans and homes in high-wind regions. In addition, the new code requires blocking between the roof framing members at braced wall panels for homes with deep truss members or roof joists, or homes in high-wind and high-seismic areas. The new requirements include prescriptive blocking details for these conditions. These changes may require revisions to stock plans and standard detailing practices.

For More Information on Construction in High Wind Areas

FEMA. Home Builder's Guide to Coastal Construction. Federal Energy Management Association. www.fema.gov/library/viewRecord.do?id=1570

Institute for Business and Home Safety. 2008. *Fortified for Safer Living Builders Guide*, 2008 Edition. www.ibhs.org.

NAHB. 2008. "Fire Official Surge Sweeps Sprinkler Mandate to Victory," *Nation's Building News* September 22, 2008. www.nbnnews.com/NBN/issues/2008-09-22/



Seismicity

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

Seismic Events

Washington, Oregon, and northern California are home to seven volcanoes that have erupted in the last 200 years and near the coastline are some of the world's most active faults.

All of the marine climate region is in seismic design categories D_0, D_1, or D_2 (see map). Construction in these areas must follow the requirements of the 2009 IRC, which addresses seismic provisions in Section R301.2.2. 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.

For More Information on Seismic Events

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

2009 IRC. 2009. *International Residential Code - One and Two-Family Dwellings*, Section R301.2.2. International Code Council, Washington, DC. www.iccsafe.org/Store/Pages

USGS. Earthquake Hazards Program. http://earthquake.usgs.gov/research/hazmaps/

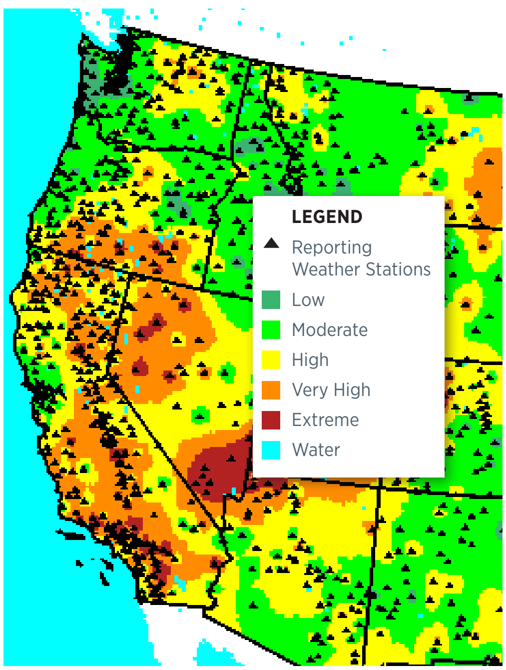
Forest fire danger is high in late summer, even in the marine climate, due to low precipitation levels July through September.

Forest Fires

Each year the United States experiences approximately 10,600 forest fires, burning an average of 960,000 acres. Most of these fires occur in the heavily forested western states. Parts of the marine climate are heavily forested and are susceptible to forest fires, particularly during the hot, dry summers and early fall.

The Institute for Business and Home Safety provides several recommendations for building in areas of high forest fire danger:

- Locate the building away from ridge tops, canyons, and areas between high points on a ridge.
- Use roofing material with Underwriters Laboratories Class A or least-combustible fire ratings (e.g., asphalt-fiberglass shingles, steel, clay or concrete tiles). With tile and shingle roofs, any gaps at ends must be blocked to prevent embers from entering underlayment. Complex roof designs are more hazardous in a fire than simple roof designs.
- Cover eave vents with a minimum 18-inch metal mesh screen.
- Use non-combustible siding, including fiber cement, traditional “three-coat” stucco, and brick, rather than vinyl or untreated wood siding.
- Install ½-inch mesh spark arrestors in fireplace chimneys.
- Use non-combustible materials like metal and stone for fences that attach to the house. Use metal rather than vinyl gutters.
- Keep plantings away from walls; plant trees far enough away so that trees will not overhang the roof; thin plants and trees within 30 feet of the structure.
- Use fire-retardant-treated wood or wood-plastic composite decking or consider stone or concrete patios rather than wood decks.



Forest Fires

Forest fire danger in the West for a typical late summer day (observed August 31, 2009.) *(Source: WFAS-MAPS Graphics, Fire Behavior Research Center, Missoula, Montana, U.S. Forest Service)*

For More Information on Construction in Wildfire-Prone Areas

FEMA. Prepare for a Wildfire. www.fema.gov/hazard/wildfire/wf_prepare.shtm

Institute for Business and Home Safety. 2008. *Protect Your Property from Wildfire, Pacific Northwest Edition*, www.disastersafety.org/text.asp?id=wildfire_main

Institute for Business and Home Safety. “Quick tips for creating a wildfire-resistant exterior” http://disastersafety.org/projects/?id=1425&category=1136

International Code Council. 2006. 2006 ICC International Wildland Urban Interface Code www.iccsafe.org/Store

NFPA. *Safer from the Start - A Guide to Firewise-Friendly Developments*, National Fire Protection Association. http://catalog.cmsassociates.com/firewise/index.php?page=item&id=469&icn=18156

University of California. “Builders Wildfire Mitigation Guide,” http://firecenter.berkeley.edu/bwmg/

Considering Solar Gain in Siting & Design

Despite the often cloudy conditions, passive and active solar design elements are still worth incorporating into homes in the marine climate. Design considerations include lot orientation, roof tilt, overhangs, windows, and shading.

Lot Orientation and Home Siting

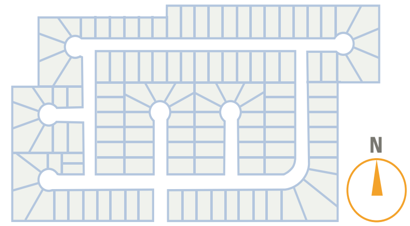
One virtually no-cost option for improving energy performance is to subdivide for solar orientation (see subdivision layout figure).

In the heating-dominated northern marine climate regions of Oregon and Washington, builders can use passive solar orientation to take full advantage of the sun's natural heat. By facing the long side of a home to the south and the short sides to the east and west, the building will capture solar heat in the winter and block solar gain in the summer. While the ideal orientation would be to face the home's long side directly into the sun, it can be oriented up to 30 degrees away from due south and lose only 5% of the potential heating savings. Locating windows on the home's south side will enhance its passive solar performance. If the south-facing window area reaches 8% to 10% of floor area, the home can be called "sun tempered." A home with south-facing glass area of 15% to 20% of floor area would be called a true passive solar home; this much south-facing glass requires thermal storage mass and summer shading to mitigate summer heat gains.

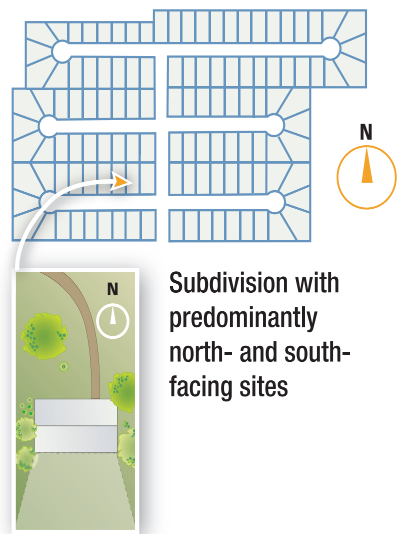
A study done in the Pacific Northwest by the Bonneville Power Administration placed passive solar home space heating savings between 10% and 20%, and a study by the City of San Jose, California, estimated savings for cooling costs between 10% and 40% (Iris Communications, Inc. 1995). The homes in both of these studies were oriented to the sun but did not include any special solar design features. East- and west-facing walls receive a large amount of solar heat from the low-angle sun as it rises and sets. To minimize overheating during spring and fall, builders should limit the amount of west-facing glass.

Home siting for active solar benefits from an orientation that provides significant south-facing roof area but due south is not necessary. However, In the marine climate, where the optimal tilt angle is 30°, at an azimuth of 0° (due south) the tilt can run from flat (0°) all the way to a roof pitch of 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 (Christensen and Barker 2001).

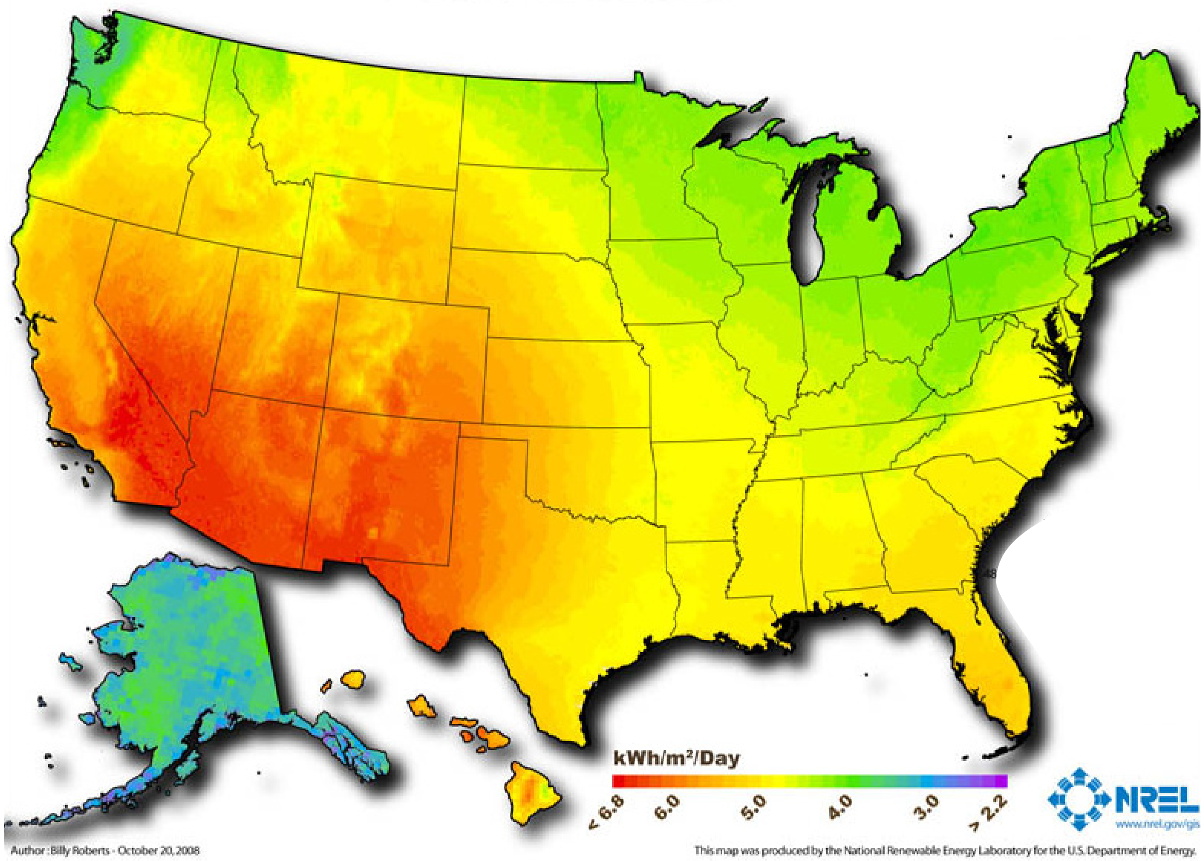
Plan subdivision lot lines and roads for predominantly north and south orientation



Typical Subdivision



Subdivision with predominantly north- and south-facing sites



This map shows an annual average of the kilowatt hours per day of solar energy available per square meter across the United States. As shown on the map, much of the marine climate has 4 or more kWh/m^2/day of solar resource available.

(Annual average solar resource data are shown for a tilt-latitude collector. The data for Hawaii and the 48 contiguous states are a 10-km satellite modeled dataset [SUNY/NREL 2007] representing data from 1998-2005. The data for Alaska are a 40-km dataset produced by the Climatological Solar Radiation Model [NREL 2003].)

(Map source: National Renewable Energy Laboratory www.nrel.gov/gis/solar.html)

For More Information on Solar Orientation

Christensen, C.B., and G.M. Barker. 2001. "Effects of Tilt and Azimuth on Annual Incident Solar Radiation for United States Locations, " NREL Report No. CP-550-32966, In *Solar Engineering 2001: Proceedings of the International Solar Energy Conference*, S.J. Kleis and C.E. Bingham (eds.), Presented at FORUM 2001, April 21–25, 2001, Washington, DC, The American Society of Mechanical Engineers (ASME), New York.

DOE. 2007. Building America Best Practices Series for High-Performance Technologies: Volume 6, Solar Thermal & Photovoltaic Systems. U.S. Department of Energy Building America Program, www.buildingamerica.gov

Iris Communications, Inc. 1995. "Turn to Solar for Lower Heating Costs" *Energy Source Builder* #42, December 1995. www.oikos.com/esb/42/solar.html

National Renewable Energy Laboratory. Solar Maps, www.nrel.gov/gis/solar.html

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

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

Overhangs

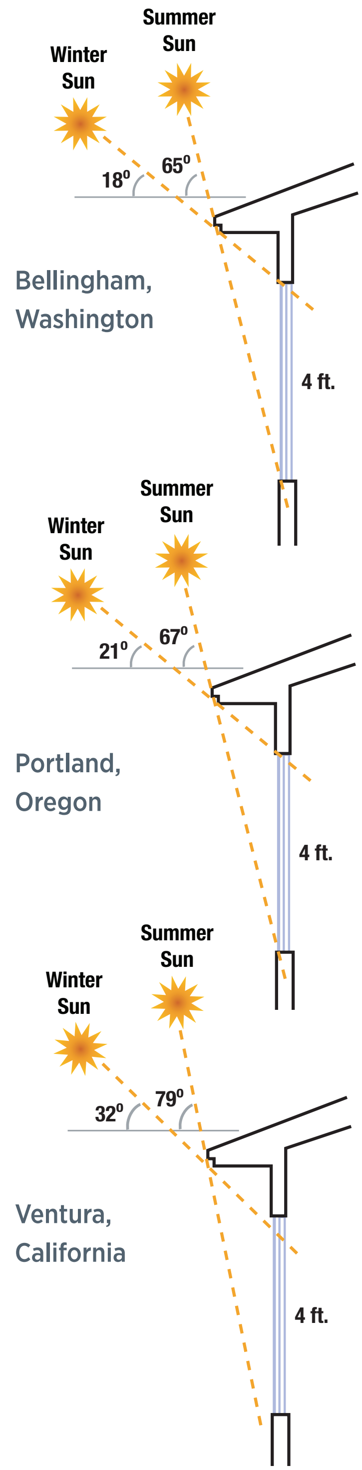
When positioning buildings to get the maximum passive solar benefit, overhangs can help manage heat gain and glare. Roofs should be designed with overhangs and porches to shade windows and doors. Overhangs also provide protection from rain, hail, and the effects of overheating and ultraviolet radiation on siding and windows. Overhangs may take the form of eaves, porches, awnings, pergolas, or trellises. Overhangs should be sized to account for differences in sun angles, elevation, window height and width, wall height above the window, and amount of shading desired based on time of day and time of year.

Free and low-cost computer programs are available for sizing overhangs based on location. 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.php. For example in Portland, Oregon, a 3-ft wide by 4-ft high window positioned 12 inches below the overhang would need an overhang extending 24 inches to provide full shade at mid-summer at 2 pm. For a listing of free and available-for-purchase energy models, including solar design tools, see DOE's Building Technologies Program website at http://apps1.eere.energy.gov/buildings/tools_directory/subjects.cfm/pagename=subjects/pagename_menu=other_applications/pagename_submenu=solar_climate_analysis. A low-cost sun angle calculator is available from the Society of Building Science Educators at www.sbse.org/resources/sac/index.htm.

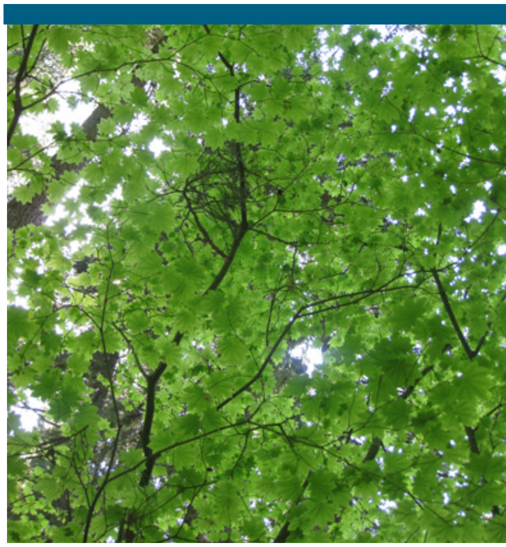
Windows

Windows should be selected to manage the quantity of heat loss and solar gain. In the cloudy, heating-dominated marine climate, it is preferable to use windows with a lower U-factor and a higher solar heat gain coefficient (SHGC). The U-factor is a measure of heat transfer. The lower the U-factor the better the window performs at stopping heat flow. The SHGC measures how well the window blocks heat caused by sunlight. The lower the rating the less solar heat the window transmits. The IECC requires a window U-value of 0.35 or lower in the marine climate; no SHGC is specified. For more information about windows, see Chapter 8 of this guide and also see the Efficient Windows Collaborative website at www.efficientwindows.org.

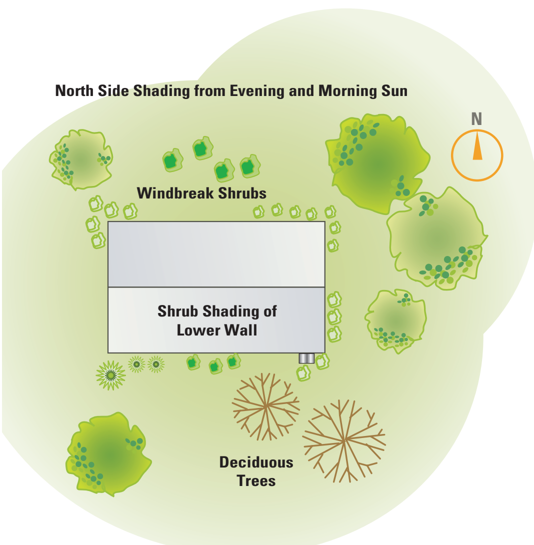
Sun angles vary by latitude



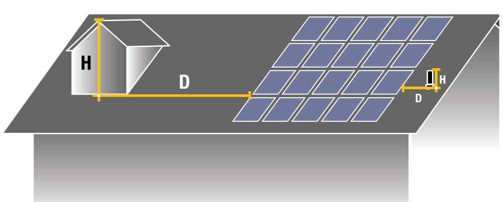
Sun angles vary by latitude, season, and time of day. Sun angles shown here are calculated for noon on June 21 and December 21. *(Source: University of Oregon, http://solardat.uoregon.edu)*



Deciduous shade trees can cut cooling loads during summer months, while allowing sunlight to warm and dry buildings during the winter.



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



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)

Shading

Shade can be provided by intentional planting or preservation of existing trees on the site. 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 (NAHB 2002). 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.

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). While evergreen trees may provide better wind protection, deciduous trees are ideal for summer shading in the northern marine climate because their lack of leaves in the winter will not block desirable solar gain during the heating season.

Trees reduce cooling requirements, particularly when located on the south and west side of the home to block low-angle, late afternoon, peak solar gain sun. Depending on the species, trees more than 35 feet from the structure are probably too far away for shade.

Care should be taken not to shade roof-mounted solar equipment (e.g., photovoltaic panels and solar thermal water heating panels) or areas of the roof that could be reserved for future solar installations. 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. Sun charts and digital tools are available 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.

Established trees can also provide a ground-stabilizing force in areas with sloped lots that may be at higher risk of erosion and mud slides. Pierce County, Washington, has produced a list of trees suited to the northwest climate (Pierce County 2005).

For More Information on Shade

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

National Association of Home Builders. 2002. *What 21st Century Homebuyers Want: A Survey of Customer Preferences*, National Association of Home Builders,
www.BuilderBooks.com.

Pierce County. 2005. *Pierce County's Recommended Tree Species, Pierce County Planning and Land Services*, Tacoma, Washington,
www.co.pierce.wa.us/xml/services/home/property/pals/pdf/rectreespechndout.pdf

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

Chapter 6.

Building Science and the Systems Approach

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

This chapter introduces fundamental principles of building science, including the systems approach to house design. The dynamic forces that drive the movement of moisture, air flow, and heat in homes are described. 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

The Systems Approach

Building America takes a systems approach to home design recognizing that as buildings become increasingly efficient, one must take into account the interactions of all of the home's components and subassemblies, both to maximize performance and to avoid catastrophe. This "whole-house" approach recognizes that changes in one or a few components can dramatically change how other components perform, affecting overall building energy use, comfort, and durability.

Building Science Basics

The successful builder needs to understand all of the forces that impact a house and how these forces interact with each other and the home's components. These forces include water, vapor, air flow, heat transfer, and occupants.

CHAPTER TOPICS

6.1 The Systems Approach

6.1 Building Scoience Basics

6.3 Water

6.4 Vapor

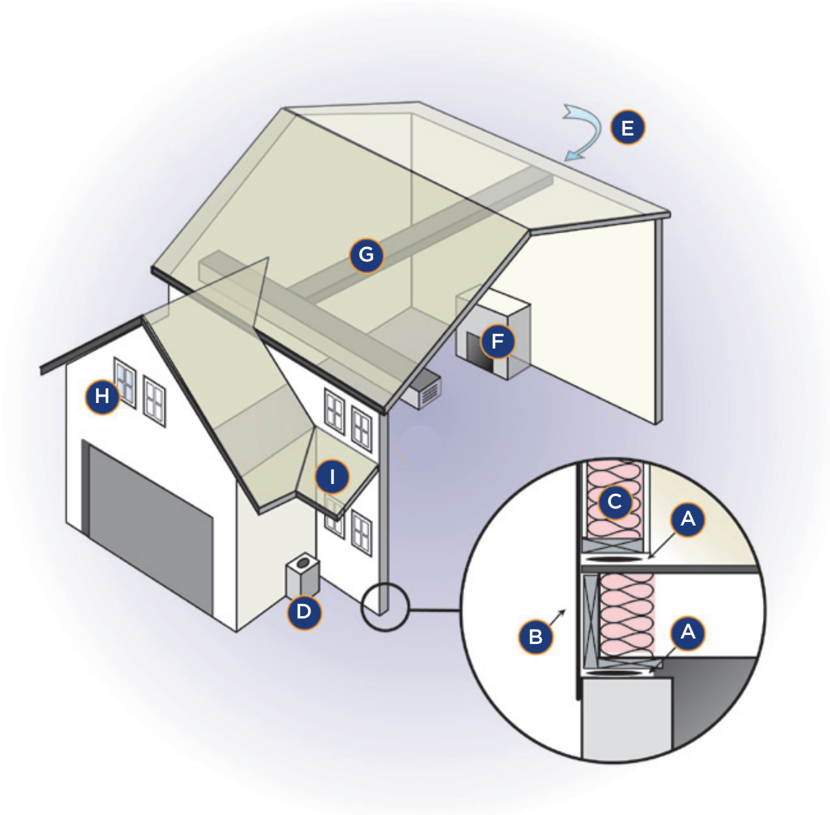
6.6 Air Flow

6.7 Heat Transfer

6.9 Occupants

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 builder callbacks while cutting energy, maintenance, and repair costs down the road.



A. **Air Sealing:** Helps maintain proper pressure balance in home and stops stack effect limiting drafts and keeping humidity, soil gases, and garage contaminants out of the house; creates a barrier to rodents and insects.

B. **Well-Designed Moisture Barriers and Drainage:** Avoids expensive structural damage and helps stop humidity, mold, and mildew.

C. **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

D. **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.

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

F. **Sealed-Combustion Appliances:** Reduce moisture buildup and ensure the safe removal of combustion gases with sealed-combustion appliances.

G. **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.

H. **Efficient Windows:** Help to reduce heating and cooling loads. Window flashing protects against water leaks.

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

New Tradition Homes' in-house building science team takes a whole-house approach, implementing complementary strategies throughout the home to improve energy efficiency, durability, air quality, and comfort for homeowners. *(Figure source: New Tradition Homes)*

Water

Homes in the marine climate are subjected to 30 to 200 inches of rain per year, most of it falling between October and June. Because of this abundance of precipitation, water management is a critical concern in the marine climate. Rain water wants to flow down and will take the path of least resistance. To minimize mold and moisture damage in homes in the marine climate, builders must become experts in moisture management techniques, learning how to guide rain water off or out of the structure and how to incorporate redundant levels of moisture protection into the home's building shell.

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. A capillary break is a non-permeable material that blocks the capillary flow of water from the ground. See Chapter 8 for more details.

One Marine Climate Builder's Whole-House Approach:

New Tradition Homes,
Vancouver, Washington

True Energy Efficiency

- ENERGY STAR windows with low-E glass
- 93% high-efficiency Goodman® gas furnace
- Rinnai® tankless water heater
- Sealed-combustion gas fireplace with electronic ignition
- ENERGY STAR fluorescent lighting packages
- Whole-house energy usage monitor
- Mastic-sealed air ducts
- ENERGY STAR rated dishwasher

Air Tight Construction

- Sealed walls dividing house and garage
- Trained and certified house weatherization team
- All wall penetrations sealed
- Tyvek® Drainwrap™ weather barrier

Healthier Indoor Air

- Fresh Air System with 4-inch high-efficiency air filter
- Air transfer vent in bedrooms
- GREENGUARD® certified EcoBatt™ insulation
- ENERGY STAR low-sone bath and laundry fans
- All low-VOC paints

Performance Tested

- ENERGY STAR third-party certification
- Duct testing
- Third-party ENERGY STAR label
- Complete system analysis
- Blower door test
- Moisture testing before drywall is hung

Environmental Responsibility

- Construction lumber waste is recycled
- Water-Conserving bath faucets
- Flyash in Concrete
- Rain Bird Rain Sensor on sprinkler system
- Native northwest landscaping
- GREENGUARD® certified laminate countertops
- Minimum 40% recycled content roofing

(top) 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)*

(middle and bottom) 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)*

Vapor

Water in its liquid state is not the only problem; water vapor can also be a source of damage. In the western United States humidity levels tend to be higher in the winter than in the summer. Field testing in the Pacific Northwest shows average interior relative humidity levels above 55% are common in the winter; whereas, in the rest of the country interior relative humidity levels are typically about 30% to 40% in the winter.

Unlike moisture in its liquid form, water vapor travels wherever air flows. Water vapor causes problems when it is trapped within a building assembly, such as a wall cavity. If it touches a cold surface it can condense, turning into its liquid form, where it can cause damage to structural components. Condensation can also form in and on ductwork, especially when air conditioning cools duct surfaces that come in contact with humid air, such as in a vented attic or crawlspace.

Air is vapor's heavy lifter. Where there are air leaks, there are vapor leaks. Water vapor also can be carried by diffusion, which can 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.

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.

Vapor retarder requirements were removed in the 2009 IECC. However, vapor retarders are addressed in the 2009 IRC R601.3, which states Class I or II vapor retarders are required on the ***interior*** side of framed walls in IECC Climate Zones 5, 6, 7, 8 and IECC Marine Climate Zone 4, except on the following: basement walls, in the below-grade portion of any wall, or in construction where moisture or frozen moisture will not damage the materials used in the assembly.

One significant change in the 2009 IRC is that Class III vapor retarders (such as latex paint) can be used instead of Class 1 or Class II vapor retarders under certain conditions, as defined in the table below.

According to the 2009 IRC R601.3, vapor retarder classes should be defined as follows (using the desiccant method with Procedure A of the American Society for Testing and Materials [ASTM] E-96):

- **CLASS I:** 0.1 perm or less
- **CLASS II:** 0.1 < perm < 1.0 perm
- **CLASS III:** 1.0 < perm < 10 perm.

According to 2009 IRC, the following vapor retarder materials would meet these class specifications:

- **CLASS I:** Sheet polyethylene, non-perforated aluminum foil
- **CLASS II:** Kraft faced fiberglass batts or low perm paint (paint with 0.1 < perm < 1.0)
- **CLASS III:** Latex or enamel paint.

Class III Vapor Retarders

Zone	Class III vapor retarders permitted for:
Marine 4	• Vented cladding over OSB • Vented cladding over plywood • Vented cladding over fiberboard • Vented cladding over gypsum • Insulated sheathing with R-value ≥ R-2.5 over 2x4 wall • Insulated sheathing with R-value ≥ R-3.75 over 2x6 wall
5	• Vented cladding over OSB • Vented cladding over plywood • Vented cladding over fiberboard • Vented cladding over gypsum • Insulated sheathing with R-value ≥ R-5 over 2x4 wall • Insulated sheathing with R-value ≥ R-7.5 over 2x6 wall
6	• Vented cladding over fiberboard • Vented cladding over gypsum • Insulated sheathing with R-value ≥ R-7.5 over 2x4 wall • Insulated sheathing with R-value ≥ R-11.25 over 2x6 wall
7 & 8	• Insulated sheathing with R-value ≥ R-10 over 2x4 wall • Insulated sheathing with R-value ≥ R-15 over 2x6 wall

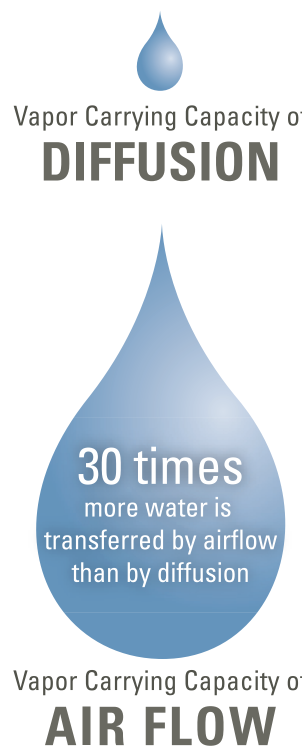
According to the 2009 IRC: "For the purposes of this section vented cladding shall include the following minimum clear air spaces. Other openings with the equivalent vent area shall be permitted."

1. Vinyl lap or horizontal aluminum siding applied over a weather-resistive barrier as specified in Table R703.4 of the *2009 International Residential Code*.
2. Brick veneer with a clear airspace as specified in Section R703.7.4.2 of the *International Residential Code*.
3. Other approved vented claddings.

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

Water Carrying Capacity of Diffusion vs. Air Flow

Air is vapor's heavy lifter—where there are air leaks, there are vapor leaks. Warmer air can carry much more vapor than cooler air.



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

Unintentional air leaks can allow leakage of significant amounts of air into and out of a home in an uncontrolled manner through unsealed seams and unplugged holes in the walls, ceiling, and floors.
(Figure source: EPA)

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.

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), temperature differences, and wind are the driving forces 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. Providing a ventilation space behind exterior wall cladding allows the material to dry out and prevents the moisture from 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.

Researchers and builders have developed methods of building unvented, conditioned attics and crawlspaces, and sealing these areas may be recommended if they are to provide conditioned space to house HVAC equipment and ducts. (See Chapter 8 for more on crawlspaces.)

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 combustion appliances can backdraft, drawing flue gases into a home rather than expelling them outdoors. Mechanical ventilation and sealed-combustion systems are described in Chapter 9.

Heat Transfer

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.

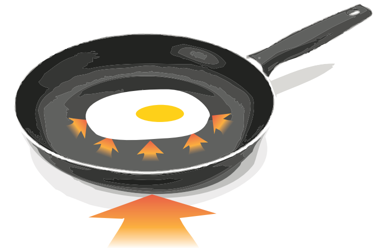
The ability of materials to resist heat flow influences conduction. Insulation is very good at resisting conducted heat flow. Dimensional lumber is not very good at resisting heat flow. The best way to slow down conduction is to add insulation to building envelope assemblies. It is important that insulation 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. Spray foam is applied as a liquid and also fills voids that may be difficult to reach with batts. Batts work well in large, uninterrupted areas if installed properly.

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. 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. However, U-values for a number of components cannot be added together to calculate the overall U-value for an assembly such as a wall.

Conduction

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



Convection

Heat transferred via air or liquid movement in a pattern of cooling/ falling and warming/ rising like hot water that rises and falls in a percolating 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.

Stack Effect

The stack effect is the flow of air that results from warm air rising, creating a positive pressure area at the top of a building and a negative pressure area at the bottom of a building. The stack effect can overpower the mechanical system and disrupt ventilation and circulation in a building. It can pool unfiltered air and soil gasses into a home through cracks in the foundation and around doors and windows and it can draw conditioned air up and out through air leaks around ceilings, chimneys, flue, and pipe chases.

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.

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.

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 windows sometimes have condensation in wintertime.

In air-conditioned structures, colder air sinks, drawing in warmer air through leaks in the building envelope. The warmer air can carry moisture; so as it cools this moisture may condense inside structural assemblies. It can also increase indoor humidity levels, causing occupants to turn up the air conditioner, which exacerbates the problem.

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, and 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.

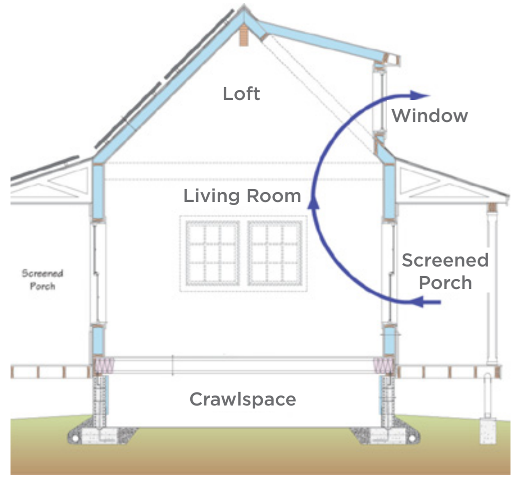
Radiation

Radiation is the movement of heat by solar or 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 in the marine climate include tree shading and window awnings or overhangs. Radiant barriers installed in the attic and light-colored roofing material are used to minimize solar heat gain in the hot dry and hot humid climates but are not recommended in the heating-dominated areas of the marine climate.

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 ways to use radiation to the night sky as a passive way to cool homes.



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.

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. However, 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, homeowner education, and accurate 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 miscellaneous plug loads will become more and more important in how energy is managed in homes.

Occupant choices in appliances and home electronics have a big impact on plug load.

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

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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. However, the building envelope is much more complex than just the visible shell. The envelope actually encompasses three boundaries: the thermal boundary, the pressure boundary, and the weather barrier.

- The thermal boundary consists of the building assemblies surrounding the space that is purposefully cooled or heated. The insulation plus the air barrier form the thermal boundary.
- The pressure boundary is the point at which inside air and outside air are separated. The line where the pressure difference across the building shell is greatest between the inside and outside of the house is the pressure boundary. This boundary is where air sealing should occur. Thermal and pressure boundaries should be aligned.
- The weather barrier includes screens to shed rain.

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.

"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

7.1 Advanced Framing

7.4 Insulation Materials

7.8 Air Sealing

7.9 The Thermal Bypass Checklist

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. Using less lumber

(left) Advanced framing details are specified in plans for the framing contractors.

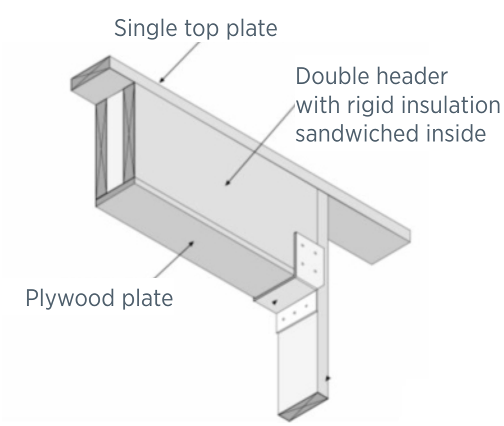
(right) Framing details include ladder blocking and two-stud corners. *(Photo source: Tommy Williams Homes)*

leaves more room for insulation 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 Partnership for Advancing Technology in Housing [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.

A sample of advanced framing techniques includes the following:

- **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 reduces waste and cuts material costs.
- **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 because some jurisdictions in high-wind areas may not allow 24-inch on-center (PATH ND).



Closed, insulated double headers are one advanced framing technique. *(Figure source: CARB)*

- **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 [2009 IRC R602.3.2]. 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.

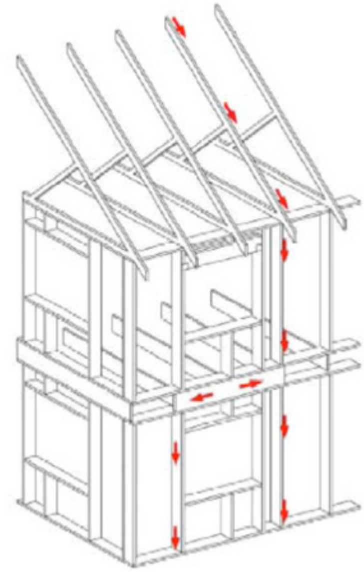
- **SIZE HEADERS FOR ACTUAL LOADING CONDITIONS.** Headers are often oversized for the structural work that they do. Doubled-up 2x6 headers end up in non-load-bearing walls. Doubled-up 2x12 headers end up in load-bearing walls, regardless of specific loading conditions. Nonbearing walls do not need structural headers [2009 IRC R602.7.2]. 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.

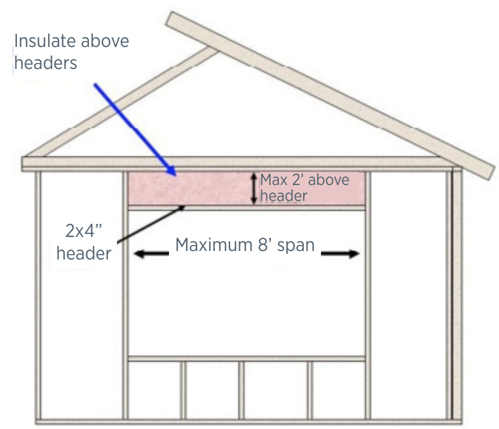
- **USE TWO-STUD CORNERS.** Exterior wall corners are typically framed with three studs. The third stud generally only provides a nailing edge for interior gypsum board and can be eliminated. Drywall clips, a 1x nailing strip, or a recycled plastic nailing strip can be used instead. Using drywall clips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

- **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.

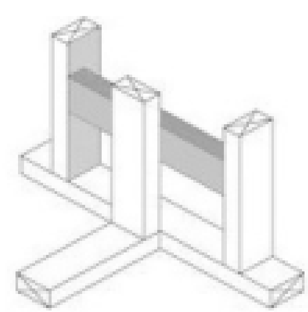
- **USE 2X3s FOR PARTITIONS.** Interior, non-load-bearing partition walls can be framed with 2x3s at 24-inch on-center or 2x4 "flat studs" at 16-inch on-center [2009 IRC R602.5].



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



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.

For More Information on Advanced Framing

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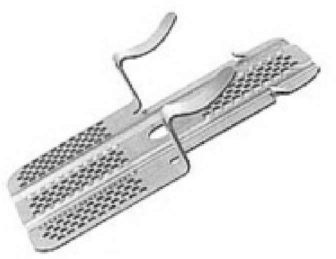

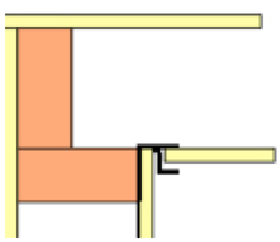

Two-stud corners with drywall clips use the least wood and give the best thermal performance.

"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

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Insulation

Insulation is usually hidden away behind finished surfaces, but insulation is the material that does the most to block heat loss through conduction. 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
Expanded Polystyrene (EPS)	• Rigid foam board	R-3 to R-4
	• Beads	R-2.3
Extruded Polystyrene (XPS)	• Rigid foam board	R-5
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 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, fiberglass, or textile fibers. 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 marine climate.

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 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. Other common areas include the band joists at the intersection of the foundation and floor and between floors.

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; water may be used as the blowing agent.

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

(top) Masonry walls are insulated with interior rigid insulation.

(bottom) 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.

"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

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 FOAM INSULATION: Rigid insulation is made from fibrous materials or plastic foams that are pressed or extruded into sheets and molded pipe coverings. Rigid insulation provides 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, so it 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 or foundation 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 or rain screen, and create additional R-value near the exterior surface of the wall. Insulation on the outside of the wall helps to temper the wall's interior temperature and avoid condensation. Here is a summary of rigid insulation materials:

- **Polyisocyanurate – 5.6 to 8.7 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 it is resistant to liquid moisture penetration. 2010 is the EPA deadline to switch to a non-ozone-depleting, VOC-free blowing agent.

- **Expanded Polystyrene (EPS) – 2.3 to 4 R-value per inch**
  Beadboard uses a non-ozone-depleting blowing agent (pentane). Spaces between beads can absorb water. It is not a vapor retarder.

It is 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; and comes in many densities and grades.

- **Fiberglass – 2.2 to 4.3 R-value per inch**
  Drainable and resistant to insect degradation; excellent for soil contact.

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. 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. These systems are applicable for sunny portions of the marine climate dominated by cooling rather than heating. The California Energy Commission allows use of radiant barriers to comply with Title 24. CEC's specific requirements are described in CEC 2005. In the Oregon and Washington portions of the marine climate where solar heat gain is less of an issue, reflective insulation is not necessary and installation of higher levels of blown fiberglass or cellulose would be a more cost-effective way to get higher R-values.

For More Information on Insulation

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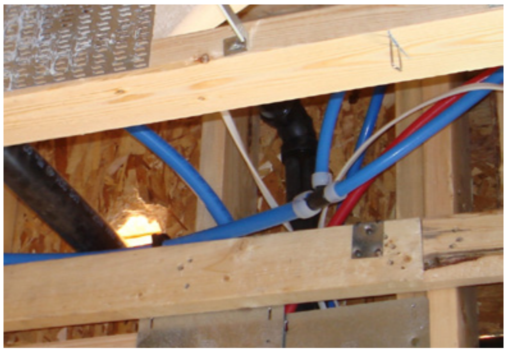
(top) Bob Ward Companies used an exterior wall sheathing consisting of a 1/8-inch layer of laminated fiber board covered with 1/8-inch of extruded polystyrene foam board. This layer goes on the exterior side of the studs under the stone or wood siding. Joints are taped so the foam board serves as an air barrier as well, eliminating the need for housewrap. This exterior insulation layer 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)*

(bottom) Radiant barriers can significantly reduce solar heat gain through the roof. They are recommended in cooling-dominated climates, including southern portions of the marine climate zone.



(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. *(Source: Linda Morrison of Loudon County Habitat for Humanity)*

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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. It is also mandated by the 2009 IECC 402.4 which identifies several areas for air sealing and requires verification with a blower door test or visual inspection.

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. Health and safety are essential factors to consider when air sealing, especially if the home contains combustion appliances.
See Building America's Air Sealing guide for more information (www.buildingamerica.gov).

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 to supply air. Air leaks also carry water vapor; if this water vapor condenses, it can cause mold and other moisture problems. An important job for air barrier systems is separating garages from conditioned spaces to keep pollutants out of the house.

The key to the control of airflow is the use of a continuous air barrier. This barrier may be made up of several types of materials as long as it provides an unbroken barrier between conditioned space (indoors) and unconditioned space (outdoors, attic, crawlspace, and garage).

Typically mudded and taped gypsum board serves as an air barrier on the home's interior. Alternatively, stucco or taped and caulked rigid foam may serve as an air barrier on the home's exterior.

Building America researchers have worked with three building approaches that push the air and thermal barriers toward the exterior of the building shell: 1) conditioning crawlspaces and basements or using slabs, 2) installing insulated exterior sheathing, with sealed seams, and 3) conditioning attics. These approaches make it easier to provide an uninterrupted air barrier (see Chapter 12).

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. Chimneys and flue chases are notorious for air and thermal leaks. A direct-vent fireplace can also eliminate the need for a chimney entirely. Ducts located in conditioned space eliminate penetrations through the building shell and avoid the intake of unconditioned air that can occur through duct leaks. More information on these systems is included in Chapter 8.

(top) Seams are caulked to provide a good air seal before installing insulation and dry wall.

(middle) Air sealing the wall between the garage and the home is vital for occupant health and safety.

(bottom) Framing is sequenced to install an air barrier of OSB, plywood, or rigid foam between the porch and the attic.

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.

"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

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

(left) Factory-built modular walls and extra attention to caulking and sealing helped Equity Residential achieve energy savings of 20% to 30% over Washington State's already tough building energy code at Ft. Lewis Army Base.

(right) Quadrant achieves airtightness rates of less than 3 air changes per hour at a pressure of 50 Pa (3 ACH@50Pa) on all of its homes, while ENERGY STAR builders in Washington State typically achieve infiltration rates of about 4.5 ACH@50 Pa, according to Dave Hales of Washington State University Energy Office, a Building America research partner. Air tightness is achieved by sealing the wall panels in the factory and additional caulking and sealing of holes and seams on site.

For More Information on Air Sealing

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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 complicated 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

8.1 Foundation Assemblies

8.12 Wall Assemblies

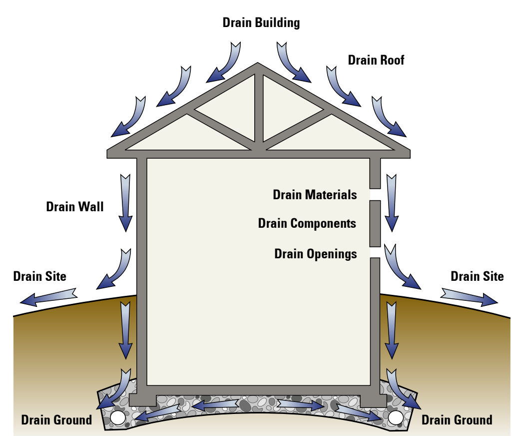
8.21 Roof Assemblies

8.24 Window and Door Assemblies

Foundation Assemblies

Slab, crawlspace, and basement foundation types are all common in the marine climate. The foundation forms the solid underpinning for a house's structural integrity. It also provides the boundary between the house and the ground, preventing the unwanted transfer of moisture, air, heat, and soil gases from the ground to occupied living spaces. It plays an important role in building durability and occupant health as well as in building energy efficiency. See Chapter 12 for detailed foundation drawings that show measures for controlling moisture, air, and heat flow.

Drain all water away from the structure



(Figure adapted from Building Science Corporation)

Controlling Liquid Water in Foundations

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. All building foundations should be designed and constructed to prevent the entry of moisture.

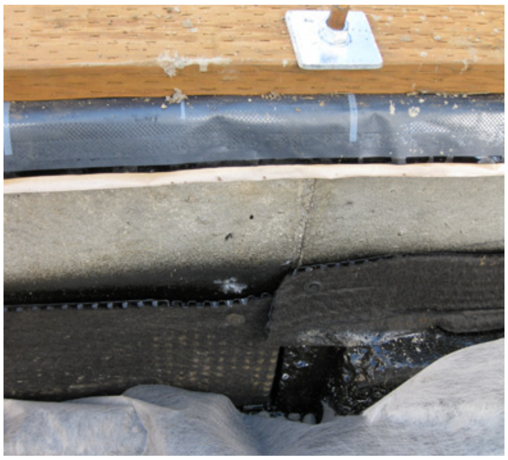
Most foundation water leakage or intrusion is due to either bulk moisture leaks or capillary action. Bulk moisture is the flow of liquid water. Capillary action occurs when water wicks or is absorbed into small cracks and pores in building materials, such as masonry block, concrete, or wood. Moisture can also be carried by soil gas into the home. Moisture may cause structural decay and can contribute to human health problems.

The following practices apply to all foundation systems.

- Design the house structure with overhangs, gutters, drainage planes, and flashing to shed rainwater and conduct it away from the house **[as required in 2009 IRC R703.1 and R703.8]**.
- Slope top soil to drain away from the house. **[2009 IRC R401.3 requires that the lot be graded to fall at least 6 inches in the first 10 feet from the foundation.]** Building America recommends 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. **[IRC 2009 R401.3 requires that impervious surfaces within 10 feet of the building foundation be sloped at least 2% away from the building.]**
- Keep all untreated wood away from contact with earth and concrete. Keep wood and fiber cement siding at least 8 inches from the soil surface to minimize damage from rain splashing up from ground surface.
- Install a protective shield such as a plastic L bracket, gasket, or water-proof membrane to keep capillary water from wicking into the wall from the foundation. Metal flashing can also serve this function and serve as a termite shield **[per 2009 IRC R318.3]**.
- Damp-proof all below-grade portions of the exterior concrete foundation walls **[2009 IRC R406]**.
- Cover exposed earth in crawlspace floors with 6-mil polyethylene sheeting. All joints of the vapor retarder shall overlap by 6 inches and be sealed or taped. The edges of the vapor retarder shall extend at least 6 inches up the stem wall and shall be attached to the stem wall. **[2009 IECC 402.2.9 and 2009 IRC 408.3 require vapor retarder over exposed earth in unvented crawlspaces only.]**

In addition to these code requirements, Building America makes the following recommendations for foundation moisture management:

- Damp-proof the exposed portion of the foundation with latex paint or other sealants.



(top) Don't leave downspouts disconnected! Extend downspouts to at least 3 feet from the house. Install flashing at the roof valleys and edges and install rain gutters to guide water off the roof and away from the house. *(Photo source: EPA, photo by Terry Brennan)*

(middle) 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 a perforated drainage pipe that runs along the outside of the footing. A gasket keeps moisture from migrating up through the footing into the treated sill plate.

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

- Apply a protective coating over rigid foam exterior foundation wall insulation at above-grade applications. Examples of protective coverings include flashing, fiber-cement board, parging, treated plywood, or EPDM membrane.

- Place a continuous drainage plane or free draining materials 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 impervious plastic mats, high-density fiberglass foam insulation boards, and uniformly graded gravel.

- Place slabs and crawlspace floors above the surrounding grade.

- Treat footings poured independent of slabs or foundation walls 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.

- Place 6-mil polyethylene sheeting or rigid foam insulation directly beneath the slab or basement floor. Wrap sheeting continuously over the slab and footings up to grade [per 2009 IRC R406.3.2].

- Do not place a sand layer between the vapor retarder and the concrete slab or basement floor. Differential drying and reduction of cracking is is better handled with a low water-to-concrete ratio and wetted burlap covering during initial curing.

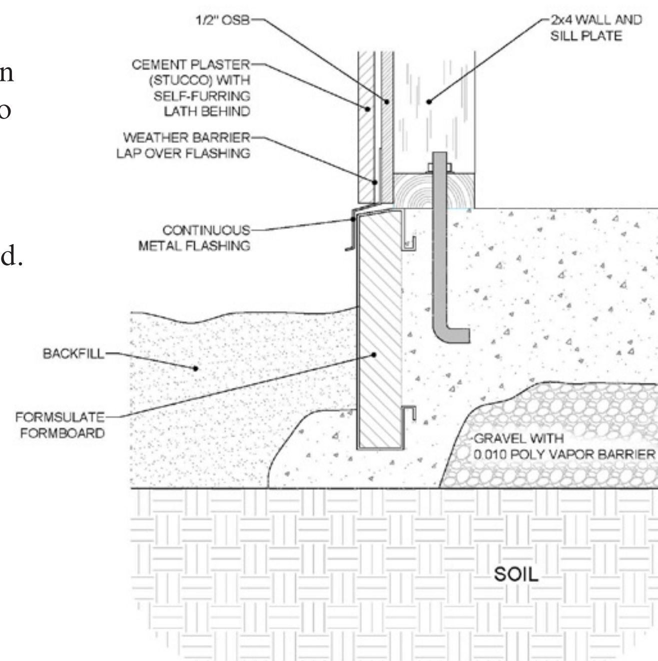
- Place a 4-inch-deep, ¾-inch gravel bed directly beneath the polyethylene sheeting to act as a capillary break and drainage pad.

- Install a perimeter drain below the drainage plane along the side (not on top of) footings for all basements and crawlspaces where the floor is below grade.

- Ensure that the lowest excavated site foundation level is above the local groundwater table at its maximum elevation [per 2009 IRC R408.6].

- Place drainage systems below basement floors.

Davis Energy Group of the CARB Building America team developed a method for insulating slab perimeters. The method, which is commercially available, uses termiticide-treated rigid foam insulation encased in PVC as the form for the concrete foundation.



Detail of insulating form for slab perimeters. *(Source: Davis Energy Group)*

Controlling Water Vapor in Foundations

In the Pacific Northwest, crawlspaces are a common foundation type, and the dominant source of crawlspace moisture is bulk water, not water vapor from indoor or outdoor air condensing in the crawlspace. Water enters the crawlspace because of improper irrigation practices, ground slope, rain runoff, high groundwater tables, rain and snow during the construction process, and leaks in plumbing (Baker and Murray 2006). These sources can be controlled by careful site grading, installation of drainage systems, proper foundation design and water-proofing measures, appropriate landscaping, and other measures listed above.

Some moisture in crawlspaces occurs from soil vapor. To control water vapor from soil in all crawlspaces, do the following:

- Install 6-mil polyethylene across the entire ground surface.
- Overlap all seams by 12 inches and tape them.
- Seal the polyethylene to the walls with pressure-treated wood strapping nailed at least 6 inches up the walls or to a height equal to ground level.

Some Building America teams recommend installing one polyethylene groundcover at the beginning of construction; then, when construction is completed, installing a second sheet to cover any rips in the first one and sealing it to the walls. To improve durability, a minimum 2-inch concrete slab can be poured over the polyethylene.

In some parts of the country, the condensation of water vapor due to temperature differences in vented crawlspaces can be a significant source of crawlspace moisture. In areas with humid summers, moisture is carried into vented crawlspaces by air drawn through the wall vents. When this warm moist air reaches cooler structural framing, the moisture can condense out and cause mold and structural problems. In humid areas with freezing winter temperatures, cold air may be drawn into vented crawlspaces where it can lower temperatures, cause condensation, and freeze exposed water pipes. In these climate conditions, which are common east of the Mississippi, unvented, conditioned crawlspaces are recommended by Building America research teams (Building Science Corporation).

In the West, summers are dry and winters north of the hot-dry climate zone are heating-dominated so relative humidity in vented crawlspaces is likely to stay low enough throughout the year to avoid moisture. In the marine climate, research regarding the value of vented versus unvented crawlspaces seems to indicate either method could be preferable depending on the specific location of the house being built (in a high radon area or not) and specific circumstances of the home (ducts in the crawlspace or not) (Nordeen 2008; Dave Hales, WSU Energy Extension Program, personal communication October 2009). See the accompanying sidebar for a discussion of the study.

Marine Climate Crawlspaces: To Vent or Not to Vent? Results from One Study

Researchers from the Washington State University (WSU) Energy Extension Program conducted an 18-month study funded by Building America to compare vented and unvented crawlspaces in the marine and cold climates. The researchers looked at four homes built in Vancouver, Washington (marine climate) and four homes built in Moses Lake, Washington (cold climate), with two vented crawlspaces and two unvented sealed crawlspaces in each location. They found that daily conditions rarely reached dewpoint in the vented crawlspaces. The conditioned crawlspaces in Vancouver were power vented with a motorized fan ducted to the outside and had passive radon stacks. The WSU study found there was an increased cost to do an unvented conditioned crawl and no energy advantage; in fact there was a slight energy penalty, which increased when supply air was provided to the space.

However, the greater concern in the WSU study was indoor air quality. The Pacific Northwest has areas with high radon levels. Radon levels were measured at Moses Lake and at Vancouver. At both sites WSU reported that radon levels were less than 2 picocuries per liter in the vented crawls but 12-16 pCi/L in the sealed crawls. The 12-16 pCi/L levels were reached while the sealed crawls were being power vented using a fan-powered radon mitigation system. Radon measurements taken inside the homes at the same time, showed that inside radon levels never exceeded 4 pCi/L. Based on these findings WSU recommended that builders using sealed crawls in the marine climate integrate the power vented crawl system with an active (fan powered) radon mitigation system, with the fan installed in the attic. (The EPA requires mitigation at 4 pCi/L or higher.)

Based on tracer gas studies, WSU found that in the typical vented crawl, approximately 40% of the house air came from the crawlspace in the winter. If the sealed crawl was power vented (50 cfm 24/7 in 1000 ft^2) less than 6% of the house air came from the crawl. By power venting the crawl it is possible to substantially reverse the winter time stack effect and decouple the house from any contaminants that may be in the crawl. A drawback is that it requires the continuous operation of an exhaust fan. If the fan fails and is not replaced, the indoor air quality (IAQ) may actually become worse because the air now entering the house does not benefit from the passive dilution that takes place in a vented crawl.

Based on these findings, vented crawlspaces are acceptable in the marine climate if rainwater management techniques can be effectively deployed; the floor above the crawlspace should be air sealed and insulated. Unvented crawlspaces are also acceptable, and there may be non-energy-related reasons for wishing to install them, including homebuyer aversion to critters in the crawlspace. While unvented crawlspaces can provide a better environment for HVAC equipment than a vented crawlspace, the best practice is to locate furnaces and ducts in conditioned space. Ducts that are located in the crawlspace must be mastic sealed. In areas with high radon levels, mitigation measures should be taken, including gravel under the slab and installation of a radon/soil gas vent stack. The crawlspace question can be avoided by designing houses with slab-on-grade foundations on a properly graded site.

New Tradition Homes of Vancouver, Washington does extensive site preparation to ensure good drainage. For homes with crawlspaces, they will raise and grade building sites so that all crawlspaces can drain to daylight. Excavators dig out the crawlspace, grade it flat, then dig out a sloped trench diagonally across the crawlspace that exits to a low-point drain sleeve with a one-way valve to let water out but not in. This drain sleeve directs the water to an infiltration system (a drywell) or out to the street via a curb cut.

Once the sloped trench is dug, 4 to 6 inches of crushed rock are laid over the entire crawlspace and foundation area. Then the concrete footing, stem, and foundation are poured on top of the rock. When the house is complete, 6-mil visquene is laid over the crawlspace ground. This can be covered with a concrete slab that is sloped to drain to the low point drain where water can exit to daylight.

"When water finds its way into the crawlspace because of our persistent rains, it has a natural channel to flow out via the low-point drain," said Steve Tapio, head of New Tradition's in-house building science team. On foundation walls, the builder adds damp-proofing, dimpled plastic drainage sheets, and a perimeter drainage pipe if there is living space below grade.

Unvented crawlspaces are allowed by Washington State code in counties that are not listed as high risk for radon by the EPA. Unvented crawlspaces are allowed by code in Oregon and California. **[They are also permitted in the 2009 IRC R408.3 as long as the exposed earth is covered with a class 1 vapor retarder that is overlapped at edges, taped, and sealed to walls; the walls are insulated, and the crawlspace is mechanically vented with an exhaust fan or supplied with conditioned air and a return duct.]**

For More Information on Foundation Moisture Control

Baker, Ken, and Chuck Murray. 2006. *Crawlspace Issues in the Northwest.* Washington State University Extension Energy Program. www.kenergy.us/pdf/Regional%20Crawlspace_final.pdf

Building Science Corporation, BSC Information Sheet 512 Crawlspace Insulation, www.buildingscience.com/documents/information-sheets/5-thermal-control/crawlspace-insulation/?searchterm=512

EPA. *Consumer's Guide to Radon Reduction*. U.S. Environmental Protection Agency www.epa.gov/radon/pubs/consguid.html

Lstiburek, Joseph. 2004. *Builders Guides*. Guides to mixed humid, hot-dry, mixed-dry, and cold climates, available 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

Lubliner, Michael, Larry Palmiter, David Hales, and Andrew Gordon. 2007. "Crawlspace Design in Marine and Cold Climates," in *Thermal Performance of the Exterior Envelopes of Buildings X, proceedings of ASHRAE THERM X*, Clearwater, FL, Dec. 2007. www.ornl.gov/sci/buildings/2010/Session%20PDFs/96_New.pdf

Nordeen, Gary. 2008. *Unvented Crawl Spaces,* WSU Extension Energy Program, www.energy.wsu.edu/pubs/

Controlling Air Infiltration in Foundations

The greatest challenges for air sealing are at the intersections of different building assemblies. **[The 2009 IECC Sec 402.4 requires air sealing of the building thermal envelope at rim joists, utility penetrations, and other areas.]** Building America recommends the following foundation air sealing techniques:

- Install a sill gasket between the concrete foundation wall and the bottom plate to control air infiltration and to serve as a capillary break.
- Seal all panel joints to stop air leakage through subfloor sheathing installed over unconditioned spaces such as vented crawlspaces, unconditioned garages, or cantilevered floors over exterior walls.
- Use spray foam to ensure a continuous seal and to serve as an insulator where exterior walls meet the subfloor at rim joists and at band joists between stories.

Controlling Heat Flow in Foundations

Insulation techniques for slab, crawlspace, and basement foundations are described below.

Slab Foundation Insulation

Slabs in the marine climate should be insulated at the perimeter with borate-treated foam board or rigid fiberglass insulation approved for below-grade use. **[The 2009 IECC Sec 402 requires a slab R-value of R-10 on the interior or exterior side of the foundation wall, plus an additional R-5 if the slab is heated in the marine climate.]** Some code officials may require a gap between exterior insulation and wood foundation elements to provide a termite inspection area. Exterior insulation should be applied from the top of the foundation wall to the bottom of the frost line. The exterior face of the insulation exposed to outside air should be covered with flashing, fiber cement board, parging (stucco type material), treated plywood, or EPDM membrane material.

A shallow, frost-protected slab foundation can be used in areas subject to seasonal ground freezing **[if the building is maintained at a minimum of 64°F per 2009 IRC R403.3]**. With this approach, foundation footings need not be placed below frost depth. However, rigid insulation, approved for below-grade use, should be placed vertically on the exterior of the grade beam and must be placed to extend away from the foundation horizontally at the base of the grade beam for a distance equivalent to frost depth. Rigid insulation is also needed vertically on the inside of the grade beam and must extend horizontally under the slab, on top of the gravel capillary break, for two feet. **[2009 IRC 403.3 requires R-5.6 of expanded or extruded polystyrene vertical insulation on the exterior side of the beam and does not require horizontal insulation in most counties in the marine climate but check with local code officials.]** Code officials may require that a structural engineer review and approve specific plans.

For more information on Slab Foundations

Houses that Work (BSC 2004), www.nrel.gov/docs/fy04osti/34585.pdf

The American Society of Civil Engineers standard (number 32-01), *Design and Construction of Frost-Protected Shallow Foundations*.

University of Minnesota, Building Foundations Research Program, *Frost Protected Shallow Foundations Design Specifications*. www.buildingfoundation.umn.edu/MHFAfrostFoundation.htm

Building Science Corporation. 2009. *Slab Edge Insulation*, Information Sheet 513, www.buildingscience.com/documents/information-sheets/5-thermal-control/slab-edge-insulation/

Code/Above Code

Insulation for Slab on Grade

A comparison of the 2009 IECC climate zone marine 4, state codes, and Building America recommendations

Code	
2009 IECC Unlimited WWR	Unheated R-10, 2 ft Heated* R-10 +5, 2 ft
WA 13%, 25%, and unlimited WWR	Unheated R-10, 2 ft Heated* R-10, underneath entire slab
OR Unlimited WWR	Unheated R-15 Heated* R-15 edge plus R-10, underneath entire slab
CA ≥20% WWR	Unheated NR Heated* R-5**
Above Code	
Building America Recommendations	Unheated R-15 Rigid foam at perimeter, exterior or interior Heated* R-15 perimeter plus R-10 underneath entire slab

** Heated slab refers to a slab floor with radiant floor heat. Location of insulation—between heated slab and foundation wall. Vertical insulation extends down from top of slab to top of horizontal insulation.*

*** California location of insulation—edge of slab either inside or outside foundation wall. If outside, extends from top of slab down 16 inches, or to frost line, or to top of footing.*

WWR = window-wall ratio

Code/Above Code

Floor Insulation for Vented Crawlspaces and Unconditioned Basements

A comparison of the 2009 IECC climate zone marine 4, state codes, and Building America recommendations

Code	
2009 IECC Unlimited WWR	R-30
WA 13%, 25%, and unlimited WWR	R-30
OR Unlimited WWR	R-30
CA ≥20% WWR	R-19
Above Code	
Building America Recommendations	Vented Crawlspace R-30 under floor deck, recommend spray foam to air seal and insulate
WWR = window-wall ratio	

Crawlspace Insulation

Two methods are in use for insulating crawlspaces. The first, in common use over the last several decades, is to insulate the underside of the building floor and locate screened vents above grade in the foundation walls to provide the unconditioned crawlspace with ventilation. With ventilated crawlspaces, it is essential to air seal and properly insulate the underside of the first floor and tightly seal and insulate any ducts located in the crawlspace. **[2009 IECC 402 requires R-30 floor insulation, or at least enough to fill the framing cavity to a minimum of R-19.]** Research has shown that vented crawlspaces can have moisture problems, especially in areas with frigid air or warm humid air. These conditions are not common in the marine climate (Building Science Corporation 2009).

Another approach **[permitted by 2009 IECC Sec 402.2.9]** is referred to as conditioned crawlspaces, or mechanically vented crawlspaces. With this type of system, foundation side walls are insulated on either the interior or exterior (or both) and no passive outside air vents tunnel through the foundation wall. **[2009 IECC 402 requires R-10 rigid foam on interior or exterior or R-13 cavity insulation on interior in the marine climate.]** Unvented, conditioned crawlspaces can provide a conditioned space for ducts and air handlers, although best practice is not to place HVAC equipment in the crawlspace.

When insulating a conditioned crawlspace, some Building America researchers recommend installing insulation on the exterior side of the foundation wall. Exterior insulation will help to protect the foundation from the freeze-thaw cycle and a warmer wall is less likely to condense moisture. Products such as borate-treated foam board or rigid fiberglass insulation work well. Extruded polystyrene (R-5 per inch) is durable and moisture resistant. Expanded polystyrene (R-4 per inch) is less expensive, but it has a lower insulating value. Rigid fiberglass insulation does not insulate as well as foam but provides a drainage plane. Some code officials may require a gap between exterior insulation and wood foundation elements to provide a termite inspection area. Insulation that is exposed above grade must be covered with a protective coating such as flashing, fiber cement board, parging (stucco type material), treated plywood, or EPDM membrane material. **[The 2009 IRC 406 requires damproofing of the foundation wall below grade.]**

If placed on the interior of a conditioned crawlspace, wall insulation must extend down the wall to a depth at least 2 feet below grade level **[2009 IECC 402.2.9]** and be rated for crawlspace and basement exposure. Polyisocyanurate rigid foam insulation with an aluminum facing is a good interior insulation choice and has an R value of

R-7.1 to R-8.7 per inch. If the crawlspace wall extends less than 2 feet below grade level, then the remaining insulation must be placed horizontally along the ground at the base of the wall.

For more information on Crawlspace Insulation:

Broniek, John. *Builder System Performance Packages Technical Report*. Prepared by IBACOS for the Building America Program. www.buildingamerica.com

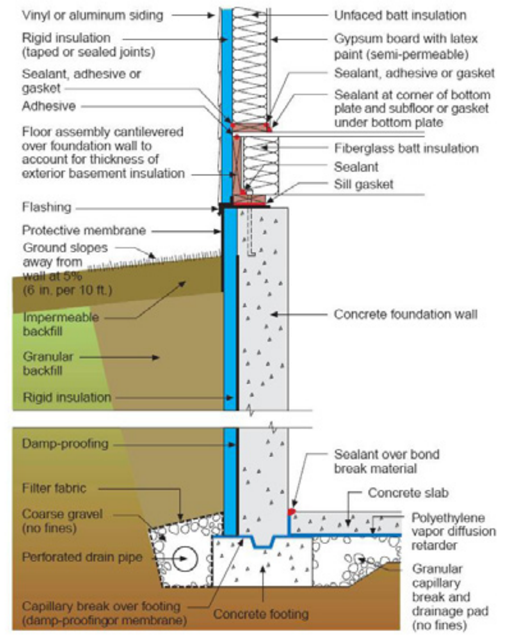
Building Energy Codes Resource Center, *Details for Mechanically Vented Crawlspaces - Code Notes*, http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article//131 (includes information on sizing the mechanical ventilation).

Building Science Corporation. 2009. Crawlspace Insulation, Information Sheets 512. Building Science Corporation, 05/14/2009, www.buildingscience.com/documents/information-sheets/5-thermal-control/crawlspace-insulation

U.S. EPA. 1995. Passive Radon Control System for New Construction, EPA 402-95-012, U.S. Environmental Protection Agency, www.epa.gov/radon/rrnc/moreinfo.html

Yost, Nathan. May 2003. "The Case for Conditioned, Unvented Crawlspaces." *Building Safety Journal*. www.buildingamerica.com

www.crawlspaces.org

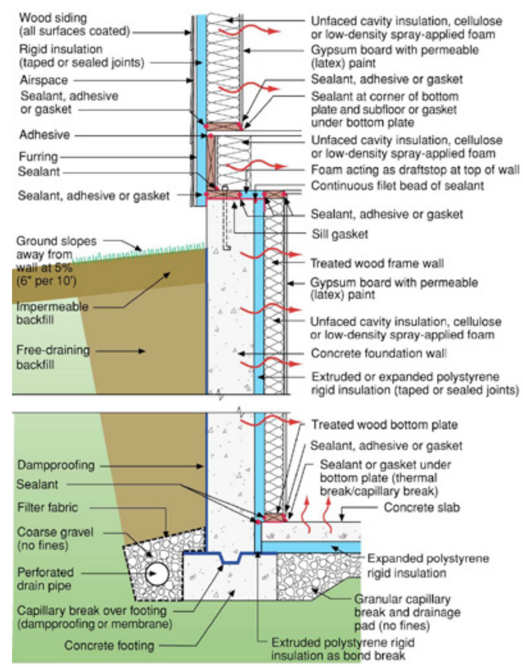


Building Science Corporation recommended this exterior basement wall insulation design. *(Source: Building Science Corporation).*

Basement Insulation

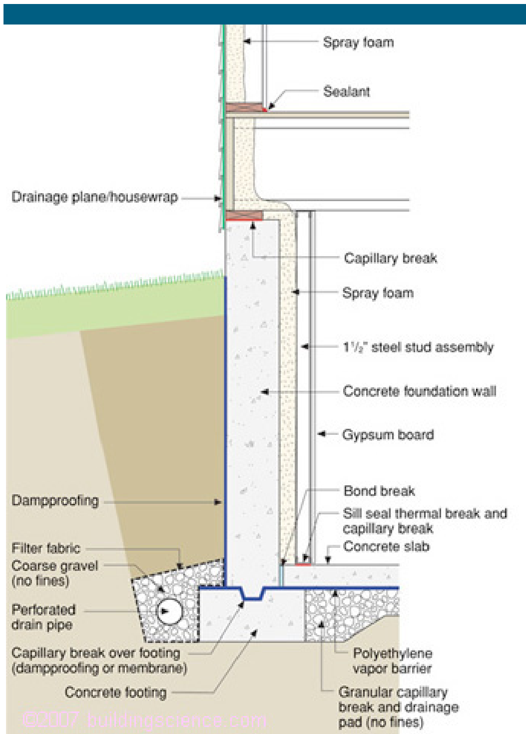
Basements are a common foundation system in the marine climate. Wall insulation in basements is similar to that described for crawlspaces. Basement floors are insulated in ways similar to slabs. **[2009 IECC 402 requires R-10 rigid foam on the interior or exterior surface of the walls or R-13 cavity insulation on interior basement walls in the marine climate. R-10 slab floor edge insulation is required extending 2 feet horizontally under the slab or out from the building.]**

Placing rigid insulation on the exterior sides of basement walls is one method for insulating the basement (Broniek 2003; Yost and Lstiburek 2002). Exterior insulation will help to protect the basement wall from freeze-thaw cycles and will help make the wall warmer, giving condensation less chance of forming and improving thermal comfort. Exterior wall insulation must be approved for below-grade use. Exterior insulation is an especially good choice in areas with high water tables or poorly draining soils.



An interior basement wall insulation plan using EPS or XPS rigid insulation and additional wall cavity insulation *(Source: Building Science Corporation).*

If interior insulation is used, the insulation should be permeable enough to allow drying to the inside. Building Science Corporation (2009) recommends using up to two inches of unfaced extruded polystyrene (R-10), four inches of unfaced expanded polystyrene (R-15), three inches of closed cell medium density spray polyurethane foam (R-18), or up to ten inches of open cell low density spray foam (R-35) on the interior walls. The foam should be installed in a manner that forms an air barrier to prevent interior conditioned air from meeting the cold concrete basement wall, where



An interior basement wall insulation plan using spray foam insulation *(Figure source: Building Science Corporation).*

Code/Above Code

Wall Insulation for Conditioned Crawlspaces and Conditioned Basements

A comparison of the 2009 IECC climate zone marine 4, state codes, and Building America recommendations

Code	
2009 IECC Unlimited WWR	Continuous R-10 Cavity R-13
WA 13%, 25%, and unlimited WWR	Interior R-21 Exterior R-10
OR Unlimited WWR	R-15
CA ≥20% WWR	R-0
Above Code	
Building America Recommendations	Exterior R21 Exterior of foundation wall insulated with rigid fiberglass or borate treated XPS Interior R21 Interior of foundation wall insulated with rigid fiberglass, rigid EPS or XPS foam, or poly-iso spray foam

** For a conditioned crawlspace, mechanical ventilation to the outside is recommended where there are high radon or soil gas concentrations.*

WWR = window-wall ratio

condensation could form. The foam should be covered with a fire/ ignition barrier such as gypsum board per local building code. If a stud frame wall is used, additional insulation can be added to fill the stud cavities. Building Science Corporation notes that regardless of the insulation type used, a capillary break should be installed on the top of the footing between the footing and the perimeter foundation wall to control "rising damp," and a second capillary break should be installed between the foundation wall and framing.

For More Information on Basement Insulation

Broniek, John. 2003. *Builder System Performance Packages Technical Report*. Prepared by IBACOS for the Building America Program. Available at www.buildingamerica.gov in the publications section.

Building Science Corporation. 2006. *Read this Before You Design, Build or Renovate*, Building Science Primer 040, www.buildingscience.com/documents/primers/plonearticlemultipage.2006-12-05.5229931729/

Building Science Corporation. 2009. Basement Insulation, Info-511, May 14, 2009, www.buildingscience.com/documents/information-sheets/5-thermal-control/basement-insulation

DOE. 2009. *Basement Insulation.* U.S. Department of Energy, Energy Savers, www.energysavers.gov/your_home/insulation_airsealing/index.cfm/mytopic=11470

Yost, Nathan, and Joseph Lstiburek. 2002. *Basement Insulation Systems.* Prepared by the Building Science Consortia for the Building America Program. www.eere.energy.gov/buildings/building_america/pdfs/db/35017.pdf

Controlling Other Foundation Issues

Radon Control

The EPA divides counties into one of three zones based on radon-level potential. The EPA radon maps below show radon potential in the marine climate states by county. The EPA recommends that all homes built in Zone 1 areas (high radon potential) have radon reduction systems. The EPA cautions that local levels may vary and recommends that all homes be tested regardless of geographic location. Other than identifying areas that have had radon problems, it is not possible to predict radon levels in houses prior to construction, so it is important to include inexpensive radon control measures.

Measures taken to control foundation moisture are also important first steps in controlling radon. A layer of gravel (4-inch minimum) under the slab provides a path for radon and other soil gas to escape to the atmosphere rather than being drawn into the house. A sealed vapor retarder helps to block soil gas entry into the house.

EPA's "Model Standards and Techniques for Control of Radon in New Residential Buildings" discusses techniques for controlling radon with various foundation types. One measure recommended by the EPA to control potentially high radon levels and other soil gases is a passive soil gas stack that vents to the roof and is connected to a horizontal perforated drain pipe embedded in the gravel under the slab, basement floor, or crawlspace ground cover. The stack may also be attached to a strip of geotextile drainage matting. This system is often installed as a precaution even when no evidence of radon has been shown, as it is far easier to install during construction than to come back later and retrofit an under-slab venting system. The pipe can act as a passive vent. If it turns out the house has unacceptable radon levels, a fan can be added to the stack to actively draw soil gas away from the house. An electrical outlet should be installed in the attic for possible future fan installation.

To determine potential radon levels in the county in which you are building, see the maps on this page, which were produced by the EPA. Visit the EPA's radon potential map at www.epa.gov/radon/zonemap.html.

[Many of these radon control recommendations can be found in the 2009 IRC Appendix F, which has recommended methods that are not required unless specifically referenced in the adopting ordinances.]

For More Information on Radon Control

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.

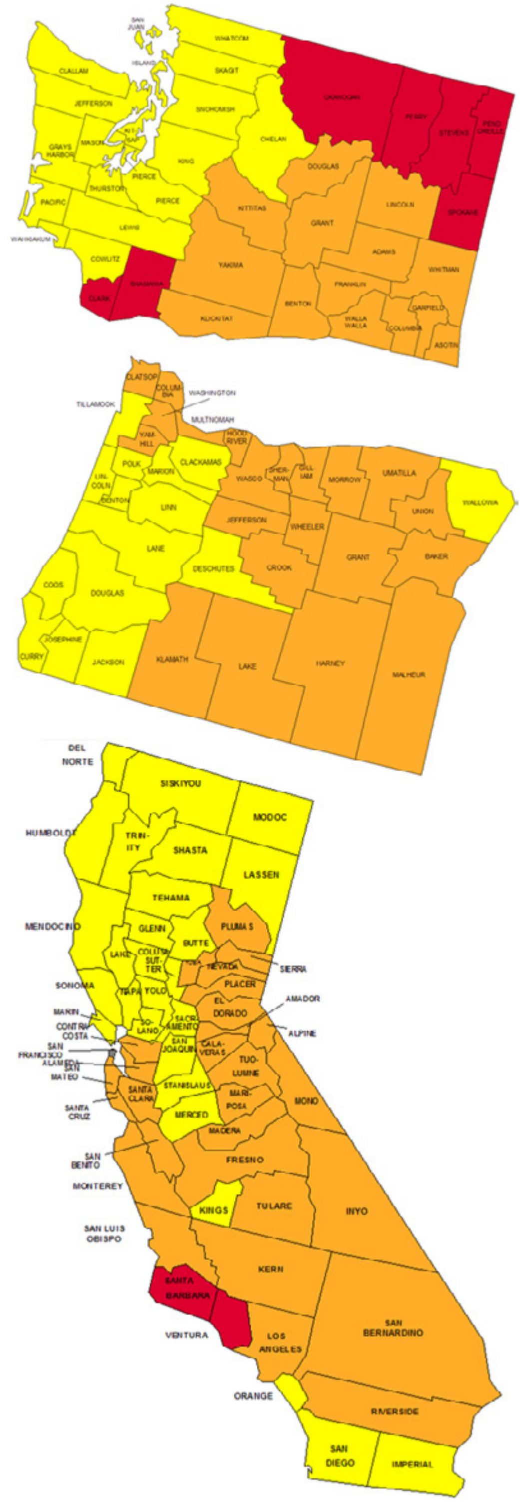
U.S. Environmental Protection Agency. 2009. *EPA Map of Radon Zones*, www.epa.gov/radon/zonemap.html

U.S. Environmental Protection Agency. 1995. Passive Radon Control System for New Construction, EPA 402-95-012, May 1995 www.epa.gov/radon/rrnc/moreinfo.html

Landscaping

Landscaping is a critical element in the marketability of a house. Plants also can be used to shade foundations and reduce cooling loads. Choosing native plants results in the need for less irrigation and less chance for irrigation water to create a moisture problem in the house.

Building America recommends plants be kept at least 18 inches from the finished structure, with any supporting irrigation directed away from the finished structure. Decorative ground cover, such as mulch or pea stone, should be no more than 2 inches deep for the first 18 inches from the finished structure to assist drainage.



(red)	**Zone 1** counties have a predicted average indoor radon screening level greater than 4 pCi/L (pico curies per liter) **(red zones)**	**Highest Potential**
(orange)	**Zone 2** counties have a predicted average indoor radon screening level between 2 and 4 pCi/L **(orange zones)**	**Moderate Potential**
(yellow)	**Zone 3** counties have a predicted average indoor radon screening level less than 2 pCi/L **(yellow zones)**	**Low Potential**

EPA Radon Zone Maps for Marine Climate States
(Source: www.epa.gov/radon/zonemap.html)

(top) Place plants at least 18 inches from the finished structure and direct irrigation away from the foundation.

(bottom) Carpenter ants are attracted to wet wood and can be very destructive. *(Photo source: Michigan State University Extension)*

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. **[The Termite Infestation Probability Map, Figure R301.2(6) in the 2009 IRC, shows Oregon and Washington to have slight to moderate probability of termite infestation while California has moderate to very heavy probability of infestation.]**

The 2009 IRC R318.1 dictates one or more of the following termite treatments:

- **Chemical termiticides; termite baiting; pressure/preservative treated wood; naturally termite resistant wood; physical barriers, and steel framing.**

In addition Building America recommends the following:

- Keep all wood (including siding, decking, and fencing that attaches to the house) from soil contact to minimize the presence of wet wood, which attracts carpenter ants.

- Use termite flashing and insulation products with termiticides or use fiberglass rigid insulation when insulating slab edge or exterior foundation walls.

Wall Assemblies

Controlling the intrusion of water and the movement of water vapor, air, and heat through the building envelope by proper design and construction of wall assemblies are major goals in the marine climate zone.

Controlling Liquid Water in Walls

Experience with buildings in most regions of North America has shown that drained and screened cladding systems are the preferred approach to reliably provide rain control. Drainage within the wall complements the shedding on the exterior surface.

Builders must assume some rainwater will penetrate the outer surface of the wall. This water is removed or drained via a drainage screen within the wall. Some examples of drainage screened walls include stud cavity walls with lap siding, brick veneer, stone veneer, or vinyl siding.

Walls in all climates should be constructed with flashing and drainage planes to direct water away from the structure and to the exterior. All drained enclosure systems must have a screen or cladding, a drainage gap (a clear air space), a drainage plane (a water-repellent plane), flashing at the base to direct water outwards, and drain holes (weep holes) to allow water out of the drainage gap. Although drained-screened walls provide excellent rain penetration control, problems can still develop at interruptions in the plane of the wall.

Care should be taken to overlap all wall layers to provide an exit pathway for all precipitation down and out of the building assembly as follows:

- Lap all materials in shingle fashion to direct water down and out, away from the wall assembly.
- Flash all wall penetrations and interruptions (windows, decks, and the termination of walls at grade).
- Incorporate extended overhangs in the design to keep water away from walls and windows and to provide shade. Sizing of overhangs for shade is described in Chapter 5.
- Install gutters.
- Back prime and back vent siding.
- Use housewrap.
- Elevate the bottom of the wall enough to prevent rain from splashing up on the siding.

For More Information on Controlling Liquid Water in Walls

Straube, John. *Rain Control in Buildings*, Building Science Digest 013: last updated 2009/08/10
www.buildingscience.com/documents/digests/bsd-013-rain-control-in-buildings?full_view=1

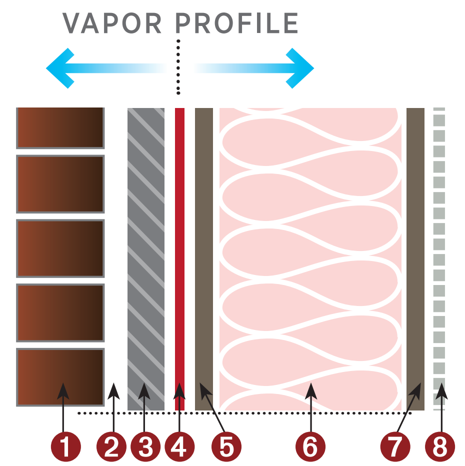
Drainage Planes

Elevation drawings should specify building paper, housewrap, or taped insulating sheathing (rigid foam insulation) behind the exterior cladding to serve as a drainage plane or water-resistive barrier **[per 2009 IRC R703.2]**. This drainage plane can sometimes also serve as the exterior air 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).

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, rigid 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 on exterior walls)

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.

Most building paper is UV-resistant, whereas housewrap UV-exposure limits vary. 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.

Installation is key for all types of housewraps. See the Installers Guide on installing housewraps in Chapter 12. During construction and operation, it is important that housewraps remain clean. Surface contaminants interfere with the wrap's ability to hold out water. 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 cementation, but cementitious cladding systems to avoid water saturation, migration, and potential warping and rot. Stucco should never be installed in direct contact with any of the plastic-based housewraps. However, two layers of building paper behind stucco are needed for minimal drainage (Lstiburek 2008).

Drainage Gaps

It is essential to provide an air gap or air space between cladding and housewraps to reduce the quantity and time liquid-phase water is trapped in the exterior of the wall assembly. A drainage gap between wood or fiber cement cladding and housewraps can be provided by 1x4 furring strips ("cedar-breather"), contoured housewrap, or some other space. Building America recommends a gap of at least $^{1}/_{6}$-inch behind lap siding and a drainage space of ¾ inch between stucco and plastic housewraps to control liquid-phase water penetration. A 1-inch air gap is needed behind brick veneer **[as required by 2009 IRC R703.7.4.2]**.

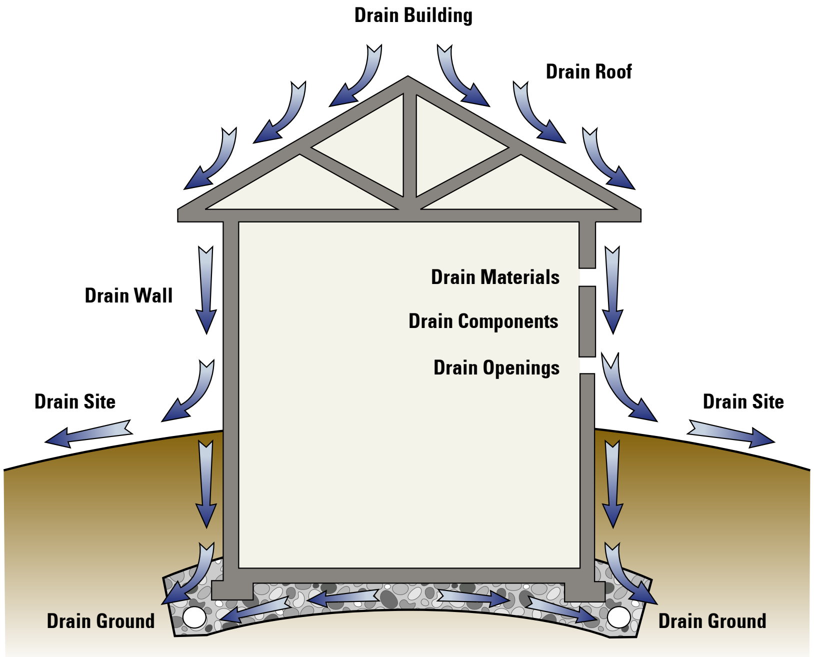
(top) This pipe is flashed with flexible flashing. Housewrap is layered shingle style over the top edge of the flashing.

(bottom) New Tradition Homes of Vancouver, Washington, flashes the bottom edge of its wall sheathing, then layers housewrap over the top edge of the flashing.

Flashing

Details should be provided for flashing for all windows and doors; wall-roof junctions; attachments (such as porches and decks); projections and offsets (such as bay windows); and pipes, vents, wiring, exterior light fixtures, and other penetrations through the wall. See Chapter 12 for instructions on installing window flashing. **[Flashing should be specified in accordance with the 2009 IRC R703.8.]** Additional guidance can be found in the EEBA Water Management Guide and DOE's *Technology Fact Sheet on Weather-Resistive Barriers* (DOE 2000), available on the Web at www.eere.energy.gov/buildings/info/documents/pdfs/28600.pdf.

Drain all water away from the structure



Controlling Water Vapor in Walls

Vapor pressure moves water vapor from indoors to outdoors during cold, dry weather and from outdoors to indoors during hot, humid weather. Movement of this vapor through walls by diffusion is undesirable when temperature differences cause this moisture to condense inside building cavities, resulting in moisture-related problems like mold. Vapor barriers and retarders will stop this vapor diffusion; however, "vapor barriers aren't necessary or even desirable in all buildings or in all climates because they can trap moisture" (Krigger and Dorsi 2009). Building assemblies should be allowed to dry to either the exterior or the interior or both (Lstiburek 2006a).

Vapor Retarders

[According to the 2009 IRC R601.3], in the marine climate Class 1 or 2 vapor retarders are required on the interior side of unvented, framed walls, except for basement walls, the below-grade portion of any wall, or construction where moisture or its freezing will not damage the materials. Examples of Class 1 vapor retarders include sheet polyethylene and unperforated aluminum foil. An example of a Class 2 vapor retarder is kraft-faced fiberglass batt insulation.

[According to the 2009 IRC R601.3], in the marine climate (in IRC language "climate zone marine 4"), Class 3 vapor retarders (e.g., latex paint) can be used instead of Class 1 or Class 2 vapor retarders when walls are designed with the following conditions:

Drainage Plane Choices (House Membrane or Rain Barrier)

None of these are waterproof but they serve to shed rain water that penetrates exterior cladding while remaining vapor permeable.

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)*

- vented cladding over OSB
- vented cladding over plywood
- vented cladding over fiberboard
- vented cladding over gypsum
- insulated sheathing with R-value > or equal to 2.5 over 2x4 wall
- insulated sheathing with R-value > or equal to 3.75 over 2x6 wall.

Class 3 vapor retarders include latex or enamel paint. Vapor retarders are further described in Chapter 6.

To avoid trapping moisture in walls, Building America recommends that Class 1 or 2 vapor retarders not be placed on the interior side of the building envelope between gypsum board and insulation; rather, Class 3 vapor retarders, such as latex paint, should be used instead. Vinyl-coated wall paper is not recommended on the walls or ceilings that form the building envelope of homes in the marine climate.

One alternative to interior vapor retarders allowed by the 2009 IRC is to install rigid foam on the exterior side of the walls. This insulated sheathing reduces the probability of condensation inside the wall. In 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. In cold weather, the exterior foam layer minimizes thermal bridging from the studs to the outside and keeps the wall cavity temperature above dew point, reducing the likelihood of condensation. If the foam is taped at the seams and caulked at the edges, it serves as an air barrier and rain screen.

Drainage Spaces

Cladding should have a drainage space behind it of 1 inch for brick and stone veneer, 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 1-inch gap [as required by 2009 IRC R703.7.4.2] allows the vapor to dissipate before entering wall cavities. An air space stops capillary movement of moisture, discourages vapor diffusion, stops the contamination of the drainage plane via contact with the cladding, and allows air circulation for better drying. In some wall assemblies, ventilation openings to the exterior at both the top and bottom further encourage drying (Murray 2005). See Straube (2009) for information about the performance of drainage spaces with different wall types.

Windows

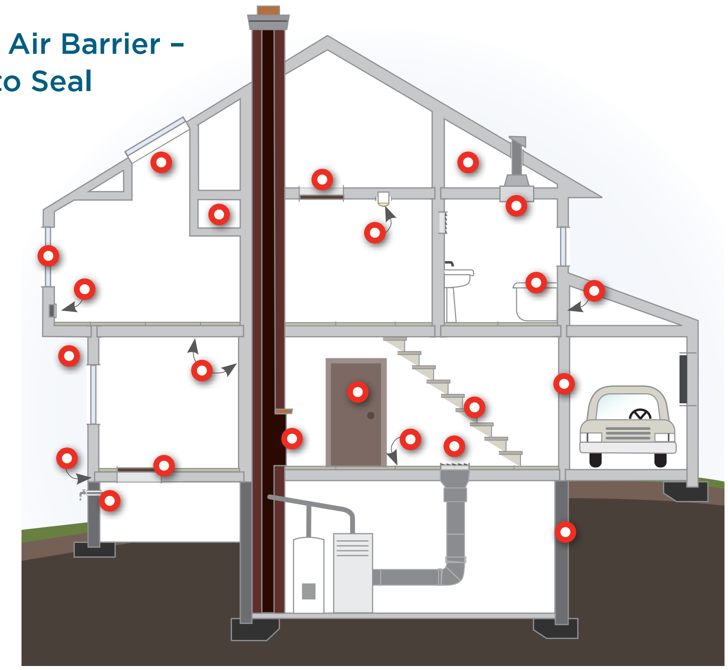
One critical point of concern is water leakage around windows. The EEBA Water Management Guide (Lstiburek 2006) offers examples of many window flashing applications. See Chapter 12 for detailed examples of window flashing for homes with housewrap and plywood or OSB sheathing. Window and door flashing 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).

Water is directed to flow into the wall, which could soon lead to water intrusion and damage.

Air Sealing

In addition to water diffusion, water vapor can be carried by air. Therefore, air sealing is an important method for preventing water vapor movement into walls. To be effective the air barrier must be continuous, meaning that it extends over the entire envelope of the structure, but the barrier may be made up of many materials. 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.

Interior Air Barrier – Points to Seal



Exterior Air Barrier with Rigid Foam Sheathing – Points to Seal

(top) When rigid foam insulation is applied to the exterior side of the wall cavity under the cladding, with seams taped and glued down, it acts as a vapor barrier, preventing moisture in brick and stucco finishes from being driven inward during drying. It also serves as an air barrier and rain screen, and during the heating season, it maintains the temperature of the wall cavity above dew point, to prevent condensation.

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

(see house figures at left) Air sealing is needed throughout the house to ensure an airtight shell. The house on top uses conventional approaches. The house on the bottom 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 12.)

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

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

Controlling Air Infiltration in Wall Assemblies

[The 2009 IECC Sec 402.4 requires that the building thermal envelope be durably sealed to limit infiltration and specifies that the following areas should be caulked, gasketed, weather-stripped or otherwise air sealed: all joints, seams, and penetrations; site-built windows, doors, and skylights; window and door openings; utility penetrations; dropped ceilings or chases on exterior walls; knee walls; walls and ceilings separating a garage from the conditioned space; behind tubs and showers on exterior walls; common walls between dwelling units; attic access openings; rim joist junction; and other sources of infiltration. Air leakage is to be tested with a blower door or visual inspection.]

A comprehensive air sealing strategy begins with indicating on the house plans the location of the conditioned space by outlining the building envelope. The plans should 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. The plans also should show were insulation and draft-stopping should be installed.

If the air barrier will be on the interior side of the envelope, it is important to specify that all drywall joints be caulked, mudded, and taped. To ensure an airtight envelope when the air barrier is on the inside of the building envelope, builders should address the following common sources of air leakage through walls:

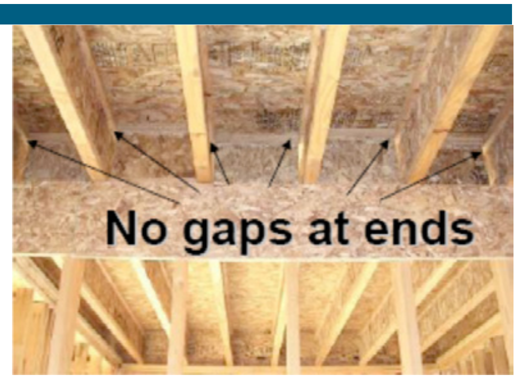
- Insulate and air seal behind tubs and shower stalls on the exterior walls by filling the wall cavity with insulation, and then installing and sealing rigid sheathing material on the interior surfaces of the wall before the tub or shower is installed.
- Line fireplace enclosure framing with rigid sheathing material, like gypsum board, plywood, wafer board, or foil-covered pressed paper, and seal edges to box in sides, top, and bottom of fireplace enclosure. Wood burning fireplaces should have gasketed doors and outdoor combustion air **[per 2009 IECC 402.4.3]**.
- Air seal chimney chases and around the chimney flue where it penetrates the ceiling using sheetmetal and heat-resistant caulk.
- Box in tops and ends of soffits and dropped ceilings with sheathing that is caulked to framing on all edges.
- Fill in the rough opening around windows and doors with foam, caulk, or backer rod.
- Apply housewrap and flashing as shown in Chapter 12.
- Caulk, foam, or seal with gaskets all penetrations for electrical boxes, outlets, switches, and plumbing.

Cladding should have a drainage space behind it of

- 1 inch for brick,
- 3/4 inch for stucco, and
- 1/16 inch for siding.

Alternatively, the air barrier can be placed on the outside of the building envelope. One method for doing this is to install rigid foam on the exterior side of the wall under the cladding. This foam sheathing can provide a continuous air barrier when all seams are taped and caulked. This exterior air-barrier system can also help control wind washing.

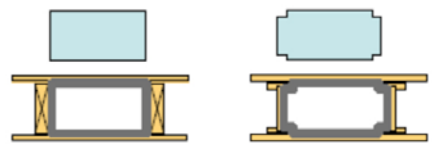
For occupant health and safety, builders should pay close attention to sealing shared walls and ceilings between attached garages and living spaces. When the garage is attached to the house, the gaps created by joists spanning both conditioned space and the garage must be blocked off and sealed. Creating air barriers to close gaps between the garage and the conditioned space is more difficult with irregularly shaped joists, such as I-joists and web-trusses. A simple solution is to plan ahead and align the ends of the joists with the wall adjoining the conditioned space to allow for end blocking.



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")*

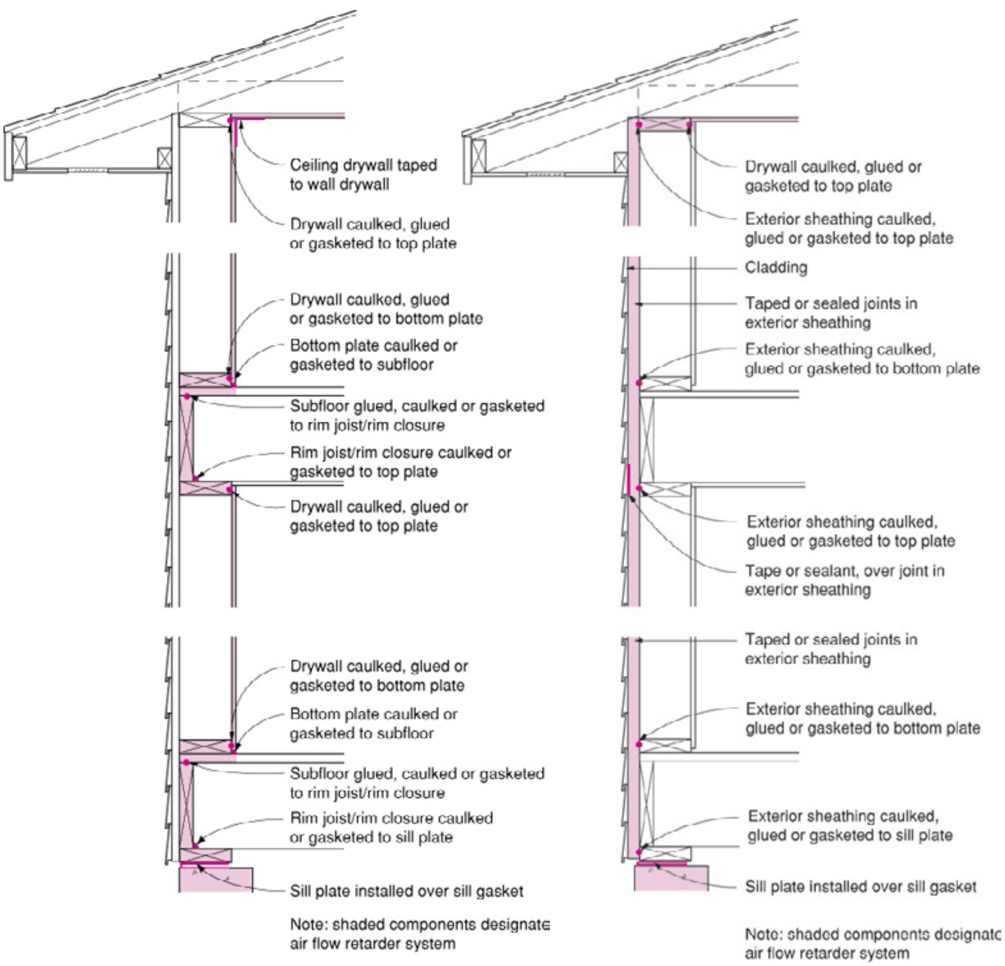
Filler blocking is a simpler shape with dimensional lumber

Filler blocking is a harder shape to cut with engineered lumber



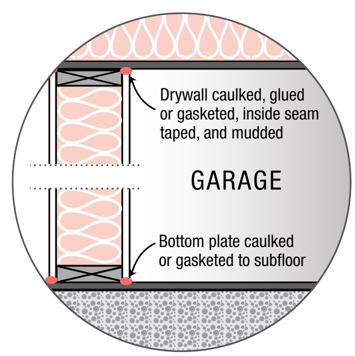
Wood or rigid foam filler blocking is needed to close off the gaps between floor joists to form an air break between conditioned and unconditioned spaces.

Envelope Air Sealing

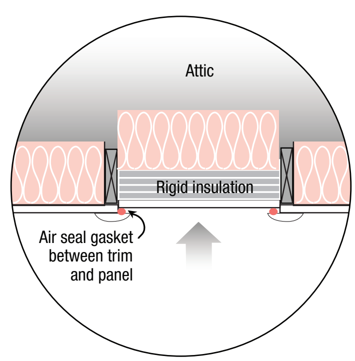


(Figure source: Building Science Corporation)

Garage common wall air sealing



Attic access panel air sealing



Code/Above Code

Wall Insulation Above Grade

A comparison of the 2009 IECC climate zone marine 4, state codes, and Building America recommendations

Code	
2009 IECC Unlimited WWR	R-20 or R-13+5*
WA 13%, 25%, and unlimited WWR	R-21 intermediate framing**
OR Unlimited WWR	R-21
CA ≥20% WWR Climate Zones 1-5	CA CZ 1 = R-21 CA CZ 1-5 = R-13
Above Code	
Building America Recommendations	R-21 fiberglass batt + 1"-2"rigid foam** R-19 blown fiberglass or blown cellulose + 1" to 2" rigid foam

** R-13 cavity insulation + R-5 rigid foam sheathing*

*** Insulate the headers with R-10 (2 inches) of rigid foam board*

WWR = window-wall ratio

CZ = climate zone

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. **[The 2009 IECC 402 requires a wall R value of R-20 for wood-frame walls (or R-13 cavity plus R-5 insulated sheathing). For mass walls (concrete block, concrete, ICF, brick, etc.), the requirement is R-13 for exterior insulation or R-17 if more than half the insulation is on the interior in the marine climate.]** Consider implementing the following above-code recommendations:

- Use advanced framing techniques to cut lumber costs and provide more space for insulation. Provide advanced framing details on plans.
- Specify that cavity walls separating conditioned and unconditioned spaces be insulated with high-density batt insulation, dense-packed fibrous insulation, or spray-applied foam.
- 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 eliminates thermal bridging at the studs.
- Use third-party inspectors or HERS raters to inspect insulation installation before dry walling.
- Specify energy-efficient windows that control solar energy gains and help reduce heating and cooling loads. Maximum U-values of 0.3 or lower are recommended **[2009 IECC Table 402.1.3 requires ≤ 0.35 U-value]**.
- 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, and away from the house. Consider implementing the following recommendations:

- Properly flash valleys and roof edges.
- Size gutters and downspouts to accommodate anticipated storms. Show gutter sizes on elevations and specify sizes in construction documents.
- Provide downspout 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.
- Keep roof geometry simple. The more complex the roof—the more dormers, ridges, and valleys—the more likely the roof will leak.

(top & middle) New Tradition Homes of Vancouver, Washington, uses a basic roof shape in the back of its houses and adds design interest with architectural details in the front to keep roofs simpler and therefore easier to flash and waterproof.

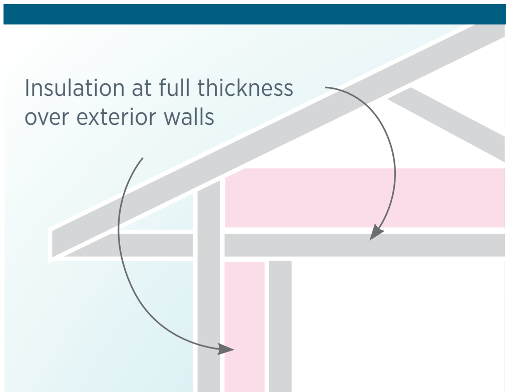
(bottom) Kick-out flashing should be installed to divert water runoff into gutters rather than flowing down the wall.

Controlling Water Vapor in Roof Assemblies

Vapor diffusion should be considered as a secondary moisture transport mechanism when designing and building roofs. Specific vapor retarders are often unnecessary if appropriate air movement control is provided or if control of condensing surface temperatures is provided (Lstiburek 2004b).

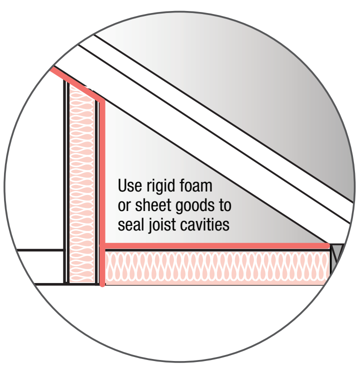
Controlling Air Flow in Roof/Attic Assemblies

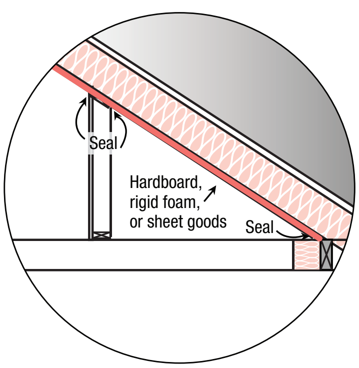
Air sealing of the ceiling uses techniques similar to those used for the walls, although roof air sealing may be made more challenging by irregularities in the roof shape. **[The 2009 IECC 402.4 requires that the building thermal envelope be air sealed, including all joints, seams, and penetrations; dropped ceilings; knee walls; walls and ceilings separating a garage from conditioned space; attic access openings; rim joist junctions; and other sources of infiltration.]**



(top) 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.

(bottom) Martha Rose Construction, a Building America partner in Seattle, used rigid foam insulation in this attic.





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

Air sealing details to consider include:

- Provide details on plans for air sealing, especially of complex structures like kneewalls, gable windows, porch-attic interfaces, and cathedral ceilings.
- Seal all penetrations and seams in ceiling gypsum board so that it functions as a continuous air barrier.
- Draft-stop soffits with rigid air barrier caulked at seams.
- Gasket or weather strip attic access hatches or doors and insulate to ceiling insulation depth **[as required by 2009 IECC 402.2.3]**.
- Install recessed lighting fixtures that are airtight and caulk or gasket the housing to the ceiling drywall **[per 2009 IECC 402.4.5]**.
- Provide a weather-stripped cover for whole house fans.
- Ensure that skylights have a labeled infiltration rate of no more than 0.3 cfm/ft^2 **[per 2009 IECC 402.4.4].**

Controlling Heat Flow in Roof Assemblies

Maintaining the 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. Raised heel energy trusses allow the thickness of the ceiling insulation to be maintained above the top plates of the exterior wall framing. Baffles should be installed at each rafter bay to prevent wind washing of thermal insulation and to prevent insulation from blocking ventilation in vented roof assemblies. **[The 2009 IECC Sec 402.1 requires a ceiling R value of R-38 in the marine climate, and a minimum of R-30 in cathedral ceilings. If raised heel trusses are used allowing full height of insulation over the wall top plate, then R-30 is permitted instead of R-38 (Sec 402.2.2).]**

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

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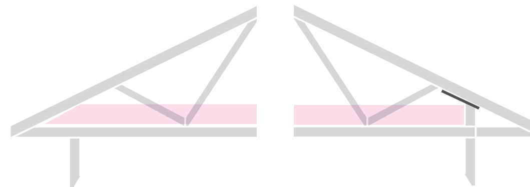
Baffles allow ventilation under roof decking while keeping wind from blowing insulation back from the edges of an attic.



(left) Traditional roof trusses pinch insulation where the roof meets the walls

(right) Raised heel trusses allow space for the full depth of insulation. Dark line is a baffle, which allows ventilation of roof while keeping wind from blowing back insulation.

Code/Above Code **Ceiling Insulation**

A comparison of the 2009 IECC climate zone marine 4, state codes, and Building America recommendations

Code	
2009 IECC Unlimited WWR	R-38
WA 13%, 25%, and unlimited WWR	R-49 or R-38 advanced framing
OR Unlimited WWR	R-38
CA ≥20% WWR Climate Zones 1-5	CZ1 – R-38 CZ2-5 – R-30
Above Code	
Building America Recommendations	R-49 blown fiberglass or blown cellulose** R-49 Spray foam on ceiling deck R-49 Spray foam along underside of roof deck* R-49 Rigid foam exterior insulation on top of roof sheathing*

** Forms cathedralized conditioned attic for HVAC & ducts, and conditioned storage space.*
*** Level recommended by NWPCC 2010.*

WWR = window-wall ratio
CZ = climate zone

Vancouver, Washington, builder New Tradition homes installed ENERGY STAR doors and windows on its homes to increase energy savings.

Window and Door Assemblies

Windows are a prominent feature of any wall. Choosing highly efficient windows will add expense to your project but will increase comfort, durability, and energy savings. The National Fenestration Rating Council (www.nfrc.org) provides window labeling that includes the following performance information:

- U-factor measures 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.
- Solar heat gain coefficient (SHGC) 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 (AL rating) is expressed as the equivalent cubic feet of air passing through a square foot of window area (cfm/ft^2)—the lower the AL, the less the window leaks. A typical rating is 0.2. **[Per the 2009 IECC 402.4.4, windows, skylights, and sliding glass doors should have an air infiltration rate of ≤ 0.3 cfm/ft^2 and swinging doors of ≤ 0.5 cfm/ft^2.]**

[2009 IECC 402 requires a maximum U-factor of 0.35 with no SHGC requirement specified for the marine climate.] ENERGY STAR qualifies windows based on climate zones and divides the United States into four climate zones. See the charts and map for U-factor and SHGC guidelines for marine climate states.

The DOE-sponsored Efficient Windows Collaborative operates a website that can help designers and consumers choose windows (www.efficientwindows.org/index.cfm). The website includes a tool that allows users to analyze energy costs and savings for windows with different ratings. The website also has fact sheets with comparisons for each state.

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

ENERGY STAR Qualified Windows, Doors and Skylights Eligibility Criteria

(Version 5.0, 04/07/2009, effective 01/04/2010)

Windows

Climate Zone	U-Factor[1]	SHGC[2]	
Northern	≤ 0.30	Any	Prescriptive
	=0.31	≥ 0.35	Equivalent Energy Performance
	=0.32	≥ 0.40	
North-Central	≤ 0.32	≤ 0.40	
South-Central	≤ 0.35	≤ 0.30	
Southern	≤ 0.60	≤ 0.27	

[1] Btu/h.ft^2.°F

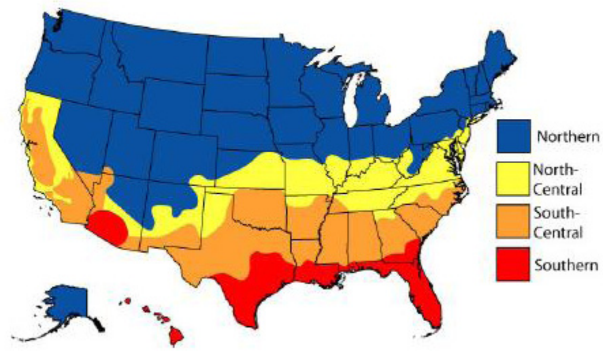
[2] Fraction of incident solar radiation

Doors

Glazing Level	U-Factor[1]	SHGC[2]
Opaque	≤ 0.21	No Rating
≤ ½-Lite	≤ 0.27	≤ 0.30
> ½-Lite	≤ 0.32	≤ 0.30

Skylights

Climate Zone	U-Factor[1]	SHGC[2]
Northern	≤ 0.55	Any
North-Central	≤ 0.55	≤ 0.40
South-Central	≤ 0.57	≤ 0.30
Southern	≤ 0.70	≤ 0.30



For More Information on Windows and Doors

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

National Fenestration Rating Council.
www.nfrc.org

Code/Above Code

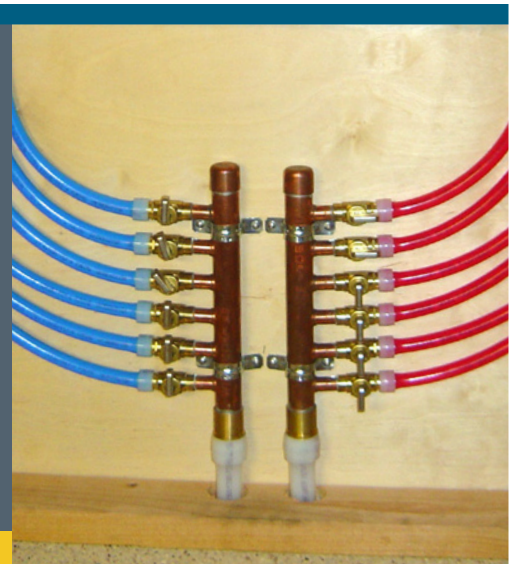
Window U Factor and Solar Heat Gain Coefficient

A comparison of the 2009 IECC climate zone marine 4, state codes, and Building America recommendations

Code	U Factor	SHGC
2009 IECC Unlimited WWR	0.35	NR
WA 13%, 25%, and unlimited WWR	>13% 0.34 >25% 0.32 Unlimited 0.30	NR
OR Unlimited WWR	0.35	NR
CA ≥20% WWR	0.40	≤ 0.40
Above Code		
Building America Recommendations	≤ 0.30 Double glazing	≥ 0.35

WWR = window-wall ratio
NR - No Requirement
SHGC - solar heat gain coefficient

Chapter 9.
Mechanical, Plumbing, and Electrical Systems



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

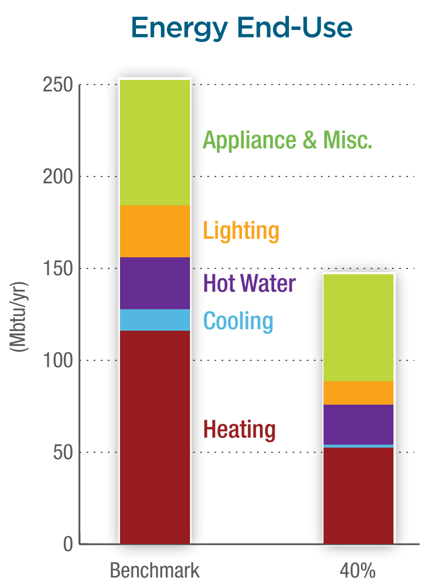
A home's mechanical systems can have a significant impact on its energy performance and comfort. As envelope performance improves, these systems are becoming more important targets for improved efficiency. The charts below show typical energy usage for the equipment described in this chapter, including HVAC (heating, ventilation, and air conditioning), plumbing and water heating, lighting, and appliances. Although placed at the end of this chapter, commissioning and safety are essential aspects of building performance.

CHAPTER TOPICS

9.1 Heating, Ventilation and Air Conditioning (HVAC)
9.14 Plumbing and Water Heating
9.19 High-Performance Lighting
9.21 Appliances
9.22 Commissioning
9.25 Occupant Health and Safety

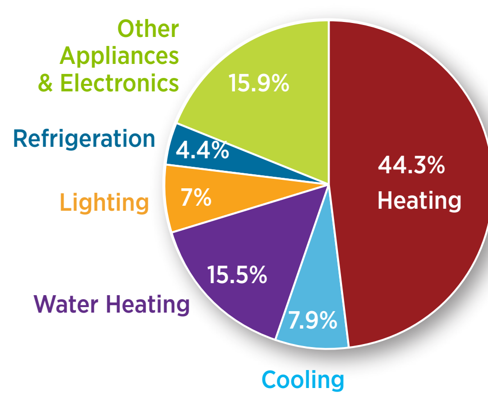
Heating, Ventilation and Air Conditioning (HVAC)

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 the HVAC system increases comfort while providing a remarkable opportunity for dollar savings in high-performance homes.



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 Marine Climate. *Example based on a 2-story, 1,884 ft² house in Portland, OR. Analysis by BIRA.*

2005 Typical Residential Onsite 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.)*

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 airconditioner 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.

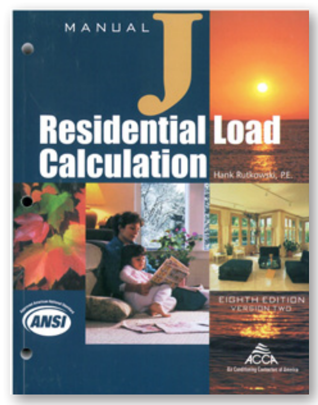
Use MERV 8 air filters in the air handler for cleaner indoor air.

For the best results in comfort, efficiency, and durability, HVAC and duct design must be integrated in the overall architectural design. Builders should work closely with their HVAC engineer to properly size and select the HVAC equipment, design and install ducts, and provide appropriate ventilation. **[The 2009 IECC 403.1 requires that the forced air furnaces come with a programmable thermostat and the heat pumps with electric resistance backup heat should be equipped with controls that prevent the supplemental heater from coming on when the heat pump compressor can meet the load.]** These steps will go a long way toward improved energy efficiency, comfort, and cost savings.

Heating and Cooling Equipment

A well-designed house should have an HVAC system properly sized to its demands. The Air Conditioning Contractors of America (ACCA) has published simple but effective methods for determining loads and sizing of ductwork and heating and cooling equipment (available for purchase at www.acca.org).

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



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

[The 2009 IECC 403.6 mandates that heating and cooling equipment be sized in accordance with the 2009 IRC M1401.3, which cites ACCA Manuals S and J for equipment sizing and load calculations. Equipment serving multiple dwelling units should comply with 2009 IECC Sec 503 and 504 for commercial buildings, rather than 403 for residential buildings.]

For central gas-fired heating systems, sealed-combustion gas furnaces should be installed. Sealed-combustion furnaces draw combustion air directly from outdoors rather than from the surrounding space, eliminating the potential for backdrafting. Declining costs make high-efficiency furnaces an increasingly good value. Look for ENERGY STAR-qualified furnaces, heat pumps, and air conditioners.

Heat pumps are preferable to electric resistance heating in the marine climate. A unit with an HSPF of 7.7 or more will reduce the electric consumption during heating by more than 50% relative to electric resistance heating. In colder areas where temperatures often fall below 30˚F, typical air source heat pumps require an electric resistance backup system to properly heat a home. This can be a costly method of supplemental heating; a backup gas or propane furnace may be a cost-effective alternative.

One technology showing promise is a mini-split ductless heat pump, which uses a single compressor/condenser outside connected to one or more indoor air handler units that provide energy-efficient zone heating and cooling with no ducts to install. Another promising technology is the all-climate heat pump, which according to the manufacturer, can maintain comfortable indoor temperatures without supplemental heat even when the temperature outdoors falls below zero.

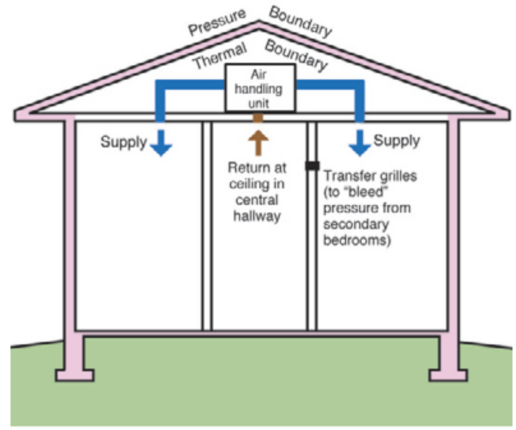
Geothermal or ground-source heat pumps can be very efficient for heating and cooling because they use the constant temperature of the earth as the exchange medium instead of the outside air temperature. This allows the system to reach fairly high efficiencies (300%-600%) on the coldest of winter nights, compared to 175%-250% for air-source heat pumps on cool days. The disadvantages are their initial cost and the need for yard space to install the piping. For more information on various HVAC technologies, see www.energysavers.gov.

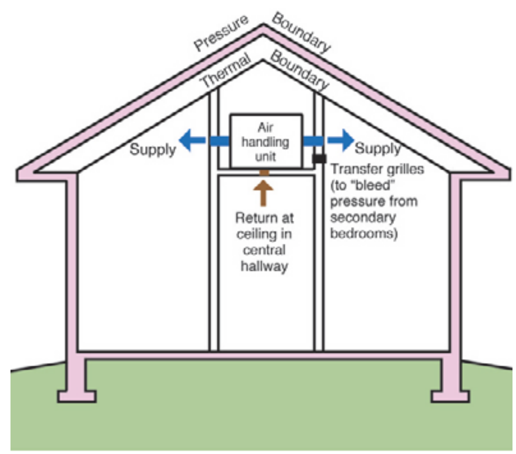
Radiant flooring is another option that can be energy saving depending on the source of energy used, for example, hydronic radiant floor heating using solar-heated fluid; this would require a thick concrete thermal storage floor to hold heat from the day to release at night when the sun is not heating the water.

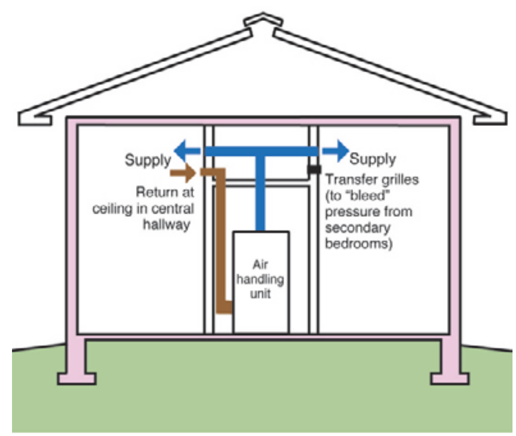
For home cooling in the marine climate, heat pumps are preferable to standard air conditioning. For either system, it is important to verify that the refrigerant level is correct at installation. The EPA reports that 75% of installed air conditioners had the wrong amount of refrigerant when tested. Incorrect refrigerant levels can lower efficiency by 5% to 20% and can cause premature component failure, resulting in costly repairs (see EPA Heating and Cooling Refrigerant Charging guidelines www.epa.gov). Building America recommends a MERV 8 or higher filter on the HVAC return. MERV (Minimum Efficiency Reporting Value) is a measure of an air filter's efficiency at removing particles. **[This exceeds the ASHRAE 62.2-2010 6.7 recommended MERV 6 or better.]**

Duct Run Configurations

Here are three example designs for putting ducts in conditioned space.







(Source: Building Science Corporation)

Space-conditioning systems should meet the ACCA Quality Installation Specification

For More Information on 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

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). 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

Cowan, Laura. “How Heat Pumps Work.” 13 May 2009. HowStuffWorks.com. http://home.howstuffworks.com/home-improvement/heating-and-cooling/heat-pump.htm 08 November 2009.

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

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

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

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

EPA. Heating and Cooling: Sizing and Installation – Proper Refrigerant Charging, U.S. Environmental Protection Agency. www.energystar.gov/index.cfm?c=heat_cool.pr_properly_sized

U.S. Department of Energy. Energy Savers – Heating Systems, DOE, www.energysavers.gov

Ducts and Air Handlers

Duct System Design and Layout

In the Pacific Northwest, standard practice is to locate the furnace in the garage, supply ducts in the crawlspace, and return ducts in the attic. As typically installed, this "default" design is assumed in codes to reduce system efficiency by about 20%; whereas placing ducts in conditioned space is assumed to cut air loss to about 4% (ICC 2006 as reported in Lubliner et al. 2008). Moving ducts inside has been estimated to save a homeowner 795 to 1902 kWh per year in Portland and Seattle (Regional Technical Forum 2006).

As the data confirm, 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. Ducts may be run through open-web floor trusses in a two-story home; through a dropped hallway ceiling in a one-story home; or through a conditioned attic, conditioned crawlspace, or conditioned basement. Ducts should not be located in exterior walls. Air handlers should be located in conditioned space, such as a closet inside the home, in a conditioned attic or basement, or in an air sealed and conditioned closet in the garage.

In all cases, duct systems should be designed using *ACCA Manual D* **[2009 IRC M1601.1]**; duct runs should be as short as possible, and duct sizes and layouts should be shown on plans. Building cavities should not be used as supply ducts **[2009 IECC 403.2.3]** or return ducts.

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.

Calculated Savings for Moving Ducts Inside

Climate	ENERGY STAR with HP (kWh/year)	WA state code with HP (kWh/year)
Portland	795	1,874
Seattle	811	1,902

Both cases assume an 8.5 HSPF heat pump; the ENERGY STAR case assumes commissioning for charge, flow and controls.

HP = heat pump

Source: Regional Technical Forum (2006)

Marine climate builders Schneider and Quadrant run ducts through open-web floor trusses to keep the ducts in conditioned space (shown here). Open-web trusses allow subcontractors the flexibility to run plumbing, electrical, and ductwork easily between floors, with little to no "trade damage" or "trade fighting." Air handlers are located in conditioned space in the home or in an air-sealed closet in the garage.

"We have over 300 plans in our portfolio and we were able to move ducts inside on nearly all of them."

Quinn Wyatt, Assistant Design Manager, Quadrant Homes

(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.

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

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

The Seattle-area production builder Quadrant Homes worked with Bob's Heating in Kirkland, Washington, to design systems that brought the furnace and ducts into conditioned space. "It is easier for installers to do a quality job in the home when they are not lying in mud, deep in a corner of the crawlspace," said Wade Craig of Bob's Heating. When ducts are installed between floors, they are clearly visible to the general contractor and inspector, encouraging better installations. Another major concern is "trade damage" when electrical or plumbing subcontractors compromise ducts to squeeze their wires and pipes into the same space. With open-web trusses there is enough room for all trades, making each subcontractor's work easier.

Craig said his firm can lower its bid when the HVAC system is moved inside. Additionally, Craig points out that moving the furnace from the attic to a mechanical closet on the second floor facilitates easier equipment servicing and increases worker safety for installation and retrofit. Quadrant is aware of the potential for air leakage pathways between floors and the need to reduce those pathways via proper insulation and sealing of the rim joists. All ducts in Quadrant homes are well sealed with mastic and tested with a Duct Blaster™ (Lubliner et al. 2008).

If ducts are not in conditioned space, one alternative is to locate the ducts on the ceiling deck of an unconditioned attic and "bury" the ducts with blown-in insulation. Burying ducts is accepted as part of California's Title 24 building code. In more humid climates this strategy is not recommended because condensation could occur at the duct exterior surface.

Locating air handlers and return ducts in the garage is not recommended because of the potential for drawing carbon monoxide and hazardous fumes into the home. If the air handler must be located in the garage, it should be enclosed in an insulated, air-sealed closet. Ducts located in the garage may not have any openings in the garage [2009 IRC R302.5.2] and furnaces and air handlers that supply air to living spaces shall not supply air to or return air from a garage [2009 IRC M1601.6]. The air handler and any return-air ductwork should be thoroughly sealed with UL 181-BM-compliant mastic, with a target leakage between the duct system and the garage of 0 CFM @25Pa.

Duct Sealing and Insulating

Leaky duct systems cause energy losses, but they can also depressurize the house, which can pull outdoor, unfiltered air into the house from attics, crawlspaces, attached garages, and through building walls.

All ducts, air handlers, and filter boxes should be air sealed and joints and seams should comply with the 2009 IRC M1601.4.1. The 2009 IRC describes several UL 181 approved sealing methods. Building America recommends water-based mastic that complies with UL 181-BM, as appropriate. Duct-drywall connections should be sealed with caulk or foam sealant. Mastic provides the most reliable duct-sealing method for new construction. 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 room to room that can cause unwanted airflow. The process of sealing each joint reduces the chances of unconnected ductwork, a surprisingly common mistake.

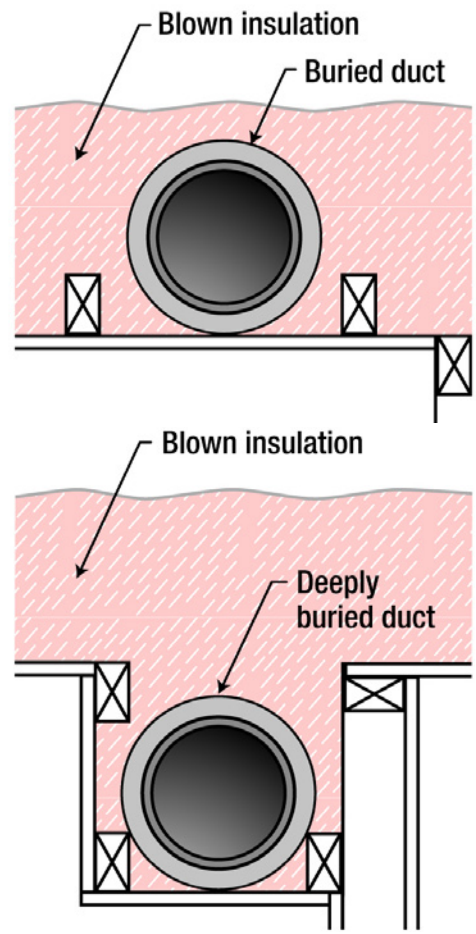
Although mastic is the most reliable duct-sealing method, the 2009 IRC M1601.4.1 allows and DOE research has found that some tapes perform adequately for sealing ducts, particularly fiberglass duct board (see sidebar). However, high-performance tapes may be difficult to identify and traditional duct tape (cloth-backed rubber adhesive tape) 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 in attics should be insulated to R-8 minimum and all other ducts should be insulated to R-6 minimum, except insulation is not required for ducts located inside the building's thermal envelope [per 2009 IECC 403.2].

Duct air tightness should be verified with duct blaster pressure testing. **[The 2009 IECC 403.2 requires that ducts be tested for air tightness and allows for the testing to occur either before or after drywall is put up. If tested at pre-drywall or rough-in, they must be ≤ 6 cfm per 100 ft^2 of conditioned floor area at 25 Pa; if ducts are tested after construction, then ≤ 8 cfm at 25 Pa. (If the air handler and all ducts are in conditioned space, duct leakage testing is not required.)]** Building America recommends testing at rough-in when leaks can be easily accessed and sealed.

For More Information on Duct Layout and Sealing

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



Ducts Buried In Insulation

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

Quadrant Put Ducts in Conditioned Space to Reach Tax Credit Level

While working with the WSU Energy Office, a Building America research partner, to redesign its homes to achieve the 50% savings federal tax credit level, it became evident to Quadrant that moving ducts inside conditioned space was the best option for meeting the energy savings target. Quadrant met with its HVAC subcontractor, Bob's Heating, to design a new system that moved the supply ducts into conditioned space and put the furnace in a mechanical closet on the second floor. This practice decreased costs by allowing shorter duct runs and smaller furnaces. It increased quality by getting subcontractors out of the crawlspace and into a work environment that is easier, faster, and safer to work in and much more easily inspected.

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

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.

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. 2003. *Home Builders Guide to Ducts in Conditioned Space.* P500-03-82-A16. www.sabreargentina.com/downloads/FinalAttachments/A-16_Bldrs_Guide_Ducts_6.3.4.pdf

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

2009 IECC. 2009. *International Energy Conservation Code*, Section 403.2.2 "Sealing," and "Table 4.4.5.2(.2) – Default distribution system efficiencies for the proposed design." International Code Council (ICC), Washington, DC. www.iccsafe.org/Store/Pages

2009 IRC. 2009. *International Residential Code - One and Two-Family Dwellings*, International Code Council (ICC), Washington, DC. www.iccsafe.org/Store/Pages

Lubliner, Michael, Ryan Kerr, Andy Gordon, and Chuck Murray. 2008. Moving Ducts Inside: Big Builders, Scientists Find Common Ground, *2008 ACEEE Summer Study on Energy Efficiency in Buildings*, www.energy.wsu.edu/documents/code/ACEEE_Ducts_Inside.pdf

Regional Technical Forum (RTF). 2006. *Deemed Savings for New Construction Homes.* Portland, OR.

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

Pressure Balancing

Pressure imbalances from indoors to outdoors or room to room can draw moisture-laden air into wall cavities. Imbalanced airflows can also cause drafts and temperature differences between rooms or floors, leading to comfort complaints.

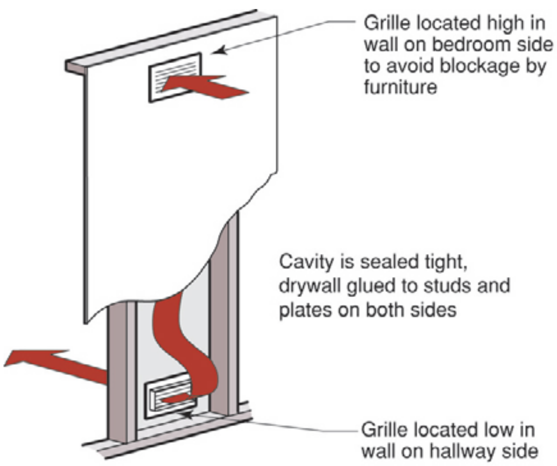
One key factor in eliminating pressure imbalances is providing an adequate return air path to the air handler. Four methods for providing a return air path are as follows: 1) ducted returns from each room to the air handler; 2) room-to-room ceiling jump ducts; 3) transfer grilles or transoms; and 4) door undercuts. Door undercuts are not recommended by Building America because they are often too small and/or are blocked by the installation of carpeting.

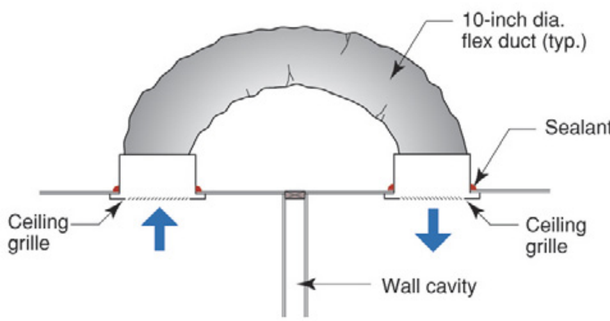
Sound transmission in jump ducts or transfer grilles can be minimized by the use of flex duct, duct lining with sound-absorbent material, a slightly circuitous path, or some combination of these strategies.

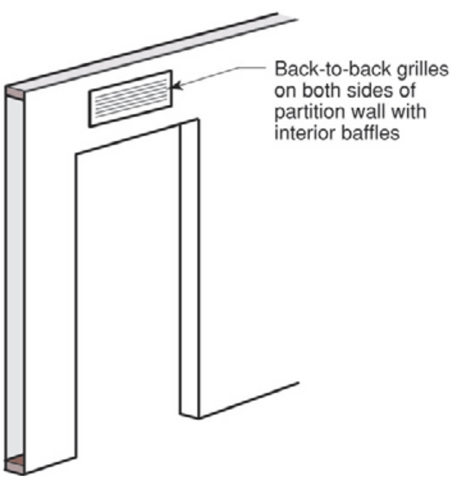
(left) Installing jump ducts from room to room is one way to balance pressures. *(Photo source: IBACOS)*

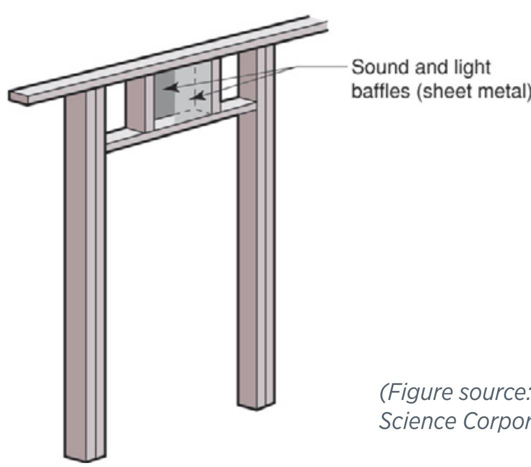
(right) Transfer grilles help balance air pressure between rooms, which helps to minimize drafts and comfort complaints.

Example of Jump Ducts and Grilles









(Figure source: Building Science Corporation)

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

Air Distribution Fans

Fan motors on HVAC equipment can have a large impact on year-round energy use because they are often shared by heating, cooling, and ventilation systems. Nearly all furnace manufacturers offer "variable-speed" brushless permanent magnet (BPM) direct current motors. These motors have higher efficiency and, unlike permanent split-capacitor motors, BPM motors retain their high efficiency at reduced fan speeds. Although BPM motors may have a price premium of $200 or more, 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, supply-only systems, and balanced systems. Mechanically balanced systems use heat and energy recovery ventilators; semi-balanced systems use a combination of exhaust and supply techniques.

Supply-Only Ventilation Systems

A supply-only ventilation system brings outside air to the intake side of a home's central air handler. A central fan-integrated supply ventilation system uses an exterior air intake that is ducted to the return air side of the HVAC system. Code requires that outdoor air intakes and exhausts be equipped with automatic or gravity dampers that close when the ventilation system is not in operation [per 2009 IECC 403.5]. Building America recommends that the damper on this fresh air intake be motorized to allow control of the air intake, and electronic controls operate the HVAC fan to draw in outside air and time the operation of the 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). A disadvantage of supply-only ventilation is that it can positively pressurize the home.

Supply-only ventilation can be integrated with the HVAC systems central fan if it has an energy-efficient variable-speed ECM motor. A standard one-speed motor will blow too much air (up to 1400 cfm when 50 to 100 cfm is desired for ventilation) and use too much energy. Central fan-integrated ventilation works well when installed by a knowledgeable contractor who understands how to program the blower operation.

ASHRAE 62.2

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 Standard is on a three-year publishing cycle and has been republished in 2004, 2007, and 2010 with minor updates. 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.

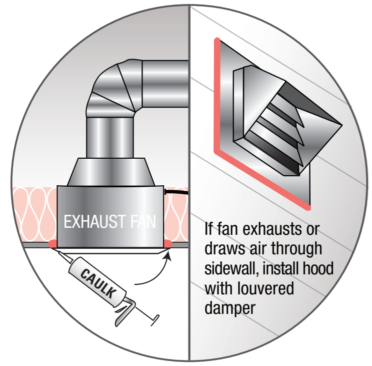
ASHRAE Standard 62.2 requires a continuous ventilation rate of 1 cfm per 100 ft^2 of building area plus 7.5 cfm x (# bedrooms +1). An intermittent fan can meet this requirement if the airflow rate is adjusted upward based on specific ventilation effectiveness requirements published in the standard.

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.

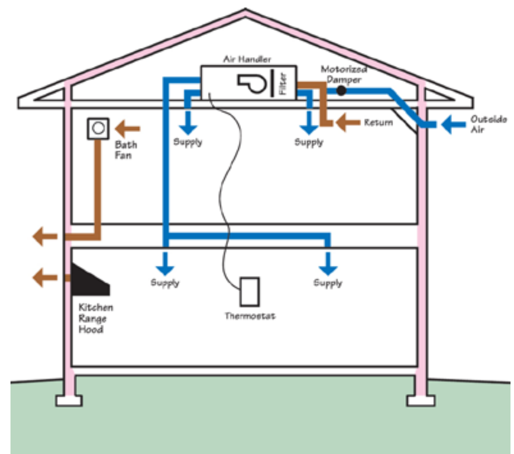
Exhaust-Only Ventilation

Continuously operating an exhaust fan located in a bathroom or central area of the house provides low-cost ventilation. 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 home's 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, this negative pressure pulls outside air in through cracks around doors and windows and leaks in walls. 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 can cause the home to become negatively pressurized. This can increase the risk of backdrafting any atmospheric-vented combustion (fuel-burning) appliances that may be in the home. Backdrafting occurs when the flue's natural ability to draw combustion fumes out of the house has been overpowered and instead, these fumes (including carbon monoxide) are pulled into the house. Negative pressure in a house can also draw in hot outside air, soil gasses, garage fumes, and pollens.



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



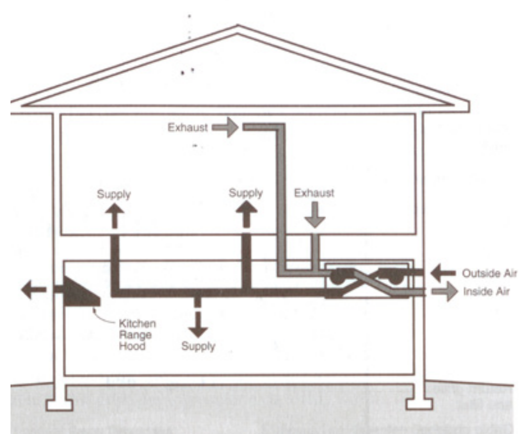
Balanced ventilation system using a supply ventilation system integrated with heating and A/C with a stand-alone exhaust fan.

Balanced Systems

Heat recovery ventilators (HRVs) and energy recovery (or enthalpy-recovery) ventilators (ERVs) both provide a controlled way of ventilating a home while minimizing energy loss by using conditioned exhaust air to warm or cool fresh incoming air. These ventilators are typically whole-house systems that share the furnace duct system or have their own duct system.

The main difference between an HRV and an ERV is the way the heat exchanger works. With an ERV, the heat exchanger transfers water vapor along with heat energy, while an HRV only transfers heat. The ERV helps keep indoor humidity more constant.

Most energy recovery ventilation systems can recover about 70%–80% of the energy in the exiting air. They are most cost-effective in climates with extreme winters or summers and where fuel costs are



Balanced ventilation system with heat recovery via an air-to-air heat exchanger. *(Source: Lstiburek 2004)*

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. When combined with timed exhaust fans, this provides low-cost balanced ventilation.

high. Consider these recommendations for selecting an HRV or ERV (Holladay 2010b):

- For a small, tight house in a cold climate—especially a house with a large family—choose an HRV.
- For a large house in a cold climate—especially a house with few occupants—choose an ERV.
- In a hot, humid climate, know that an ERV will cost a little less to operate during the summer than an HRV.
- In mixed climates, choose either appliance.
- Understand the most important quality is energy efficiency.
- Find an installer who understands how ERVs and HRVs work and knows how to install them properly.

A lower-cost alternative is a "semi-balanced" system consisting of a combination of the supply and exhaust systems described above.

Ventilation for Nighttime Cooling

Airconditioning energy use can be significantly reduced by ventilating homes with cool night air. Ventilation cooling is practical in locations where temperature swings of 30° or more between day and night and summer daytime highs above 80°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 effective, but still require opening of windows and some diligence on the part of the homeowner. Two automated systems have been developed by Building America research partner Davis Energy Group that ventilate and cool the house with outside air. The systems, called SmartVent and NightBreeze use the HVAC system fan coupled with an outside air intake damper and controlled by temperature sensors to provide filtered outside air without the homeowner having to open windows (Hoeschele 2008).

For More Information on Ventilation Systems

2009 IECC. 2009. *International Energy Conservation Code*, Section 403.5, "Mechanical Ventilation," Section 403.6, "Equipment Sizing," International Code Council (ICC), Washington, DC. www.iccsafe.org/Store/Pages

2009 IRC. 2009. *International Residential Code - One and Two-Family Dwellings*, Section M1502.1 "Clothes Dryer Exhaust – General," International Code Council (ICC), Washington, DC. www.iccsafe.org/Store/Pages

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

ASHRAE Standard 62.2-2010 *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings (ANSI/ASHRAE Approved)* 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

Hoeschele, Marc. 2008. *Development of an Integrated Residential Heating, Ventilation, Cooling, and Dehumidification System for Residences*, Prepared by Davis Energy Group for the U.S. Department of Energy, www.davisenergy.com/docs/FinalReport_SBIR2_I-HVCD_061808.pdf

Holladay, Martin. 2010a. "Designing a Good Ventilation System Ventilating Is Easy — It's Ventilating Right That's Hard" Green Building Advisor.com posted June 15, 2010. www.greenbuildingadvisor.com/blogs/dept/musings/designing-good-ventilation-system

Holladay, Martin. 2010b. HRV or ERV? Choosing the right equipment for a balanced ventilation system," Green Building Advisor.com posted January 22, 2010. www.greenbuildingadvisor.com/blogs/dept/musings/hrv-or-erv

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

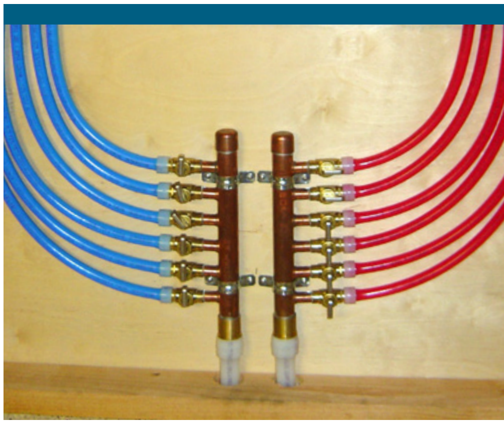
Piazza, T., R.H. Lee, M. Sherman, and P. Price. 2007. *Study of Ventilation Practices and Household Characteristics in New California Homes*. CEC-500-2007-033. California Energy Commission, Sacramento, CA., www.energy.cq.gov/2007publications/CEC-500-2007-033/CEC-500-2007-033.PDF

Rudd, Armin. 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

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

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

U.S. Environmental Protection Agency. 2009. *Indoor airPLUS Construction Specifications*, available at www.epa.gov/indoorairplus/index.html



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:

- Insulate hot water supply lines to R-4 and ensure tanks have at least R-12. **[2009 IECC 403.3 requires R-3 minimum.]**
- Consolidate bathrooms and other hot water-consuming activities into the same area(s) of the house.
- Use a higher-efficiency sealed-combustion water heater to minimize risk of backdrafting.
- Place the sealed-combustion water heater in a central location inside the home to minimize piping trunk lengths. Use a central manifold distribution system.
- 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.
- Install high-efficiency electric or gas water heaters. Specify sealed-combustion, power vented, or direct vented gas water heaters.
- Consider alternative technologies like on-demand gas or electric water heaters, solar thermal water heaters, and ground-source heat pumps and desuperheaters.
- Do not use continuous recirculation pumps. If recirculating pumps are specified, the pumps should be controlled by timers or on-demand to stop continuous operation.
- Do not install plumbing in exterior walls.
- Seal around plumbing penetrations in all exterior surfaces, surfaces that border on unconditioned spaces, and between floors. Use fire-resistant sealant in plates between floors.
- Specify insulation requirements for pipes, especially pipes that will be covered by the slab, or will otherwise be inaccessible.

Code/Above Code
Water Pipe Insulation

A comparison of the 2006 uniform plumbing code, state codes, and Building America recommendations

Code	
2006 Uniform Plumbing Code	R-3 insulation for hot or cold piping outside cond. space
WA	R-3 insulation for hot or cold piping outside cond. space
OR Unlimited WWR	Insulate any piping that will operate at temperatures that will form condensation on exterior of pipe
CA	2009 Uniform Plumbing Code R-3 insulation for hot or cold piping outside cond space
Above Code	
Building America Recommendations	Insulate all piping inside and outside of conditioned space to R-4

WWR = window-wall ratio

Hot Water Distribution

Essentially there are three types of hot water distribution systems: 1) 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; 2) the central manifold (homerun) where the water heater feeds a manifold with dedicated lines running to each household fixture; and 3) 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.

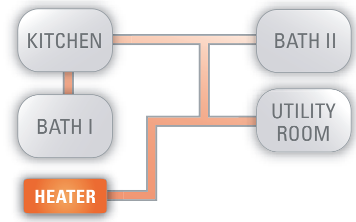
The NAHB Research Center tested the three water distribution systems—trunk and branch, central manifold, and remote manifold—and found that, while all three supplied sufficient flow, the central manifold system provided the quickest hot water to the fixtures and the most stable pressure when multiple fixtures were used.

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.

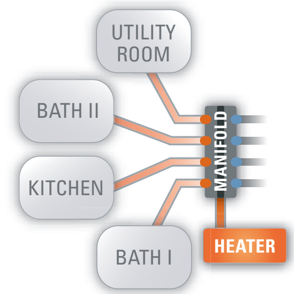
PEX piping should not connect directly to a hot water tank or solar water heater where the temperature of the water could exceed 200°F. PEX piping should not be used in installations subject to continual ultraviolet light exposure.

Hot Water Distribution Systems

Traditional Trunk System



More Efficient Manifold System



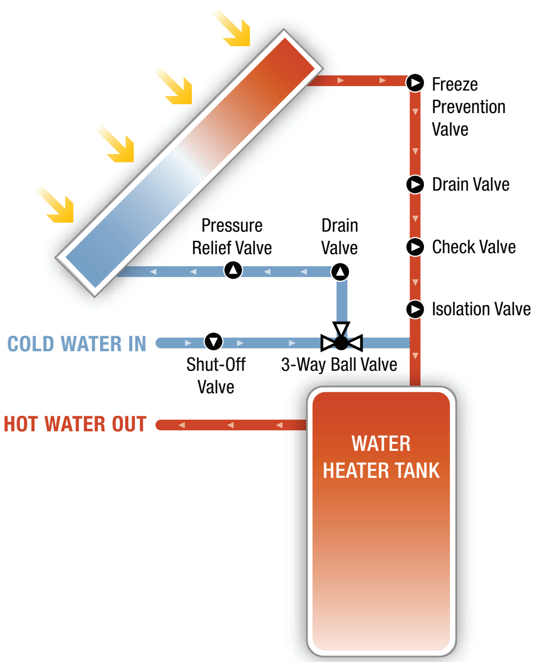
Hot Water Circulation Pumps and Controls

Do not use *continuous* recirculation systems for hot water. These systems keep hot water continuously flowing through pipes and result in substantial heat loss. If solar thermal water heating systems are used, 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 control, which will minimize the energy penalty associated with recirculation systems and insulate the pipe to R-2 **[per 2009 IECC 403.4]**. 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 minimize wasted water and is and is best suited for fixtures located far from the water heater. On-demand recirculators do not save energy except in comparison to continuous recirculation systems.

Solar Thermal Water Heating: Integrated Collector Storage vs. Indirect Antifreeze Systems

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.



Integrated Collector Storage (ICS) systems are the least expensive solar thermal water heaters.

Water Heaters

Performance rating information for conventional storage water heaters, electric heat pumps, and instantaneous water heaters is available from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) (www.ahrinet.org). AHRI'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 are now available: high-efficiency gas storage, gas condensing, gas tankless, solar, and heat pump water heaters. (For a list, see www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters.)

Conventional Storage 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 water heaters is 0.60 or higher. 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 exhaust outdoors.

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

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.

Heat pump water heaters are now commercially available like this one seen at the 2010 International Builders Show.

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. Builders considering installing tankless gas water heaters in a development need to plan for adequate gas line size. Tankless water heaters draw approximately 150,000 BTUs compared to a standard water heater that draws 35,000 BTUs. Therefore, much higher capacity is demanded of the gas lines during peak usage times, such as in the morning.

Heat Pump Water Heaters

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. A heat pump water heater works like a refrigerator, but moves heat from its environment to the water.

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.

Solar 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.

- 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 should be equipped with a solar pool heater.

Tankless Coil and Indirect Water Heaters

Two technologies that use the home's space-heating furnace to also heat water are the tankless coil heater and the indirect water heater. Tankless coil water heaters provide hot water on demand without a tank, but because they rely on the homes' space-heating furnace to heat the water they are most efficient from an energy perspective in homes where the furnace is on often; they are inefficient in mild and warm climates including the marine climate. Indirect water heaters also use the space-heating furnace but instead of heating water directly the furnace heats a fluid that in turn heats water in a water storage tank via a heat exchanger. Because the tank allows for heating with less turning the furnace on and off, indirect water heaters are more efficient.

For More Information on Plumbing and Water Heating

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

2009 IRC. 2009. *International Residential Code - One and Two-Family Dwellings*, Section 403.4, "Circulating Hot Water Systems," International Code Council (ICC), Washington, DC. . www.iccsafe.org/Store/Pages

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 15% of electricity use in the typical American home (DOE 2009). The typical incandescent lamp wastes 90% of the energy it uses, producing heat rather than light. High-performance lighting, including CFL and LED products, provides excellent visual quality that is also very energy efficient.

Compact fluorescent lamps (CFLs) use 70%-75% less energy than their incandescent equivalents with comparable brightness and color rendition. They cost more, but last 10 to 13 times longer than incandescent lamps, making them cost effective if used at least 2-3 hours per day. Compact fluorescent lamps come in both pin-based models and screw-based models that fit most standard fixtures found in homes today. ENERGY STAR first established criteria for CFL lamps in 2007. Today thousands of models of ENERGY STAR-labeled CFL bulbs and fixtures are available in a wide variety of sizes, shapes, and color renditions.

Light emitting diode (LED) lights are becoming more commonplace as new models are developed with better lighting performance, higher efficiency, and lower cost. DOE tracks and tests LED products as they enter the market via its CALiPER program and other lighting programs (see www.ssl.energy.gov). ENERGY STAR criteria for solid-state lighting (LED) went into effect in 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 at least 25,000 hours for indoor, residential products.

[The 2009 IECC 404 requires that at least 50% of the lamps in permanently installed lighting fixtures be high-efficacy lamps.] It is likely this requirement will be raised to 75% in the 2012 IECC. Building America recommends 100% high-efficacy lamps. Almost all fluorescent lamps equipped with electronic ballasts qualify as high-efficacy light sources. LEDs and metal halide lamps can also be high efficacy. Incandescent, quartz halogen, low-voltage halogen MR, and mercury vapor lamps do not qualify as high efficacy.

Energy-efficient ENERGY STAR rated fixtures come in many attractive styles, like these CFL-based fixtures 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)*

California's Title 24 building energy standard mandated high-efficacy lighting in 2005 and updated the requirements in 2008 (CEC 2008) to require pin-based (not screw-based) high-efficacy lamps in the following locations:

- ***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 photo control/motion sensor combination.

Recessed "can" ceiling fixtures, or downlights, that are recessed into insulated ceilings are required **[by the 2009 IECC 402.4.5]** to be rated for insulation contact (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. **[Per the 2009 IECC 402.4.5]** the fixture should bear a label showing it meets the ASTM E 283 guideline of ≤ 2.0 cfm of air movement from the conditioned space to the ceiling cavity when tested at 75 Pa and the housing should be caulked or gasketed where it meets the ceiling. IC-rated downlight fixtures are available for CFL lamps.

LIGHTING for tomorrow

DOE partners with lighting organizations to host three CFL and LED lighting design competitions. Visit the competition websites to see competition winners, including some of the most energy-efficient, eye-catching designs on the market: Lighting for Tomorrow (www.lightingfortomorrow.com), Next Generation Luminaires (www.ngldc.org), and the L-Prize (www.lightingprize.org).

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.

Example of Recessed Downlight Performance Using Different Lighting Sources

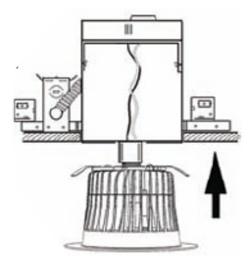
	INCANDESCENT*	FLUORESCENT*		LED**
	65W R-30 Halogen	13W triple tube Spiral CFL	15W R-30 CFL	LR6 LED downlight by Cree
Delivered light output (lumens), initial	678	466	653	697
Luminaire wattage (nominal W)	65	10	13	6.4
Luminaire efficacy (lm/W)	11	46	49	109
Price (average prices as of Aug 2009)	$3	$8	$5	$80
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. For more about CALiPER, see www.ssl.energy.gov

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



LED Recessed Can Gives off 650 Lumens from 6.5 Watts.

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. In 2010, CREE came out with a model that produces 697 lumens of light with only 6.5 Watts of power.

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

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

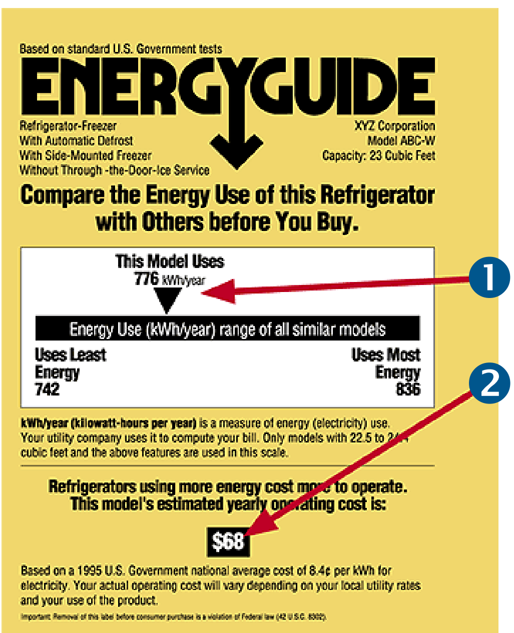
Appliances

When it comes to selecting appliances and electronic equipment, 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

A refrigerator labeled with both the ENERGY STAR label and the EnergyGuide label.



The EnergyGuide label helps consumers compare the energy efficiency of appliances

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.

energy consumption or energy efficiency. They also show the highest and lowest energy consumption or efficiency estimates of similar appliance models.

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 stove ranges and ovens.

ASK ABOUT ENERGY STAR

[The 2009 IECC 403.8 requires that electronic snow and ice melting equipment have automatic shutoff controls when the pavement temperature reaches 50°F and automatic or manual controls when the outdoor temperature reaches 40°F.]

For More 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/

Comissioning

Basic commissioning of the house and its mechanical systems is a requirement for high-performance housing and should be completed before the home is considered ready for the homeowner to take possession. Commissioning activities include whole-house air leakage testing with a blower door test, duct air tightness testing, pressure testing of each room, and combustion safety testing. Additional testing is needed for advanced systems like combination water/space heating systems, ground-source heat pumps, solar thermal systems, and photovoltaic arrays.

[The 2009 IECC 402.4.2 requires verification of air-sealing measures by blower door testing or extensive visual inspection. Blower door air leakage results should be less than 7 air changes per hour at a pressure of 50 Pa (7 ACH@50Pa).]

[The 2009 IECC 403.2 requires duct leakage testing, either after rough-in or after drywall is installed. If at rough-in, duct leakage to the outdoors should be ≤ 6 cfm/100 ft^2 of conditioned floor area at 25 Pa; if post-construction, duct leakage should be ≤ 8 cfm/100 ft^2 of conditioned floor area at 25 Pa. Systems with the air handler and all ducts in conditioned space are exempt from testing.]

Building Science Corporation developed a commissioning checklist called the SNAPSHOT form. This form is shown on the next page and is available at www.buildingscience.com/documents/reports/rr-0413-the-snapshot2014a-quick-description. Also, the Air Conditioning Contractors of America (ACCA) has developed guidance on commissioning of residential mechanical systems, *HVAC Quality Installation Specification*, ANSI/ACCA 5 QI-2007, which is available at www.acca.org/quality/.

Homeowners should also be given information on maintenance and operation of the HVAC equipment in their new home. Building America's Building Science Consortium team put together a homeowner's manual for the EcoVillage project in Cleveland, Ohio, that can serve as a sample for builders wishing to create a homeowner's manual for their developments. The manual can be downloaded at www.buildingscience.com/documents/reports/rr-0310-ecovillage-homeowner-handbook

These commissioning steps can reduce callbacks and litigation risks for builders:

- Develop a commissioning plan appropriate to the home and the equipment installed.
- Review commissioning results with installers.
- Provide the homeowner with information on the proper operation and maintenance of mechanical systems and other equipment.

For More Information on HVAC Commissioning

Air Conditioning Contractors of America (ACCA) *HVAC Quality Installation Specification* – ANSI/ACCA 5 QI-2007, www.acca.org/quality/

Building Science Corporation. 2004. *The "SNAPSHOT"- A Quick Description*, Research Report 0413a, www.buildingscience.com/documents/reports/rr-0413-the-snapshot2014a-quick-description

Building Science Corporation. 2004. *EcoVillage Homeowner Handbook*, Research Report 0310, www.buildingscience.com/documents/reports/rr-0310-ecovillage-homeowner-handbook

Building Science Corporation. 2008. *Quality Assurance Roadmap for High Performance Residential Buildings*, http://74.125.155.132/search?q=cache:http://www.toolbase.org/PDF/BestPractices/QualityAssuranceRoadmap.pdf

SNAPSHOT© "The Form"

Lot #:	Subdivision:	Address:	Date and time:
Model:			

INITIALIZATION

	Square feet	sq. ft.
	Surface area (all outside surfaces, including foundation)	sq. ft.
	Volume	cu. ft.
	Windspeed (approximate mph)	mph
	Outside temperature (estimated)	° F
	Check that all registers and bedroom doors are open.	Yes☐ No☐
	Measure static pressure in return between fan & filter.	pa
	Static pressure in Supply and Return	S Pa / R Pa
	Is there a ventilation system?	Yes☐ No☐
	Type of ventilation system (e.g., exhaust-only, HRV, ERV)	
	If there is an AirCycler™, enter the off / on times.	off on
	Enter outside air duct pressure.	pa
	Type of outside air duct (flex/sheet metal; diameter)	
	Is there an adjustable outside air damper?	Yes☐ No☐
	Is there a fireplace or wood stove?	Yes☐ No☐
	Duct location (approximate % in attic, conditioned space, basement, etc.)	

PRESSURE TESTING

	Stack Pressure (baseline with blower door installed; covers on)				pa
	Dominant Duct Leak Effect (baseline with HVAC system running)				pa
	Master Bedroom Door Closure Effect (ÄP from main space to outdoors)				pa
	All Doors Closed Effect (ÄP from main space to outdoors)				pa
	Fireplace/Wood Stove Zone HVAC Test				pa
	Pressure In Each Closed Room (room label and pressure)		pa		pa
			pa		pa
			pa		pa
			pa		pa
			pa		pa

BLOWER DOOR TESTING (BDT)

	Blower Door Location	
	Total CFM50 (add C & n values if available on multipoint test)	CFM50= C= n=

DUCT AIRTIGHTNESS TESTING (DAT)

	DAT CFM25 TOTAL	
	DAT CFM25 OUTSIDE	

MECHANICALS

	Furnace or air handler	Make:	Model:
	Air Conditioning	Make:	Model:
	Domestic hot water	Make:	Model:

Building Science Corporation

Snapshot Form

RR-0413b: Snapshot Form

Occupant Health and Safety

As houses become tighter, indoor air quality becomes a more important issue. To address occupant health and safety, the EPA has developed an Indoor airPlus checklist, shown on the following page, that recommends these actions (www.epa.gov/indoorairplus): 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 quality including a properly engineered system, sealed ducts, and 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; and 6) selection of low-chemical-content materials, keeping materials dry during construction, and airing out the home prior to move in.

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 should be a sealed-combustion 90%+ (AFUE of 90 or greater) unit. Any water heater inside conditioned space should 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 hoods. Range hoods capable of exhausting more than 400 cfm must provide makeup air at a rate equal to the exhaust air rate [2009 IRC M1503.4].

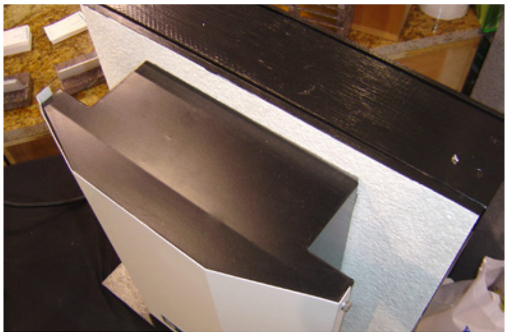
- Use sealed-combustion gas fireplaces that vent harmful combustion gases to the outside.

- Vent bathrooms, kitchens, toilets, and laundry rooms directly outdoors. Outdoor air intakes and exhausts should be equipped with automatic or gravity dampers that close when the ventilation system is not in operation [per 2009 IECC 403.5]. Kitchen fans should ventilate at a rate of 100 cfm intermittent or 25 cfm continuous; bathroom fans should ventilate at a rate of 20 cfm continuous or 50 cfm intermittent [2009 IRC Table M1507.3]. Use energy-efficient and quiet fans (see the section on ventilation).

(top) Some cabinetmakers 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.



(top) 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.

(bottom) 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.

Code/Above Code **Duct Insulation**

A comparison of the 2009 IECC climate zone marine 4, state codes, and Building America recommendations

Code	
2009 IECC Unlimited WWR	R-8/R-6*
WA 13%, 25%, and unlimited WWR	R-8**
OR Unlimited WWR	R-8
CA >20% WWR	R-6
Above Code	
Building America Recommendations	R-8, ducts buried in attic or, better, located in conditioned space; mastic seal all joints

** R-8 for supply ducts in attic, return ducts R-6*
WWR = window-wall ratio

*** WA R-8 for ducts in crawlspace, attic or garage; R-5 for ducts in ground or under slab.*

- 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 M1502.4.4]** 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.

- 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. **[ASHRAE 62.2-2010, citing NFPA 54, permits atmospherically vented combustion appliances inside provided the total net flow of the two largest exhaust fans does not exceed 15 cfm/100 ft^2 of occupiable space when in operation at full capacity. If the designed total net flow exceeds this limit, the net exhaust flow must be reduced by reducing the exhaust flow or providing compensating outdoor airflow.]**

- Provide filtration 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. **[This exceeds the ASHRAE 62.2-2010 6.7 recommended MERV 6 or better.]**

- Maintain indoor humidity in the range of 30% to 50% 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. **[NFPA 720 says CO detectors shall be installed near bedrooms, and on every occupiable level of a dwelling unit, including basements, excluding attics and crawlspaces. NFPA 101 Section 24.3.4.1 requires smoke alarms in all sleeping rooms, outside of each separate sleeping area, in the immediate vicinity of the sleeping rooms, and on each level of the dwelling unit, including basements.]**

- Maximize hard surface areas (tile, vinyl, hardwood) to better manage dust for health purposes.

- 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 [per 2009 IECC 402.4.1 and ASHRAE 62.2-2010, 6.5.1]. 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 airtight 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. Keep windows open while paints and adhesives are applied and until they are dry to dissipate initial concentrations.

This Building America home used low-VOC paints and finishes (shown in lower photo) to meet local green building guidelines.

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EPA United States Environmental Protection Agency

Indoor airPLUS Verification Checklist

EPA Indoor airPLUS QUALIFIED HOME

Address or Div/Lot#:

City/State/Zip: **Date:** **Verified by**

Section		Requirements (see Indoor airPLUS Construction Specifications for details)	N/A	Builder	Rater
Moisture Control		**Water-Managed Site and Foundation**			
	1.1	Site & foundation drainage: sloped grade, protected drain tile, & foundation floor drains		☐	☐
	1.2	Capillary break below concrete slabs & in crawlspaces (Exception - see specification)	☐	☐	☐
	1.3	Foundation wall damp-proofed or water-proofed (Except for homes without below-grade walls)	☐	☐	☐
	1.4	Basements/crawlspaces insulated & conditioned (Exceptions - see specification)	☐	☐	☐
		Water-Managed Wall Assemblies			
	1.5	Continuous drainage plane behind exterior cladding, properly flashed to foundation		☐	☐
	1.6	Window & door openings fully flashed		☐	☐
		Water-Managed Roof Assemblies			
	1.7	Gutters/downspouts direct water a minimum of 5' from foundation (Except in dry climates)	☐	☐	☐
	1.8	Fully flashed roof/wall intersections (step & kick-out flashing) & roof penetrations		☐	☐
	1.9	Bituminous membrane installed at valleys & penetrations (Except in dry climates)	☐	☐	☐
	1.10	Ice flashing installed at eaves (Except in Climate Zones 1 - 4)	☐	☐	☐
		Interior Water Management			
	1.11	Moisture-resistant materials/protective systems installed (i.e., flooring, tub/shower backing, & piping)			☐
	1.12	No vapor barriers installed on interior side of exterior walls with high condensation potential		☐	☐
	1.13	No wet or water-damaged materials enclosed in building assemblies		☐	☐
Radon	2.1	Approved radon-resistant features installed (Exception - see specification)	☐	☐	☐
	2.2	Two radon test kits & instructions/guidance for follow-up actions provided for buyer (Advisory-see specification)	☐	☐	☐
Pests	3.1	Foundation joints & penetrations sealed, including air-tight sump covers			☐
	3.2	Corrosion-proof rodent/bird screens installed at all openings that cannot be fully sealed (e.g., attic vents)		☐	☐
HVAC	4.1	HVAC room loads calculated, documented; system design documented; coils matched			☐
	4.2	Duct system design documented & properly installed OR duct system tested (check box if tested) ☐	☐		☐
	4.3	No air handling equipment or ductwork installed in garage; continuous air barrier required in adjacent assemblies			☐
	4.4	Rooms pressure balanced (using transfer grills or jump ducts) as required OR tested (check box if tested) ☐	☐		☐
	4.5	Whole house ventilation system installed to meet ASHRAE 62.2 requirements			☐
	4.6	Local exhaust ventilation to outdoors installed for baths, kitchen, clothes dryers, central vacuum system, etc.			☐
	4.7	Central forced-air HVAC system(s) have minimum MERV 8 filter, no filter bypass, & no ozone generators			☐
	4.8	Additional dehumidification system(s) or central HVAC dehumidification controls installed (In warm-humid climates only)	☐		☐
Combustion Pollutants		**Combustion Source Controls**			
	5.1	Gas heat direct vented; oil heat & water heaters power vented or direct vented (Exceptions - see specifications)	☐		☐
	5.2	Fireplaces/heating stoves vented outdoors & meet emissions/efficiency standards/restrictions	☐		☐
	5.3	Certified CO alarms installed in each sleeping zone (e.g., common hallway) according to NFPA 720			☐
	5.4	Smoking prohibited in common areas; outside smoking at least 25' from building openings (Multi-family homes only)	☐	☐	☐
		Attached Garage Isolation			
	5.5	Common walls/ceilings (house & garage) air-sealed before insulation installed; house doors gasketed & closer installed	☐		☐
	5.6	Exhaust fan (minimum 70 cfm, rated for continuous use) installed in garage & vented to outdoors (controls optional)	☐		☐
Materials	6.1	Certified low-formaldehyde pressed wood materials used (i.e., plywood, OSB, MDF, cabinetry)		☐	☐
	6.2	Certified low-VOC or no-VOC interior paints & finishes used		☐	☐
	6.3	Carpet, adhesives, & cushion qualify for CRI Green Label Plus or Green Label testing program	☐	☐	☐
Final	7.1	HVAC system & ductwork verified dry, clean, & properly installed			☐
	7.2	Home ventilated before occupancy OR initial ventilation instructions provided for buyer		☐	☐
	7.3	Completed checklist & other required documentation provided for buyer		☐	☐

Rater/Provider:	**Builder:**
Company:	**Company:**
Signature:	**Signature:**

Guidance for Completing the Indoor airPLUS Verification Checklist:

1. Only ENERGY STAR qualified homes verified to comply with these specifications can earn the Indoor airPLUS label. See Indoor airPLUS Construction Specifications for full descriptions of the requirements, terms, exceptions, abbreviations, references, and climate map used in this checklist. Verification is not complete until this checklist is completed in full and signed.
2. Check one box per line. Check "N/A" for specifications that do not apply for specific conditions (e.g., climate) according to the Exceptions described in the Indoor airPLUS Construction Specifications. Check either "Builder" or "Rater" for all other items to indicate who verified each item. Items may be verified visually on site during construction, by reviewing photographs taken during construction, by checking documentation, or through equivalent methods as appropriate. If using a performance testing alternative to meet requirement 4.2 or 4.4, the box marked "Tested" must be checked and testing documentation must be provided in the Home Energy Rating System/Builder Option Package (HERS/BOP) file.
3. The rater who conducted the verification, or a responsible party from the rater's company, must sign the completed verification checklist. The builder must sign the checklist if any items in the "Builder" column are checked, and by so doing accepts full responsibility for verifying that those items meet Indoor airPLUS requirements.
4. The builder provides one copy of the completed and signed checklist for the buyer. The HERS/BOP provider or rater files a copy with HERS/BOP and ENERGY STAR documentation (e.g., Thermal Bypass Checklist) for the home.
5. The checklist may be completed for a batch of homes using a RESNET-approved sampling protocol when qualifying homes as ENERGY STAR. For example, if the approved sampling protocol requires rating one in seven homes, then the checklist will be completed for the one home that was rated.

Note: The Indoor airPLUS Construction Specifications are designed to help improve indoor air quality (IAQ) in new homes compared with homes built to minimum code. These measures alone cannot prevent all IAQ problems; occupant behavior is also important. For example, smoking indoors would negatively impact a home's IAQ and the performance of the specified Indoor airPLUS measures.

Notes:

For further information on the Indoor airPLUS program, visit epa.gov/indoorairplus.

Qualified homes earn the Indoor airPLUS label. Place it next to the ENERGY STAR label.

All Indoor airPLUS qualified homes meet strict guidelines for energy efficiency set by ENERGY STAR, the nationally-recognized symbol for energy efficiency.

Chapter 10.

Durability and Energy Efficiency Checklist

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. It is important to 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 onsite pre-job and post-job inspection checklists for each trade contractor.

CHAPTER TOPICS

10.1 Foundation Assemblies

10.4 Wall Assemblies

10.6 Roof Assemblies

10.7 Whole-House Air Leakage

10.7 Mechanical Systems

10.11 Commissioning

Foundation Assemblies

Slab, crawlspace, and basement foundation types are all common in the marine climate. The checklists below address control of moisture, airflow, and heat flow in each foundation type.

Controlling Moisture in All Foundation Types

- ☐ Maintain a surface grade of at least a 6-inch drop for at least 10 feet around and away from the entire structure [2009 IRC R401.3].
- ☐ Drain impervious surfaces such as driveways, garage slabs, patios, stoops, and walkways away from the structure at ≥ 2% drop within 10 feet of the building [2009 IRC R401.3].
- ☐ Specify and show in details that 6-mil polyethylene sheeting or rigid foam insulation is to be placed directly beneath the slab or basement floor. The sheeting should continuously wrap the slab as well as footings up to grade.

- ☐ Damp proof all below-grade portions of the exterior foundation **[2009 IRC R406]**. Damp proof the exposed portion of the foundation with latex paint or other sealant.
- ☐ 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.
- ☐ Ensure that the lowest excavated site foundation level is above the local groundwater table at its maximum elevation.
- ☐ Place a 4-inch-deep, ¾-inch gravel bed directly beneath the polyethylene sheeting to act as a capillary break and drainage pad.
- ☐ Do not place a sand layer between the vapor retarder and the concrete slab or basement floor. Differential drying and cracking is better handled with a low water-to-concrete ratio and wetted burlap covering during initial curing.

Controlling Moisture in Crawlspace and Basement Foundations

- ☐ Install a perimeter drain below the drainage plane along (not on top of) footings for all basements and crawlspaces where the floor is below grade (use perforated PVC pipe covered with gravel, landscape fabric, and backfill).
- ☐ In all crawlspaces, install 6-mil polyethylene across the entire ground surface. Overlap all seams by 12 inches and tape them. Seal the polyethylene at least 6 inches up the walls or to a height equal to ground level.

Controlling Air Infiltration in All Foundation Types

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

Controlling Heat Flow in Slab Foundations

- ☐ Slabs may be insulated at the perimeter with borate-treated foam board or rigid fiberglass insulation. Use only insulation approved for below-grade use.
- ☐ Exterior insulation should be applied from the top of the foundation wall to the bottom of the frost line. Cover the exterior face of the insulation exposed to outside air using flashing, fiber cement board, parging, treated plywood, or membrane material.
- ☐ When a shallow frost-protected slab is used, foundation footings do not need to be placed below the frost depth. Rigid insulation, approved for below-grade use, must be placed vertically on the exterior of the grade beam, and must be placed to extend away from the foundation horizontally at the base of the grade beam for a distance equivalent to frost depth. Rigid insulation is also needed vertically on the inside of the grade beam, and must extend horizontally under the slab, on top of the gravel capillary break, for two feet.

Controlling Heat Flow in Crawlspace Foundations

- ☐ The preferred approach is to install insulation on the exterior side of the foundation wall. Products such as borate-treated foam board or rigid fiberglass insulation work well. Insulate exterior side of beam to R-5.6 **[2009 IRC 403.3]**.
- ☐ Insulation that is exposed above grade must be covered with a protective coating such as flashing, fiber cement board, parging, treated plywood, or membrane material.
- ☐ If insulation is placed on the interior, it must extend down the wall to a depth at least 2 feet below grade level and be rated for crawlspace and basement exposure.
- ☐ If the floor is insulated instead, insulate to R-30 in the Marine climate **[2009 IECC 402]**.

Controlling Heat Flow in Basement Foundations

- ☐ Wall insulation in basements is similar to the approaches described for crawlspaces. Basement floors are insulated similar to slabs. **[2009 IECC 402 requires R-10 rigid foam on the interior or exterior surface of the walls or R-13 cavity insulation on interior basement walls in the marine climate; insulation must extend the full length of the wall. R-10 slab floor edge insulation is required extending 2 feet horizontally under the slab or out from the building.]**
- ☐ Exterior wall insulation is preferable in basement foundation applications.
- ☐ Material in contact with the foundation wall and the concrete slab must be moisture tolerant. A capillary break must be placed between materials that transport moisture and moisture-sensitive materials.
- ☐ Interior insulation, if used, should employ one of the following methods:
  - ○ Use foil-faced polyisocyanurate rigid insulation attached directly to the above-grade portion of the wall. Extruded or expanded polystyrene can be attached to the below-grade portion of the wall. The polystyrene would require a gypsum board or equivalent covering. Foam sill seal or foam board can be used between the bottom plate of the wall and the concrete floor to provide a capillary break.
  - ○ Use either expanded or extruded polystyrene foam board attached to the entire foundation wall. Additional insulation can be added to a frame wall built on the interior of the foam insulation. If no additional insulation is desired, wood furring strips can be attached over the foam and gypsum board attached to the furring strips.
  - ○ Use pre-cast concrete foundation walls that come with a minimum of 1 inch of rigid foam insulation attached to the interior.

Other Foundation Issues

RADON CONTROL

- ☐ Use a layer of gravel under the 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. **[Also see radon map and radon control recommendations in the 2009 IRC Appendix F.]**
- ☐ 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.

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. [See also 2009 IRC R318.1.]
- ☐ 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.
- ☐ Install a metal termite shield at the sill plate [per 2009 IRC R318.3].

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 [per 2009 IRC R703.2], 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 (Marine Climate)

- [ ] 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.
- [ ] Leave a drainage space of at least 1/16-inch behind lap siding and 3/4 inch between stucco and plastic housewraps to control liquid-phase water penetration. A 1-inch air gap is needed behind brick veneer **[as required by 2009 IRC R703.7.4.2]**.
- [ ] Use a Class 3 vapor retarder (latex paint) on interior side of walls with vented cladding over wall sheathing in the marine climate **[per 2009 IRC 601.3]**.

Controlling Air Infiltration in Wall Assemblies

- [ ] 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 **[2009 IECC 402.4]**.
- [ ] 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. **[Per 2009 IECC 402 insulate the wood wall cavity to R-20 or insulate the cavity to R-13 plus R-5 insulated sheathing; insulate mass walls to R-13 exterior or R-17 interior in the marine climate.]**
- ☐ Properly install wall insulation to ensure the cavity is completely free of voids.
- ☐ 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 **[2009 IECC Table 402.1.3 requires ≤ 0.35]**.
- ☐ 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 the walls and roof, including attics, cathedral ceilings, and knee walls. Use blown-in foam for tight sealing of the 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 (soffits, fans, registers, light fixtures) **[per 2009 IECC 402.4]**.

- ☐ Use draft-stopping in dropped ceiling areas.
- ☐ Use ceiling light fixtures that are rated for insulation contact (IT) 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. **[The 2009 IECC 402.1 requires a ceiling R value of R-38 in the marine climate, and a minimum of R-30 in cathedral ceilings.]** 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. **[If raised heel trusses are used allowing full height of the insulation over the wall top plate, than R-30 is permitted instead of R-38 (2009 IECC 402.2.2).]**
- ☐ In vented attics, install baffles to prevent blocking of soffit vents and wind washing (when thermal insulation is blown back from the edges of the 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 **[2009 IECC 403.6]**.
- ☐ 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 the refrigerant charge on the air conditioner or heat pump verified in writing by the 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. **[ASHRAE 62.2-2010 6.7 recommends MERV 6 or better.]**
- ☐ Keep pressurization balanced from room to room by providing individual 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 the hallway.
- ☐ Air seal 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 the air handler in the 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 the house layout.
- ☐ Centrally locate the 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. **[2009 IECC 403.3 requires R-3 minimum.]**
- ☐ Insulate tanks to at least R-12.
- ☐ Use a central manifold (home-run) 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 an 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. **[The 2009 IECC 404 requires that at least 50% of the lamps in permanently installed lighting fixtures be high-efficacy lamps.]**
- ☐ In California, follow these lighting requirements, which were updated in 2008 and became 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 requirement.
  - ○ 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.
- ☐ Use recessed ceiling lights that are ICAT rated (approved for insulation contact and air tight) **[per the 2009 IECC 402.4.5]**.
- ☐ 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 **[2009 IRC M1503.4]**.
- ☐ 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 entering the house.
- ☐ Install CO detectors and smoke alarms **[per NFPA 720 and NFPA 101 24.3.4.1]**.
- ☐ 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 the home **[per 2009 IECC 402.4.1 and ASHRAE 62.2-2010, 6.5.1]**.
- ☐ Vent clothes dryers and central vacuum cleaners directly outdoors **[2009 IRC M1502.4.1]**.
- ☐ Use low-VOC paints, finishes, varnishes, and adhesives whenever possible.

Commissioning

- ☐ Test ducts for air leakage at rough-in. **[Per 2009 IECC 403.2, at rough-in, duct leakage to the outdoors should be ≤ 6 cfm/100ft^2 of conditioned floor area at 25 Pa.]**
- ☐ Test whole-house air leakage with a blower door. **[Per 2009 IECC 402.4.1 blower door air leakage results should be ≤ 7 ACH@50Pa).]**
- ☐ Do combustion safety testing.
- ☐ Provide homeowners with operation and maintenance guidance to HVAC and mechanical systems.

Chapter 11.

Construction Site Scheduling, Training, and Inspecting

The construction process brings together piles of materials and equipment, armies of trade subcontractors, and site supervisors—all the ingredients to turn ideas into homes. Getting a high-performance home requires having good plans, and the proper contracts, permits, and materials, in combination with properly trained and competent installers, scheduled at the right time, and verified with testing.

Key topics that can help smooth the construction process include

- using construction and contract documents
- training
- scheduling work
- inspections and testing.

CHAPTER TOPICS

11.1 Construction and Contract Documents

11.3 Train Installers

11.5 Scheduling

11.6 Inspections and Tests

Construction and Contract Documents

Builders should use construction and contract documents to describe and define exactly what you want from your subcontractors.

Construction documents may include plans and specifications, scopes of work, and job-ready and job-complete checklists as described in Chapter 3. Plans and specifications should include sufficient building and equipment details for the code inspector **[as required by the 2009 IECC 103]**. Site supervisors should review construction documents before they are folded into contracts and continue to provide recommendations as these 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

(left) Use plans to spell out details that will ensure energy efficiency and durability like framing techniques, duct layouts, housewrap, flashing, and air sealing.

(right) Hold a preconstruction meeting with all subcontractors present to talk about the schedule and trade interactions, especially any changes from the typical routine to accommodate new methods or technologies.

back to designers and managers so that documentation can capture those improvements. Although individual improvements may seem small, capturing them into construction documents helps to apply them to superior building in the field.

Clear contract documents make for clear expectations with trade contractors. Ensure that trade contracts include the following provisions adapted from the NAHB Research Center 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.
- Trades will confirm in writing that all materials and equipment were installed according to field specifications and manufacturers' instructions, using pre-job and post-job checklists. Copies of both field specifications and the manufacturers' instructions should be available on the jobsite.

"We have every trade fill out job-ready and job-complete forms. We want to know what was ready and what wasn't when they showed up at their job. Those delays frustrate them and cost us money. "

Vern McKown, co-owner of Ideal Homes, in Norman, Oklahoma, shared these tips at the EEBA National Conference in Denver, Colorado, September 2009

Train Installers

High-performance home construction does not just happen. Training is essential. 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. Here are some ideas for training:

- Schedule a pre-construction meeting with all of your subcontractors present to review required interactions between trades.
- Meet with your subcontractors at the jobsite to explain how to use new techniques and materials.
- Provide your contractors with manufacturers' installation instructions and material data sheets and go through those instructions together. Other installation guides you may want to share with subcontractors include the field guides for installers shown in Chapter 12 of this guide and the DOE Building Energy Program's Code Notes. (See examples in Appendix 3.)
- Encourage in-house staff and regular subcontractors to take advantage of web-based videos, online training, and classroom training at community colleges during the off season.

Training on the jobsite can include reviewing manufacturers' installation instructions, going through job-ready and job-complete checklists, and using HotSpot forms.

For More How-To Information on Constructing Energy-Efficient Homes

Air Conditioning Contractors Association, www.acca.org

American Architectural Manufacturers Association, www.installationmastersusa.com

Building America, www.buildingamerica.gov

Building Energy Codes Resource Center, http://resourcecenter.pnl.gov/

Building Science Corporation, www.buildingscience.com.seminars.com

CARB Steven Winters Associates, www.carb-swa.com

Energy and Environmental Building Alliance, www.eeba.org

Florida Solar Energy Center, www.fsec.ucf.edu/en/

IBACOS, www.ibacos.com

National Association of Home Builders Research Center, www.nahbrc.org

Partnership for Advancing Technology in Housing, www.pathnet.org

Southface Energy Institute, www.southface.org

The California Energy Commission, www.energyvideos.com

"We hold meetings with our trade contractor steering committee. We ask our employees and our subs, what can we do better? The construction supervisor walks the sites to identify any recurring issues. And we do NAHB quality certification audits of the whole company on a regular basis."

Vern McKown, co-owner of Ideal Homes, in Norman, Oklahoma, shared these tips at the EEBA National Conference in Denver, Colorado, September 2009

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.

HotSpot Inspections and Training

Systematically checking work is an important aspect of quality construction. The NAHB Research Center developed the concept 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. Builders can create their own HotSpot forms using the sample below.

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

Scheduling

Building an energy-efficient home requires careful attention to scheduling. Several new construction techniques require changing the order of subcontractors or a shifting of responsibilities, and some new activities will need to be added into the schedule. Here are some 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 penetrations before the drywall is completed and after 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.

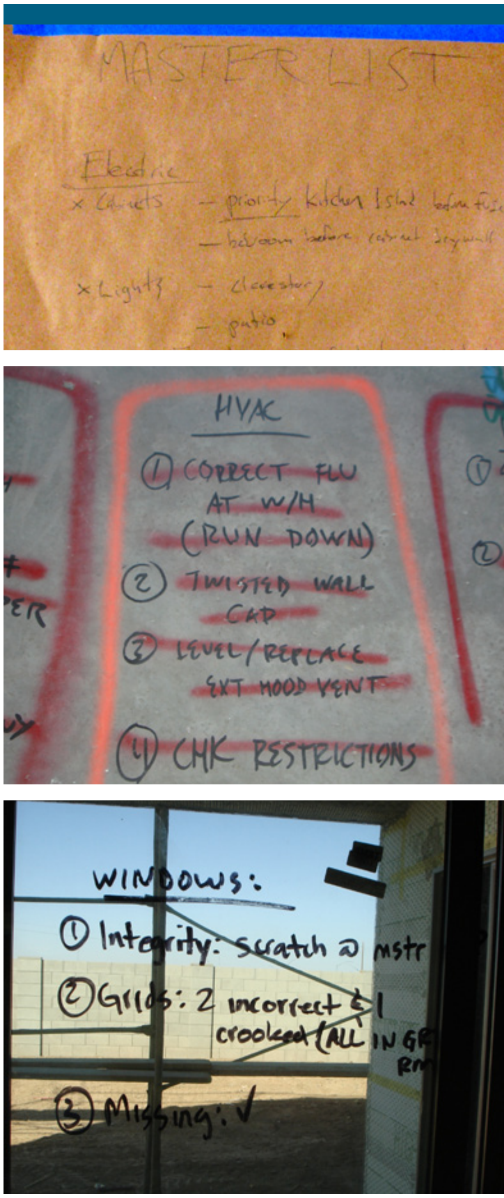
Some situations that may require a shifting of responsibilities include the following:

- 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.

Quadrant Homes, a Building America builder in Belleveue, Washington, builds its wall panels in a factory to ensure consistency and shorten site construction time.

"Quadrant gives us a schedule and we know we can count on it. With most of our other builders, if they have a job they want us to start tomorrow, we need to stop by and make sure the work will be ready. With Quadrant, we don't have to do that. They are predictable and reliable, and that is very nice from a trade standpoint."

Wade Craig, manager of Bob's Heating and Air Conditioning, the HVAC contractor for Quadrant Homes of Bellevue, Washington



Make your expectations clear with onsite meetings and visible inspection checklists.

- Some post-finish caulking can be avoided by having the electrician use pre-fabricated airtight 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 12 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.
- Draftstops 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 draftstopping material. The plumber can be asked to install the draftstopping and insulation.

Efficient scheduling of subcontractors can bring huge rewards in reduced costs and improved quality.

Inspections and Tests

In addition to required inspections by the code inspector, Building America recommends that site supervisors 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.

Walkthroughs

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 what is required of them and how to implement it. After the process has become more routine, you might get by with spot inspections. HotSpot inspections done by the site supervisor and training and pre-job/post-job checklists filled out by the subcontractor can help solve recurring problems and tie together many aspects of quality assurance and site management.

> "You can expect what you inspect."
>
> Dr. W. Edwards Deming, the originator of total quality management

Pre-Dry Wall Inspection and Duct Pressure Testing

[The 2009 IECC 403.2 requires that ducts be tested for air tightness and allows for the testing to occur either before or after drywall is put up. If the ducts are tested at pre-drywall or rough-in, they must be ≤ 6 cfm per 100 ft^2 of conditioned floor area at 25 Pa; if tested after construction, than ≤ 8 cfm at 25 Pa. (If the air handler and all ducts are in conditioned space, duct leakage testing is not required.)] Building America recommends testing duct pressure before drywalling, with the HVAC contractor present. If the ductwork fails to meet the pressure criteria, a smoke test will reveal the worst leaks and they can be sealed while they are still accessible. The HVAC contractor should also test the HVAC system to ensure that thermostats and zone dampers are operating correctly and that bypass dampers are properly adjusted. The pre-drywall inspection is also a good time to ensure that insulation and draft-stopping have been properly installed.

Pre-Occupancy Inspection and Whole-House Pressure Testing

After completion of the home, including all interior and exterior finishes but before occupancy, the whole-house air tightness is tested. **[The 2009 IECC 402.4.2 gives two options for demonstrating building air tightness. The home can be blower door tested and must show leakage of less than 7 air changes per hour at 50 Pa. Or, the 2009 IECC allows a visual inspection of all of the areas listed in the 2009 IECC 402.4.2.2.]** Building America recommends a blower door test. Also at this time, you should verify that all specified energy-efficient lighting and appliances were installed and check the air-conditioner or heat pump refrigerant charge if your HVAC contractor has not already done so.

Duct testing and whole-house pressure tests can be conducted by a certified HERS rater, and the HERS rating itself can be a valuable marketing tool for an energy-efficient house. The HERS rater should conduct a combustion safety test of all fuel-fired equipment as part of the rating certification.

To identify a certified rater in your area, check the registry at the Residential Energy Services Network (RESNET) website: www.natresnet.org.

For More Information on Site Supervision and Construction

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

(top) Duct blaster testing confirms that ducts are well sealed *(Photo source: NREL)*

(bottom) Before the drywalling starts, you should conduct a pre-drywall inspection to test ducts and make sure insulation is properly installed.

"Monitoring progress is the only way you are going to change behavior."

Nat Hodgson, Vice President of Construction, Pulte Homes Las Vegas Division

Chapter 12.

Field Guides 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
- Foundation System, Insulation, Moisture and Air Leakage Control
- Masonry Construction
- Housewrap
- Window Flashing
- Wall-to-Roof Flashing
- Interior Air Sealing
- Exterior Air Sealing with Insulating Sheathing Panels
- Plumbing Air Sealing
- Electrical Air Sealing
- Installing Fiberglass Batt Insulation
- Installing Windows in Walls with External Rigid Foam Insulation
- Duct Location
- Air Handler and Duct Sealing
- Radiant Barriers

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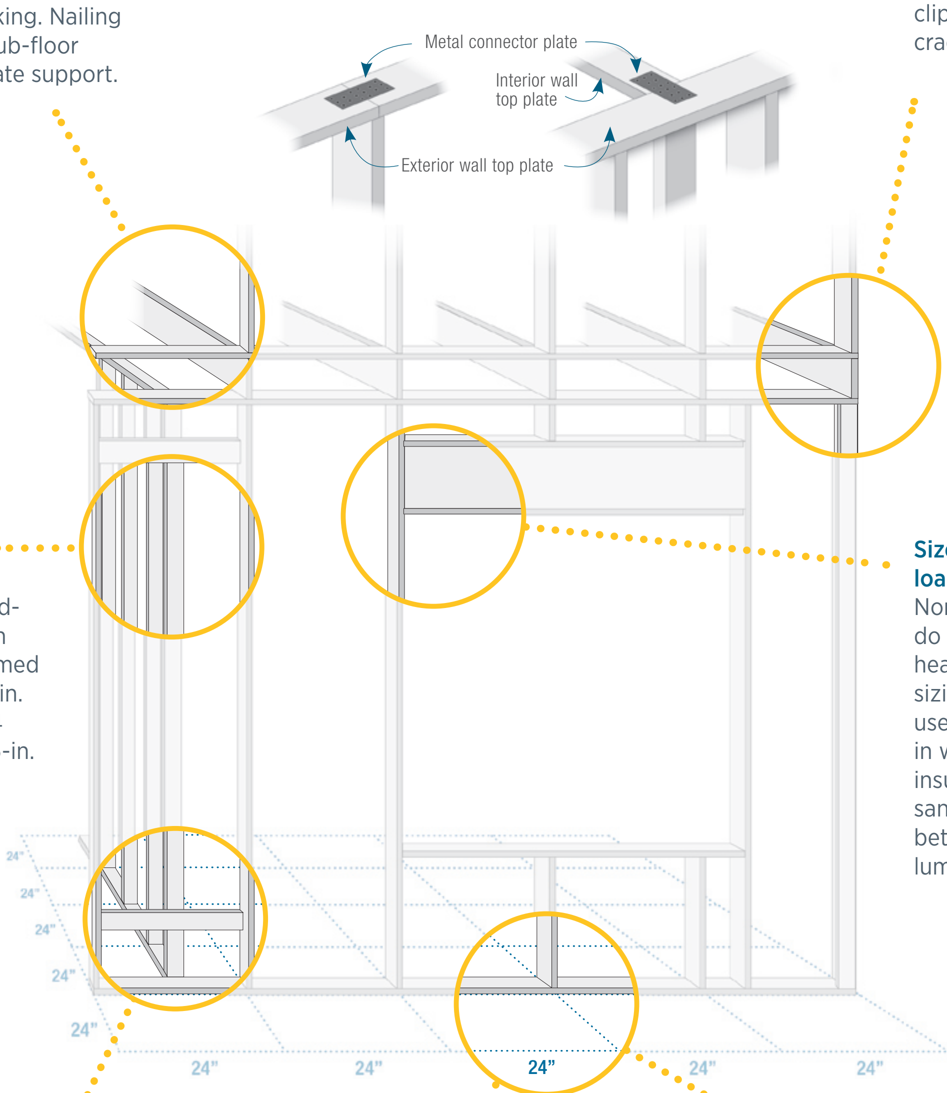
Advanced Framing

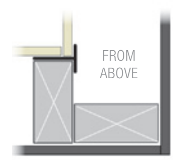
The following tips show examples of framing techniques that can create more open space to hold insulation while reducing framing cost and waste. The following page shows a typical framing plan which should be included in construction documents.

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 metal flat-plate connectors. Metal connectors can be used at partition wall intersection. Underside blocking is another option for single top plate butt joints. For multistory homes, this may increase the stud size on lower floors to 2x6.

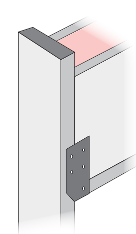
Use two-stud corners: Rather than using a third stud as a nailing edge for interior gypsum board, use drywall clips, a 1x nailer strip, or a recycled plastic nailing strip. Using drywall clips also reduces drywall cracking and nail popping.





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.

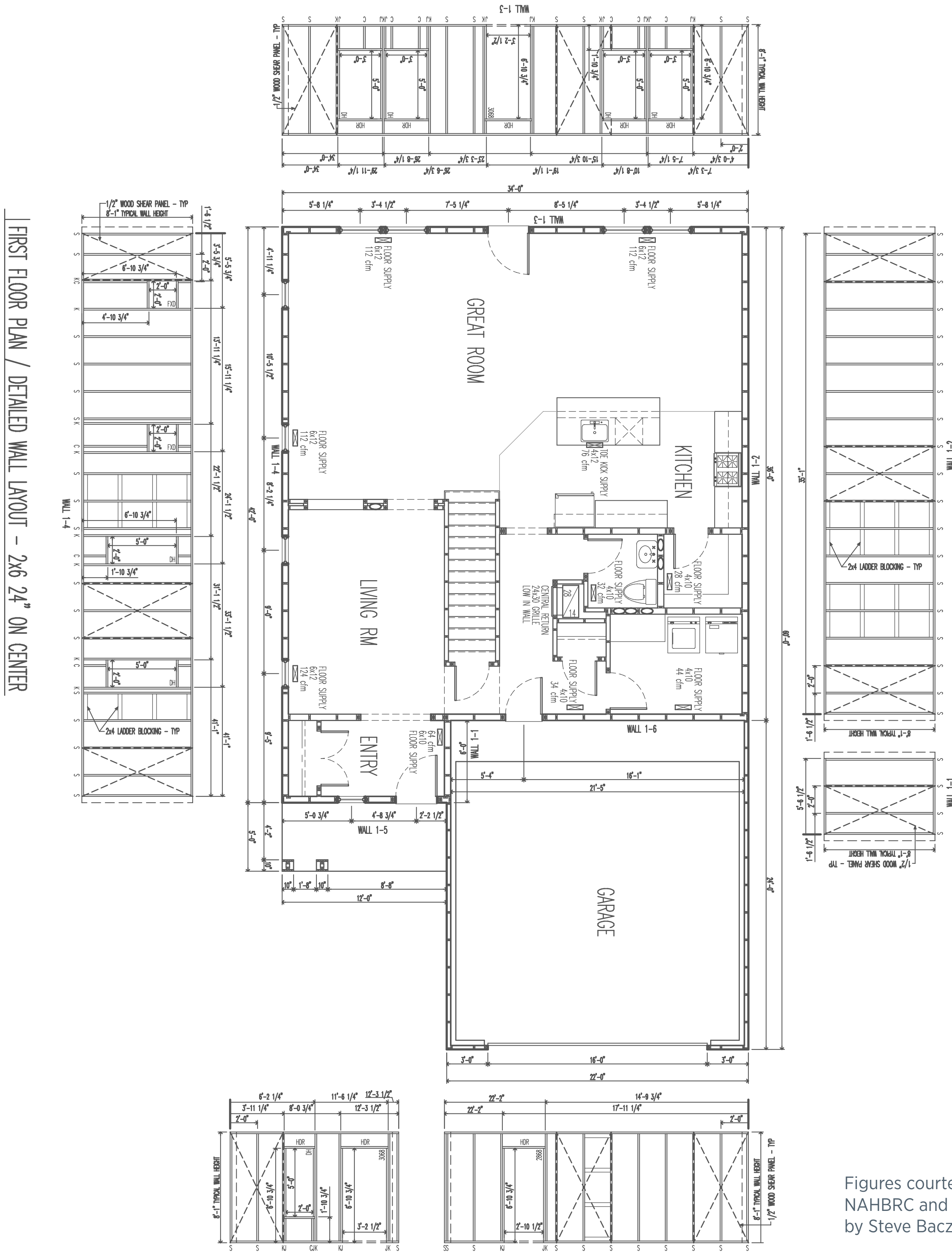


Ladder-block exterior wall intersections: Partitions can be nailed either directly to a single exterior wall stud or to flat blocks inserted between studs.

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.

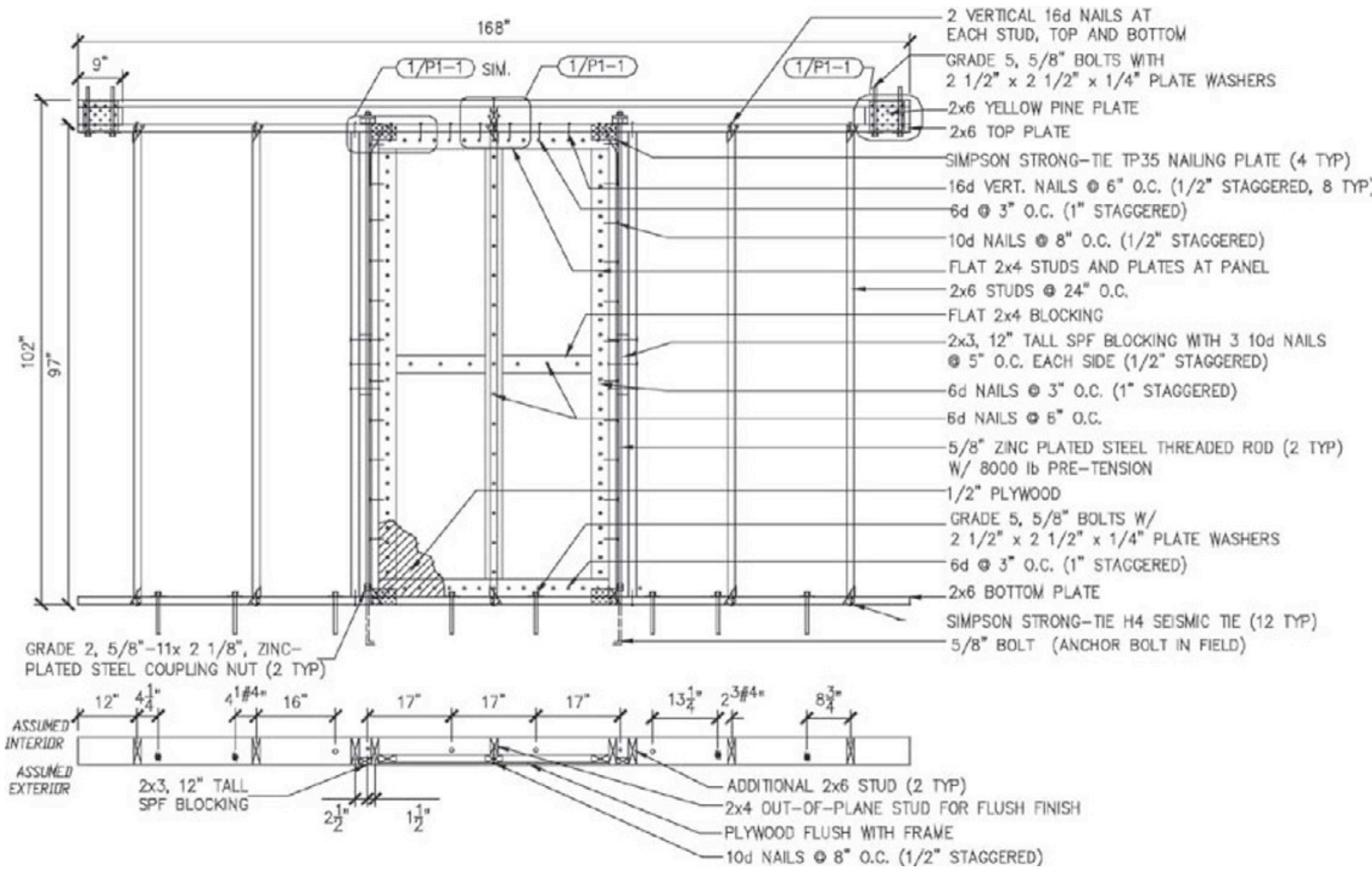
Frame 24-in. on center: 24-in. on center studs are structurally adequate for most residential applications. Even when the stud size must be increased from 2x4 to 2x6, 24-in. spacing can significantly reduce framing lumber needed.

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.

Wall design for seismic regions



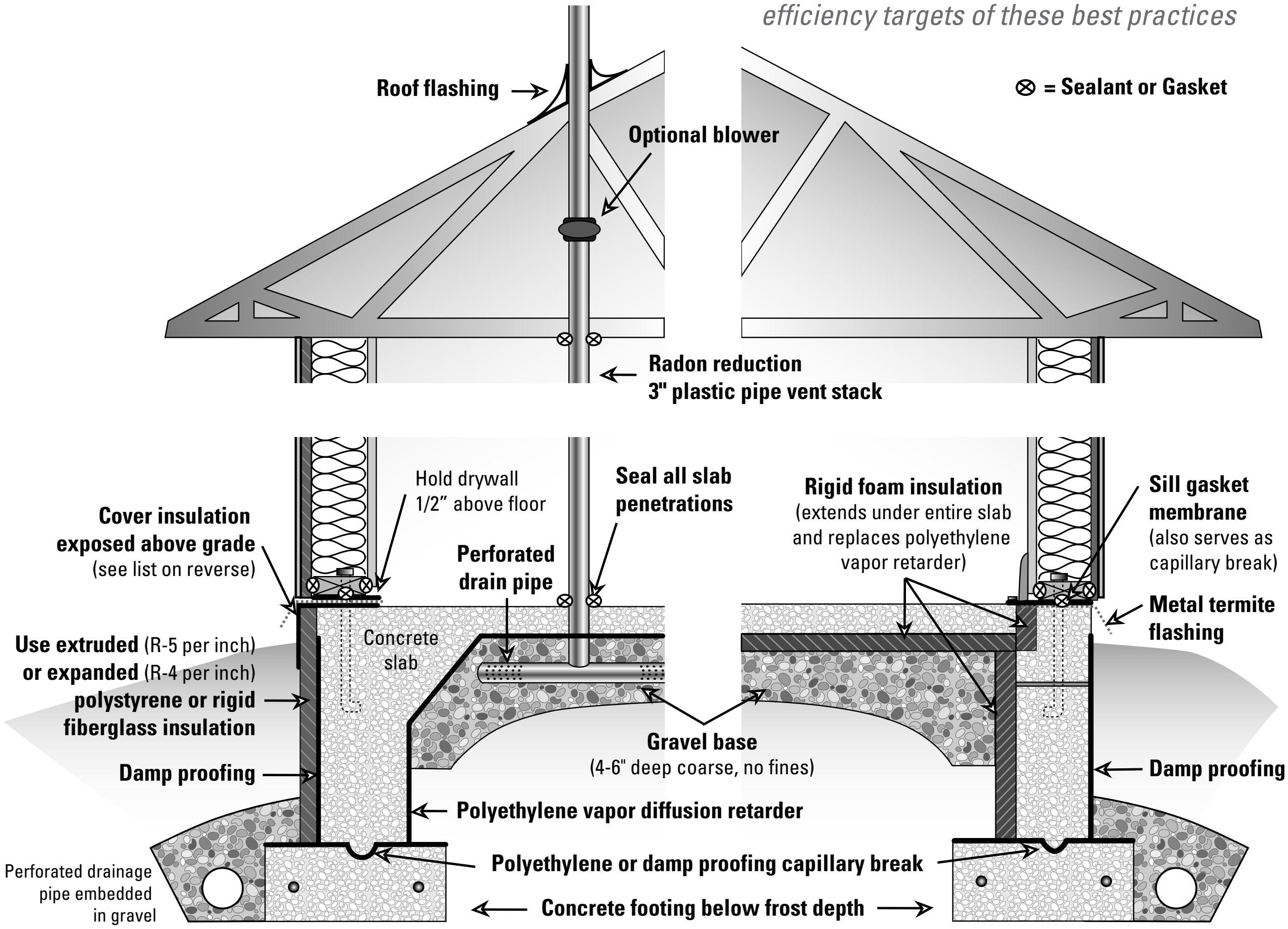
This advanced framing wall panel for seismic regions was designed and tested by Building Science Corporation and the U.S. Army Construction Engineering Research Laboratory (CERL) with funding by DOE's Building America program. The panel was designed to provide lateral capacity that is as good as or better 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 Seismic Events

Building Science Corporation. 2009. *Enclosures That Work - Building Profile: Hot-Dry/Mixed-Dry: Sacramento*, 2009, www.buildingscience.com/documents/profiles/etw-sacramento-profile/#F11

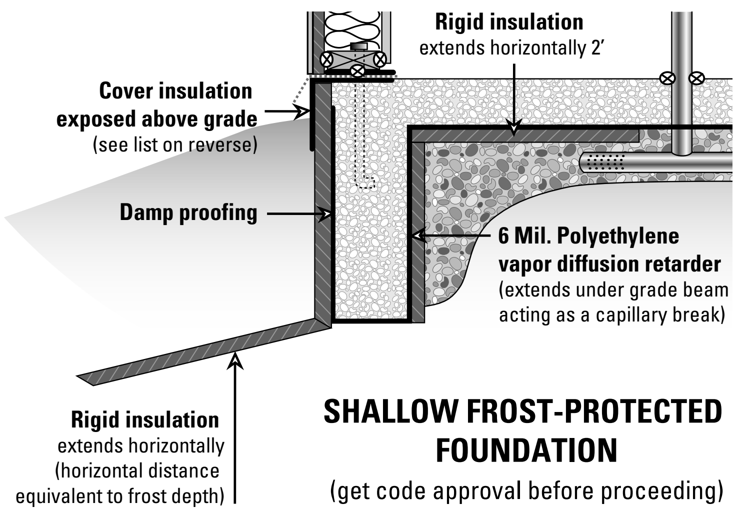
Foundation System, Insulation, Moisture and Air Leakage Control

** Slab insulation may not be needed to reach energy efficiency targets of these best practices*



EXTERIOR INSULATION PACKAGE

INTERIOR INSULATION FOR FLOATING SLAB



SHALLOW FROST-PROTECTED FOUNDATION

(get code approval before proceeding)

See more information on the following page.

Slab Foundation System, Insulation, Moisture and Air Leakage Control

- 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.
- Use a sill gasket for air sealing
- 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.
- Slabs require a foundation drain where the slab (or floor) is located below grade. Install a foundation drain 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.
- Exterior rigid fiberglass insulation may provide a drainage plane that will channel water to the foundation drain and relieve hydrostatic pressure.
- 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).
- Note that some code jurisdictions may require a gap between exterior insulation and wood foundation elements to provide a termite inspection area.
- Install damp proofing or a polyethylene sheet over the footing to block capillary water wicking into the foundation side wall.
- 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.
- Install radon control measures (check local requirements and EPA recommendations).

**EPDM stands for Ethylene Propylene Diene Monomer.*

Sources & Additional Information

U.S. DOE, *Technology Fact Sheet on Slab Insulation.*
www.eere.energy.gov/buildings/documents/pdfs/29237.pdf

U.S. EPA, *Building Radon Out: A Step-By-Step Guide oni How to Build Radon Resistent Homes.*
www.epa.gov/199/iaq/radon

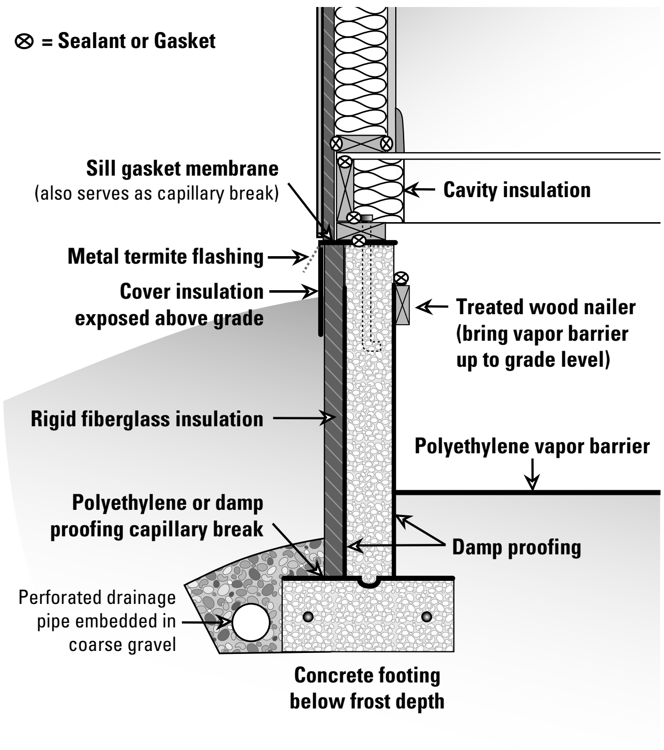
Southface Energy Institute. *Fact Sheets #29: Insulating Foundation and Door*s.
www.southface.org/home/sfpubs/techshts/29_insulatefloors4PDF.pdf

Southface Energy Institute. *Fact Sheets #30: Radon-Resistant Construction for Builders.*
www.southface.org/home/sfpubs/techshts/30_radonresistantconst.pdf

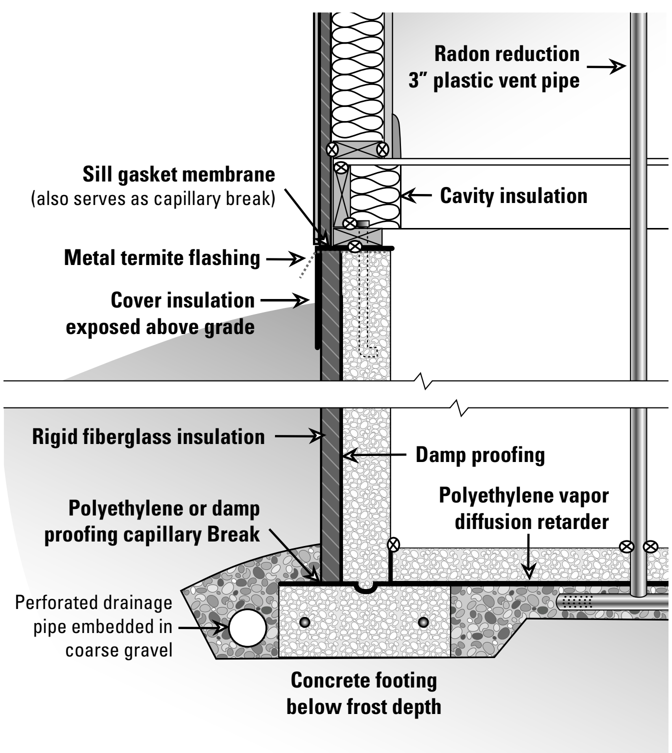
Building Science Consortium. *Introduction to Building Systems Performance: Houses that Work II*.
www.buildingscience.gov

Basement & Conditioned Crawlspace Insulation, Moisture and Air Leakage Control

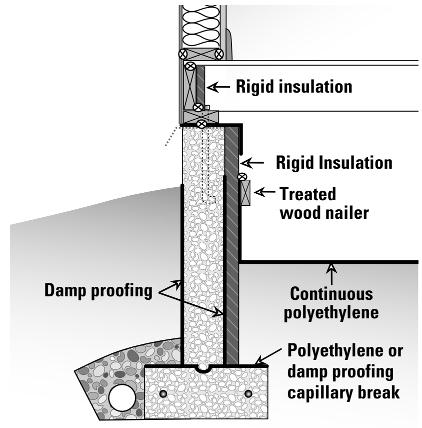
EXTERIOR CRAWLSPACE INSULATION

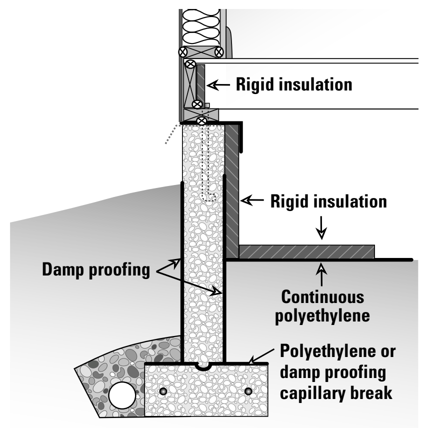


EXTERIOR BASEMENT INSULATION



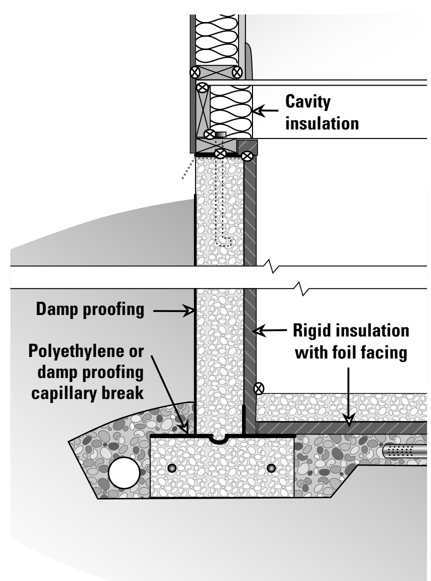
INTERIOR CRAWLSPACE INSULATION





If depth does not extend two feet below grade, place remaining insulation horizontally along the ground.

INTERIOR BASEMENT INSULATION



See more information on the following page.

Installation Tips

- Exterior and interior insulation approaches may be combined to provide needed insulation levels.
- Properly installed exterior rigid fiberglass insulation provides the best moisture management properties of the available insulation types.
- Interior nailing strips for finished walls should be installed over rigid foam (extruded polystyrene is more moisture tolerant than expanded polystyrene) insulation so that the foam is sandwiched between the nailing strip and the basement wall.
- Seal joints with adhesive or mastic on interior foam insulation applied directly to foundation walls.
- If interior blanket or batt insulation is used, it should be combined with exterior or interior rigid insulation attached directly to the foundation wall. The blanket or batt insulation should be unfaced or have a facing that allows moisture to pass through, and should be used in a conditioned basement. The drywall should be tightly air sealed to keep interior moist air from condensing on the foundation wall.
- Foil-faced rigid insulation is a good interior insulation choice for unfinished basements.

Crawlspace and Basement Foundation System Moisture and Air Leakage Control

- 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.
- Damp-proof all below grade portions of the exterior foundation wall to prevent the absorption of ground water.
- Use a sill gasket for air sealing
- 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.
- Crawlspaces require a foundation drain when the crawlspace floor is located below grade. Always install a foundation drain in basements. Install a foundation drain 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.
- Exterior rigid fiberglass insulation may provide a drainage plane that will channel water to the foundation drain and relieve hydrostatic pressure.
- 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).
- Note that some code jurisdictions may require a gap between exterior insulation and wood foundation elements to provide a termite inspection area.
- Install damp proofing or a polyethylene sheet over the footing to block capillary water wicking into the foundation side wall.
- Install a capillary break and vapor retarder under slabs and basement floors 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.
- Install radon control measures (check local requirements and EPA recommendations).

**EPDM stands for Ethylene Propylene Diene Monomer.*

Sources & Additional Information

IBACOS. 2002. *Consider the Crawlspace* (www.buildingamerica.gov)

IBACOS. 2002. *Don't Forget About the Basement* (www.buildingamerica.gov)

Lstiburek, Joseph. 2004. *Builders Guide to Cold* Climates (www.eeba.org/bookstore)

U.S. DOE, *Technology Fact Sheet: Basement Insulation* (www.buildingamerica.gov)

U.S. DOE, *Technology Fact Sheet: Crawlspace Insulation* (www.buildingamerica.gov)

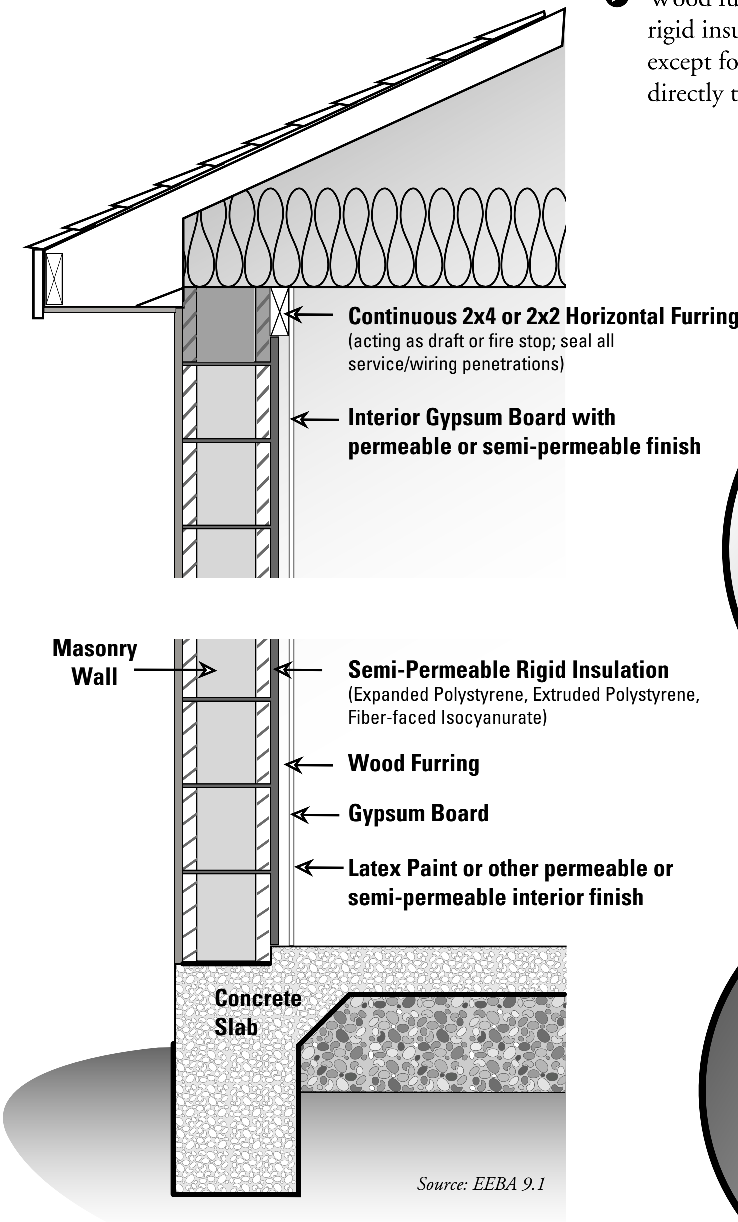
U.S. EPA, *Building Radon Out: A Step-By-Step Guide on How to Build Radon Resistent Homes* (www.epa.gov/1999/iaq/radon)

Yost and Lstiburek. 2002. *Basement Insulation Systems* (www.buildingamerica.gov)

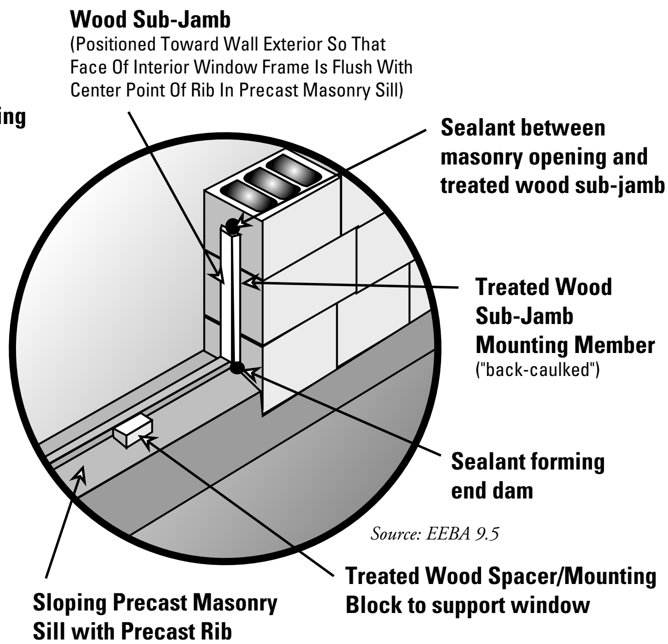
Masonry Construction

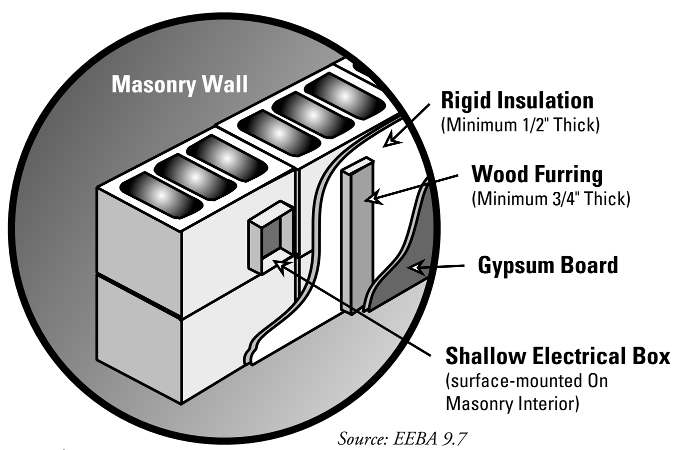
- Semi-vapor permeable rigid insulations used on the interior of wall assemblies should be unfaced or faced with permeable skins. Foil facings and polypropylene skins should be avoided.

- Wood furring should be installed over rigid insulation; the rigid insulation should be continuous over the surface of the wall, except for the 2x4 furring near the ceiling. This blocking attaches directly to the masonry block and is above the insulation, not behind it.



WINDOW SILL DRAINAGE





- Electrical boxes can be surface-mounted eliminating chiseling/chipping masonry

ELECTRICAL BOX

Sources & Additional Information

Lstiburek, J. W. 2000. *Builders Guides*. Minneapolis, MN. Energy and Environmental Building Association. www.eeba.org.

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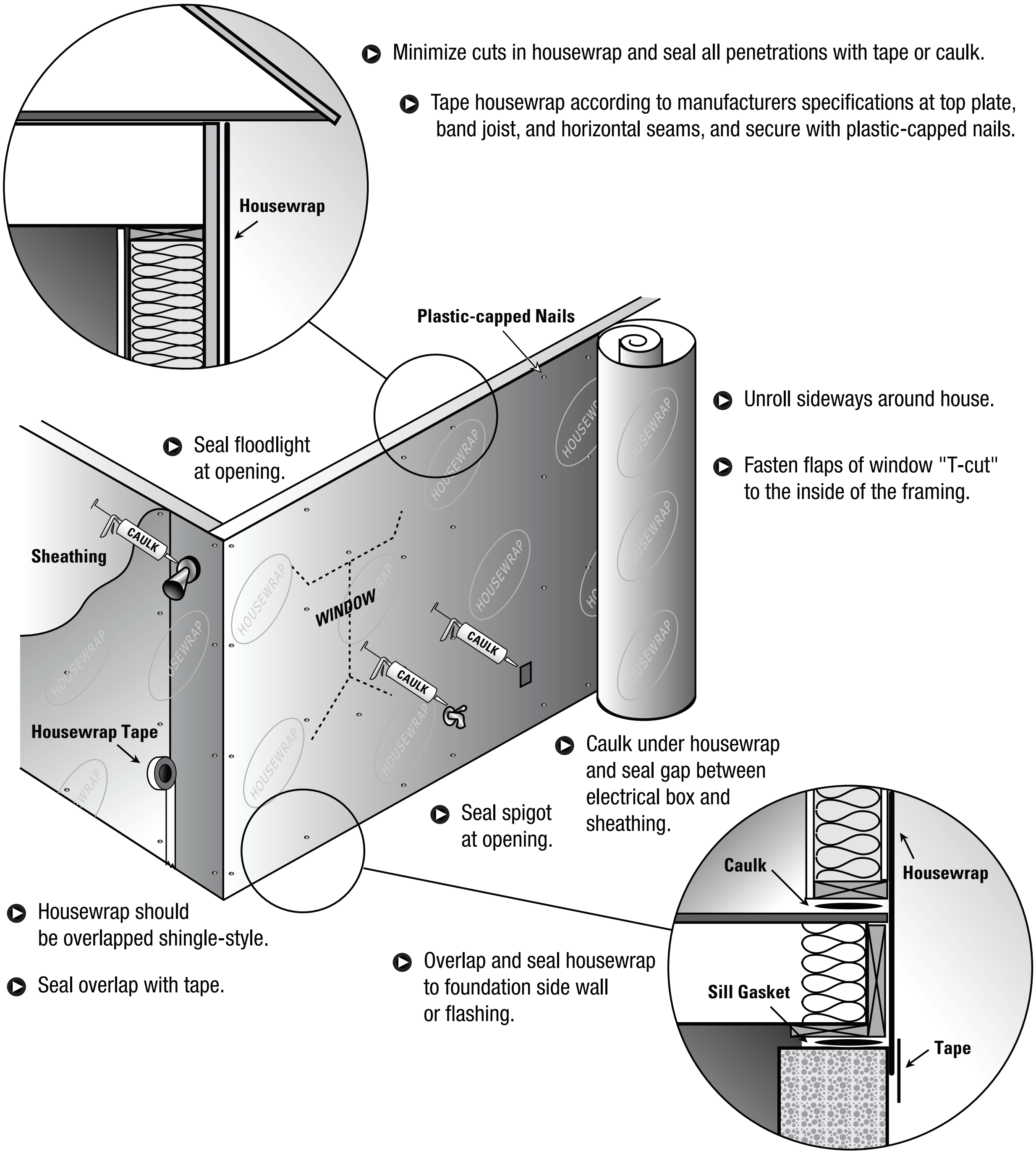
Housewrap

Example of housewrap strategies



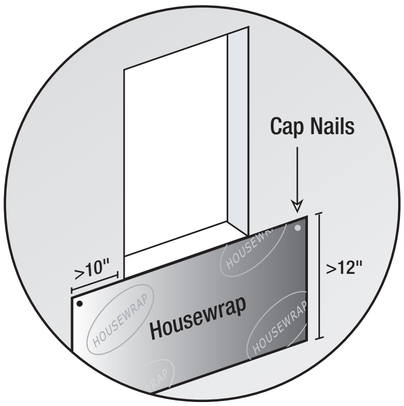
DO's and DON'Ts of Housewrap

- **Do** follow manufacturers' instructions.
- **Do** lap all layers properly—the upper layer should always be lapped over the lower layer.
- **Do** weatherboard-lap horizontal joints at least 6 inches.
- **Do** lap vertical joints 6 to 12 inches (depending on the potential for wind-driven rain).
- **Do** use 1-inch minimum staples or housewrap nails spaced 12 to 18 inches throughout.
- **Do** tape joints with housewrap tape.
- **Do** allow drainage at the bottom of the siding.
- **Do** extend housewrap over the sill plate and foundation joint.
- **Do** install housewrap such that water will never be allowed to flow to the inside of the wrap.
- **Do** avoid complicated details in the design stage to prevent water intrusion problems.
- **Don't** forget to cover the gable ends.
- **Don't** forget to cover the band joists. If you wrap the wall before standing it, go back and insert a strip of house wrap to cover the band joist. The strip should extend 6-12 inches underneath the bottom edge of the wall wrap.
- **Don't** forget to cover outside corners. Do overlap wrap 6 to 12 inches at corners.
- **Do** integrate wrap correctly with window flashing so that wrap goes over top edge of flashing.
- **Don't** rely on caulk or self-sticking tape to "fix" improver lapping of housewrap. Caulk will fail over time.
- When sealant is required:
    - **do** use backing rods as needed,
    - **do** use sealant that is compatible with the climate, and materials it is being applied to,
    - **do** make sure surfaces are clean (free of dirt and loose material).

Window Flashing

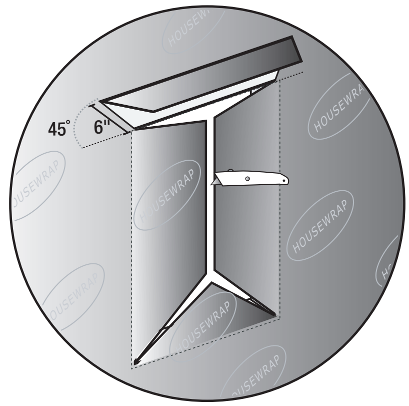
Window flashing details for home with housewrap and plywood or OSB wall sheathing

STEP 1 - IF HOUSEWRAP HAS NOT YET BEEN INSTALLED



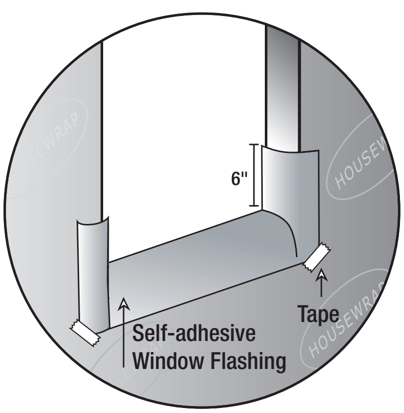
- Apply at least a 12-inch flap, or apron, of building paper or housewrap just below the window sill.
- If the window sill is close to the sill plate, the apron can extend all the way to the sill plate.
- The apron should extend at least 10 inches past the sides of the window opening, or to the first stud in open wall construction.
- Attach only the apron's top edge with cap nails.

STEP 1 - IF HOUSEWRAP HAS BEEN INSTALLED



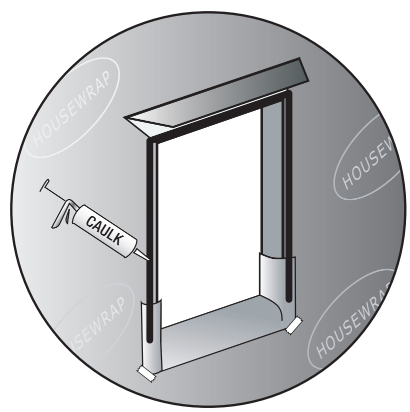
- Cut the housewrap covering the rough opening in the shape of a modified "Y."
- Fold the side and bottom flaps into the window opening and secure.
- Above the window opening, cut a head flap and flip up to expose sheathing, and loosely tape in place out of the way.

STEP 2 - SILL FLASHING



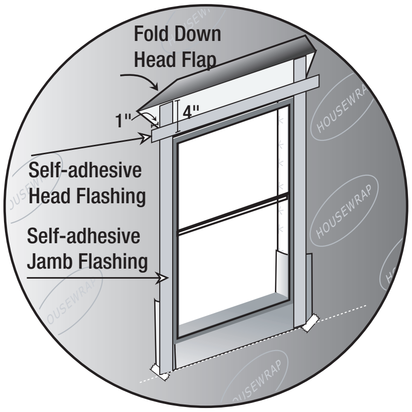
- Install self-adhesive flashing to the sill, ensuring that flashing extends up jambs at least 6 inches.
- One commercial product comes with two removable strips over the adhesive. Remove the first strip to expose half the adhesive and apply this area to the sill. Begin pressing in the middle of the 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



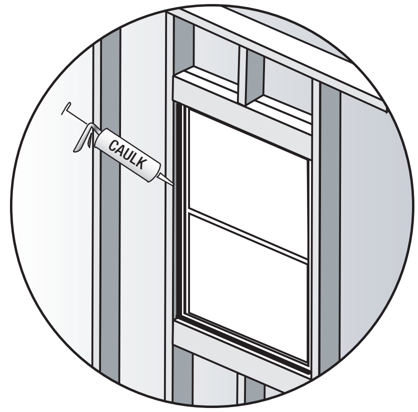
- Caulk the outside edges of the head and side jambs.
- Do not caulk across the sill.
- Install the window using corrosion-resistant nails and following manufacturer's specifications.

STEP 4 - JAMB AND HEAD FLASHING



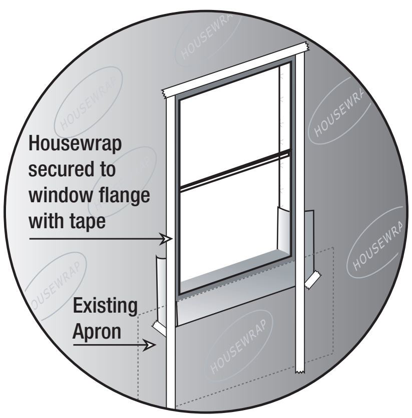
- Install self-adhesive jamb flashing extending 4 inches above the top of the head flange and even with the bottom of the sill flashing.
- Install self-adhesive head flashing extending 1 inch beyond the jamb flashing.
- If housewrap has been installed, be sure that the head flap, when it is folded down, will cover the top of the flashing.

STEP 5 - SEAL ROUGH OPENING GAP



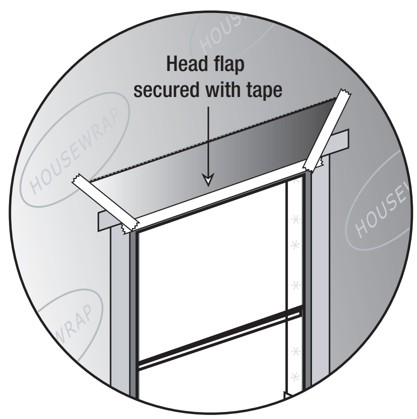
- On the interior side of the window, seal gap between the window and the rough opening with backer rod or non-expanding foam and caulk.

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

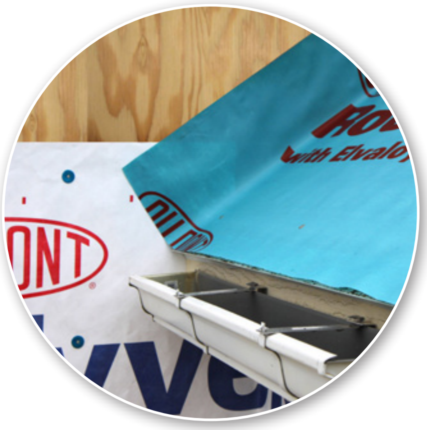


- If headflap was created, fold it over the head flashing and tape across the top window flange and the 45° angle seams.

Wall-to-Roof Flashing

Kick-Out Diverter Flashing Details

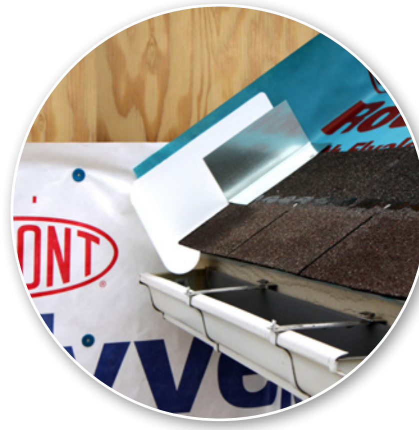
Water runoff from roof-wall intersections can flow down the exterior wall and eventually find its way into the wall where it can cause serious damage. Anywhere roof sections adjoin wall sections, kickout flashing should be used to divert water away from the walls and preferably into rain gutters where it can be carried down and away from the structure.



STEP 1 Apply drip edge and roof underlayment over roof deck continue lapping up the sidewall and over the weather-resistive barrier (in this case housewrap) a minimum of 6 inches.

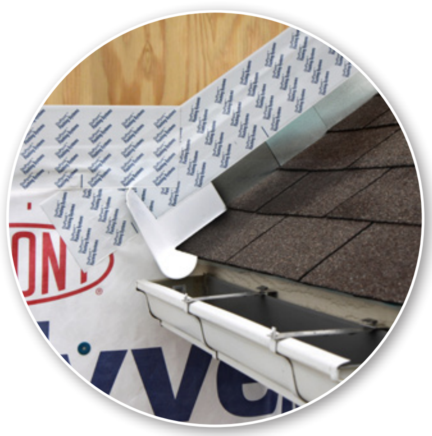
STEP 2 Install shingle starter strip at roof eave in accordance with roofing manufacturer's instructions.

- Place seamless one piece non-corrosive kick-out diverter flashing as the first piece of step flashing.
- Slide kick-out diverter up roof plane until the starter trough stops at the shingle starter strip.
- Diverter must be flat on the roof and flush to the sidewall.
- Fasten and seal diverter to the roof deck and starter strip. (Do not fasten to the sidewall.)



STEP 3 Place first shingle and next section of sidewall flashing over up-slope edge of diverter, lapping a minimum of 4 inches over diverter. (Sidewall flashing height requirement should be determined by design professional and local building codes.)

STEP 4 Install remaining sidewall flashing, appropriate counter flashing and shingles in accordance with manufacturer's instructions.



STEP 5 Apply self adhesive flashing over top of wall flashing and diverter and WRB.

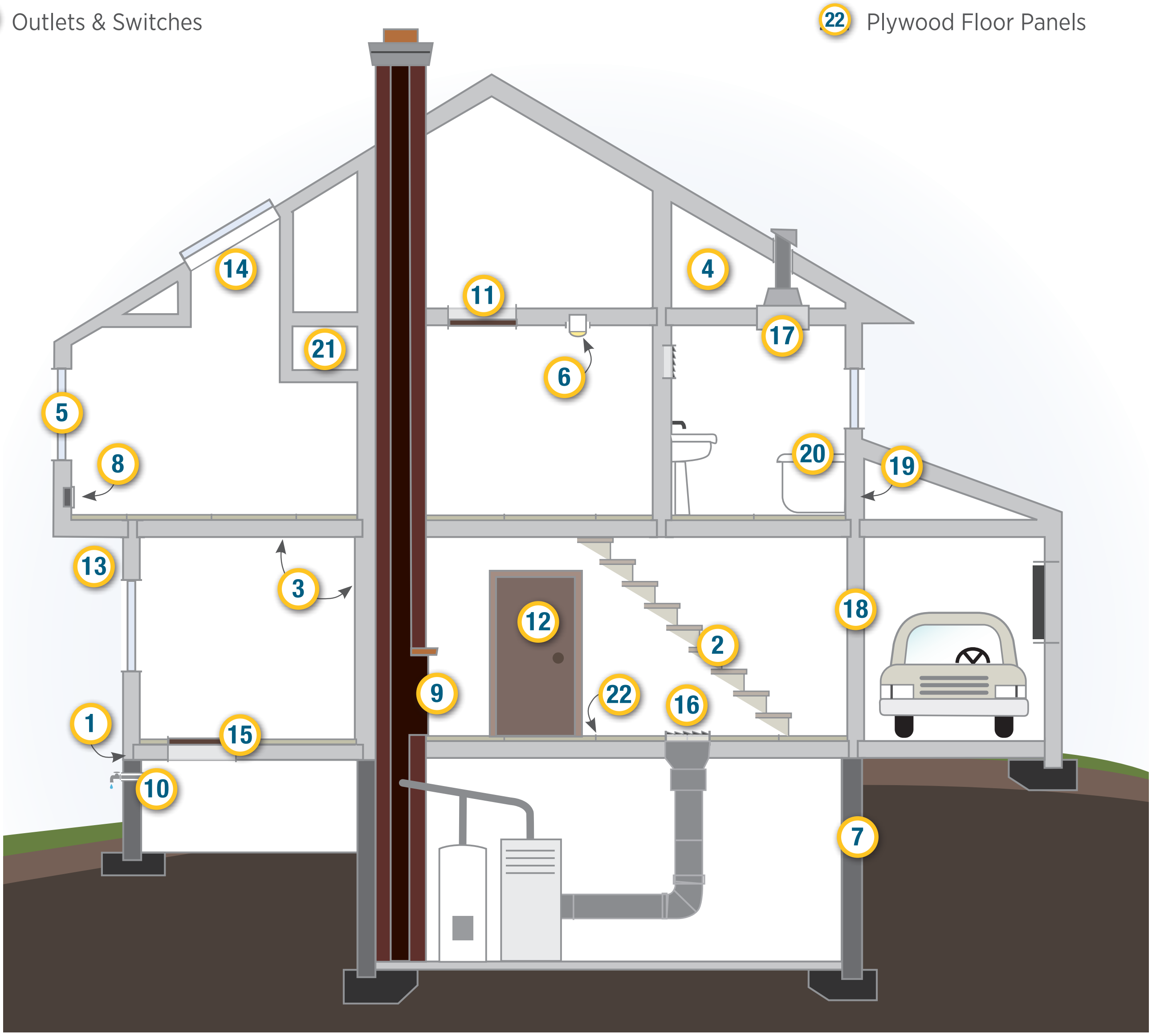
STEP 6 Install house wrap, cut the house wrap to fit over the self adhesive flashing and sidewall flashing.

STEP 7 Apply siding over house wrap.

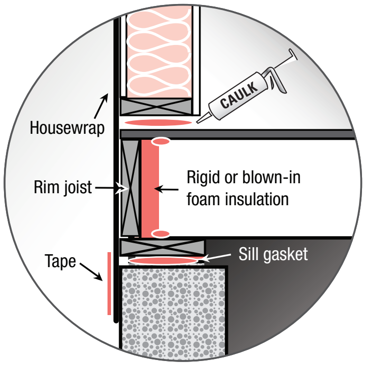
Interior Air Sealing

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



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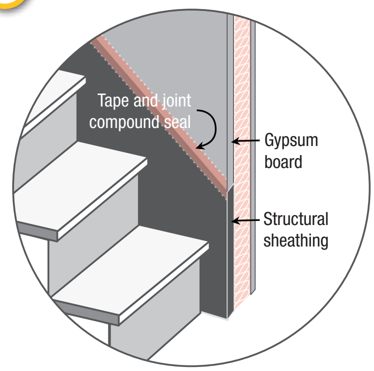
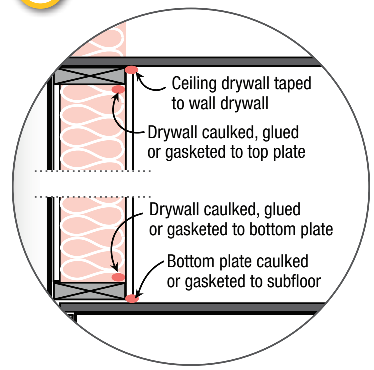
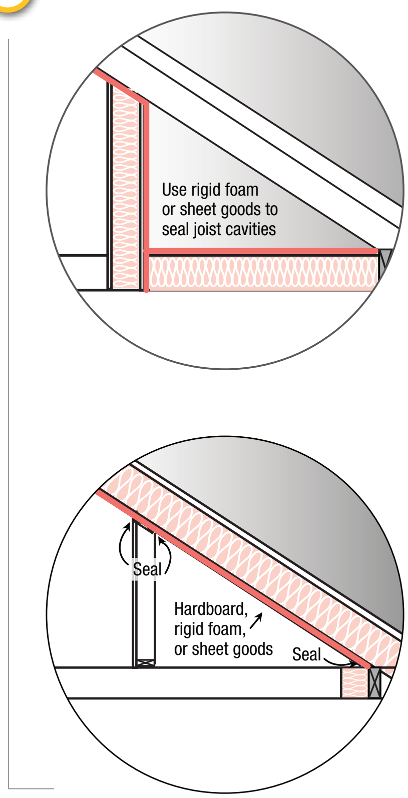


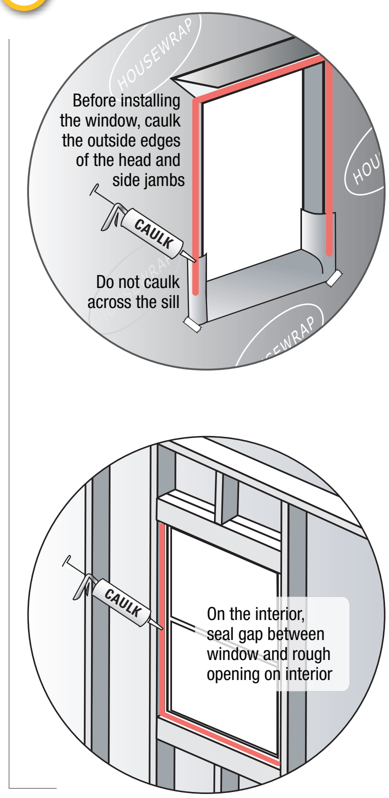
3 Wall & Ceiling Drywall



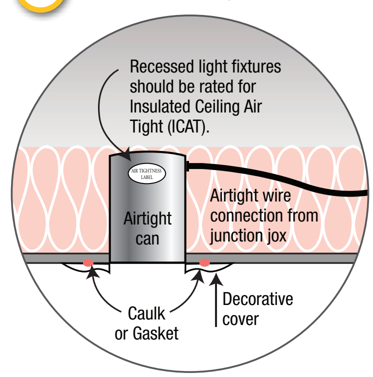
4 Kneewalls



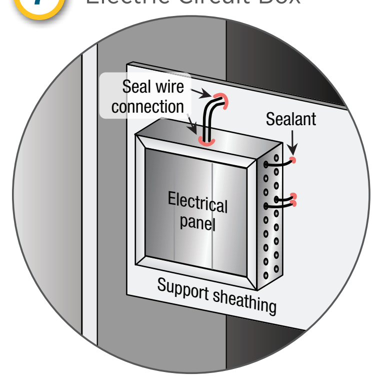
5 Windows



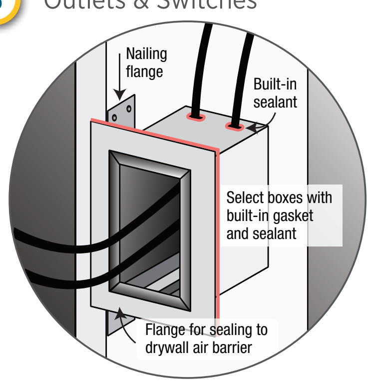
6 ICAT Can Light



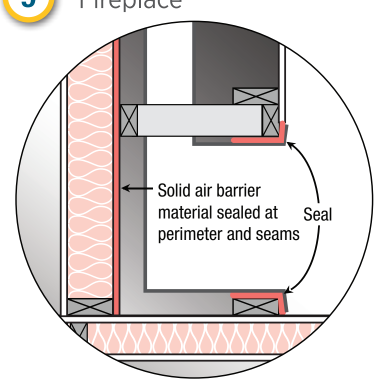
7 Electric Circuit Box



8 Outlets & Switches

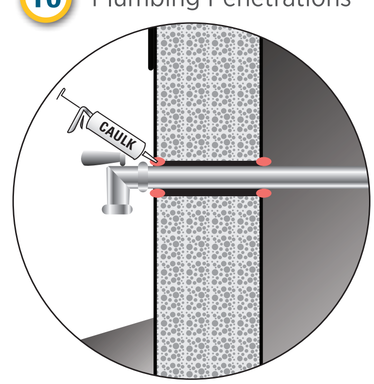


9 Fireplace

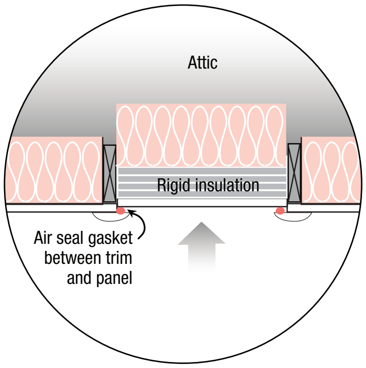


Direct vent fireplace eliminates the chimney;
but seal fireplace alcove

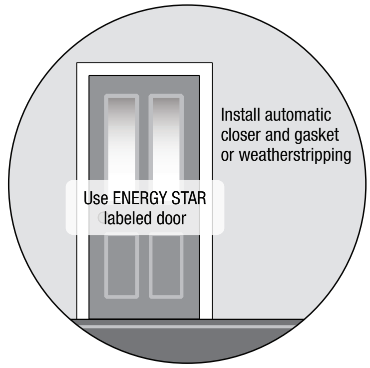
10 Plumbing Penetrations



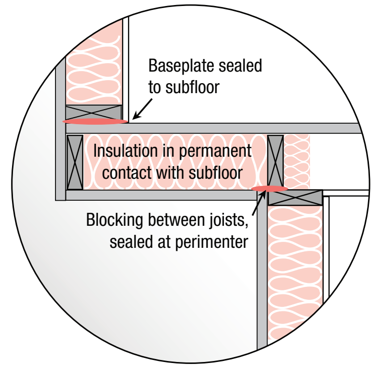
11 Attic Access



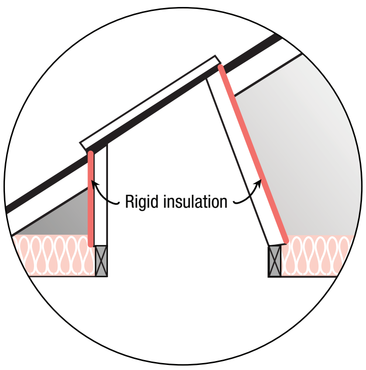
12 Doors



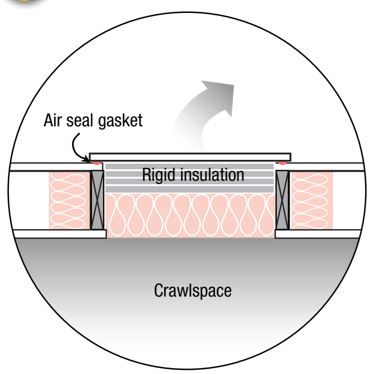
13 Cantilever



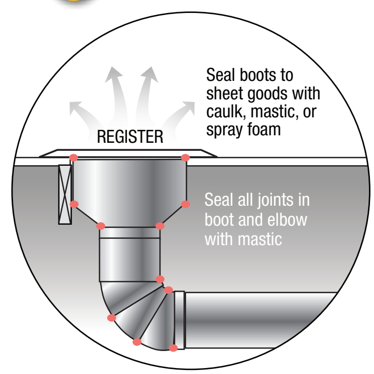
14 Skylight



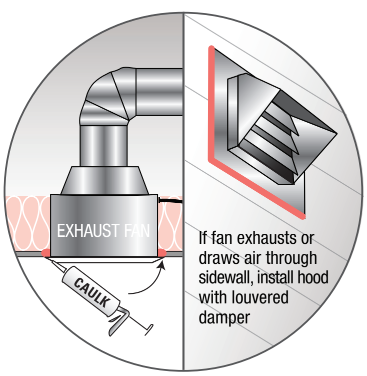
15 Crawlspace Access



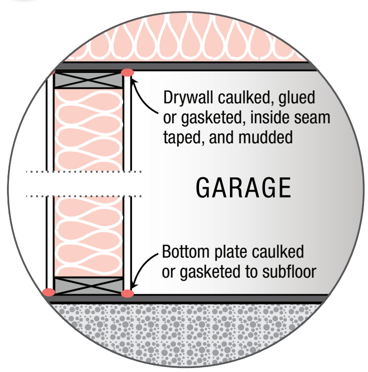
16 Registers



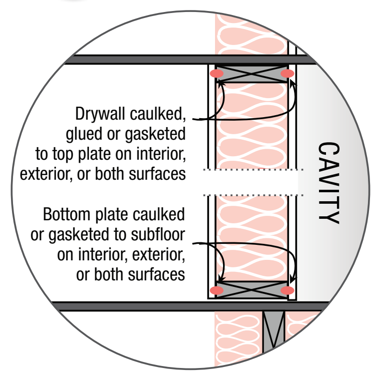
17 Exhaust Fan



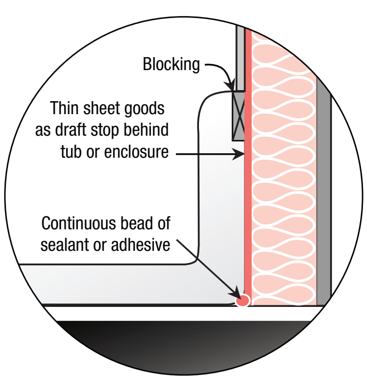
18 Garage Common Wall



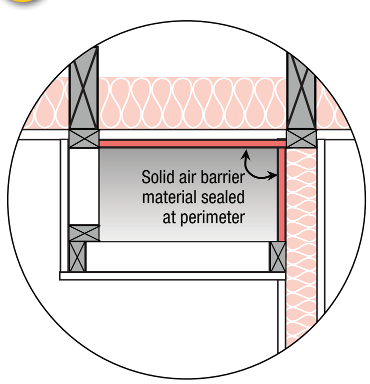
19 Wall Adjoining Cavity



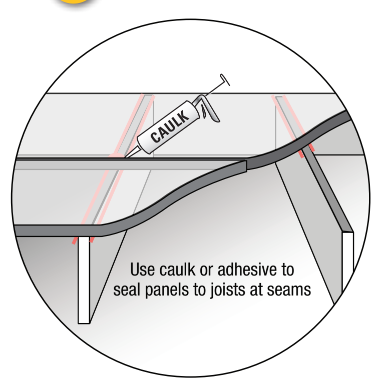
20 Tub



21 Interior Soffit



22 Plywood Floor Panels



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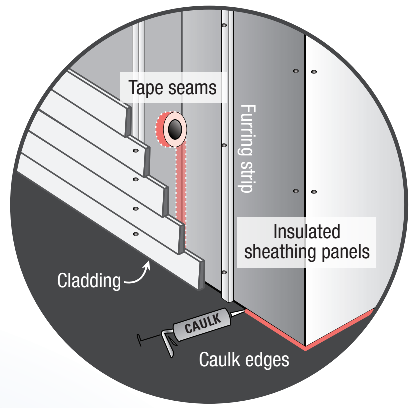
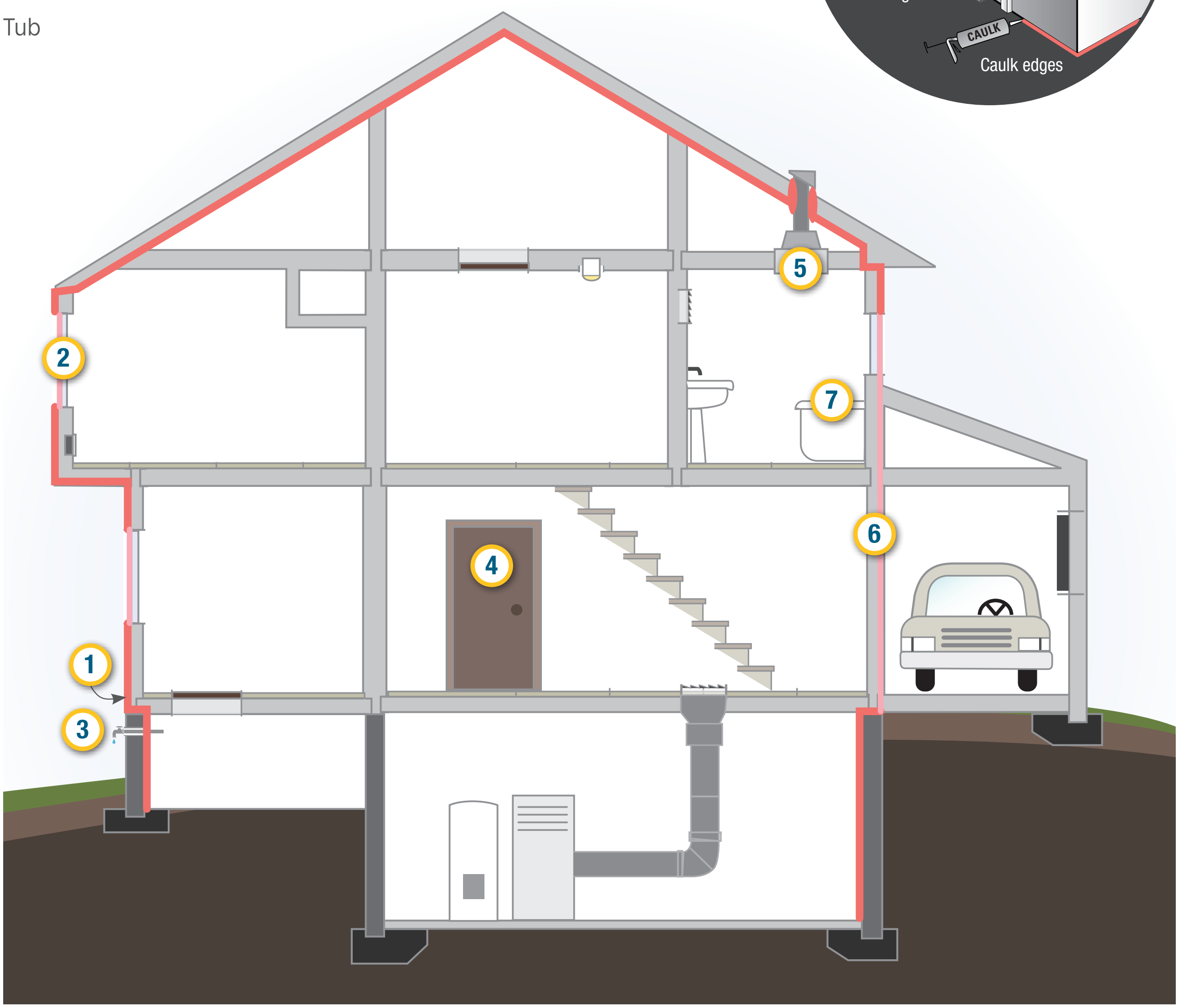
Exterior Air Sealing with Insulating Sheathing Panels

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.

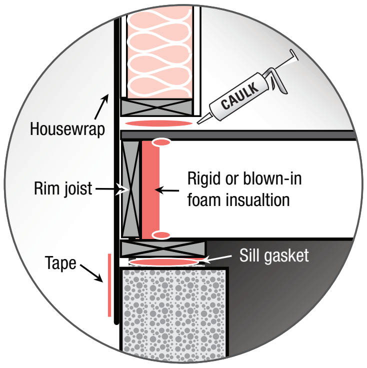
1. Sillplate & Rim Joist
2. Windows
3. Plumbing Penetrations
4. Doors
5. Exhaust Fan
6. Garage Common Wall
7. Tub

Insulating Sheathing Detail

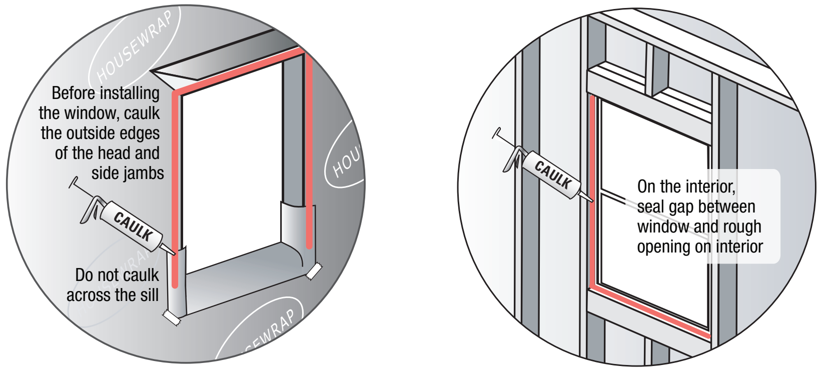




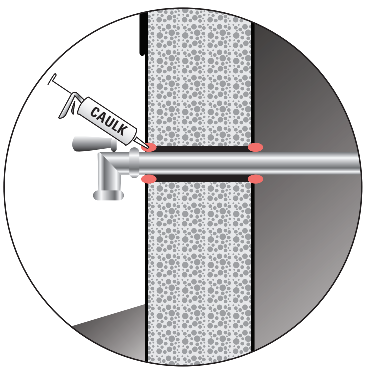
1 Sill Plate & Rim Joist



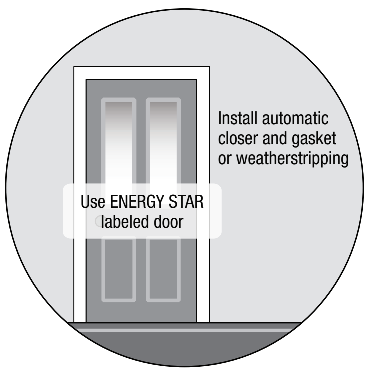
2 Windows



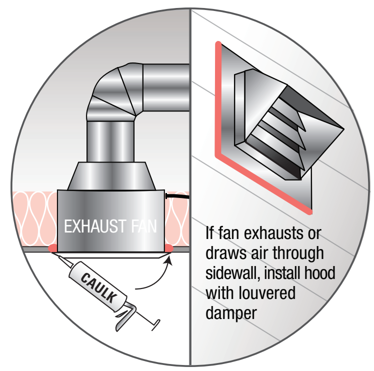
3 Plumbing Penetrations



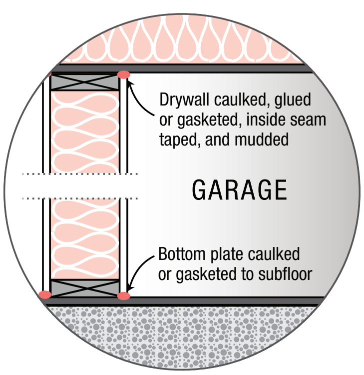
4 Doors



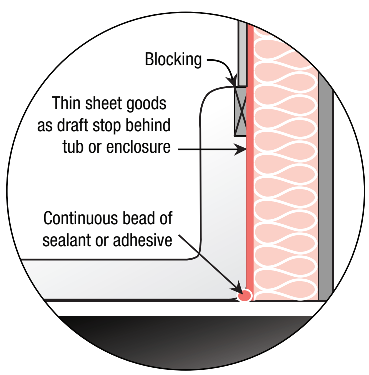
5 Exhaust Fan



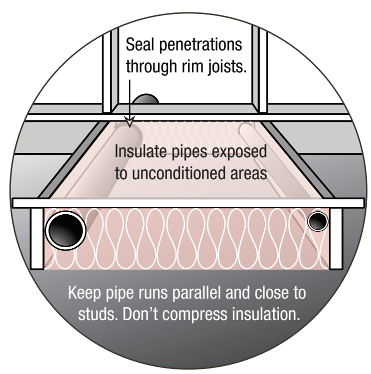
6 Garage Common Wall



7 Tub

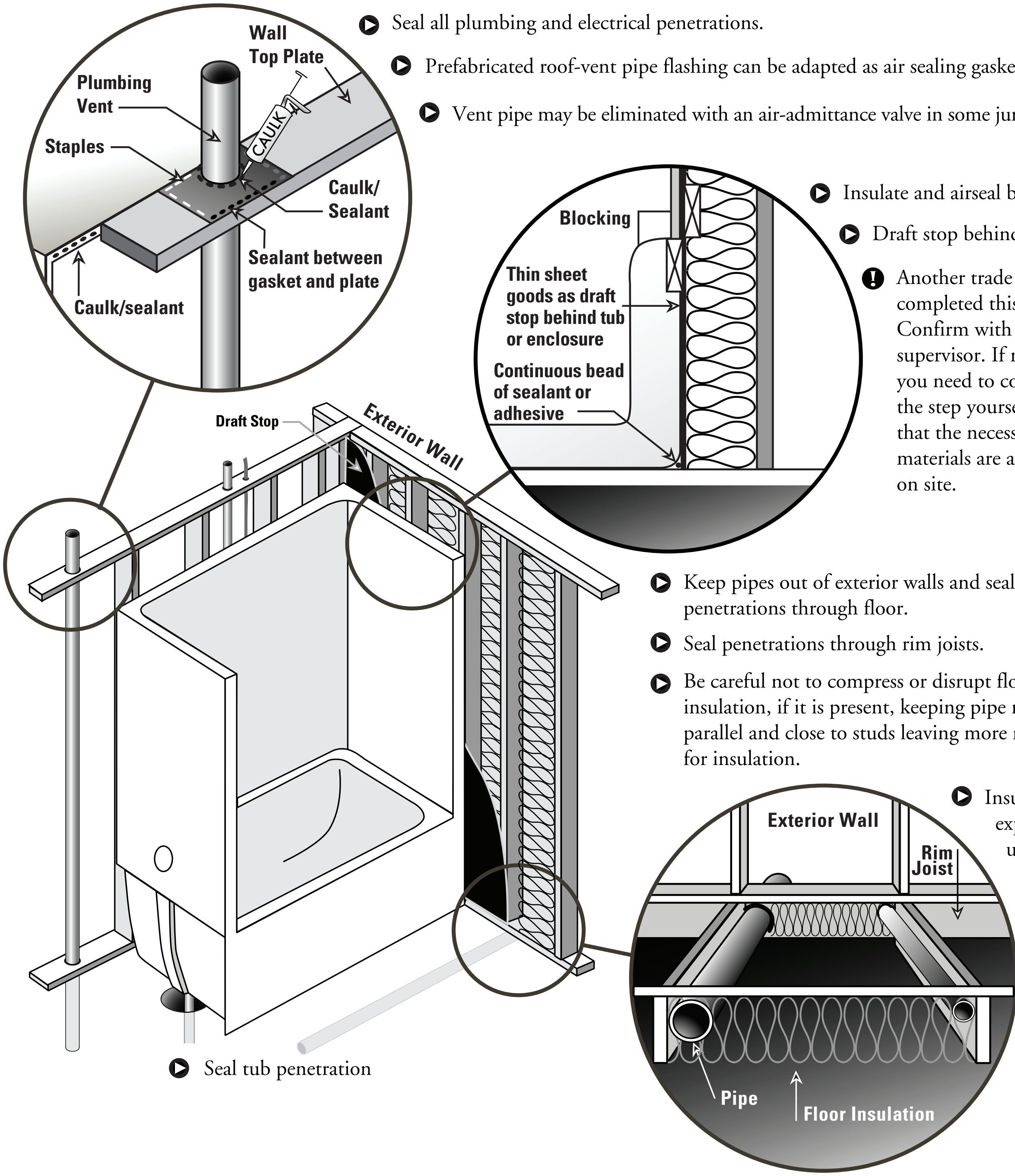


Plumbing Floor Penetrations



Keep pipes out of exterior walls and seal penetrations through floor.

Plumbing Air Sealing



- Seal all plumbing and electrical penetrations.
- Prefabricated roof-vent pipe flashing can be adapted as air sealing gaskets.
- Vent pipe may be eliminated with an air-admittance valve in some jurisdictions.
- Insulate and airseal behind tub.
- Draft stop behind enclosure.
- ! Another trade may have completed this step. Confirm with the site supervisor. If not, and you need to complete the step yourself, ensure that the necessary materials are available on site.
- Keep pipes out of exterior walls and seal penetrations through floor.
- Seal penetrations through rim joists.
- Be careful not to compress or disrupt floor insulation, if it is present, keeping pipe runs parallel and close to studs leaving more room for insulation.
- Insulate pipes exposed to unconditioned areas
- Seal tub penetration

Sources & Additional Information

Lstiburek, J. W. 2000. *Builders Guides*. Minneapolis, MN. Energy and Environmental Building Association. www.eeba.org.

U.S. DOE *Technology Fact Sheet on Air Sealing* (www.eere.energy.gov/buildings/documents/pdfs/26448.pdf).

www.toolbase.org: click on *New Building Technology > Plumbing > Distribution Systems > Air Admittance Vents*

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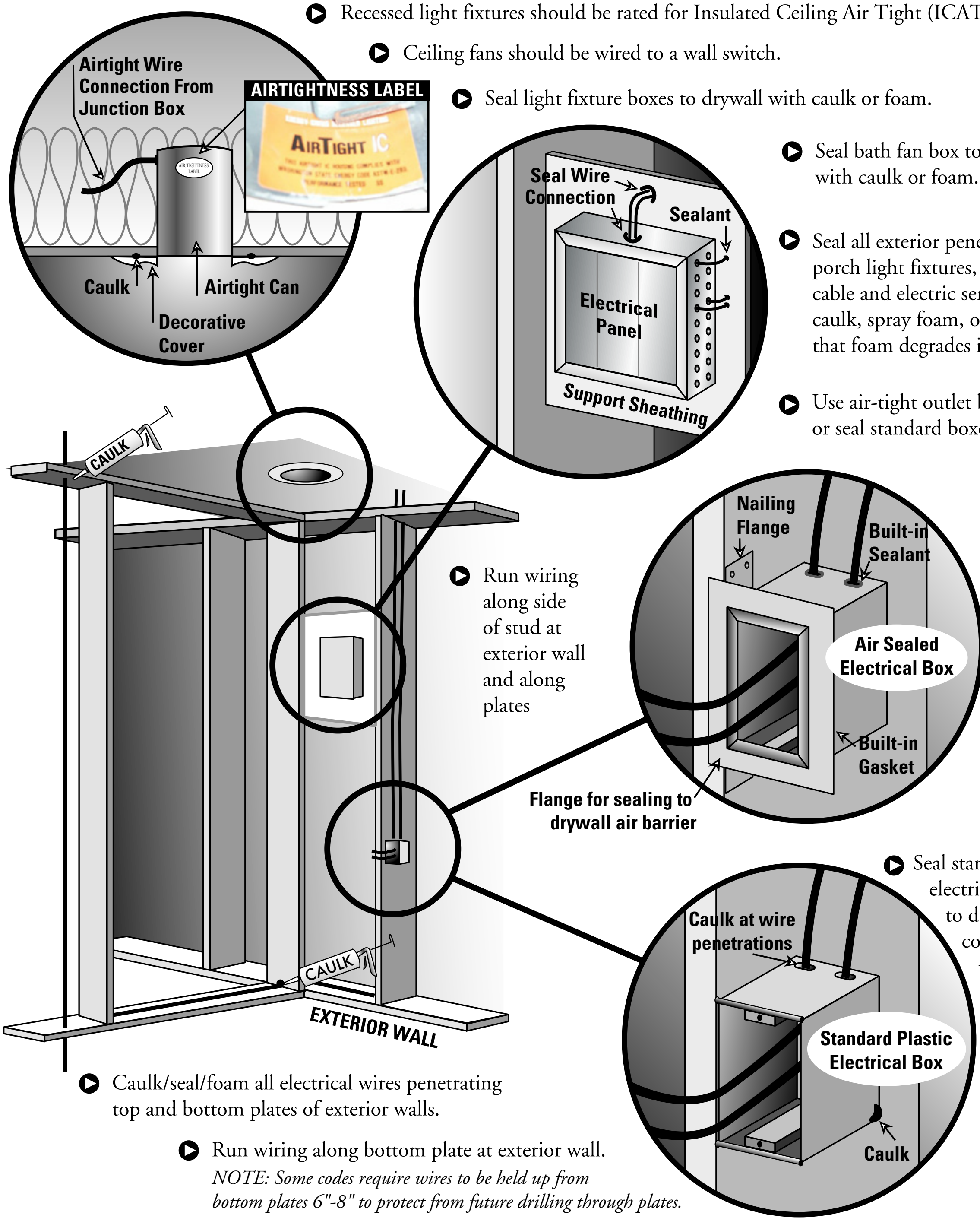
Electrical Air Sealing

- Recessed light fixtures should be rated for Insulated Ceiling Air Tight (ICAT).
- Ceiling fans should be wired to a wall switch.
- Seal light fixture boxes to drywall with caulk or foam.
- Seal bath fan box to drywall with caulk or foam.
- Seal all exterior penetrations, such as porch light fixtures, phone, security, cable and electric service holes, with caulk, spray foam, or gaskets - note that foam degrades in sunlight.
- Use air-tight outlet boxes or seal standard boxes.
- Run wiring along side of stud at exterior wall and along plates
- Seal standard plastic electrical box at face to drywall with joint compound or cover the plate gasket with caulked foam.
- Caulk/seal/foam all electrical wires penetrating top and bottom plates of exterior walls.
- Run wiring along bottom plate at exterior wall.
  NOTE: Some codes require wires to be held up from bottom plates 6"-8" to protect from future drilling through plates.



Sources & Additional Information

Lstiburek, J.W. 2000. *Builder Guide Hot-Humid Climates*. Minneapolis, MN: Energy and Environmental Building Association (ww.eeba.org).

U.S. DOE. *Technology Fact Sheet on Air Sealing* (www.eere.energy.gov/buildings/documents/pdfs/26448.pdf).

See also *Air Sealing Building Tips* in the chapter.

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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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Installing Windows in Walls with External Rigid Foam Insulation

Installing rigid foam insulation on exterior walls reduces thermal bridging and may reduce the chance of condensation in wall cavities. Many cold-climate builders now install 4 or 6 inches of EPS, XPS, or polyisocyanuarate rigid insulation on exterior walls.

Innies or Outies?

Builders installing thick exterior wall foam can install windows two ways: with the window flanges in the same plane as the back of the siding or with the window flanges in the same plane as the OSB or plywood wall sheathing.

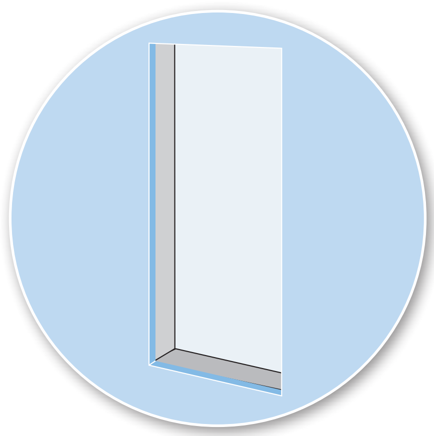
The following apply to any window installation:

1. Foam panels should be installed with windows in mind—windows should not be installed where there is a seam in the foam sheathing, even if the foam is taped.
2. Water management details should specify that flashing around the perimeter of the window must tie into a water resistive barrier regardless of the approach taken.
3. Ensure that foam sheathing does not bear the weight of the window. The weight of the window should be supported by the wall frame.

Interior Ledge Window Installations:

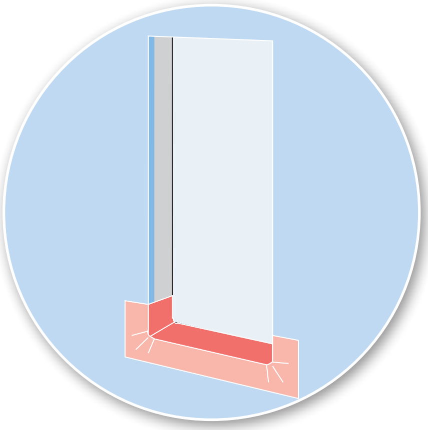
STEP 1 Rough in window openings, oversizing by 1 ½ inches in both dimensions.

STEP 2 Line rough opening with a frame made of plywood strips ¾" thick by wall dimension + ¾" (the plywood should be flush on the interior surface and extend ¾" beyond the outside face of the foam).

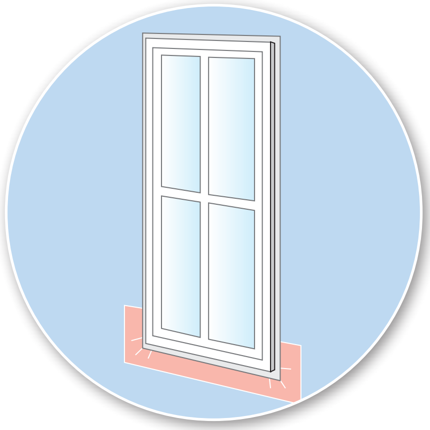


STEP 3 Once the exterior foam is installed, a frame of ¾" strapping, fastened flat to the foam, is installed around each plywood window projection. The outer face of the strapping should be flush with the outer edge of the plywood frame.

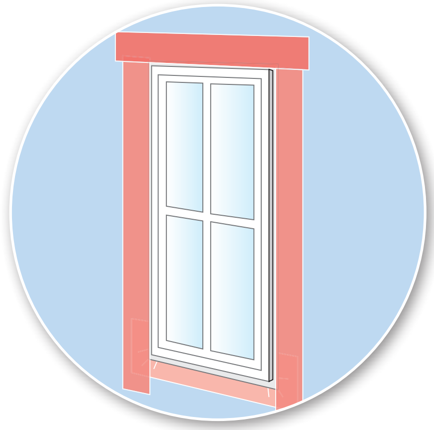
Interior Ledge Window Installations - *Continued*



STEP 4 Flash the bottom of the plywood box with peel and stick flashing.



STEP 5 Install windows in the plywood frames. Attach through the plywood frame to the wall studs with metal masonry clips.



STEP 6 Install peel and stick flashing on the top and sides of the window, covering the window flanges and extending back to the foam.

STEP 7 Install housewrap over the foam. The housewrap laps over the peel-and-stick flashing shingle style. At the bottom of the window frame, peel-and-stick flashing laps over the housewrap.

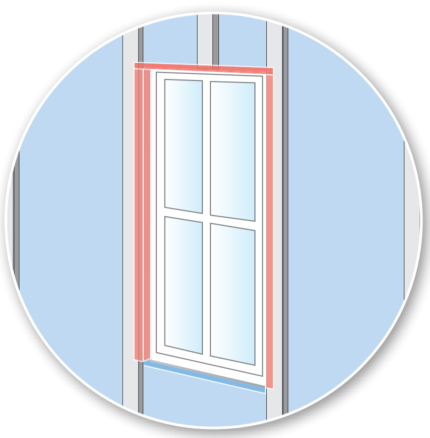
STEP 8 Install vertical wood strapping on top of the foam and housewrap to use when attaching siding.

Exterior Ledge Windows Installations:

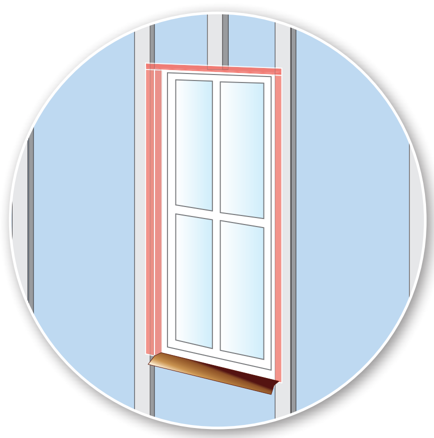
STEP 1 Install housewrap over OSB sheathing.

STEP 2 Install windows with flanges on top of OSB sheathing, integrating the housewrap with the window flashing.

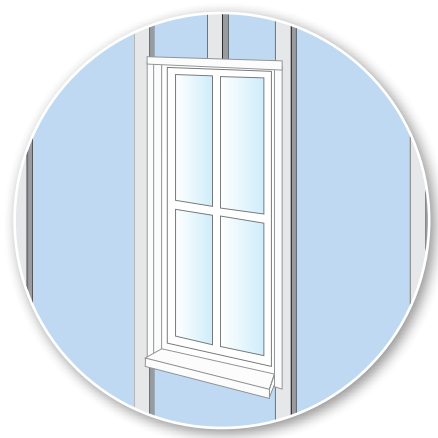
STEP 3 Install exterior foam on top of the housewrap.



STEP 4 Install vertical strapping on top of the foam.



STEP 5 Cut exposed foam under the window sloping outward and protect with copper flashing.



STEP 7 Trim out exterior of the window with water-resistant jamb extensions made of cedar or cellular PVC.

Sources & Additional Information

www.greenbuildingadvisor.com/blogs/dept/musings/innie-windows-or-outie-windows

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Duct Location – Dropped Ceiling Soffit

Ducts can be placed in a dropped ceiling soffit to keep them in conditioned space.

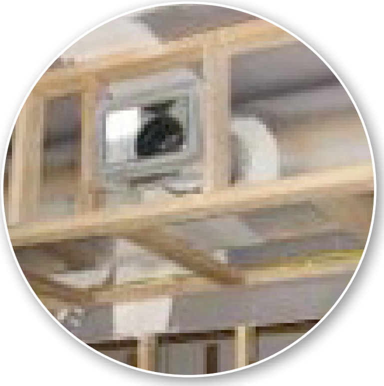
STEP 1 Use Manual J to determine appropriate HVAC size.

STEP 2 Design duct layout plan emphasizing compact layout with inside wall throws and air handler located in conditioned space. For cost savings consider using transoms over doors and one central return instead of ducted returns.

STEP 3 Hold meeting at home site after dry-in with designer, HVAC, framer, sheetrock and other pertinent trades to discuss approach, if this is a new method.

STEP 4 Install sheet rock above chase. One method is to keep top plate of non-load bearing interior walls ¾" from bottom cord of roof trusses. Slip drywall in this space.

STEP 5 Fabricate and seal drywall on the ground. Use hard ducts wherever possible. Fabricate a duct board box affixed to trunk line to serve as supply boot.



Original method

Improved method

After framing

Supply boot comes directly from main trunk, as shown in "improved method" rather than connecting boot to trunk with a length of flex duct, as shown in original method. Thus duct chase can be narrower.

STEP 6 Hang duct from the drywall using 2" nylon strapping material.

Hard Duct

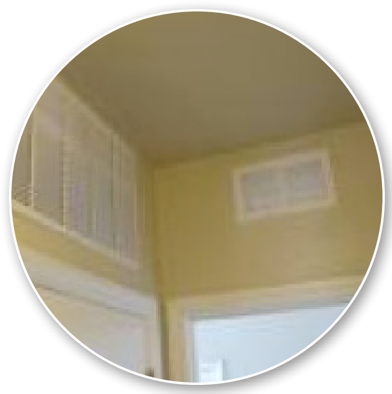
Hard ductwork is used wherever possible.

Flex Duct

STEP 7 Install sheetrock around ducts to form chase, when sheetrocking the rest of the house (this is the second visit for sheetrockers).

Ducts are enclosed in soffits that add architectural interest to finished rooms.

STEP 8 Install air handler in conditioned space in interior closet with large return air grill located over air handler. Use transoms over bedroom doors for return air path.



Air handler is located in the home in a closet with return grill above. Transoms over interior doors provide a return air path.

Fonorow, Ken, Dave Jenkins, Stephanie Thomas-Rees, and Subrato Chandra. 2010. "Low Cost Interior Duct Systems for High Performance Homes in Hot Climates," *Proceedings of the 2010 ACEEE Summer Study on Energy Efficiency in Buildings*, Pacific Grove, CA, http://www.aceee.org/conf/10ss/index.htm

Duct Location – In Open Web Floor Trusses Betweeen Floors

Ducts can be placed in open web trusses between floors to keep them in conditioned space.

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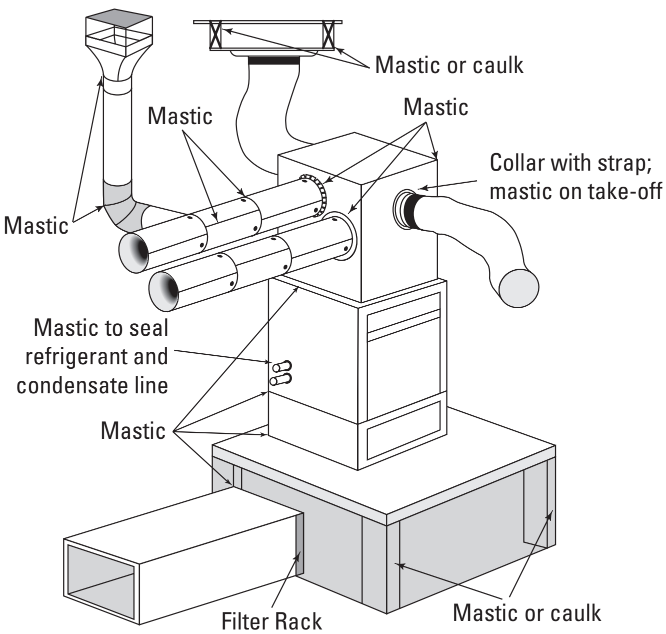
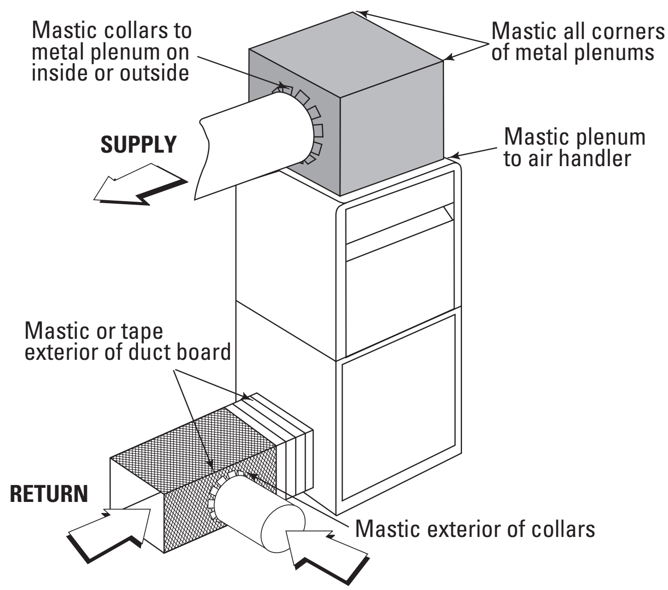
Air Handler and Duct Sealing

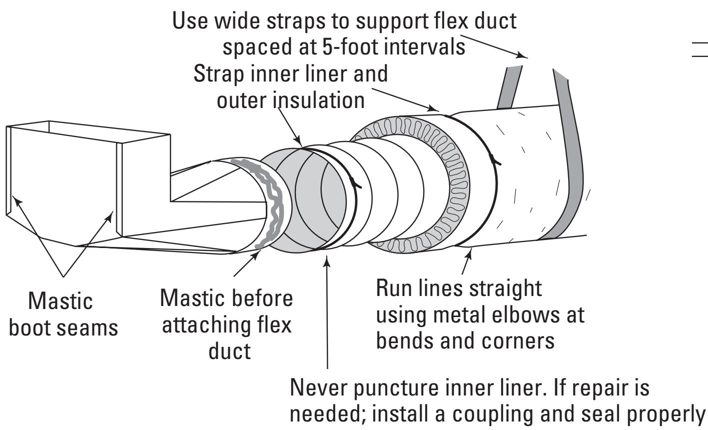
AIR HANDLER



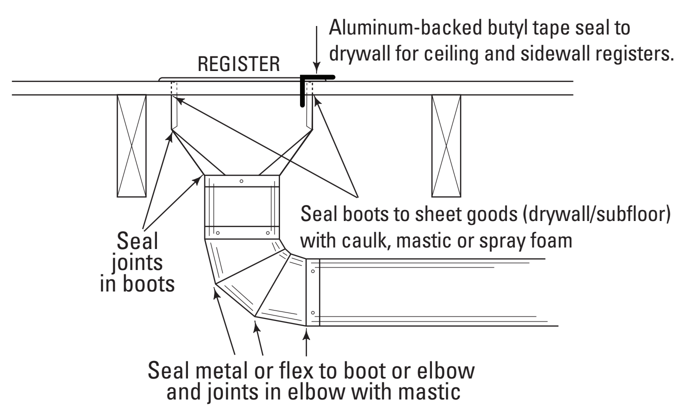
SUPPLY AND RETURN PLENUMS



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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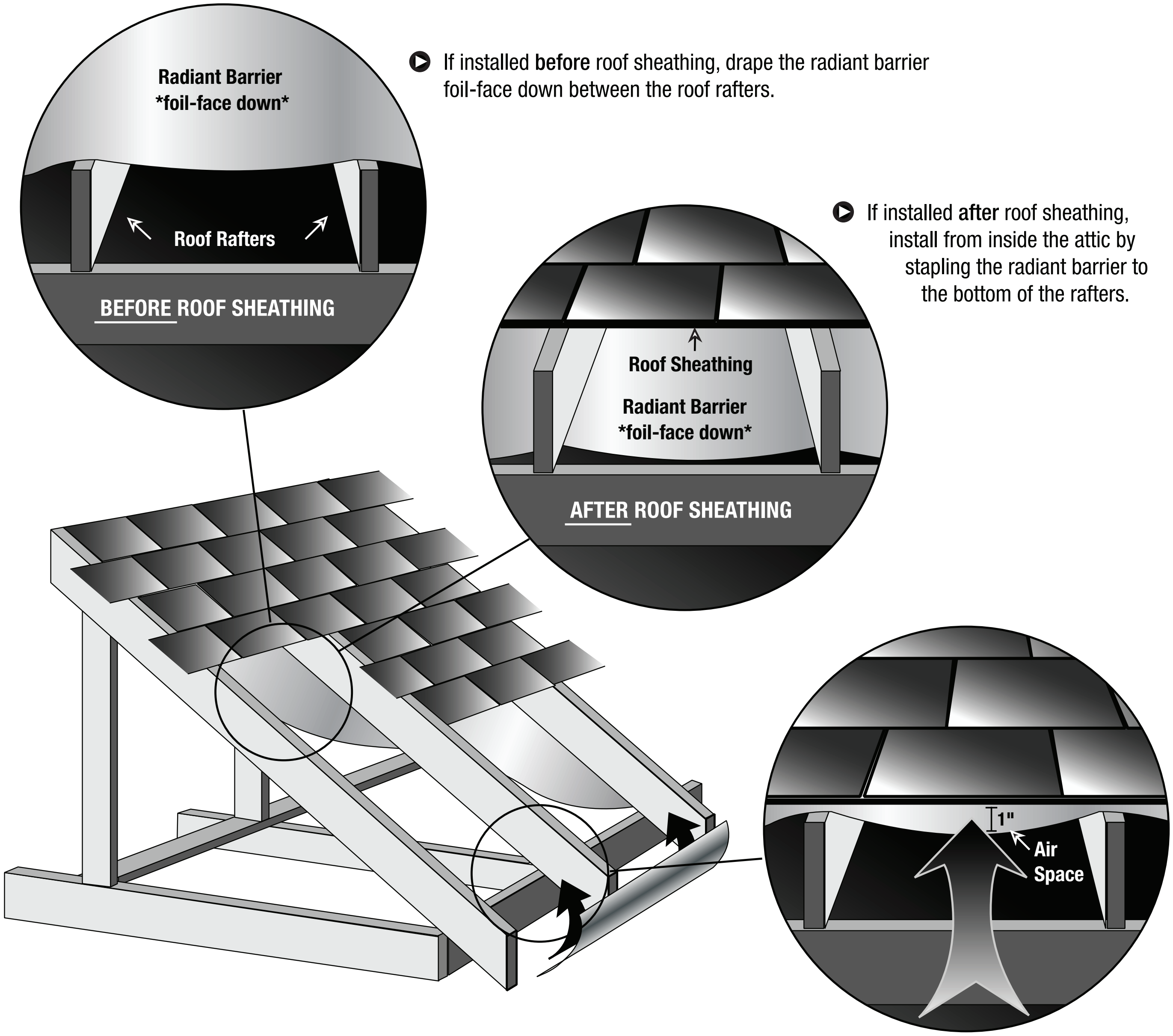
Radiant Barriers

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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40% Whole-House Energy Savings in the Marine Climate

Case Studies

Several builders are building energy-efficient homes in the marine climates. The following case studies showcase four of these builders. The energy-efficient measures they incorporate in their homes are summarized in the table below.

Table 1. Summary of Energy-Efficiency Measures Incorporated in Case Study Homes in the Marine Climate

Measure	New Tradition Homes Vancouver, WA	Quadrant Homes Bellevue, WA	Schneider Homes Tukwila (Seattle), WA	Tom Walsh & Co. Portland, OR
HERS	65	68	66-68	65-66
Walls	2x6 16-inch on-center	2x6 16-inch on-center	2x6 16-inch on-center	2x6 24-inch on-center
Wall Insulation	R-21 GreenGuard-certified EcoBatt wall insulation	R-21 batts	R-23 formaldehyde-free, blown-in fiberglass insulation (BIBs)	R-21 batts within 5/8-inch drywall
Attic Insulation	R-49 blown-in cellulose	R-49 blown-in cellulose	R-38 to R-42 blown-in cellulose	R-49 blown-in cellulose
Radiant Barrier	No	No	No	No
Foundation Insulation	Slab-on-grade	Vented crawlspace with R-30 batts in the floor joists	R-10 foam perimeter insulation	Vented crawlspace with R-38 fiberglass batts in the floor joists
Ducts	In conditioned space	In conditioned space within open-web trusses between the 1st and 2nd stories	In conditioned space within open-web trusses between the 1st and 2nd stories	In conditioned space within open-web trusses between the 1st and 2nd stories
Air Handler	In sealed utility closet in house or garage	In a 2nd floor sealed utility closet	In a sealed utility closet in the garage	In sealed utility closet

Measure	New Tradition Homes Vancouver, WA	Quadrant Homes Bellevue, WA	Schneider Homes Tukwila (Seattle), WA	Tom Walsh & Co. Portland, OR
Air Sealing	Per ENERGY STAR Thermal Bypass Checklist	All envelope penetrations	Gaskets, foam sealing, caulking	Gasketing the crawl and attic access hatches, foaming bottom and top plates of walls, and caulking penetrations
HVAC	93% AFUE sealed-combustion gas furnace, SEER 14 AC	94% AFUE gas furnace; SEER-13 air conditioner	92.5% AFUE gas furnace	94% AFUE gas furnace. No AC
Windows	Double-pane, low-e, argon-filled windows, U-0.32+	Double-pane, low-e, vinyl-framed, U-0.29; whole-house glazing area 13.5%	Double-pane, low-e, vinyl framed, U-0.34; 0.35 SHGC; whole-house glazing area 15%	Double-pane, low-e, vinyl-framed, U-0.29; whole-house glazing area 14.1%.
Water Heating	61% energy-efficient gas, tank	62% energy-efficient gas, tank	80% energy-efficient tankless gas, with some replaced to 40-gallon 63% gas	62% energy-efficient gas, tank
Ventilation	Fresh air intake ducted to air handler return	100% ASHRAE 62.2; upgraded bathroom exhaust	Mechanical upgraded bathroom exhaust	Upgraded bathroom exhaust only, trickle vents over windows
Green	Low VOC paints, GreenGuard certified laminate countertops, recycled content roofing and fly-ash concrete	3-Star Built Green™ Certified (Kentlake Highlands)	Many homes certified 3-Star Built Green™	Pre-finished, tongue and groove bamboo flooring; low- and no-VOC adhesives and finishes; no urea-formaldehyde
Lighting and Appliances	ENERGY STAR refrigerators, dishwashers, and clothes washers; 100% hardwired CFL lighting	Hardwired 50% CFLs, optional ENERGY STAR refrigerator, dishwasher, and clothes dryer	80% CFLs; ENERGY STAR refrigerator, dishwasher, and clothes washer	100% CFLs and ENERGY STAR refrigerator, dishwashers, and clothes washer
Solar	No	No	No	No
Verify	3rd party HERS rater duct and blower door test on one of every three houses	Testing for Northwest ENERGY STAR certification	Testing for Northwest ENERGY STAR certification	Testing for Northwest ENERGY STAR certification

Building America Best Practices Series

Builders Challenge Guide to 40% Whole-House Energy Savings in the Marine Climate

Case Study: New Tradition Homes

Landover Commons | Vancouver, WA

Despite the slow economy, New Tradition Homes is one of only a handful of builders who continued to build and sell new homes in southwest Washington during the recession thanks to energy-efficient design changes made with help from Building America's Building Industry Research Alliance.

BUILDER PROFILE

Builder's Name: New Tradition Homes

Where: Vancouver, Washington

Founded: 1988

Employees: approx. 25 (without subs)

Size: 6,000 homes since 1988

Square Footage: two-story, three-bedroom, 1,625 to 2,304 sq. ft.

Development: Landover Commons, Vancouver, WA, 94 units

Price Range: $180,000 - $399,000 (fall 2009 prices)

Energy Efficient Commitment: All Northwest ENERGY STAR, all Earth Advantage

Building America U.S. Department of Energy

A Culture of Energy Efficiency

The Landover Commons community in Vancouver, Washington, is a great example of production builder New Tradition Home's commitment to keep improving. All 94 homes achieve Northwest ENERGY STAR and the gold level of Earth Advantage (a regional efficiency program). With input from the U.S. Department of Energy's Building America Program, New Tradition has committed to building the newest 13 homes at Landover Commons to even higher levels of efficiency to qualify for the federal tax rebate, which requires heating and cooling energy savings of 50% over the 2004 International Energy Conservation Code.

The Federal Tax Credit homes include ducts and air handlers in conditioned space. One includes a tankless water heater. starting in January 2009, New Tradition committed to including tankless water heaters, 93% efficiency gas furnaces, and 100% CFL lighting in all of its homes in southwest Washington and eastern Washington.

"New Tradition Homes is committed to building energy efficiently, even implementing its own building science team, a step most builders across the nation have yet to take," said Steve Vang of Building America's Building Industry Research Alliance (BIRA) team.

Commitment to Energy Efficiency Nets Builder Regional and National Awards

In both 2007 and 2008, New Tradition Homes won the Regional ENERGY STAR Builder of the Year award, which is given each year to only one builder in the four-state region including Oregon, Washington, Idaho, and Montana. In 2009 New Tradition Homes was recognized with an ENERGY STAR Leadership in Housing Award.

(top) Water conservation features include water-conserving bath faucets, a rain sensor on lawn sprinklers, and native Northwest landscaping. Roofing material contains a minimum 40% recycled content, concrete driveways contain recycled flyash, a recycled byproduct of coal burning, and construction lumber waste is recycled.

(bottom) Locating the ducts and airhandler in conditioned space was a significant step toward increasing the homes' energy performance and indoor air quality. New Tradition installed the ducts in a duct chase in a dropped ceiling, shown here before and after drywalling. *(Photo source Mike Lubliner, WSU Energy Office)*

Energy Efficiency, Comfort, Health, and Sustainability

New Tradition began working with DOE's Building America program in 2004. In January 2005 New Tradition Homes joined the Earth Advantage program and began building all of its homes in southwest Washington to their green and high performance standards. In 2006 New Tradition became the first southwest Washington builder to commit to making all of its homes to Northwest ENERGY STAR. Since 2005 it has certified more than 950 Earth Advantage homes and 500 ENERGY STAR homes.

Building America research shows one of the most significant things a builder can do to improve a home's energy performance is to move ducts into conditioned space. Working with Building America and its HVAC contractor, New Tradition has experimented with several ways to incorporate ducts in conditioned space in all its existing home plans including putting ducts in a dropped hallway ceiling chase, running ducts between floors through open-web floor trusses, and framing in ducts in the attic.

"Our goal is to bring all ducts into conditioned space. In this economy that would be a difficult move to make all at once, but we are incrementally working toward that, plan by plan," said Steve Tapio, head of New Traditions' building science team.

Attic insulation was increased over ENERGY STAR homes from R-38 to R-49 blown-in cellulose. The federal tax credit homes have slab-on-grade foundations. New Tradition has also used vented crawlspace foundation, which are common in the northwest. The key is good site drainage and New Tradition excels at site moisture management.

Excavators raise the building site, dig out the crawl, grade it flat, then dig out a sloped trench diagonally across the crawlspace that exits to a low-point drain sleeve with a one-way valve to let water out but not in. This drain sleeve directs the water to an infiltration system (a drywell) or out to the street via a curb cut. Once the sloped trench is dug, 4 to 6 inches of crushed rock are laid over the entire crawlspace and foundation area. Then the concrete footing, stem, and foundation are poured on top of the rock. When the house is complete, 6-mil plastic is laid over the crawlspace ground. A water-proof gasket separates the foundation stem wall from the sill plate. Damp proofing and dimpled plastic drainage sheets are applied to exterior of foundation walls, and a perimeter drainage pipe is laid at the footing. Homes are wrapped with Tyvek Drainwrap that is overlapped shingle fashion and taped at seams to serve as a continuous drainage plane. All wall penetrations are gasketed to prevent water leakage.

Every house comes equipped with a whole house energy usage monitor so homeowners can track their electricity usage and dollars spent in real time. The homes are equipped with ENERGY STAR dishwashers; ENERGY STAR refrigerators and clothes washers are offered. Hard-wired lighting is 100% CFL. The low-emissivity, argon-filled double-pane windows have a U value of 0.32 or better. The walls are constructed with 2x6, 16-inch on-center wood-framing and insulated to R-21 with GreenGuard-certified EcoBatt non-offgassing insulation that is properly installed to avoid gaps and voids.

A fresh air intake is ducted to the air handler return air plenum; a timer operates both the air handler and a mechanical damper on the air intake duct to open the damper, drawing fresh air into and through the house on a continuous on-off cycle throughout the day. Additional ventilation is provided by low-sone ENERGY STAR bath and laundry fans. Transfer grilles between rooms balance pressures and encourage air circulation. Other indoor air quality features include a 4-inch high-efficiency air filter on the furnace, the use of only low-VOC paints, and GreenGuard-certified laminate kitchen countertops.

New Tradition's quality management program includes an in-house building science team, a corporate commitment to energy efficiency, ongoing training of staff, participation in federal and regional energy-efficiency programs, hiring a dedicated air sealing contractor, third-party performance testing, consumer research, and an ongoing interactive relationship with an HVAC contractor interested in high quality. New Tradition uses a trained and certified home weatherization contractor whose only responsibility is caulking and sealing everything not sealed by the other trades. All wall penetrations are sealed per the ENERGY STAR Thermal Bypass Checklist.

Dollars and Sense

As calculated by BIRA, Table 1 shows the energy savings New Tradition achieved in its 2,264-square-foot house compared to a house built to the Building America benchmark (MEC 1993) and a house built to the Washington state code for 2006. The New Tradition home achieved calculated energy savings of 44.1% over the Building America benchmark.

As shown in Table 1, even with $3,635 in increased builder costs, annual energy cost savings are sizable enough to offset increased mortgage costs, resulting in an annual net positive cash flow to the home buyer of $700 per year, not including any federal or local tax rebates or incentives.

New Tradition's own survey of local realtors found 9 out of 10 reporting that homebuyers are inquiring about the energy-efficient features of a home before they buy. The incentive to choose an energy-efficient home is made even stronger when home buyers can be shown that the investment would actually put them dollars ahead of a standard home purchase.

Key Features

- Air handler in sealed utility closet
- Ducts in conditioned space
- SEER 14 AC
- 93% efficient sealed-combustion gas furnaces
- Dedicated weatherization contractor for caulking and sealing
- Third party duct blaster and blower door testing on one of every three homes
- Meets Northwest ENERGY STAR and Earth Advantage criteria
- Air sealing per ENERGY STAR Thermal Bypass Checklist
- ENERGY STAR low-emissivity, argon-filled double-pane windows U-0.32
- Tankless gas water heaters
- Whole House Energy Usage Monitor that tracks electricity usage and dollars spent in real-time
- R-21 GreenGuard-certified EcoBatt wall insulation
- R-49 blown-in cellulose attic insulation
- ENERGY STAR refrigerators, dishwashers, and clothes washers
- 100% hardwired CFL lighting
- Fresh air intake ducted to airhandler return
- Low-sone ENERGY STAR bath and laundry fans on timer for continuous ventilation
- Transfer grilles to balance room air pressures
- Low VOC paints, GreenGuard certified laminate countertops, recycled content roofing and flyash concrete
- Water-conserving bath faucets, a rain sensor on lawn sprinklers, and native Northwest landscaping.

Table 1. Estimated Costs and Energy Savings for a New Traditions home (2,264 square feet) compared to Building America benchmark and Washington State Energy Code homes

Energy Efficient Features of the Building America Home	% Energy Savings Per Year		Annual Utility Bill Savings[a]	Estimated Consumer Cost[b]	Annual Increase to Mortgage Cost[c]
End Use	Vs. Benchmark[d]	Vs. WA Code	Vs. Benchmark		
Space Heating, includes	25.9%	10.4%	$651.96		
• Moving ducts in conditioned space				$742.50	$59.28
• Duct and envelope sealing, and testing				$1,485.00	$118.56
• 92.5% AFUE furnace				$495.00	$39.52
• R-49 attic insulation				$352.00	$28.10
61% Energy-efficient Water Heater	2.1%	1.7%	$57.45	$165.00	$13.17
70% CFL Lighting	6.6%	8.7%	$110.25	$132.00	$10.54
ENERGY STAR Appliances	3.4%	5.4%	$67.26	$264.00	$21.08
Space Cooling	6.2%	0.1%	$103.69	-	-
Total Usage/Savings	**44.1%**	**26.2%**	**$990.61**	**$3,635.50**	**$290.25**
Annual Utility Bill Savings vs. Benchmark					**$990.61**
Net Annual Cash Flow to Consumer					**$700.37**

(a) Based on Clark Public Utilities electricity rates for Vancouver, Washington, of $0.0736/kWh and Northwest Natural gas rates of $1.128/therm. Energy usage and savings values are in source energy and not site energy. The annual utility bill savings were calculated by BIRA using the computer model BEopt. It should be noted that this savings includes no fluctuations in utility rates or inflation.

(b) Consumer costs include an assumed 10% markup to the builder's cost. Builder costs based on talks with TWC.

(c) Assumes a 7% loan over 30 years with inflation not considered. Net cash flow does not include the $2,000 federal tax credit or the $1,000 per home tax credit from Energy Trust of Oregon for reaching the federal tax credit level.

(d) The benchmark represents a house built in the 1990s. DOE uses the benchmark to consistently calculate energy and financial performance for consumers for energy-efficient features.

When asked how much it costs to build to these levels, Tapio said, for a builder who is currently building just to code, trying to jump up to the federal tax credit level in one leap would probably seem cost prohibitive, costing $3,000 to $5,000 per home. However, Tapio saidNew Tradition was able to implement changes gradually, by working with Building America and vendors to identify cost-effective products.

Bottom Line

"With the economy the way it is and the number of existing houses on the market, the only builders in Clark County doing new construction and still selling are builders like New Tradition, who are building really energy-efficient homes," said Chris Taylor, the installation manager at Area Heating and Cooling, New Tradition's HVAC contractor. "If I was going to buy a new home myself in Clark County, I wouldn't buy anything but a New Tradition home," said Taylor.

For More Information

Contact the EERE Information Center 1-877-EERE-INF (1-877-337-3463) or visit eere.energy.gov/informationcenter.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

PNNL-SA-73921 September 2010

Building America Best Practices Series

Builders Challenge Guide to 40% Whole-House Energy Savings in the Marine Climate

Case Study: Quadrant Homes

Kentlake Highlands | Kent, WA

Quadrant worked with DOE's Building America BIRA (Building Industry Research Alliance) research team, to develop Quadrant's Energy Sound™ package.

Building America Helps Quadrant Develop its New Energy Sound™ Option

Bellevue, Washington, based home builder Quadrant Homes offers buyers of its "custom" production homes over 300 house plans and 10,000 feature options to choose from. With technical assistance from DOE's Building America program, Quadrant now offers homebuyers another option, one that pays buyers back. In 2007 Quadrant teamed with the Washington State University Extension Energy Office, a member of Building America's BIRA (Building Industry Research Alliance) research team, to develop Quadrant's Energy Sound™ package.

This energy-efficiency package helps homeowners achieve total energy savings of 40% over the Building America benchmark. The homes also qualify for the federal energy tax credit, achieving 50% in heating and cooling savings over the 2004 International Energy Conservation Code (IECC). The WSU Energy Office calculated utility bill savings of $951 per year on a 2000-square foot Quadrant Energy Sound house. After subtracting $159 in increased mortgage costs to cover the energy package, homeowners would still gain $791 in net savings each year.

Quadrant Homes, one of six Weyerhaeuser real estate companies, is the number one residential homebuilder in the Pacific Northwest. Quadrant started 873 homes in 20 developments in Washington State in 2008. In the first six months of 2009 Quadrant sold approximately three homes a day, 85% of them to first-time buyers. Quadrant started building in the 1960s, and was purchased by the Fortune 500 forest products company Weyerhaeuser in 1969.

BUILDER PROFILE

Builder's Name: Quadrant Homes, one of six Weyerhaeuser real estate companies

Where: Headquarters in Bellevue, WA, with showrooms in cities of Bellevue and Lacey

Founded: 1960s; acquired by Weyerhaeuser in 1969

Employees: approximately 130

Size: 300 units

Square Footage: Olympic 2011 plan—2,082 square feet

Development: Kentlake Highlands

Price Range: starting at $248,900 for the Olympic 2011 plan

Energy-Efficient Commitment: Energy Sound™ package

Building America® U.S. Department of Energy

(top) All of the walls in Quadrant's homes start with panels assembled inside a factory so wood is dry, measurements and angles are precise, quality and worker safety are enhanced, and waste is minimized.

(bottom) Open-web trusses between the panelized walls of the first and second floor show why it is essential to properly seal ducts within this space.

"Our relationship with WSU [a Building America Partner] is beneficial both ways. I think we have been able to help them gather some research and data about the feasibility of putting ducts in conditioned spaces. They have helped us better understand the energy efficiency of our homes and what areas we need to improve on. We really enjoy working with them."

Quinn Wyatt, *assistant design manager at Quadrant homes*

A Process for Energy Efficiency

Before they began working with Building America, Quadrant already was offering ENERGY STAR as an upgrade which is at least 15% more energy efficient than a house built to code. "They were already exceptional with the overall air tightness of their buildings," noted David Hales, a building systems specialist with WSU. According to Hales, the typical infiltration for an ENERGY STAR builder in Washington State is about 4.5 air changes per hour at a pressure of 50 Pascals. "Quadrant often comes in under 3 ACH@50 PA," said Hales, who attributed the impressive rate to Quadrant's use of a panelized wall system and their recognition of the importance of a tight building envelope.

The Panelized Walls

The wall panels for all Quadrant homes are built in a factory by Woodinville Lumber and delivered to the job site pre-built. Craig MacKay, president of Woodinville Lumber, sees many advantages to this process. First, he cites efficient use of material. "Waste on the job site that might go into a dumpster or a landfill is immediately claimed in the factory for everyone's benefit."

Another advantage is the time saved. "While we are building the floor in the field in a more traditional manner, simultaneously we are building walls for the same house in a controlled environment factory. In a just-in-time way, when the flooring is done, the walls are done. So, instead of having to build the walls on site, which is a several-day process, those walls go to the site built," said MacKay.

The wood for the walls is cut and assembled using precise measurements that are computer calculated for each wall design. "It is uniform, very clean, very dry, and quick," said MacKay." The structure is exposed to the weather for less time, and the quality of the walls is precise."

MacKay is quick to point out that "we custom build the walls for every home. There is no pre-build." Customer-selected options are entered into computer files developed for each home. From this electronic record, custom wall designs are generated for each house."

After the house is framed, other vendor partners air seal and insulate the walls. In the case of the Energy Sound (50% better than code) option, the walls are insulated using R-21 fiberglass batts within wall frames that are 2x6 16-inch on center.

Increased Insulation, Upgraded Furnace, and Ducts in Conditioned Space

Because the envelope was already tight, the WSU researchers analyzed Quadrant homes with computer models to determine what other big-gain options might be available for reaching 50% energy savings over code. The modeling showed two areas for big gains. One involved upgrading the 80% AFUE (annual fuel utilization efficiency) furnace to a 94% AFUE furnace. Quadrant now provides this option on all Energy Sound™ packages.

The second potential for big gain—involved moving the ducts into conditioned space.

When considering this change, Quadrant and WSU relied on the expertise of the vendor partner Bob's Heating and Cooling, the company that installs the HVAC (heating, ventilation, and air conditioning) systems for all Quadrant homes. Wade Craig, a manager with Bob's Heating, explains that his team made changes to Quadrant's HVAC system about five years earlier, and these changes provided a clear path for moving the ducts inside.

Originally the furnaces were in the unconditioned garage and the ducts were in the crawlspace. For smoother production and cost savings, the furnaces were moved up into the attic. Also, at about this time, as explained by Ryan Kerr, Quadrant switched to open-web trusses between the first and second floors of their homes. This was originally done to enable the floors of the homes to be panelized, like the walls. The company no longer uses panels for floors, but it kept the open-web trusses between the floors. Now, for almost all house plans (with the exception of some one-story homes) the ducts are located in conditioned space within the open-web trusses between the first and second floor. The supply ducts provide HVAC to the first story through registers in the ceiling and to the second story through registers in the floor. The return ductwork is in the attic and is insulated to R-8, per Washington Building Code, and surrounded by additional insulation.

"So, in the first step, we put the furnaces up into the attics," said Craig. "It was a step in the right direction, but we still had concerns." These concerns included access, placement because of the pitch of some roofs, lighting, and adequate platforms. "So, the next step was to put the furnace in a closet inside the house," said Craig.

For almost all Quadrant homes, the furnace is now in a mechanical closet on the second floor, where installation and servicing is easier. As Kerr explains, "The mechanical closet is actually built to outside-space code requirements (with insulated walls and door) to accommodate an 80-AFUE furnace with nondirect venting. A 90+ AFUE furnace, as required by ENERGY STAR, would not require this feature, although it would require other features, such as a gas condensation drain."

Finally, to reach the 50% energy savings goal, Quadrant also increased the blown-in cellulose attic insulation from R-39 to R-49, hardwired 50% of the light fixtures to only accept compact fluorescent light bulbs, and provided ENERGY STAR appliances as options (a refrigerator, dishwasher, and clothes washer).

Energy-Efficient Features

(based on the Olympic 2011 model, which is 2,082 square feet, with an Energy Sound upgrade)

- **HERS:** 68 HERS rating
- **Walls:** 2x6 16-inch on center with R-21 batts
- **Attic Insulation:** R-49 blown-in cellulose
- **Wall insulation:** R-21 batts, 2x6 16-inch on center
- **Roofing Material:** Asphalt shingles medium
- **Foundation:** Vented crawlspace with R-30 batts in the crawlspace ceiling
- **Ducts:** Inside conditioned space within open-web trusses between the 1st and 2nd floors
- **Air Handler:** Within a 2nd floor closet in conditioned space
- **Air Sealing:** Tested envelope as 3.4 ACH 50
- **HVAC:** 94% AFUE furnace; SEER 13 air conditioner
- **Windows:** 13.5% whole-house window area, U-29 (0.29), double-pane, low-e, vinyl-framed
- **Water Heating:** 62% efficient gas tank
- **Ventilation:** 100% ASHRAE 62.2; upgraded bathroom exhaust
- **Green features:** Built Green Certified
- **Lighting and Appliances:** Hardwired 50% CFLs, ENERGY STAR refrigerator, dishwasher, and clothes washer
- **Commissioning/Certification:** Northwest Energy Star, $2,000 Federal Tax Credit, and Built Green certified

Building America recommended that Quadrant put the furnace and ducts in conditioned space to increase energy savings.

Quality Management Solutions

In 1996, Quadrant changed its building process. Before then, the company used the traditional model of "if you build it, they will come" in which the company constructed an inventory of speculative homes and waited for buyers to buy. Today Quadrant pre-sells its homes driven by the choices of the homebuyer. It follows a strict 54-day just-in-time and lean manufacturing process that starts with a customer qualifying for a loan. Following qualification, the homebuyer selects a specific development, lot, and floor plan. The process ends on day 54 with the customer receiving the keys to their completed home.

Within this process, Quadrant focuses on first-time homebuyers. During the first 6 months of 2009, 85% of their homebuyers were buying their first home, and they paid an average of $280,000. "People value the process of buying a home at Quadrant," said Quinn Wyatt, assistant design manager at Quadrant Homes. "They get to create the house that they have always dreamed of. They get to make the choices. It is all very personalized." Surveys of homebuyers show that 96% are willing to refer friends.

In addition to meeting the needs of its customers, the process ensured the company did not carry a housing backlog during the economic downturn. Before the downturn, the company built seven homes a day. In 2008, two a day were built. In fall 2009 that number was up to three a day.

"Most of the big builders got caught with huge amounts of unsold inventory, but Quadrant's business model helps avoid having unsold inventory," said Hales.

Dollars and Sense

In 2009, with Quadrant selling its homes at an average price of $280,000 to first-time homebuyers, the company was as committed as ever to keeping its operating and construction costs low. A 2008 BIRA report shows an approximate $2,000 cost to the company for building to the Energy Sound level. In 2009 according to staff at a Quadrant showroom, the Energy Sound upgrade for a 2000-foot house wass $2,250, which includes all installation costs.

Bottom Line

"We don't pretend to know what each homebuyer wants," said Wyatt. "We like to provide choice and let people build the house of their dreams." However, Wyatt sees the need for education about energy efficiency. "One of the things we find surprising is how little knowledge there is still out there about energy efficiency and green building in general. So, we do a lot of educating in our showrooms. A lot of people know what the ENERGY STAR logo is [but] they don't know much more than that [about what an ENERGY STAR home is]."

For More Information

Contact the EERE Information Center 1-877-EERE-INF (1-877-337-3463) or visit eere.energy.gov/informationcenter.

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PNNL-SA-73922 September 2010

Building America Best Practices Series

Builders Challenge Guide to 40% Whole-House Energy Savings in the Marine Climate

Case Study: Schneider Homes, Inc.

Village at Miller Creek | Burien, WA

Schneider Homes worked with researchers at Washington State University's Extension Energy Office, a member of Building America's BIRA (Building Industry Research Alliance) team to design 28 federal tax credit homes near Seattle.

BUILDER PROFILE

Builder's Name: Schneider Homes, Inc.

Where: Tukwila, WA (near Seattle)

Founded: 1976

Employees: 40

Development: Village at Miller Creek

Size: 37 detached townhouses

Square Footage: 2,019 square feet

Price Range: $350,000

Energy Efficient Commitment: All homes Northwest ENERGY STAR Certified; 28 meet 50% federal tax credit standard

Schneider Homes Earns Federal Tax Credit on 28 Homes Near Seattle

In 2008, Schneider Homes earned federal tax credits for 28 of its 37 homes at the Village at Miller Creek, a detached townhouse development in Burien, Washington. To be eligible, these homes achieved greater than 50% energy savings in heating and cooling over the 2004 International Energy Conservation Code (IECC). These homes also meet the Building America 40% whole-house energy-savings goal for the marine climate.

"We could qualify every plan but one, which was stubborn and would have required lots of changes to qualify," said Tom Balderston, a consultant who works with builders to qualify and verify for ENERGY STAR and other state and federal programs.

"We were the first production builder in the area to be 100% ENERGY STAR," said Pat Shea, a 30-year employee with Schneider Homes and the project manager for single-family construction. "All of our homes are ENERGY STAR rated." These homes are certified 15% more energy efficient than the 2004 International Residential Code (IRC).

So when Schneider Homes decided to reach for 50% energy savings, they approached Balderston, and he contacted researchers at Washington State University's Extension Energy Office, a member of Building America's BIRA (Building Industry Research Alliance) team to determine how to achieve such savings.

"Schneider Homes is innovative. They are willing to try things, and they have always been interested in energy," said Balderston.

Building America® U.S. Department of Energy

(top) An insulated, conditioned closet within the garage contains the forced-air 92.5% AFUE gas furnace.

(bottom) Blown-in cellulose insulation rated at R-38 to R-42 helps the townhouses meet the Building America 40% goal.

"We have made a commitment to energy efficiency. We build 100% to ENERGY STAR, and in this market, that is a big deal."

Pat Shea, *Schneider Homes project manager*

Energy Efficiency

"For this particular job, it was not hard for us to get to the federal tax level [50% energy savings in heating and cooling]," said Shea. "There was a whole perfect storm of events that came together to make this project work well."

For example, because all of its homes are built to Northwest ENERGY STAR standards, the production team was trained in proper air sealing. They caulked all mechanical penetrations, foamed the bottom and top plates of walls, and used gaskets for attic access hatches. "When we tested at Village at Miller Creek, we found a consistent pattern of 3.9 to 4.4 air changes per hour [at 50 Pascals]. Standard construction is 6 to 7 air changes per hour," said Balderston.

In addition, because the 37 homes were being built near Seattle's major airport, Sea Tac, additional sound-reduction measures were required. One of these involved using a sound-reducing insulation in the walls. Schneider chose Johns Manville Spider® Custom Insulation, a blown-in blanket insulation (BIBS). This formaldehyde-free, spray-in fiberglass with a non-hazardous adhesive filled the 2x6 wall cavities with R-23 insulation and very few gaps or voids. It is treated with a U.S. EPA-registered mold inhibitor to protect the insulation against mold.

Also, analysis from the BIRA research team showed that moving the furnace and ducts into conditioned space would result in significant energy savings. The Village at Miller Creek house designs contained open-web trusses between the first and second floor. "We put the ducts on the warm side of the insulation blanket in the floor trusses over the unheated garage," said Shea. The supply registers are in the ceiling for the first story and the floor for the upstairs. A portion of the return duct is outside conditioned space within the attic.

For some homes, the gas furnaces, rated at 92.5 AFUE (annual fuel utilization efficiency), were placed in conditioned basements. The majority of the homes were built on 2-foot concrete slabs, and insulated closets were constructed within the garage for the furnaces.

"Building on slab is not unusual for townhouses," said Balderston. "The houses have a garage and a small living area downstairs, and they just extend the slab out from the garage [to cover the living area]." The slab has R-10 foam perimeter insulation.

"The attic insulation is blown-in cellulose R-38 to R-42 depending on the unit," said Shea. "We also used sound-reduction windows, but I don't think these impacted the U value." The two-pane, low-emissivity windows with vinyl frames have a 0.34-U factor.

Other above-code energy reduction features that allowed Schneider Homes to reach the federal tax credit level include making 80% of the light fixtures hardwired for compact fluorescent lightbulbs; providing an ENERGY STAR refrigerator, dishwasher, and clothes washer; and installing an 80% energy-efficient gas tankless water heater. However, as discussed in the next section, Quality Management Solutions, some of the tankless water heaters had to be replaced with traditional tank water heaters.

Final Home Energy Rating System (HERS) scores ranged from 66 to 68. "What I see in an ENERGY STAR home, which is officially 85, is anywhere from 75 to 85," said Balderston.

"We have always tried to give our customers the most livable home we can for the price," said Joanna Colman, assistant vice president. "Energy efficiency is something that we jumped on right away; the company believes it is a huge benefit for our customers to provide increased comfort and economic savings through lower energy costs," said Colman.

Roger Fowler, who is the president of the development's homeowner's association, speaks to this livability: "We feel comfortable in the home, and we never feel drafty, nothing like that. They [the homes] are very tight."

Quality Management Solutions

"We offer a structural extended warranty on all of our homes [6-year Washington State RWC warranty], and we back this with a one-year comprehensive warranty from the builder," said Colman. "Schneider Homes really stands behind their homes."

As part of this commitment to quality and comprehensive warranty, employees at Schneider Homes replaced about six gas tankless water heaters with 40-gallon water heaters after homeowners complained about the pressure and temperature of their water.

"Here's the problem," said Shea, "everyone in the development gets up at 6:30 in the morning and takes a shower. All of the sudden, you have 40 of these many thousand BTU hot water tanks coming on at the same time, and there is tremendous draw on the system."

"Builders have to plan for larger gas piping from the beginning," said Balderston. "A standard water heater might be 35,000 BTUs, but a tankless is 160,000 BTUs. A lot of builders have had this happen. They laid out their utilities in the ground, and then decided to put in tankless water heaters because these are efficient. It is a key problem," said Balderston. A larger infrastructure of gas piping would fix the problem. The advantage of tankless water heaters is that they burn gas only when hot water is being used, which is why the tankless heaters can burn at higher BTUs and still be more efficient than tank heaters, which burn gas on and off throughout the day to keep the tank water continuously hot.

Energy-Efficient Features

(based on a 2,019-square-foot home)

- **HERS:**
  66, 67, 68
- **Walls:**
  2x6 16-inch on-center
- **Attic Insulation:**
  R-38 to R-42 blown-in cellulose insulation
- **Wall insulation:**
  R-23 formaldehyde-free, blown-in fiberglass insulation (BIBs)
- **Roofing Material:**
  Asphalt shingles
- **Foundation:**
  2-foot concrete slabs with R-10 foam perimeter
- **Ducts:** In conditioned space, mostly 3 to 4 ACH @ 50
- **Air Sealing:**
  Gasketing attic access hatches, foaming the bottom and top plates of the walls, and caulking all penetrations
- **HVAC:**
  Forced-air 92.5% AFUE gas furnace
- **Windows:**
  Two-pane, low-e, vinyl-framed, 0.34-U, 0.35 SHGC, 15% glazing area
- **Water Heating:**
  80% gas tankless, with some replaced to 40-gallon 63% gas tanks
- **Ventilation:**
  Mechanical upgraded bathroom exhaust
- **Lighting and Appliances:**
  80% CFLs; ENERGY STAR refrigerator, dishwasher, and clothes washer
- **Commissioning/Certification:**
  $2,000 federal tax credit certified and Northwest ENERGY STAR rated

(top) 28 homes at Schneider Home's Village at Miller Creek met the Building America 40% goal and qualified for the $2000 federal tax credit.

(bottom) Standard kitchen features in a Village at Miller Creek home include custom cherry cabinetry, slab granite countertops, a stainless steel double sink, a kitchen island, ENERGY STAR lighting, and stainless steel appliances, including an ENERGY STAR dishwasher.

Schneider Homes has its own real estate company (Schneider Family Homes) and one way that realtor Debra Alfieri sees this commitment to quality is that energy efficiency and other "extras" are not "upgrades" but included as standard features in their homes. "[For some builders] everything is an upgrade; you buy a stripped down house,…On all of ours, this [energy efficiency] is standard," said Alfieri, "and buyers still have the option to select additional upgrades to customize their new homes to their tastes."

All Schneider Homes are built to Northwest ENERGY STAR standards. Also, at Village at Miller Creek some of the standard features included CEM-Plank™ fiber cement siding, 30-year warranted shadow-blend roofing, insulated fiberglass entry door, small landscaped and fenced yards with sprinkler systems, 9-foot ceilings on the main floor, custom cherry cabinetry and slab granite countertops in kitchens and baths, cherry laminate flooring, quality plumbing fixtures, master bedroom ceiling fan, garbage disposal, stainless steel ENERGY STAR rated appliances, gas fireplaces with slab granite facing, and pre-wired for surround sound and other electronics.

Dollars and Sense

For the Village at Miller Creek townhouses, Schneider Homes benefitted from two incentive programs. As mentioned previously, 28 of the homes qualified for the $2,000 federal tax credit (for 50% greater heating and cooling energy savings than the 2004 IECC). In addition, Puget Sound Energy provided approximately $1,000 in rebates per house for energy-efficient building, such as air sealing and lighting. "The [Puget Sound Energy] rebate that we received through ENERGY STAR and the federal tax credit more than offset the additional construction cost [for the energy upgrades]," said Shea.

It is the homeowners who really appreciate the energy cost savings, as expressed by Colman: "We bought a new Schneider home three years ago that was ENERGY STAR rated. We moved from a smaller house, built in the 1970s, and our energy costs are significantly less for this bigger house than they were for our old home. Before we had about 2,300 square feet, and this house is 3000 square feet."

Bottom Line

Balderston says "the great thing about the project with Building America" is hearing from the construction manager how much energy savings they achieved with just a small financial investment. The homes meet the Building America 40% whole-house energy-savings goal for the marine climate, and "for a small investment, [after rebates] of about $1,000 a home, they received the tax credit on 28 homes, which amounts to $56,000," said Balderston.

For More Information

Contact the EERE Information Center 1-877-EERE-INF (1-877-337-3463) or visit eere.energy.gov/informationcenter.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

PNNL-SA-73920 September 2010

Building America Best Practices Series

Builders Challenge Guide to 40% Whole-House Energy Savings in the Marine Climate

Case Study: Tom Walsh & Co.

New Columbia | Portland, OR

TWC achieved HERS scores of 59 to 66 on 22 homes in Portland, Oregon, with technical assistance from the Building Industry Research Alliance (BIRA), a research team leader in the U.S. Department of Energy's Building America program.

BUILDER PROFILE

Builder's Name: Tom Walsh & Co. (TWC)

Where: Portland, OR

Founded: 1962, incorporated 1999

Employees: 5 in 2007

Size: 40 single-family houses a year in 2007

Development: 20 homes in New Columbia (beginning in October 2006)

Square Footage: average 1,884 square-foot two-story, three-bedroom, 2.5 bath homes

Price Range: $229,000 – $278,000

Energy Efficient Commitment: Federal tax credit level

Building America U.S. Department of Energy

Tom Walsh & Co. Reaches 50% Energy Savings in 20 Homes in New Columbia, Portland, OR

In 2007, Tom Walsh & Co. (TWC) became one of the first production builders in Oregon to earn the $2,000 federal tax credit for new energy-efficient homes. Under the direction of Ben Walsh, TWC earned the tax credit on 20 new homes built in the New Columbia neighborhood in Portland, Oregon. These homes earned Home Energy Rating Scores (HERS) that represent greater than 50% energy savings in heating and cooling over the 2004 International Energy Conservation Code (IECC).

TWC achieved HERS scores of 59 to 66 on each of the 20 federal tax credit homes with technical assistance from Earth Advantage, the Energy Trust of Oregon, and the Oregon Department of Energy. These homes meet the Building America 40% goal for the marine climate. Before becoming aware of the federal tax credit, TWC had completed 24 homes in 2006 that qualified for Northwest Energy Star and Earth Advantage certification.

In total, TWC built 46 speculative, detached, single-family houses in New Columbia for first-time and middle-income families. The homes were priced at sale between $199,000 and 278,000. All of the homes had sold by March 2008.

"We were half way into sheet rocking of phase I in New Columbia with 24 ENERGY STAR and Earth Advantage certified homes when I heard about the federal tax credit," said Ben Walsh, project manager, owner,

(top) TWC became the first builder in Oregon to earn the $2,000 federal energy-efficient new homes tax credit on a production-scale project. The 20 homes in Portland, Oregon, achieved greater than 50% energy savings in heating and cooling over the 2004 International Conservation Code (IECC) standard.

(bottom) To encourage community, garages are located behind houses, and off-street parking is located on alleys behind houses.

and son of the company founder. "I asked our ENERGY STAR/Earth Advantage verifier what it would take to for us to hit this standard. He said, 'You guys are pretty close.' It is remarkable what you can accomplish when you simply ask the question: Is there anything that we can do better?"

However, for Ben Walsh, reaching 50% energy savings compared to code was only important if it could be achieved cost effectively for subcontractors. "If people are working on slim margins and if you ask them to up-end their processes, they see this as one thing, and they are absolutely right—loss. They can't do it," says Walsh. "Every one of my subcontractors has to know that their profitability is of paramount importance to me."

"They were able to really improve energy efficiency, quite frankly, without spending much more money," said Chris Bonner, a broker with Hasson Company, who listed all 46 homes in phase I and II. "It really came down to creating opportunities for their subs to learn a new system. I remember one thing clearly that Ben told me, 'In the end, getting all that extra energy efficiency didn't really cost as much as we thought. It was really about communicating with people a new way of doing things.'"

"Ben has been on the phone countless times with 'what ifs,' so we have gone back to our Building America partners to answer these questions."

Brady Peeks, energy analyst for the Oregon Department of Energy

Energy Efficiency

Walsh credits two improvements with providing most of the energy-efficiency gains that moved his homes from 15% savings in phase I to 50% energy savings over code in phase II: improving air sealing and moving ducts out of the crawlspace and into conditioned space.

In phase I, some of the blower door tests showed infiltration rates of 7.0 ACH_{50}. To meet ENERGY STAR requirements in Oregon the infiltration rates need to be at 7.0 ACH_{50} or lower. For phase II, Walsh's team reached infiltration rates between 4.2 and 4.6 ACH_{50}.

"We put a lot more attention into gasketing the crawl and attic access hatches," said Walsh. "We took care to instruct our insulators to foam the bottom plates of the walls and foam the top plates of the top floor walls. Then, we caulked around all the penetrations—the wires, pipes, ducts." According to the Building Industry Research Alliance (BIRA), the Building America research team that provided analysis of the houses, the estimated incremental time to implement this extra sealing was only 1.5 hours per house.

The construction team identified two challenges for moving the ductwork into conditioned space: allocating space for the ducts and addressing a potential added cost from the mechanical contractors. Through discussions with his subcontractors and research information from BIRA, Walsh implemented a cost-effective method for placing the ducts in conditioned space, which saved $275 per house.

TWC located the ductwork between the first and second stories of the home. The 9-foot first-floor ceilings allow a trunk duct to be run perpendicular to the floor joist in a soffit beside the support beam for the joists. In some cases, the soffit was enlarged well beyond the size required by the ducts so it would function as part of an architectural entry vault for the houses.

The branch ducts run within the joist space eliminating the need for additional soffits or dropped ceilings. Air is supplied to the first story through ceiling registers and to the second story through floor registers. The furnace is located in an interior closet, making the ducts and furnace considerably more accessible than a crawlspace for installation, sealing, and inspection.

Final duct blaster testing showed duct leakage of 31 to 40 CFM_{50}. "For a new average home at 2000 square feet, you can expect 240 to 300 CFM_{50} for a normal house. The leakage of this house is minimal" said Eli Caudill, technical director for Conservation Services Group, which supports the Energy Trust of Oregon.

Caudill states another important benefit of moving ducts into conditioned space: "If the ducts leak to inside the house, it is not that big of a deal; it is still heating the house. If the ducts are in the crawlspace or the attic and are leaking, we would be looking at a situation where we are paying to heat places we don't want to heat."

Ventilation for such a tightly constructed envelope is provided with a whole house fan and trickle vents in the windows, which provide small, operable, louvered vents within the window frame.

Other energy-efficient features included the following, some of which were in the phase 1 ENERGY STAR and Earth Advantage certified houses and carried through to the phase II houses: R-21 fiberglass batt insulation within 2x6 intermediate framing; R-49 blown-in cellulose attic insulation; U-0.29 windows; 62% energy-efficient gas water heater; 94% AFUE furnace; 100% compact fluorescent lighting; ENERGY STAR refrigerator, dishwasher, and clothes washer; a vented crawlspace with a 10-mil poly vapor barrier on the ground; and R-38 insulation in the floor joists.

One feature of the houses that Ben Walsh stated he will not build again is ventilated crawlspaces. "It is dark and damp in crawl spaces. We condition crawl spaces now," said Walsh.

Brady Peeks, an energy analyst with Oregon Department of Energy, is not surprised by Walsh's openness to change in building practice. "He is a builder who is really interested in doing more," says Peeks. "Ben has been on the phone countless times with 'what ifs,' and we have gone back to our Building America partners to get answers to his questions."

Energy-Efficient Features

(Tom Walsh & Co. New Columbia Phase II Homes)

- **HERS:** 56 and 59 for two homes with solar hot water heaters and 65 to 66 for the other 20 homes
- **Walls:** 2x6 24-inch on center
- **Attic Insulation:** R-49 blown-in cellulose
- **Wall insulation:** R-21 batts
- **Roofing Material:** Asphalt shingle, no radiant barrier
- **Foundation:** Vented crawlspace with R-38 fiberglass batt insulation in the floor joists
- **Ducts:** In conditioned space using 40% less ductwork than when in the crawlspace; ducts insulated to R-8
- **Air Handler:** Whole-house fan and trickle vents in the windows
- **Air Sealing:** Gasketing the crawl and attic access hatches, foaming the bottom and top plates of the walls, and caulking all penetrations
- **HVAC:** High-efficiency 94% AFUE furnace. No air conditioner
- **Windows:** Window area 14.1%. U-0.29
- **Water Heating:** 62% efficient gas
- **Ventilation:** Upgraded bathroom exhaust only, trickle vents over windows
- **Green features:** Pre-finished, tongue and groove bamboo flooring; low- and no-VOC adhesives and finishes; no urea-formaldehyde
- **Lighting and Appliances:** 100% CFLs and ENERGY STAR refrigerator, dishwashers, and clothes washer
- **Commissioning/Certification:** Independent, third-party certification

The arched entry adds aesthetic appeal and hides the ductwork, which is kept in conditioned space to increase energy savings.

"Typically ducts are installed in crawlspaces and attics and the garage. The decision to move the ducts and heating system inside into the conditioned space made a big gain for the HERS number for these houses and a reduction in the energy heating use."

Eli Caudill, technical director for Conservation Services Group, which technically supports Energy Trust of Oregon

Dollars and Sense

According to Rob Del Mar, an energy analyst with the Oregon Department of Energy, "The ducts-inside installation resulted in cost savings of $275 per house or $5,500 on the total bid." The central location of the furnace inside a closet made it possible to use 40% less ductwork than would have been needed if the system had been installed conventionally. There were no additional framing costs as the soffit containing the ductwork was already required to conceal a structural beam. The soffit was enlarged beyond the needs of the ductwork as an architectural feature of the entryway. "The arched entry vault was seen as an attribute by the homebuyers," said Del Mar.

Chris Bonner, the realtor, experienced the difference that 50% energy savings made in selling homes. "I listed all 46 homes," said Bonner. "In phase I, when we were Earth Advantage and ENERGY STAR rated, we were competitive with the other builders at New Columbia. So, we were all out there singing the same song. Then, on the second phase, having increased energy efficiency, it let us really stand out from the competition."

"One of those 46 homes is now owned by a friend I have known since I was 6 years old," says Walsh. "The value that the 46 houses represent to their buyers…is that people's equity has been preserved [in the collapsing housing market]. The homes were not overpriced. They were value minded. They were not intended to generate enormous profit. I think the people who bought those homes have, still to this day, solid investments and solid homes in a solid neighborhood within a solid community, and that is important."

Bottom Line

"In the end, it really wasn't about spending a whole lot more money; it was about asking the questions to do it a little differently," said Bonner. "I have been extremely proud to represent those homes."

In 2007, Tom Walsh, who is Ben's father, retired as the owner of TWC, and Ben formed Green One Construction Services. "We are constructing a new 18-unit development [of net zero-energy homes]," said Ben Walsh. He is working with the Oregon Department of Energy and Energy Trust of Oregon to test and analyze his house design for this development of hybrid (gas and electric) net-zero-energy homes.

"It is remarkable what you can accomplish when you simply ask the question, 'Is there anything we can do better?'" Ben Walsh.

For More Information

Contact the EERE Information Center 1-877-EERE-INF (1-877-337-3463) or visit eere.energy.gov/informationcenter.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

PNNL-SA-73919 September 2010

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 sealed-combustion gas furnace of 90 AFUE* or higher	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	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 U-factor of 0.40 or less and SHGC of 0.40 or less	Yes			
MOISTURE MANAGEMENT (take a look at a house under construction before exterior siding is installed)				
Ground slopes away from house	Yes			
Housewrap, building paper, or rigid foam exterior insulation, taped at seams and caulked at edges, covers OSB walls in wood-framed houses	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			
Trees planted ten feet from house, no overhanging branches	Yes			
Plantings 18 to 36 inches away from the foundation	Yes			
No wood or siding in direct contact with ground	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
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 slab 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	Yes			
Carbon monoxide detector installed in homes with a combustion appliance or attached garage	Yes			
Attached garages are ventilated	Yes			
FRAMING				
Use Optimum Value Engineering (also called Advanced Framing): - 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*

Appendix II.

Counties in the Marine Climate

This section contains a list of all the counties, by state, that are within the marine climate. 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.

= MARINE CLIMATE

CALIFORNIA
Alameda
Del Norte
Humboldt
Marin
Mendocino
Monterey
Napa
San Benito
San Francisco
San Luis Obispo
San Mateo
Santa Barbara
Santa Clara
Santa Cruz
Sonoma
Ventura

OREGON
Benton
Clackamas
Clatsop
Columbia
Coos
Curry
Douglas
Jackson
Josephine
Lane
Lincoln
Linn
Marion
Multnomah
Polk
Tillamook
Washington
Yamhill

WASHINGTON
Clallam
Clark
Cowlitz
Grays Harbor
Jefferson
King
Kitsap
Lewis
Mason
Pacific
Pierce
Skagit
Snohomish
Thurston
Wahkiakum
Whatcom

Appendix III.

DOE Building Energy Code Resource Center 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 Crawlspaces
- 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.

Building Energy Codes
RESOURCE CENTER

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.

Code Citations

Appendix IV.

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)

The previous umbrella organization for the three nationally recognized model code organizations in the United States: the Building Officials & Code Administrators International, Inc. (BOCA), the International Conference of Building Officials (ICBO), and the Southern Building Code Congress International (SBCCI). All were incorporated into the International Code Council in ICC in November of 1997 with the goal of developing a single national building code in the United States.

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 airtight, well insulated and sturdy wall as the insulation is inherently aligned with the exterior and interior air barriers.

Insulation Contact, Airtight (ICAT) Lighting Fixture

Rating for recessed lights that can have direct contact with insulation and constructed with airtight 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 onsite 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 to deliver energy to a site, including power generation and transmission and distribution losses (also called primary energy). Approximately three watts (or 10.239 British thermal units) of energy is consumed to deliver one watt of usable electricity. Building America energy saving targets are measured in terms of source energy rather than site energy.

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.

Appendix V.

Acronyms and Abbreviations

ACCA Air Conditioning Contractors of America

ACH air changes per hour

ACI Affordable Comfort Incorporated

ACT2 Advanced Customer Technology Test for Maximum Energy Efficiency

AFUE Annual Fuel Utilization Efficiency

AHU air-handler unit

AL air leakage

ALA American Lung Association

APA The Engineered Wood Association

ASCE American Society of Civil Engineers

ASHRAE American Society of Heating, Refrigerating, and Air Conditioning Engineers

ASTM American Society for Testing and Materials

BECT Building Energy Code Training

BEopt Software developed by NREL for identifying optimal building design

BESTEST A benchmark for building energy simulation: Building Energy Simulation Test and Diagnostic Method

BII Building Industry Institute

BIRA Building Industry Research Alliance

BPI Building Performance Institute

BSC Building Science Corporation

BSC Building Science Consortium

BTU British Thermal Unit

CAD computer-aided design

CARB Consortium for Advanced Residential Buildings

CDCU Community Development Corporation of Utah

CDD cooling degree days

CEC California Energy Commission

CFL compact fluorescent light

CFM cubic feet per minute

CGSB Canadian General Standards Board

COP coefficient of performance

CR condensation resistance

CRI color-rendering index

CT color temperature

DHW domestic hot water

DOE U.S. Department of Energy

DOE2 Building energy analysis program that can predict the energy use and cost for all types of buildings

ECM electronically commutated motor (or energy conservation measure)

EDHA Eastern Dakota Housing Alliance

EEBA Energy and Environmental Building Alliance

EEM Energy-efficient mortgages

EER Energy Efficiency Rating

EERH Energy-Efficient Reference Home

EF	energy factor
EFL	Environments for Living®
EGUSA	Energy-Gauge USA software (FSEC's residential front-end user interface for DOE2.1E simulation tool)
EPDM	Ethylene Propylene Diene Monomer
EPA	U.S. Environmental Protection Agency
EPS	expanded polystyrene
ERV	Energy recovery ventilator
EVHA	Energy Value Housing Award
FEMA	Federal Emergency Management Agency
FF	framing factor
FFA	finished floor area
FG	fiberglass
FHA	Federal Housing Administration
FSEC	Florida Solar Energy Center
GAMA	Gas Appliance Manufacturers Association
GenOpt	generic optimization program
HVAC	heating, ventilating, and air conditioning
HDD	heating degree days
HERS	Home Energy Rating System developed by RESNET
HPL	high-performance lighting
HRV	heat recovery ventilator
HSPF	Heating Seasonal Performance Factor
HUD	U.S. Department of Housing and Urban Development
IAQ	Indoor air quality
IBACOS	Integrated Building and Construction Solutions
IBHS	Institute for Business and Home Safety
IC	insulated ceiling
ICAT	Insulation-Contact-Airtight (also found Insulated Ceiling Air Tight)
ICC	International Code Council
IDEC	Indirect-Direct Evaporative Cooler
IDP	Integrated Design Process
IECC	International Energy Conservation Code
IEQ	Indoor Environmental Quality
IHP	Industrialized Housing Partnership
IOSEU	incremental overall source energy use
IRC	International Residential Code
Mcf	million cubic feet
MEC	Model Energy Code (supplanted by IECC in 1998)
MEF	modified energy factor
MERV	Minimum Efficiency Reporting Value
NAECA	National Appliance Energy Conservation Act
NAHB	National Association of Home Builders
NAHB RC	National Association of Home Builders Research Center
NASEO	National Association of State Energy Officials
NATE	North American Technician Excellence
NFRC	National Fenestration Rating Council
NHQ	National Housing Quality
NREL	National Renewable Energy Laboratory
NZEH	net-zero energy home
OA	outdoor air
OASys	an indirect/direct evaporative cooler
oc	on center
ODOE	Oregon Department of Energy
ORNL	Oak Ridge National Laboratory
OSB	oriented strand board
Pa	Pascal, unit of pressure measurement
PATH	Partnership for Advancing Technology in Housing
PEX	cross-linked Polyethylene tubing
PITI	principal, interest, tax, and insurance
PNNL	Pacific Northwest National Laboratory
PSC	permanent split-capacitor motors
PV	photovoltaics
R-Value	A measure of thermal resistance used to describe thermal insulation materials in buildings

R.A.P.	return-air pathway
RESNET	Residential Energy Service Network
RH	relative humidity
SA	supply air
SBIC	Sustainable Buildings Industry Council
SC	shading coefficient
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficient
SHW	solar hot water
SLA	specific leakage area
SIP	structural insulated panels
TAB	testing, adjusting, and balancing
TIP	Termite Infestation Probability
TMY2	Typical Meteorological Year weather data
TOU	time of use
TXV	thermostatic expansion valve
UL	Underwriter's Laboratory
USDA	US Department of Agriculture
USGBC	US Green Building Council
U-Value	The thermal transmittance of a material, incorporating the thermal conductance of the structure along with heat transfer resulting from convection and radiation.
UA	heat loss coefficient
UL	Underwriter's Laboratories
UV	ultraviolet
VA	Veterans Administration
VOC	volatile organic compounds
VT	visible transmittance
WAC	Washington Administrative Code
WSBCC	Washington State Building Code Council
WSU	Washington State University
WUFI	Modeling program for simulating heat and moisture transfer
XPS	extruded polystyrene
ZEH	zero energy home
ZNE	zero net energy

Visit our Web sites at:

www.buildingamerica.gov

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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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Building America Program

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