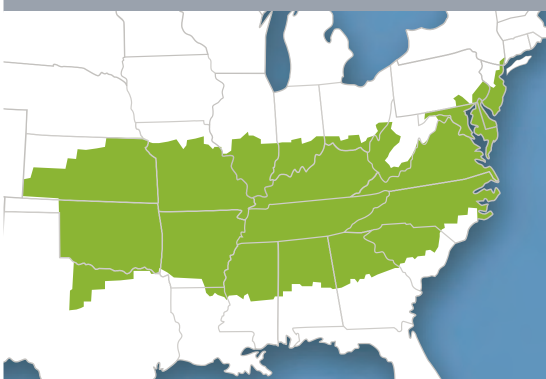
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

VOLUME 16.

BUILDING AMERICA BEST PRACTICES SERIES



MIXED-HUMID CLIMATE

40% Whole-House Energy Savings in the Mixed-Humid Climate

PREPARED BY

Pacific Northwest National Laboratory
& Oak Ridge National Laboratory

September 2011

Building America U.S. Department of Energy

September 2011 • PNNL-20890

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40% Whole-House Energy Savings in the Mixed-Humid Climate

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September 2011

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Preface

This best practices guide is the 16th in a series of guides for builders produced by the U.S. Department of Energy's Building America program. This guidebook 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 mixed-humid 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 guide 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. The recommendations in this guide will help builders achieve Home Energy Rating (HERS) scores of 70 or lower.

This guide represents a step up from our first mixed-humid best practices guide (*Volume 4. Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Mixed-Humid Climate*), which aimed at achieving energy-efficiency savings of 15% above the Building America benchmark (a home built to the 1993 Model Energy Code, the code in effect when the program began). The Building America research projects described in this guide achieve energy savings of 40% greater than the Building America (1993 MEC) benchmark home.

The national energy and building codes are revised on a 3-year cycle. The recommendations in this document meet or exceed the requirements of the 2009 International Energy Conservation Code (IECC) and the 2009 International Residential Code (IRC). Starting in fiscal year (FY) 2011, Building America research projects began using the 2009 IECC as the benchmark for analysis of home energy efficiency. The 2009 IECC requirements are shown in green throughout this guide. The 2009 IECC requirements represent a 15% improvement over the 2006 IECC. The provisions of the 2012 IECC were finalized at the Final Action Hearings in November 2010 and published in June 2011. New requirements in the 2012 IECC are shown in comparison tables throughout this guide. The 2012 requirements represent a 15% improvement over the 2009 IECC.

Building America U.S. Department of Energy

You can learn more about Building America and download additional copies of this document, other best practice guides, research reports, and case studies at

www.buildingamerica.gov

"By improving energy efficiency in homes, you are literally putting dollar bills back into the pockets of homeowners."

Steven Chu, U.S. Energy Secretary, addressing builders in New Orleans, November 9, 2010

The Building America recommendations provided in this guide meet or exceed the code requirements of the 2009 International Energy Conservation Code (2009 IECC) and the 2009 International Residential Code (2009 IRC), which are noted in tables and green text throughout this guide. Requirements of the 2012 IECC and IRC have also been indicated throughout this guide. Builders should note that local code provisions always take precedence over these recommendations.

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 research teams, four DOE national laboratories, and hundreds of builders, contractors, architect and engineering firms, manufacturers, and energy service providers. Building America also co-manages the ENERGY STAR program along with the U.S. Environmental Protection Agency, and works with other federal agencies to coordinate research efforts and disseminate findings. Together, all of these partners make the program a valuable source of knowledge and innovation for U.S. homebuilders.

The DOE Building America program funded the development of this series of guides. DOE also funded the Building America national laboratories and research teams that conducted the research described in this best practices guide. These teams are listed to the right. In FY 2011, the list of Building America research teams was expanded to 14 teams. (See www.eere.energy.gov/buildings/building_america/research_teams.html for a full list of the current teams). The research teams have taken on the hard work of applying research, field testing, training builders, and transforming results into best practices. Most of the drawings, descriptions, photos, and case studies in these guides 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 their dedication to continually improving the quality and energy efficiency of the homes they build and for their contributions to our understanding of how buildings work. Four builders from the mixed-humid climate are showcased in case studies in this document: Insight Homes, Seaford, Delaware; Pine Mountain Builders, Pine Mountain, Georgia; Tindall Homes, Princeton, New Jersey; and Urbane Homes, Crestwood, Kentucky. Examples from these and other mixed-humid climate builders are used throughout the document to illustrate construction best practices.

FY 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

Building America Industrialized Housing Partnership
led by the Florida Solar Energy Center
www.baihp.org

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

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

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

Integrated Building and Construction Solutions
www.ibacos.com

National Association of Home Builders Research Center
www.nahbrc.com

Several national laboratories participated in this project. Pacific Northwest National Laboratory and Oak Ridge National Laboratory coordinated 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 all of 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.

Contents

Chapter 1.
Welcome

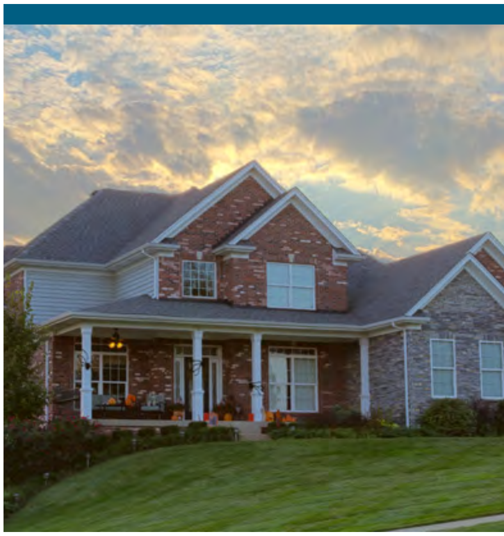
"We just keep getting busier and busier."

Abe Gilbert, co-owner, Urbane Homes, Louisville, Kentucky

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. Builders also report fewer callbacks and complaints. Instead, buyers are calling to thank them for lower utility bills. Builders of all sizes are discovering the benefits of learning from Building America. In fact, all 10 of the nation's 10 largest builders in 2010 were Building America partners.

Learn what hundreds of builders across the country have already discovered—it's good for business 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 [MEC]). You will read about builders in the mixed-humid climate who are using these whole-house building principles to exceed the 2009 International Energy Conservation Code (2009 IECC) and, in some cases, the 2012 IECC. Whether you're a large production builder with managers, sales staff, designers, site superintendents, and installers on your staff, or a custom 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.



Urbane Homes' dollar sales volume has doubled every year since they started building, and they've already had repeat buyers who sold their original Urbane homes at a significant profit.

The 2009 International Energy Conservation Code (IECC) and 2009 International Residential Code (IRC) mandate a significant increase in energy efficiency in new home construction. Changes in these codes represent an approximate 15% improvement in energy efficiency over the 2006 IECC. This guide will help builders meet and exceed these new requirements. The 2009 IECC and 2009 IRC requirements are noted in green throughout this guide. The provisions of the 2012 IECC were published in June 2011 and are now available for adoption by the states. New requirements in the 2012 IECC are listed in Chapter 2. These 2012 IECC requirements and energy-related 2012 IRC changes are shown in comparison tables in Chapter 8 and are also shown in green text throughout this guide.

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 mixed-humid climate.

Chapters 7 through 9 provide construction recommendations to architects and engineers based on Building America research, with guidance on best practices for moisture management, insulation, and air sealing of home foundations, walls, and roofs. Guidance is also provided on windows, heating, air conditioning, ventilation, plumbing, and electrical systems.

Occupant safety and health related to equipment and materials are discussed in Chapter 10. Chapter 11 provides guidance on inspecting and commissioning. Chapter 12 covers construction contracts, scheduling, and training. Chapter 13 provides a useful checklist of all of these recommendations. Chapter 14 provides handy two-page how-to field guides on specific energy-efficiency measures for installers.

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

See the appendices for a homebuyers' checklist, DOE resources for meeting codes, a glossary, and acronym list.

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.

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. The Building America teams have conducted field research with builders throughout the country to test techniques, materials, and processes in real-world situations. As of June 2011, 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.

The nation's ten largest builders are Building America partners, based on *Builder Magazine*'s Builder 100 list of the top 100 builders of 2010 (which ranks builders by home sale closings). Twenty-one of Building America's more than 300 builder partners made the top 100 list. While new home starts stayed low and many builders closed their doors, eight of Building America's partners moved up in the rankings and eight more partners held their positions on the Builder 100 list.

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.

"In today's economy, firms that specialize in green or serve this market are seeing a tremendous advantage—and they're doing good at the same time. Green building leads to healthier places for us to live and work in, lower energy and water use, and better profitability."

Harvey M. Bernstein, vice president, McGraw-Hill Construction

Building America® U.S. Department of Energy

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

CHAPTER TOPICS

Building America builders ranked highest in overall customer satisfaction in 11 of 17 new home markets and were among the top three in all 17 markets surveyed by J.D. Power in 2010.

Building America builders Shea Homes and Standard Pacific Homes each took highest ranks in three markets and KB Homes took highest rank in two markets. Building America builders also ranked in the top three in all 17 markets in J.D. Power's new-home quality study. Other Building America partners that placed highly include David Weekley Homes (shown here), Del Webb, DR Horton, John Wieland, K. Hovnanian, Lennar, Pardee Homes, Pulte, Ryan, and Ryland (J.D. Power 2010).

"In this hypercompetitive market, green features have become a crucial selling point, since new-homebuyers are seeking to save on energy costs, as well as to increase the value of their home."

Dale Haines, senior director of the real estate and construction industries practice at J.D. Power and Associates (J.D. Power 2010).

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 still down in most markets. The good news is the public's awareness of energy efficiency is up and, in most markets around the country, builders who emphasize energy-efficient construction have found that they 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 and Building America can help builders meet or exceed the new requirements.

Consumer Preferences

McGraw Hill Construction reports that the U.S. green building market is accelerating at a dramatic rate. According to their *Green Outlook 2011* report, the value of green building construction starts was up 50% from 2008 to 2010—from $42 billion to $71 billion—and represents 25% of all new construction activity in 2010. According to projections, the green building market size is expected to reach $135 billion by 2015.

The report noted "In today's economy, firms that specialize in green or serve this market are seeing a tremendous advantage." The report attributes the rapid expansion to builders' desire for market differentiation, growing public awareness, and an increase in government rules (Koch 2010; McGraw-Hill Construction 2011; Bernstein 2011).

Research shows that consumers want energy efficiency and they are willing to pay for it:

- There continues to be a strong willingness to invest in energy-efficient products to help reduce utility costs even though a troubled housing market has homeowners concerned about affordability (American Institute of Architects 2010).

- 63% of consumers said they were interested in owning or renting a green or energy-efficient home and 67% said that ENERGY STAR qualification would have the most impact when comparing two homes for purchase (Shelton Group, 2011).
- For homeowners in a 2010 study, home energy-efficiency features outshone all else. Overall, the energy-efficient features were the highest-rated home design elements of the study (Cardis 2011).
- 87% of homebuyers 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 ENERGY STAR® homes (NAHB 2009).
- 91% of homebuyers 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 Building News*, April 9, 2007).
- 90% of new homebuyers are willing to spend more for energy efficiency—up to $17,000 more (McGraw Hill 2007).

Competitive Advantage

Urbane Homes, a builder in Louisville, Kentucky, has become a leader in high-performance homes in a remarkably short time, receiving industry honors for design and construction approaches that raise the level of energy efficiency in the area. "Last year we were the 14th biggest home builder in Louisville, and now we're in the top 10," said co-founder Abe Gilbert. Gilbert says Urbane Homes sells every house they build, and they don't do any formal advertising.

"We just list the house about two weeks before it's done so people can come and see it. The longest we've had a house listed is 3 weeks. The last one we sold was on the market for just 2 weeks."

Urbane Homes' dollar sales volume has doubled every year since they started building, and they've already had repeat buyers who sold their original Urbane homes at a significant profit. "One family has just moved into the third house we've built for them," said Gilbert. "When they sold their last home, they got their asking price

Building America Partners on *Builder Magazine* Top 100 List 2010

Ranking	Building America Partner
1	D.R. Horton
2	Pulte
3	Lennar
4	NVR
5	KB Home
6	Habitat for Humanity Int'l
7	K. Hovnanian
8	The Ryland Group
9	Beazer Homes USA
10	Meritage Homes Corp.
12	Standard Pacific Corp
14	Taylor Morrison Homes
17	Weyerhaeuser Real Estate Co
18	Shea Homes
19	David Weekley Homes
32	William Lyon Homes
40	Mattamy U.S. Group
63	Heartland Homes
65	John Wieland Homes and Neighborhoods
77	ICI Homes
90	Ideal Homes

All ten of the nation's ten largest builders are Building America partners, having one or more divisions who have participated in Building America research projects. Twenty-one of Building America's 350 plus builder partners made *Builder Magazine*'s Builder 100 list of the top 100 U.S. builders of 2010 (based on home sale closings).

"The downturn of the housing market—along with intensified competition for a very limited pool of homebuyers—has reinforced the importance of customer focus for new-home builders. Many builders that were unable to maintain this focus consistently have had to exit the marketplace."

Dale Haines, senior director of the real estate and construction industries practice at J.D. Power and Associates.
(J.D. Power 2010)

Insight Homes closed on 70 homes in Sussex County, Delaware, by third quarter 2011, almost double its closings in 2009. The company, which markets its homes exclusively on their energy efficiency, has a long backlog of orders that promises to keep its sales numbers growing.

in four days and that was $40,000 more than they bought it for four years ago. Another one of our homeowners just had a job relocation to another state. He put the house we built for him up for sale and sold it in one day, for $30,000 more than he bought it for a year ago."

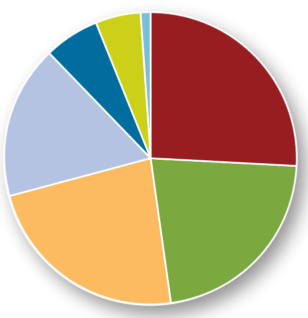
One secret to their success may be affordability. Urbane Homes worked with the National Association of Home Builders Research Center (NAHBRC), a Building America research partner, to develop homes that were energy efficient and affordable. "We set out to prove that we could build a really good house for an affordable price, and we built that first house for $36 per square foot," said Gilbert. A typical home in Louisville costs between $55 and $85 per square foot to build, not including the lot. Urbane's 1,500 to 3,000 ft^2 homes go for $150,000 to $450,000 and have HERS scores of 57 to 62.

Insight Homes of Seaford, Delaware, also committed to keeping its homes comparable to other market rate homes while increasing its energy efficiency. Insight has chosen to market its homes exclusively on the basis of energy efficiency. Growing sales figures seem to indicate that combining energy efficiency with affordability is one way to beat a down market. In 2008 and 2009, Insight had 38 closings on homes at Deep Creek as well as other communities in Sussex County, Delaware. Insight sold 54 homes in 2010 and expects to finish building and selling 70 homes by the end of 2011. Insight Homes also has a long backlog of orders for new houses that promises to keep its sales numbers growing.

Research in other parts of the country also shows that energy-efficient homes sell for more and sell faster. Homes that were green certified sold for up to 30% more on average based on May 2010-April 2011 multiple listing sales data for the Portland, Oregon, metropolitan area, according to a study by Earth Advantage Institute. Certified homes in Atlanta spent an average of 97 days on the market compared to 123 days for traditionally built homes, according to data in the Atlanta Green Home Sales Report, as reported in *Builder Magazine* (Kittower 2011).

How homeowners would spend an extra $5,000 on their new homes

(Figure source: NAHBRC 2007)



- **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

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.

Building America builders have experienced upfront cost savings in numerous ways that balance out against the increased costs of some energy-efficiency measures. For example, they have used advanced framing techniques, which cut down on lumber costs; designed on a 2-foot grid to reduce materials cost and waste; downsized HVAC equipment through better insulation and air sealing of the building envelope and right sizing of equipment; and substituted rigid foam for structural panel sheathing for better performance at neutral cost. They've cut labor costs by spray foaming rather than individually caulking rim joists, by shortening and simplifying duct runs, and by moving ducts out of awkward crawlspaces and attics into conditioned space. Builders have reduced construction time and money by prefabricating duct components on the ground and by factory-building frame wall components or using structural insulated panels (SIPs). They've streamlined processes, realized savings from vendors, reduced or eliminated callbacks, and cut back on costly schedule overruns through good upfront planning with integrated management techniques, ongoing training of subcontractors, and interim and final inspections and commissioning.

Case Studies Prove Homebuyers Profit

In 2007 through 2010, Building America researchers worked with five builders in the mixed-humid climate to build 62 homes that met or exceeded 40% energy savings. (Four of these builders are showcased in case studies at the back of this guide.) In each of those projects, homeowners' utility bill savings yielded a net profit each year, after subtracting increased mortgage costs.

Researchers from Building America research teams modeled one house plan from each builder using EnergyGauge and BEopt software. Table 2.1 shows the energy cost savings calculated for each builder's home, the incremental increase in the annual mortgage to cover the costs of the energy-efficiency features versus the cost of a mortgage for a typical house, and the net annual cash flow to the homebuyer. In every case the homebuyer came out ahead, with net gains ranging from $263 to $1,541 per year. These examples show how homebuyers can realize a positive return from energy-efficiency improvements, no matter how the stocks and bonds markets are doing.

Table 2.2 details costs associated with one builder's choices in energy-efficient features. The builder, Insight Homes in Seaford, Delaware, spent $7,660 per home to add energy-efficiency measures to achieve energy savings of 50% over the Building America benchmark. These measures included increasing the ceiling and wall insulation, switching to a tankless water heater, upgrading the furnace, air conditioner, windows, lighting and appliances and increasing air sealing. When these costs are added to the sale price of the home (at a 10% markup) and incorporated into a 30-year mortgage at 7% interest, it adds $612 per year to the homeowner's mortgage but calculated utility savings are $1,405 annually per home, so the homeowner actually nets a profit of $793 per year.

Energy-Saving Features Are "In"

Energy-saving features are "in" according to builders polled by the National Association of Home Builders at the 2010 NAHB International Builders Show in Las Vegas in January 2010. When builders were given a list of 40 features and asked which ones they were likely to include in new homes, five of their top 10 choices were energy-related.

"Builders will focus heavily on energy-saving features (low-e windows, programmable thermostats, energy-efficient appliances and lighting, an insulated front door, and lower ceilings on the first floor). Things we thought were consumer necessities—such as granite countertops in the kitchen or home offices—are not on the list," Rose Quint, assistant vice president for NAHB's Survey Research Economics and Housing Policy Group, told media at the 2010 NAHB International Builders Show (RREA 2010).

"The longer they [builders] wait to build energy-efficient houses, the further behind they are going to be. It's definitely what buyers are looking for. It is better to be pro-active than reactive."

Rich Coyle, vice president for building science at DR Horton's Sacramento division

Table 2.1. Mixed-Humid 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	Added Builder Cost for Energy Improvements	Annual Mortgage Payment Increase for Energy Efficiency	Annual Utility Bill Savings vs. Benchmark	Net Annual Cash Flow to Homeowner	Total Energy Savings
Insight Homes	$7,660	$612	$1,405	$793	50%
Pine Mountain Builders	$11,486	$917	$1,180	$263	41%
Tindall Homes	$21,290	$1,699	$3,240	$1,541	49%
Urbane Homes	$1,612	$151	$713	$562	44%
In every case study, the energy-efficiency improvements are actually money makers for the homeowners.					
Utility bill savings relative to the Building America benchmark were calculated using EnergyGauge and BEopt 0.8.6 software. Cost increases are based on builder estimates and additional data sources such as RS Means, DEER, supplier cost bids, etc. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation, incentives, and rebates are 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 Mixed-Humid Climate

The example shown here is for a typical 2,140 ft^2, 1-story, 3-bedroom, 2.5-bath, "Jerry" plan home built by Insight Homes, in Seaford, Delaware. Estimated costs for energy-efficiency measures are listed in the table below. As shown, when increased mortgage costs are balanced against utility savings, the homeowner comes out ahead $793 each year.

Energy-Efficiency Feature	Added Cost, per Home, Over Builder's Conventional Practice
Increase walls insulation to R-22 dense-packed blown fiberglass	$2,500
Increase air sealing	$500
Upgrade windows	$500
Upgrade furnace	$1,000
Upgrade Air conditioner	$200
Improve duct insulation and sealing	$200
Add timer-controlled bath fans	$300
Add tankless water heater	$1,000
Upgrade to all CFL lighting	$100
Add ENERGY STAR appliances	$700
3rd party inspections	$660
Total Added Cost	**$7,660**
Annual mortgage payment increase (when incorporated into a 30-year loan at 7% interest)	$612
Annual utility bill savings (Compared to Building America benchmark)	$1,405
Net Annual Cash Flow to Homeowner	**$793**
Conclusion: These energy-efficiency improvements are actually money makers for the owner of this home.	
Cost estimates were provided by the builder. A 10% markup is assumed. Incentives and rebates are not considered.	

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.

Although the $2,000 Federal tax credit for building a new energy-efficient home expired on December 1, 2009, other tax credits for specific measures still exist. For new home construction, until December 31, 2016, a tax credit covering 30% of the cost (with no upper limit) is available for geothermal heat pumps, small residential wind turbines, and solar energy systems. Also available until December 31, 2016, is a 30% tax credit with up to $500 per 0.5 kW of power capacity for residential fuel cells and micro-turbine systems. See www.energystar.gov/index.cfm?c=tax_credits.tx_index. This site provides easy-to-follow information about eligibility and applying for these tax credits.

The ENERGY STAR "Special Offer/Rebate Finder" website below enables a user to enter a zip code to receive accurate information about rebates and sales tax exemptions or credits for qualified products. These include most major appliances, residential ventilation fans, heating and cooling equipment, insulation, roof products, windows, doors, lighting, water heaters, and office equipment. See www.energystar.gov/index.cfm?fuseaction=rebate.rebate_locator.

ENERGY STAR has more information for builders interested in qualifying homes through ENERGY STAR's new home program at www.energystar.gov/index.cfm?c=bldrs_lenders_raters.pt_bldr.

Builders can check ENERGY STAR's New Homes Partner Locator page for state contacts for locally administered builder incentives for new ENERGY STAR homes at www.energystar.gov/index.cfm?fuseaction=new_homes_partners.locator.

Tindall Homes was able to cut energy use 50% compared to the Building America benchmark home, saving homeowners a calculated $3,240 per year on their utility bills.

"Over their lifetimes, our houses will save more in energy costs than the purchase price."

Mark Bergman, owner, Tindall Homes, Columbus, New Jersey

When Abe Gilbert and Zane Underwood founded Urbane Homes in 2007, they knew their survival depended on building better, and more affordable houses than any other builder in the Louisville area.

They worked with DOE's Building America program, to make their houses not just affordable but very energy efficient, achieving HERS scores of 57 to 62.

For More Information on the Business Side of Building

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In a 2010 study of 16,400 new homebuyers, market research organization J.D. Power found that new-home builders are increasingly using green and energy efficiency features as a selling point—65% of new home builders identified the green features of their homes to homebuyers in 2010, up from 48% in 2009, and 61% of new homebuyers perceived their new home as environmentally friendly, compared with only 31% in 2009.

"If all builders built to save 50% on energy use, we could make a big difference. We all want to make money, but at some point, as a society, we have to evaluate what we are doing. We take seriously our responsibility to the surrounding community, to the environment, and most importantly to our buyers."

Mark Bergman, Owner, Tindall Homes, Columbus, New Jersey

"Everyone needs to understand that the difference between the way we have been building in the past and the way we have to build now is night and day. Everyone complains about what a pain the change in codes is, but there is no getting around this. This is the way of the future. I think we have to start being smarter about how we build."

Todd Winnor, project manager,
S&A Homes, Pittsburgh

Codes as Drivers

New building energy codes are now a driving force in energy-efficient construction.

The International Energy Conservation Code

The 2009 International Energy Conservation Code (2009 IECC) was published in December 2008 and has gotten 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 building energy codes for residential buildings that meet or exceed the 2009 IECC. The provisions of the 2012 IECC were finalized at the Final Action Hearings in November 2010 and published in June 2011. For the current status of state code adoption, see the DOE Building Energy Codes website, www.energycodes.gov. IECC 2009 code requirements are shown throughout this document in green ink. Tables comparing the 2009 and 2012 IECC requirements for various insulation and air sealing requirements are provided in Chapter 8.

Major changes from the 2009 IECC to the 2012 IECC include the following:

- 75% high-efficacy lighting
- Energy provisions (Chapter 11) removed from 2012 IRC; reference to 2012 IECC added
- New mandatory whole-house pressure test (blower door) with stringent required leakage rates
  - Zones 1-2: ≤ 5 ACH @50 Pa
  - Zones 3-8: ≤ 3 ACH @50 Pa
- Domestic hot water piping must be either
  - Insulated to R3, or
  - Short and skinny (i.e., exempted lengths depend on diameter)
- Duct leakage rates lowered
  - Eliminated "leakage to outdoors" option
  - Changed from 12 to 4 cfm/100 ft^2 conditioned floor area (after construction)
  - Changed from 6 to 4 cfm/100 ft^2 conditioned floor area (at rough-in)
- Climate-specific insulation R-value upgrades for ceiling, wall, basement, and crawlspace walls (see tables in Chapter 8)
- Climate-specific window U-factor/SHGC increases (see table in Chapter 8).

State Energy Codes

There are 22 states that are wholly or partially in the mixed-humid Building America climate zone (which corresponds to IECC climate zones 3 (above the "warm, humid" line) and 4 moist; see maps in Chapter 5.) The status of residential energy code adoption in each state (as of September 2011) is summarized in the map below. Of the 22 states, eight states have implemented the 2009 IECC, two states (Texas and North Carolina) have adopted but the code has not gone into effect yet. Table 2.3 below provides details on each state's energy code adoption status. (Also see www.energycodes.gov/states for up-to-date state information on energy code adoption).

For More Information on Codes

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

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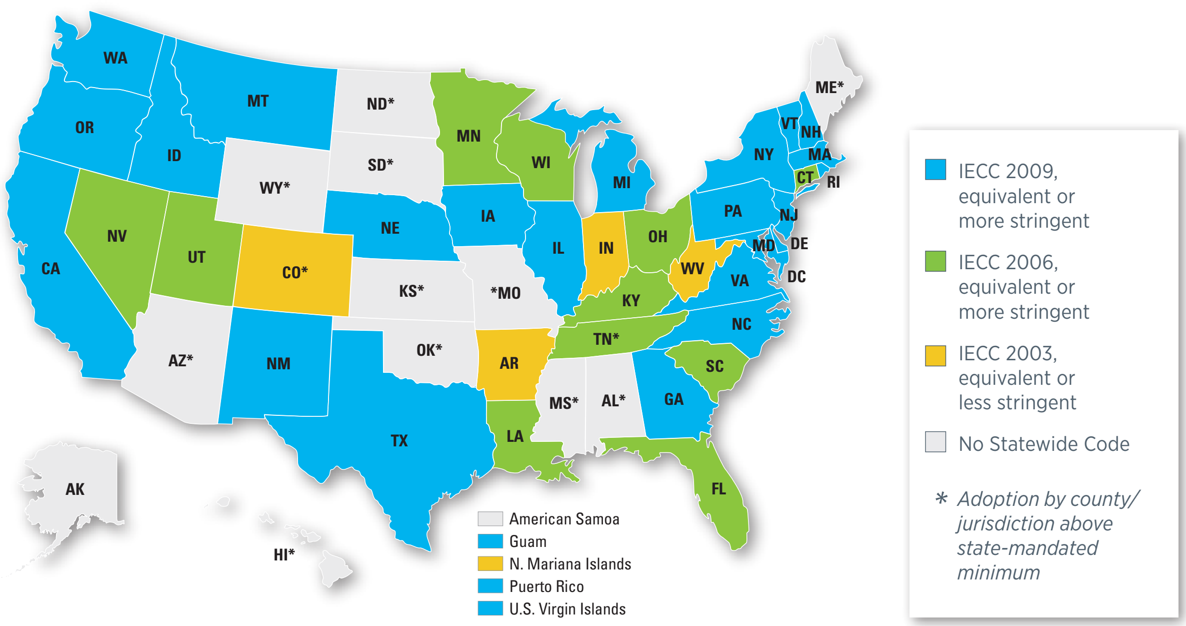
Building Energy Codes Program. U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, www.energycodes.gov

Status of Residential Energy Code Adoption
(as of September 2011)



2012 – Early Adopters

The provisions of the 2012 IECC were published in June 2011, but several Building America builders are already exceeding them. Building America builders highlighted in this guide are already meeting several of the 2012 requirements. Urbane Homes of Louisville, Kentucky, exceeds 2012 IECC wall and attic insulation and lighting requirements. Urbane's estimated improvements cost $1,600 over the Building America benchmark or $129 per year when included in a 30-year mortgage at 7% interest. The energy savings would give the homeowner $713/year in reduced energy costs for a net cash flow to the homeowner of $584 per year.

Features	2012 IECC/CZ 3&4	Urbane Homes
Walls	R-20/R-13+R-5	R-19 + R-5 insulated sheathing
Attic	CZ-3 R-38 CZ-4 R-49	R-50
Duct Leakage	4 cfm per 100 ft^2	Ducts in conditioned space
Lighting	75% high-efficacy fixtures	100% CFLs

Table 2.3. Status of Energy Code Adoption in U.S. Mixed-Humid Climate States (as of September 2011)

States	Statewide Residential Code	Adoption by Local County/ Jurisdiction	Notes
Alabama	None	Voluntary 2006 IECC with amendments contingent upon local adoption	In the process of adopting the 2009 IECC with amendments statewide
Arkansas	2003 IECC with amendments	Voluntary	
Delaware	2009 IECC	Mandatory	
Georgia	2009 IECC with amendments	Mandatory	
Illinois	2009 IECC	Mandatory	In the process of adopting the 2012 IECC
Indiana	Indiana Energy Conservation Code which is based on the 1992 Model Energy Code with amendments		In the process of adopting 2009 IECC with amendments
Kansas	None	Voluntary adoption by jurisdictions	Homebuilders or realtors must disclose information about the home energy performance parameters on the Kansas Energy Efficiency Disclosure form and provide it to potential buyers.
Kentucky	2006 IECC/IRC		
Louisiana	2006 IECC/IRC	Mandatory	2009 IRC with Chapter 11 (Energy Efficiency) to remain as the 2006 IRC provisions became effective Jan. 1, 2011
Maryland	2009 IECC	Mandatory	
Mississippi	None	Voluntary adoption by jurisdictions	
Missouri	None	Voluntary adoption by jurisdictions	
New Jersey	2009 IECC with minor amendments	Mandatory	
North Carolina	2009 IECC with amendments	Mandatory	Adopted 2009 IECC with amendments, effective Jan 2012
Ohio	2009 IECC	Mandatory	
Oklahoma	None	Voluntary adoption by jurisdictions	
Pennsylvania	2009 IECC	Voluntary adoption by jurisdictions	
South Carolina	2006 IECC	Mandatory	
Tennessee	2006 IECC	Mandatory	
Texas	2009 IECC	Mandatory	2009 IECC effective January 1, 2012. Many jurisdictions have already adopted the most recent codes.
Virginia	2009 IECC/IRC	Mandatory	
West Virginia	2003 IRC	Mandatory	

Chapter 3.

Business Management Tools

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

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 practices has value on its own, but they work best when applied as part of an overall management system suited to an individual business.

Quality Management

Quality management is a systems approach to achieving maximum customer satisfaction at the lowest overall cost to your organization while continuing to improve your building process. It encompasses quality of design and quality of process. A quality management system establishes the structure, responsibilities, and procedures required to achieve your company's goals.

Four terms are often used when describing quality programs: quality planning, quality control, quality assurance, and quality improvement. These terms are described below, based on the definitions derived in part from the American Society for Quality (www.asq.org).

Principles of Quality Management

- Customer focus to understand and anticipate needs and requirements, and meet expectations
- Leadership in unity of purpose and direction in achieving quality objectives
- Involvement of people at all levels to use their input and abilities to best advantage
- Process approach to managing activities and related resources
- Systems management approach to identifying, understanding, and managing interrelated processes
- Continual improvement of overall performance
- Factual approach to decision-making based on data analysis and information
- Mutually beneficial supplier relationships based on interdependent abilities to add value.

(ASQ 2008)

CHAPTER TOPICS

New Tradition Homes incorporates these elements in its quality management program: 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 its heating, ventilation, and air conditioning (HVAC) contractor.

- **QUALITY PLANNING:** the up-front gathering of resources to achieve quality goals and objectives and develop clear strategies and actions for achieving them. Quality planning considers people, processes, and products as interdependent factors in the management of quality. It defines the methods for achieving the targeted end results and sets a timetable for completing the associated processes (collections of activities structured to produce well-defined quality outputs).

  Planning for quality ensures that you build homes as designed to achieve targeted results with optimal energy savings. This outcome requires that you fully understand your customer's needs and expectations before proceeding with building design and development. Your planning process then should define the steps to be taken to ensure the home building effort meets quality standards and customer energy-saving expectations on schedule from start to finish.

- **QUALITY CONTROL:** the operational activities used to fulfill requirements for quality (to produce a home that achieves the desired quality for the price). These activities include evaluations, such as statistical studies to evaluate product variation, expected failure rates, and corrective actions.

  Planning for quality control begins with defining the customer's standard for design quality, then planning how to achieve it using the best practices, equipment, materials, personnel, and associated training. Builders should focus on constructing each building right the first time, evaluating and correcting any quality deficiencies as you go. Quality systems and a quality culture provide for long-term quality control (Misronet 2011; also see the Building America Quality Control Checklist and associated information sheets [Building Science Corporation 2008, 2011]).

- **QUALITY ASSURANCE:** the mechanism for ensuring that the construction process takes place within the framework of your quality management system. It involves the planned and systematic activities that provide confidence that a product fulfills the requirements for quality to achieve the targeted performance levels for construction and ultimate customer satisfaction.

  Quality assurance practices may include tests, such as blower door tests; inspections; the use of checklists; and systematic training. As recommended by the Building Science Corporation for new residential construction, quality assurance includes the following seven steps:

"While a quality home need not necessarily be a high-performance home, any high-performance home MUST be a quality home. The quality management approach is an essential element of the Building America approach to homebuilding because it is the main vehicle for moving from science to implementation."

Building Industry Research Alliance, a Building America research team lead

1. Review past construction and risk assessment to provide a baseline for future decision-making and identify specific performance problems.
2. Set performance goals to guide decisions about changes in technology and building practices.
3. Incorporate changes to drawings, specifications, contracts, and trade scopes of work based on thorough discussion, verification, and feedback.
4. Provide training for site supervision and trades as a vital part of implementing high performance measures that affect the whole house.
5. Conduct onsite inspections, verification, and trouble-shooting to confirm quality and verify whole-house characteristics.
6. Complete commissioning of mechanical systems and other equipment to ensure their proper operation and maintenance.
7. Conduct post-construction evaluation to ensure that goals are achieved. (This is a fundamental part of continuous quality improvement and achieving customer satisfaction).

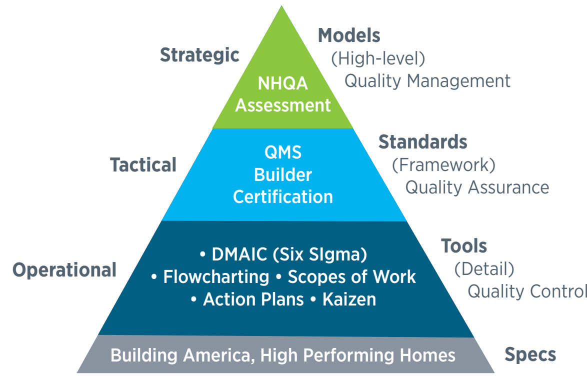
   For further reading and other quality assurance resources, see the *Quality Assurance Roadmap for High Performance Residential Buildings* (Lstiburek and Pettit 2008).

- **QUALITY IMPROVEMENT:** a formal approach to analyzing performance and systematic efforts to improve it and the reliability of achieving a targeted outcome. 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. The use of quality improvement methods and techniques, such as process mapping, quality circles, Six Sigma, DMAIC (define, measure, analyze, improve, control) and Kaizen—drives ongoing efforts to improve building process, product, and people-based performance in pursuit of optimum quality and error-free performance (Vitalo 2011).

  Quality improvement may focus on improving performance related to your product comfort and durability, work-related injuries, energy efficiency, savings, and customer satisfaction.

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.

Strategic, Tactical, and Operational Layering of Quality Management



Strategic **attention** to quality management via self-assessment relative to the National Housing Quality Award performance criteria helps identify strengths, gaps, and target opportunities for improvements that benefit customers, employees, owners, suppliers, and the business.

Applying **tactical standards**, including builder certification, ensures the quality of processes and products in accordance with agreed-upon specifications to meet established standards for high-performance homes.

Building upon Building America's specifications for high-performance homes, the use of **operational tools** and techniques ensures customer-focused planning to achieve targeted quality performance and deliverables.

(Diagram from NAHBRC 2010; also see Leonard 2011)

To ensure adherence to quality standards, Urbane Homes holds pre-construction meetings to coordinate trade contractors and ensure buy-in from the site superintendent. They provide training sessions for their subcontractors on the use of newer products like exterior rigid foam and they have developed a framing manual for the special techniques they expect their framers to use. All of Urbane's houses meet the Building America 40% savings standard and are five-star ENERGY STAR certified. ENERGY STAR provides third-party testing for energy efficiency. *(Photo source: Urbane 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

Building America Quality Management Guidelines

Building America's Integrated Building and Construction Solutions (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. This operations evaluation is based on the National Association of Homebuilders Research Center's National Housing Quality Program. 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 (DOE 2006).

In accordance with these guidelines, Building America recommends that a quality management approach include the following four components:

- **TRAINING AND EDUCATION** – for builders, trades, and sales staff (including participating in certification programs); see Chapter 12 for more information about training.
- **OPERATIONAL EVALUATION** – described above and by DOE (2006).
- **PERFORMANCE-BASED STANDARDS** – described throughout this guide; examples include DOE's Builders Challenge and EPA's Thermal Enclosure Checklist.
- **VERIFICATION/COMMISSIONING/FEEDBACK** – testing and inspections; see Chapter 11 for more details.

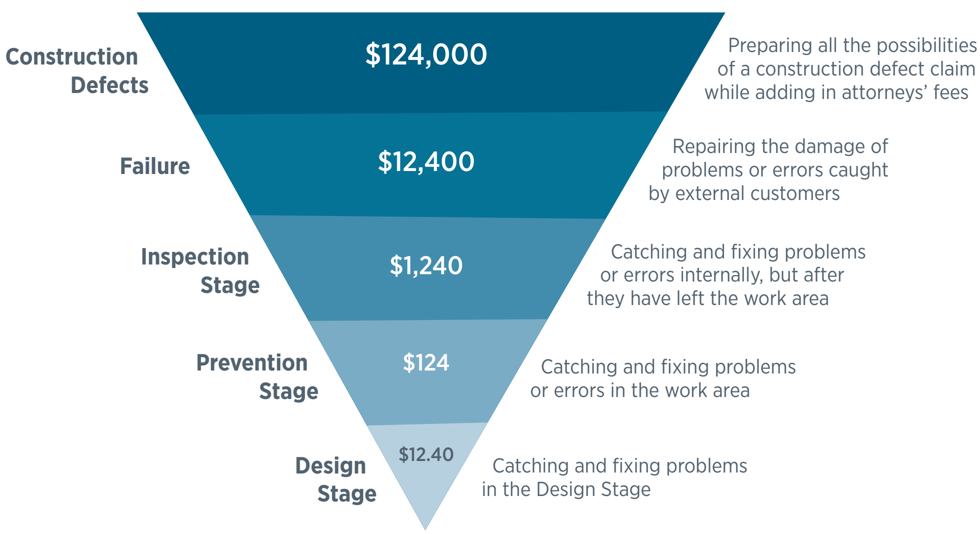
The Costs of Quality Management

Understanding the costs of quality and its potential impact is fundamental to establishing the best practices and processes for use throughout a project using quality management's customer-focused systems approach. Quality is proportional to construction process costs, so you need to identify the costs associated with quality to support your decisions.

Because the economic costs of quality management to builders can affect the economics of energy-efficiency upgrades in a high-performance home, an effective quality management system needs to create efficiencies and related savings that are greater than the investments in the quality activities required to achieve the savings. One Building America goal is for the amortized cost of energy efficiency upgrades for each high-performance home to be less than the monthly utility bill savings. To meet this goal, homebuilders must measure the cost of quality to derive a more energy-efficient home that is cost-effective for a homeowner to buy and operate.

Quality-related activities that will incur costs fall under prevention, appraisal, and failure-correction activities. Make it your goal to reduce the overall cost of quality so that most of your costs are related to preventing and catching defects rather than correcting failures. Tracking the costs and benefits of each helps you determine the most cost-effective solution and reduce failures (and associated costs), thereby increasing customer satisfaction.

The $124,000 Rule of Construction Defect Claims:



This figure developed by the American Contractors Insurance Group, Inc., represents the costs of delaying the identification and solution of problems during the construction process. The initial investment in up-front quality planning and ongoing quality management save in the long run in terms of production efficiencies, costs, and defining a clear path forward by addressing prevention and appraisal needs from project start.

(Copyright ©2009 American Contractors Insurance Group, Inc.)

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).

Costs of Quality

- Prevention costs are related to the design, implementation, and maintenance of the quality management system; quality planning; quality assurance; and training. These may involve the costs of providing better designs, more training to reduce failure costs, and more maintenance.
- Appraisal costs are related to the suppliers' and customers' quality-based evaluation of purchased materials, processes, products, and services (inspection and testing).
- Failure costs are incurred when the results of field work or the products or services delivered to the customer fail to reach design quality. These may involve the costs of callbacks, demolishing and rebuilding, production time, or delays to other trades.

(U.S. Department of Trade and Industry 2011; Misronet 2011)

Impacts of Quality Management

By coupling quality management systems with high-performance home building techniques, builders are likely to create satisfied customers and increased profits. Builders who have won the National Housing Quality Award (NHQA) have noted tremendous impacts from implementing quality management systems, as this sampling of results indicates:

- Achieved zero defects in 98% of homes at closing; net profits increased 9% (Grayson Homes, MD)
- Reduced cycle time by 15% (Pringle Homes, FL)
- 95% of trades list builder as the best to work for (Estes Homes, WA)
- 33% of homeowner recommendations resulted in sale (TS Lewis, AZ).

(*Professional Builder Magazine* 2009, as cited in NAHBRC 2010)

A certified quality management system improves performance and makes high-performance home building easier

IBACOS studied the impact of a quality management system on high-performance home builders (Prahl 2010).

Quality management was found to improve

- **performance management** (how you develop, manage, measure, and improve your key processes)
- **human resources** (how you support superior work performance and ensure organizational alignment)
- **construction quality** (how you provide training and reinforce quality standards)
- **trade relationships** (how you integrate trades to build a better company)
- **business results** (business operations, employee satisfaction, and supplier and trade satisfaction).

Home builders who use recommended quality management tools and techniques and monitor the impacts of quality management to assess its effectiveness—identifying problem areas, opportunities, savings, and priorities for action—have been shown to achieve dramatic improvements in energy and quality performance, profitability, and customer satisfaction (NAHBRC 2010).

Implementing Quality Management

As an accepted cost of doing business, quality management has a proven return on investment. Award-winning home builders who have successfully introduced quality management into their organizations report that the initial up-front investment pays for itself in long-term efficiencies and cost savings gained for builders and homeowners alike (Leonard and Dickens 2011).

These home builders offer the following steps you may find helpful in setting priorities, engaging team members and partners, and managing change.

1. Conduct a high-level assessment of your business process to define its components, who is responsible for doing what, to what standard a process should be completed, and how the success of the business process can be measured. Map out current process realities, identify gaps to be filled, and align your team members to define a roadmap for strategic planning to take you where you want to go.
2. Develop a strategic plan that sets you up for success. Set priorities to focus your plan and define improvement initiatives to foster achievement of your planned goals and objectives.
3. Create quality improvement teams and develop and communicate a clear vision, mission, and goals. Promote ownership by defining responsibilities for actions—steps to be taken by whom to implement your strategy—and determine how to measure your success. Map out individual processes for functional systems and for interactions among systems and groups.
4. Encourage successful change management by creating a sense of urgency, using a guiding coalition of building quality management advocates, empowering broad-based action, and generating short-term wins.
5. Then consolidate your gains, produce more changes, and anchor the new approaches in your operating culture.
6. Use available quality management tools and techniques—such as process mapping, DMAIC/Six Sigma, and cause-and-effect charts—to define and articulate your processes to integrate concepts, team members, and steps so that all participants know how to engage in achieving the end goal.

When implementing quality management, National Housing Quality Award (NHQA) winners (Leonard and Dickens 2011) suggest success is based on effective leadership practices, strategic planning, performance management, customer satisfaction, human resources, construction quality, and trade relationships. They recommend the following:

- As leaders in quality management, create a deep corporate culture based on a clearly articulated vision, operating transparency, open communication, and regularly posted performance measures.
- Engage your people by encouraging dialogue and input from all functional groups for interdisciplinary collaboration in doing things right together.
- Regularly set goals, align teams, and conduct master planning for major changes with clear deliverables, deadlines, and ownership.
- Engage ownership of change by inviting employee feedback to identify opportunities for improvement and consider centralizing operations for operational flexibility derived from shared resources.
- Promote customer satisfaction by creating a well-defined customer-engagement process. Know what your customer wants and remember that high-quality performance and product results will sell your business for you.
- Hire right; develop your employees through mentoring and training; then measure and recognize results.
- Define your top 5 or 10 quality metrics and use available methods and tools to manage the quality of your building process, products, and services.
- Maintain positive relationships with the trades by conducting regular construction quality and safety meetings, participating on trade councils, and measuring and recognizing trade performance. Coordinate efforts to focus on excellent strategy performance using appropriate tools and practices to achieve desired results.

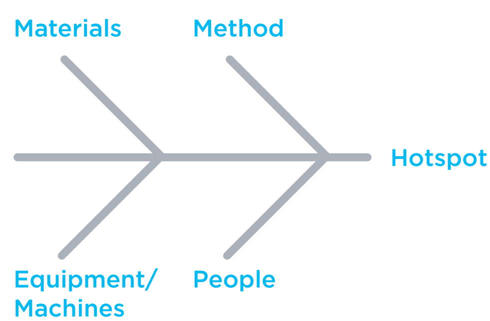
Once you have defined your standards as the fundamentals of your quality platform, regular communication and team work remain key to implementing and maintaining successful quality management programs. Plan, practice, measure success, take the right quality-promoting and cost-saving steps to sustain yourselves through tough economic times, then look to grow. Merge energy efficiency and quality management to combine technology systems with business management systems to achieve integrated solutions for sustained implementation of energy-efficient homes over the long term.

Quality Management Tools

Use **process mapping** (a flowcharting method) to define individual steps for key processes: planning and development, product design and purchasing, marketing and sales, construction, and customer care.

Use DMAIC/Six Sigma to do the following:

- **Define** the problem, the voice of the customer, and project goals.
- **Measure** key aspects of the current process and collect relevant data.
- **Analyze** the data to investigate and verify cause-and-effect relationships, determine what the relationships are, and attempt to ensure that all factors have been considered; then seek out the root cause of the defect under investigation.
- **Improve** or optimize the current process based upon data analysis using techniques to create a new, future state process; then set up pilot runs to establish process capability.
- **Control** the future state process to ensure that any deviations from the target are corrected before they result in defects, and continuously monitor the process.



Use **cause-and-effect (fishbone) charts** to identify possible causes of problems and promote structured brainstorming to help avoid tunnel vision.

(Figure from Leonard and Dickens 2011)

Customer Engagement

Definition: the emotional connection customers have with an organization.

Characteristics of Engaged Customers:

- **Retention:** They will spend more with you over their lifetime than with your competition.
- **Effort:** They will go out of their way to do business with you and will spend more to benefit from your products, service, and brand.
- **Advocacy:** They spread the good word, making it easier and cheaper for you to attract new customers.
- **Passion:** They are passionate about the brand—so passionate that they may even spend time actively promoting the brand to others or defending the brand if others speak negatively about it.

How to Create a Customer Engagement Process:

- Learn from the customers who walk away. Use customer feedback to improve your business.
- Act on customer experiences to create engagement, not just measure satisfaction.
- Find out what actions, behaviors, and services are expected and plan for them.
- Determine the associated performance standards and develop a way to measure them.
- Consistently deliver extraordinary customer service.

(PeopleMetrics 2011)

The Builders Challenge Quality Criteria

Building America's *Builders Challenge Quality Criteria Guide* promotes continuous improvement while ensuring construction quality and efficiency so builders and homeowners alike benefit from reduced callbacks and enhanced comfort, indoor environmental quality, and durability. The guide lists criteria for the three phases of construction (DOE 2008):

- The **design phase** requires design, planning, and documentation before construction.
- The **construction phase** frequently requires the builder/ superintendent to visually inspect and document proper installation by the trade contractors.
- The **verification phase** requires a third-party verifier to review and measure criteria after construction.

When implementing quality criteria, builders establish the expectations for quality practices, oversee their implementation, and keep records to confirm what was done. Trade contractors implement quality practices in accordance with their scope of work. Third-party verifiers—e.g., Residential Energy Services Network (RESNET)-certified HERS raters—confirm the implementation of the criteria via measurement, inspection, or confirmation of their implementation by builders.

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Pine Mountain Builders worked with IBACOS and Southface Energy Institute, both Building America research partners, to overcome the technical challenges to meet and exceed the high standards of Longleaf, a sustainable resort community next to the Callaway Gardens Wetlands Preserve in west Georgia. *(Photo Source: Pine Mountain Builders)*

"With IBACOS we can experiment with new systems and products. We love the Building America program. We learn and improve every day."

Mike Guinan, manager, Pine Mountain Builders, Pine Mountain, Georgia

Key Attributes of High-Performance Builders

- Cultural and corporate alignment
- Clear intent for quality and performance
- Increased collaboration across internal and external teams
- Better communication practices and systems
- Disciplined approach to quality control
- Measurement and verification of performance
- Continuous feedback and improvement
- Whole-house integrated design and specification.

(Prahl 2010)

Integrated Design

When creating a high-performance home, view each building structure, its systems, and site as an interdependent system to ensure that all of its components work synergistically rather than against one another.

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.

Integrated design assumes a systems engineering approach (DOE 2011a), which unites segments of the industry that traditionally work independently of one another. Teams of architects, engineers, builders, equipment manufacturers, material suppliers, community planners, mortgage lenders, and contractor trades collaborate to research and design optimal building solutions.

The teams assess the structure as a whole, recognizing that the design of one component can greatly affect other aspects of the house. To help establish energy savings goals, teams may use the Building America House Simulation Protocols (DOE 2011a) as a standard of comparison.

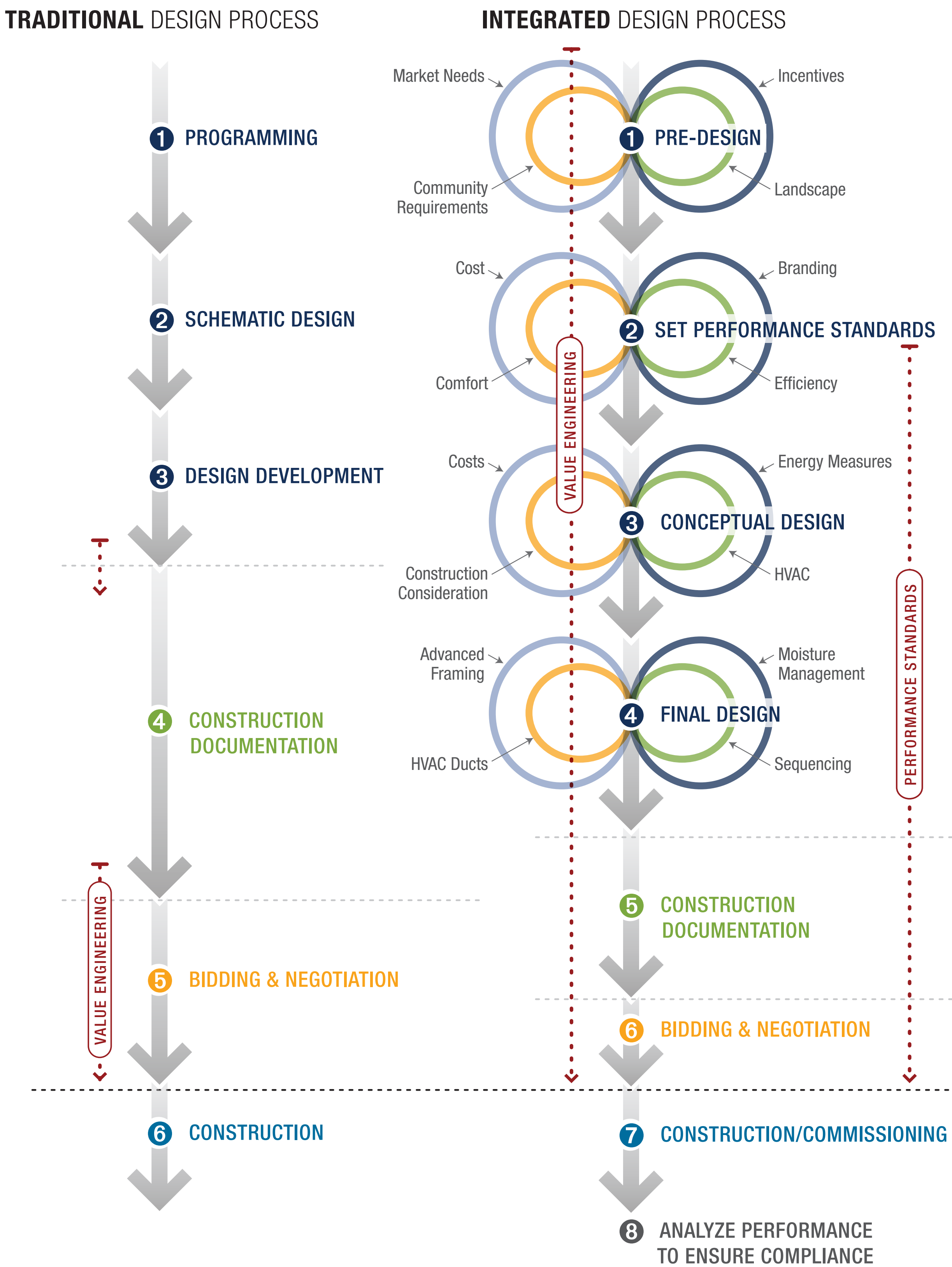
Builders who use the integrated design approach focus on whole-house performance. They start by looking at how all the systems in the house (HVAC, insulation, walls, ceilings, and windows) work together to achieve a house that performs well in terms of energy efficiency, air quality, and moisture management. The team must work together throughout the entire process to produce high-quality houses that incorporate energy- and material-saving strategies. At the very early stages of the project, the team evaluates the builder's design, business, and construction practices to identify cost savings.

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.

Traditional Versus Integrated Design Process

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



"The idea is a whole-house system integration approach. We wanted to make sure the HVAC system and mechanicals were not an after-thought. A lot of builders put up the frame and don't really consider where duct lines and supply risers need to go or how the plumbing lines and drain lines may be routed. Before the HVAC guy gets in there and starts hacking up floor trusses, plates, and walls, let's put some thought into what needs to be routed where. The best approach is to start at the initial design of the building, making sure that all of these considerations are accounted for when you are planning."

Kevin Brozyna, a project manager for IBACOS, a Building America team lead

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 as part of 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. As shown in the design process comparison figure on the previous page, a series of design loops exists for each step of the design process, separated by transitions (gray arrows) during which decisions are made about milestones. In each of the design loops, the design team members relevant for that step participate in the process.

Building America research team lead IBACOS helped Insight Homes in Seaford, Delaware, to evaluate building durability and bulk water management details. IBACOS also helped develop duct designs and system layouts for several of Insight Homes' models to address recurring comfort issues with the heating, ventilation, and air conditioning (HVAC) system. IBACOS continues to work with Insight Homes to establish quality assurance measures that will help the company consistently deliver high quality as they build homes in greater volume. *(Photo Source: Insight Homes)*

The following are steps within the integrated design process.

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

SET PERFORMANCE STANDARDS – Early in the design process, establish standards that the house model will be expected to achieve. Measure progress against these standards at each step. Use market data to determine the level of quality, performance, size, and cost the houses will achieve. Performance areas may include moisture management, indoor air quality, energy efficiency, HVAC comfort, and any certification requirements (for example, achieving a Home Energy Rating Scale [HERS] index score to qualify for a tax credit).

CONCEPTUAL AND PRELIMINARY DESIGNS – Acquire 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 including framing, electrical, plumbing, and HVAC.

CONSTRUCTION DOCUMENTATION – Base construction documents on the final design. Include statements of work for all subcontractors. Specify installation requirements. Use job-ready and job-complete checklists for self- and third-party verification.

"We like to build the most energy-efficient and best-performing home with off-the-shelf parts. It looks like an ordinary house but it performs way better."

Mike Guinan, Manager, Pine Mountain Builders, Pine Mountain, Georgia

Pine Mountain Builders has worked with IBACOS and Southface over the past few years to reach both the 30% and 40% energy savings over the Building America benchmark. They are now working together toward the 50% energy savings level in future designs. Pine Mountain Builders leverages long-standing relationships with its trade partners to ensure its performance standards are met with conventional building materials.

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. Use the NAHB-developed HotSpot tool to check and fix problem areas (see Chapter 11 for example).

PERFORMANCE ANALYSIS TO ENSURE COMPLIANCE – Use computer models to simulate the energy consumption of your designs. As construction is completed, confirm performance with the quantitative measurements listed under commissioning above, including duct blaster and blower door testing using the SnapShot form developed by Building Science Corporation (see Chapter 11 for description of tests) or use verification forms for any labeling programs in which you are participating.

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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, increasing productivity, 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.

> "Synonymous with the terms value management and value analysis, value engineering is a professionally applied, function-oriented, systematic team approach used to analyze and improve value in a product, facility design, system, or service—a powerful methodology for solving problems and/or reducing costs while improving performance/quality requirements. By enhancing value characteristics, value engineering increases customer satisfaction and adds value to your investment. Value engineering can be applied to any business or economic sector, including industry, government, construction and service. Using value engineering is a very successful long-term business strategy."
>
> Lawrence D. Miles Value Engineering Reference Center 2011

Process Overview

As a management tool for multidisciplinary teams, value engineering begins with gathering information about the requirements for a product, system, or process to analyze the importance of its function or performance characteristics in response to questions like "What does the object do? What must it do? What should it do? What could it do? What must it not do?" Once the functional baseline is established a new set of questions is asked and answered to generate alternatives design concepts, materials, and methods ("What are the various alternative ways of meeting requirements? What else will perform the desired function?"). How well each alternative meets the required functions and the associated cost savings are evaluated next, prior to selection of the best alternative to inform final decision-making for value improvement, wherein the "best value" is represented by an item or process that consistently performs the required basic function and has the lowest life-cycle cost.

Reducing Construction Costs While Improving Functionality

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. These framing techniques (described in more detail in Chapter 7) reduce the amount of lumber used to build the home while allowing more space for insulation, resulting in lower material and labor costs and improved energy performance. Advanced framing can be an important design feature, but value engineering can be applied to all aspects of home design.

Much of Building America's research is aimed at helping builders choose more efficient construction materials and methods to make their buildings more efficient. Building America's research considers energy efficiency as well as other important aspects of functionality,

The founder of Insight Homes, Rob Lisle of Sussex County, Delaware, started his company with an experiment. He set out to build 36 identical homes, three at a time, with energy improvements and cost reductions in each, until he achieved a HERS score of 56 at a price comparable to market rate. He achieved that goal by house 27 and worked with Building America's IBACOS team to further refine the home's systems to achieve average HERS scores of 50 on the 40 to 70 homes per year he is now building. *(Photo Source: Insight Homes)*

Value Engineering Saves Builders Money While Increasing Quality

Value engineering allows builders to identify improvements to the design of a home that will ultimately save money. For example,

- Designing for a tighter building envelope allows for smaller, less expensive heating and cooling systems.
- Advanced framing requires less wood and labor and allows more room for insulation.
- Placement of heating and cooling systems inside the thermal envelope allows shorter duct runs saving material and installation costs.

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 the 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.

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Managing Innovation with Prototypes

For building energy technologies to be viable innovations, they must be demonstrated to cost-effectively increase overall product value and quality while significantly reducing the use of energy and raw materials. Prototyping involves the development of functionally useful and trustworthy building designs through experimentation with evolving systems and products. It is used to demonstrate that affordable housing can be designed and constructed to reduce operating costs, while maintaining comfort, healthy indoor air quality, and durability (see "Test Houses and Community-Scale Housing" at DOE 2011a).

Many builders choose to try out Building America technical ideas in a prototype house prior to moving to full production mode. 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. The chart below shows a process for working with building scientists, such as a Building America team, a HERS rater, an engineer, architect, or trained staff member, to build a prototype house.

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

Insight Homes of Seaford, Delaware, is working with Building America team lead IBACOS to build and test two side-by-side houses: one with Insight's standard energy-efficiency features and the other with an advanced HVAC system which includes a super-efficient heat pump paired with a tankless water heater that can provide backup heating. Insight and IBACOS are working with the manufacturers to develop it as a new product.

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Go from Prototype to Full Production

It is important to test the energy-saving performance of prototype houses using carefully developed performance measures. Use these measures to evaluate your overall costs and identify opportunities for systems integration. Applying such measures helps identify any limitations of and gaps in the advanced technologies you have selected to achieve your whole-house energy-savings goals. After successful performance testing on your prototype home, you will be ready for community-scale production to extend the success of your individual test house evaluations via more broad-based implementation.

Chapter 4. Selling Performance

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 their business name and products in front of the public.

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 a recognizable brand that resonates 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 homebuyers tend to hang onto their purchases for a long time.

"People love the energy efficiency of our homes."

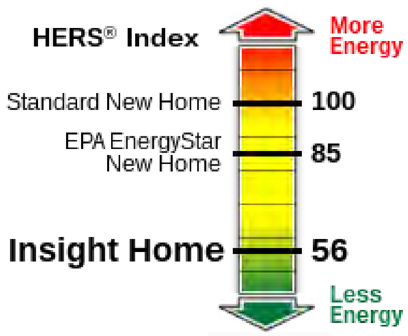
Abe Gilbert, co-owner, Urbane Homes, Louisville, Kentucky

"The builders have reaped great rewards—increased sales, increased profits, quicker turnaround times, and a reduction in callbacks and complaints."

Ken Fonorow, Florida HERO, a Building America research partner

Building AMERICA® U.S. Department of Energy

CHAPTER TOPICS



Insight Homes, of Seaford, Delaware, uses the HERS Index to market its homes, which typically achieve HERS scores of 49 to 56.

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

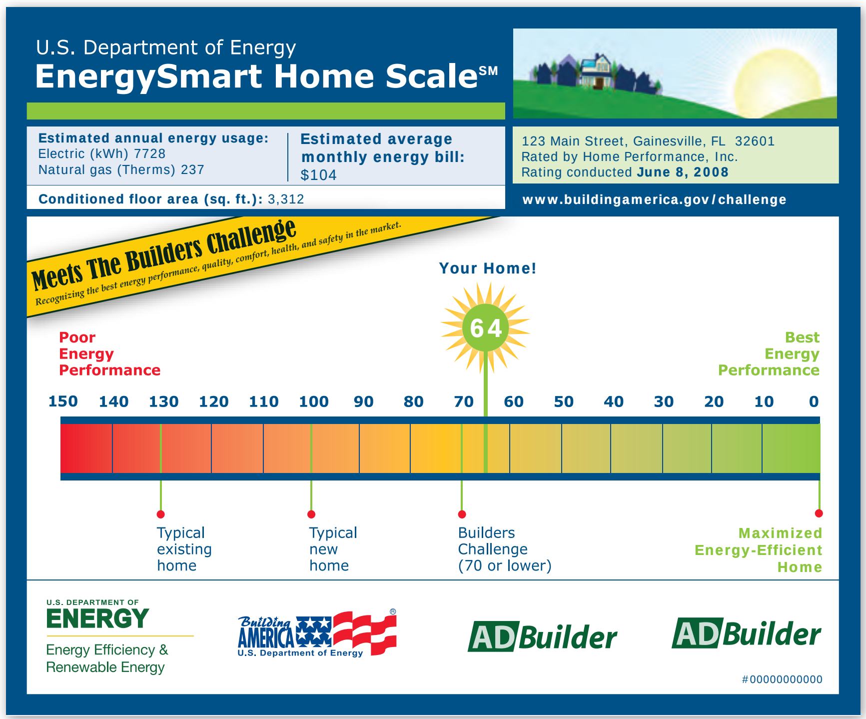
Homes that achieve a 70 or lower on the HERS Index and that meet specified quality criteria can qualify for DOE's Builders Challenge. The Builders Challenge label shown below is attached to qualifying homes. In addition to identifying the Builders Challenge brand, the label also provides useful information 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.

ENERGY STAR Update

In April 2010, the U.S. Environmental Protection Agency (EPA) announced new, more rigorous guidelines known as ENERGY STAR for New Homes Version 3.0. The updated requirements will ensure that the government's ENERGY STAR label continues to deliver a significant increase in energy efficiency over homes that are built to code and standard builder business practices. Homes that qualified for ENERGY STAR Version 2.0 are about 15% more energy efficient than the 2006 IECC requirements. Homes that earn the ENERGY STAR label under Version 3.0 will show energy savings of 20% compared to homes built to the 2009 IECC. These guidelines are being phased in during 2011 and, on January 1, 2012, will become effective for all homes permitted on or after that date.

Homes permitted before April 1, 2011, can continue to be qualified under Version 2.0 until December 31, 2011. Homes permitted between April 1, 2011, and December 31, 2011, can be permitted under a transitional Version 2.5.

For more information about ENERGY STAR for Homes, see: www.energystar.gov



The ENERGY STAR logo is a label that most consumers recognize 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. ENERGY STAR for Homes is a label that recognizes the energy efficiency of the whole house.

The ENERGY STAR (www.energystar.gov) website provides brochures and materials that builders can download for marketing.

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 Leadership in Energy and Environmental Design (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 (EFL) 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. According to Masco, homes built to the EFL gold level specifications will be at least 12% more energy efficient than homes built to the 2009 IECC. Homes built to platinum level are 18% more energy efficient, and homes built to the EFL Certified Green level are at least 20% more efficient (EFL 2011).

Training Sales Staff

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

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

Train sales staff.

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

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.

Pine Mountain Builders qualifies its homes for EarthCraft House, a regional program developed by Building America research partner Southface Energy Institute, that grades and certifies homes based on energy efficiency, indoor air quality, water efficiency, and other metrics for sustainability throughout the construction process.

Some Building America builders use the Environments for Living guarantee—the builder promises the homeowner low utility bills and agrees to pay the difference if the bill is higher than promised.

Countertop displays and model home information centers can educate homebuyers and realtors on the benefits of energy-efficient features.

Tommy Williams sales staff regularly tour finished and unfinished homes to learn about the energy-efficiency features.

"We make sure our sales team knows the details, and we present a consistent message from home to home and neighborhood to neighborhood."

John Friesenhahn, president, Imagine Homes, San Antonio, Texas

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."

Staff your website.

- Keep your website up to date.
- Make it active with a phone or email link to a live person.
- Respond to web inquiries within five minutes.

Do your own research.

- Do exit interviews with customers, buyers, and lookers.
- Drill down for specifics in problem areas.
- Do NAHB quality certification audits of the whole company on a regular basis.

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.

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. Use side-by-side displays on walls, demo walls showing wall and window features, touch screen videos, and poster board displays.
- 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 factsheets or give away Building America and ENERGY STAR brochures, reprints of magazine articles, and 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.
- Participate in building-related charity events.
- Get involved in your local home builders association.
- 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."

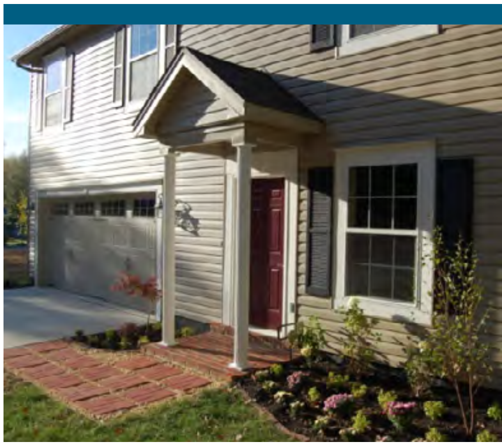
Ideal Homes of Norman, Oklahoma, has worked with Building America since 2002 to steadily improve the energy efficiency of its homes. Intensive, persistent, initial and ongoing training of its sales staff has helped Ideal differentiate its product and become one of the biggest builders in the state. *(Photo Source: Ideal Homes)*

Through 2011, Building America builders have won 121 Energy Value Housing Awards (EVHA) from the National Association of Home Builders Research Center.

Reaching 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 national or regional energy-efficiency programs, reaching a new best score for your area on 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 hiring an energy guru, or participating in research projects with colleges or DOE. News releases can cover your company's involvement in educational and charitable activities, for example, teaching school children about energy efficiency or building homes with Habitat for Humanity.

Rob Lisle, the owner of Insight Homes in Seaford, Delaware, is a frequent speaker at building conferences on the topic of energy efficiency. In 2009, he began hosting a local weekly radio show where he answers callers' questions about green and energy-efficient building.



The prototype model home built by Urbane Homes in Crestwood, Kentucky, won three major building awards in 2009, including two NAHB Energy Value Housing Awards (for affordability and production), and it was runner-up for the NAHB's Green Project of the Year.

For More Information on Marketing

EFL. 2011. Environments for Living. www.environmentsforliving.com

ENERGY STAR www.energystar.gov

EPA. 2011. "What is Indoor airPLUS?" U.S. Environmental Protection Agency, updated March 3, 2011, www.epa.gov/indoorairplus/about.html

EPA. 2011. "WaterSense: An EPA Partnership Program, New Homes," U.S. Environmental Protection Agency, updated July 7, 2011, www.epa.gov/watersense/pp/new_homes.htm

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

NAHB. 2009. ICC 700-2008 *National Green Building Standard*, the National Association of Home Builders and the International Codes Council, www.nahb.org

NAHBRC. 2007. *Building America Challenge Survey of Builders and Consumers*. National Association of Home Builders Research Center. www.nahbrc.org

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, www.nahbrc.org

USGBC. 2011. "Green Home Building Continues to Flourish." U.S. Green Building Council Press Release April 5, 2011. www.usgbc.org/Docs/News/LEED%20for%20Homes%2010k%20milestone_April%202011.pdf

Chapter 5.

The Mixed-Humid Climate

Brick veneer is a popular cladding in the mixed-humid climate. *(Photo Source: Urbane Homes)*

CHAPTER TOPICS

There are 22 states that are wholly or partially in the Building America mixed-humid climate. Conditions vary across this climate zone, which stretches from New York to South Carolina and from the Mid-Atlantic states to the Midwest as far as Kansas, Oklahoma, and northern Texas.

Builders in the mixed-humid climate must be able to address solar gains in the summer, medium to high humidity, mild to cold temperatures in the winter, torrential downpours, high winds, and tornadoes, especially in the midwestern and southern states.

The recommendations in this Best Practices guide apply to the mixed-humid climate region. If you are not sure that your project is within this climate region, check the *Building America Best Practices Series, Volume 7.1, Guide to Determining Climate Regions by County* (DOE 2010, www.buildingamerica.gov) for a list of counties and climate zones.

In addition to describing the mixed-humid climate, this chapter also provides information on building for the weather conditions that can occur in this climate. Siting and design considerations with respect to solar gain are also included. See Chapters 7 and 8 for information on moisture management, air sealing, and thermal control techniques for foundations, walls, and roofs.

Design Considerations for the Mixed-Humid Climate

The temperature variations, forces of driving wind and rain, and medium to high humidity levels can take their toll on buildings. Builders must accommodate significant heating and cooling

Insight Homes used advanced framing and located high-efficiency furnaces and ducts in a sealed, insulated crawlspace in its homes in Sussex County, Delaware. *(Photo Source: Insight Homes)*

needs and combat the effects of heavy rain and condensation from humidity, which can degrade structural materials, contribute to mold growth, and cause premature aging. Based on work with its mixed-humid case study builders, Building America makes the following recommendations for designing homes in the mixed-humid climate:

- Build slab-on-grade foundations and grade lots to drain away from the structure.
- Create a tight thermal envelope and install a positive pressure ventilation system.
- Place the air handler and ducts in conditioned space or go ductless with mini-split heat pumps.
- In cooling-dominated areas, install a reflective roof and use light or reflective exterior wall colors.
- Provide adequate spot ventilation; consider timer-controlled exhaust fans.
- Use rigid foam and braced framing instead of OSB for exterior sheathing.
- Consider high-efficiency heat pumps that can provide heating and cooling across the moderate mixed-humid temperature range.
- Use low-maintenance, high-durability exterior products – for example cement fiber board siding and composite decking materials.
- Plan for storm-water runoff with adequate gutters, flashing, and kick-out diverters. Use pervious paving, vegetation, grading, and swales to handle large storm events.
- Use impact-resistant glass as required by code.
- In tornado-prone areas, consider incorporating basements, storm cellars, or safe rooms into designs.
- Install high-performance, low-emissivity windows with low solar heat gain coefficient.
- Install overhangs, covered porches, awnings, pergolas, or shade trees to minimize solar heat gain.
- Install a dehumidifier to control shoulder-season humidity.
- Use paints that contain mildewcides.
- Use door jambs that are designed for water and rot resistance.
- Use cement backer board behind tubs and showers.

- Install a pest defense system in the walls.
- In framed homes, use borate pressure-treated lumber.
- Install a thermostat with humidity controls.
- When installing windows use sill wrap, corner shields, and adhesive flashing tape to protect against water intrusion.
- Install hurricane strapping, rods, and bolts per code.
- On roofs use fully adhered roofing membrane at eaves and gable ends, butyl-based adhesive-back flashing strips on roof sheathing joints, and hurricane-rated shingles.
- Use non-heat-producing CFL lights.
- Install ceiling fans.
- In flood- and hurricane-prone areas, install a generator-ready electrical service panel to run generator-powered shopvacs, fans, and heaters to dry out the house and reduce water damage during post-storm recovery when electric power outages are common.
- In hurricane areas, consider steel-reinforced concrete walls, outswing doors, hurricane shutters, eave designs with extended fascia providing drip edge, and recessed soffit vents (Zoeller 2006).

Pine Mountain Builders used R-3 XPS rigid foam sheathing, a moisture-resistant alternative to OSB that also provides insulation value and stops thermal bridging in framed walls. The Georgia builder insulated wall cavities with an additional R-13 low-density spray foam. *(Photo Source: Pine Mountain Builders)*

Building America Examples of Weather-Resistant Construction in the Mixed-Humid Climate

Building America worked with four mixed-humid climate production builders, whose construction practices are described in case studies at the back of this guide. These builders worked with Building America's research partners to incorporate several features that accommodate the temperature variations and moisture control issues inherent in the mixed-humid climate. All four builders consistently achieve HERS scores under 60. Three of the four use advanced framing techniques including 2x6 24-inch on-center construction. Three of the builders use XPS rigid foam as an exterior sheathing that is more water resistant than OSB. Two builders use spray foam wall cavity insulation, which air seals and insulates. Three of the builders exceed R-38 attic insulation using blown fiberglass or blown cellulose and the fourth uses R-30 low-density spray foam to provide a conditioned attic space to house ducts.

All four builders locate their ducts in conditioned space, with two locating ducts in open-web floor joists, one in the conditioned attic and one in a sealed, insulated crawlspace. All four builders emphasized the importance of using ACCA Manual J and S calculations to right

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," *ASHRAE Winter Meeting*, Chicago, January 2003 prepared for DOE by Pacific Northwest National Laboratory.

DOE. 2010. *Vol. 7.1: Guide to Determining Climate Regions by County*. PNNL-19517, Building America Best Practices Series, Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory, www.buildingamerica.gov

NOAA. 2010. National Climatic Data Center. www.climate.gov/#dataServices/pastPresent

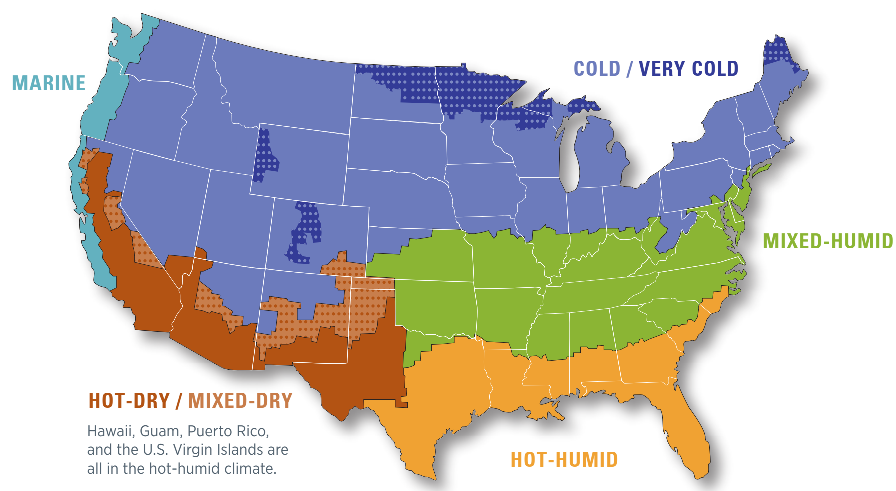
size the HVAC equipment—one installs high-efficiency gas furnaces, another high-efficiency propane furnaces, and two install high-efficiency heat pumps. All four builders met ENERGY STAR Version 2.0 criteria, and every home was third-party tested.

Climate Description – Mixed-Humid

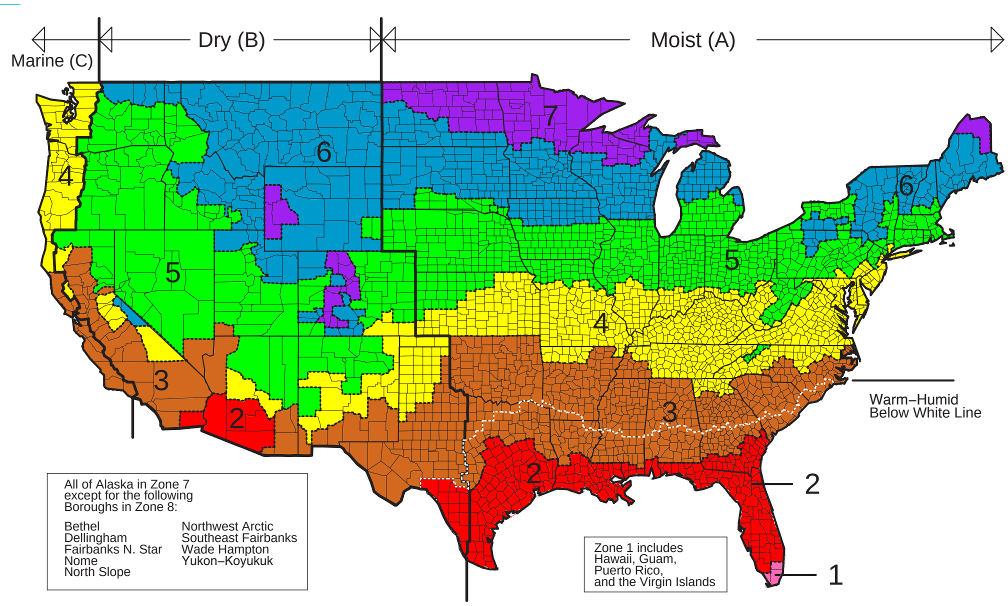
The mixed-humid climate is defined as a region that receives more than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (65°F basis) or fewer, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.

The Building America mixed-humid climate corresponds to climate zones designated 4 (non-marine) and 3 in category A above the warm-humid line on the International Energy Conservation Code (IECC) map (DOE 2010).

Building America U.S. Climate Regions



International Energy Conservation Code Map



Weather

Portions of the mixed-humid climate zones are subject to frequent and intense rain storms, severe thunderstorms, and hail. Some areas are at high risk for tornadoes and high winds. Large portions of the Midwest and the South have been subject to flooding.

The mixed-humid climate is subject to hurricanes along the Eastern seaboard. The region is at low risk of earthquakes except for localized areas around Arkansas and South Carolina (USGS 2010).

Precipitation in the mixed-humid climate varies widely, from 20 inches in the drier parts of Kansas, Oklahoma, and Texas, to more than 50 inches in Tennessee and North Carolina. Construction techniques for moisture management are described in Chapter 8.

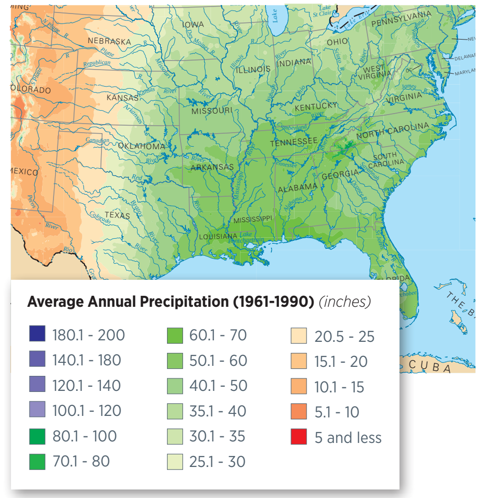
Flooding

Flooding is a concern along the coast and inland waterways of the mixed-humid climate. Large portions of the Midwest and South have been subject to flooding, with most of the counties of these areas experiencing four or more presidential disaster declarations due to flooding since 1965.

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.

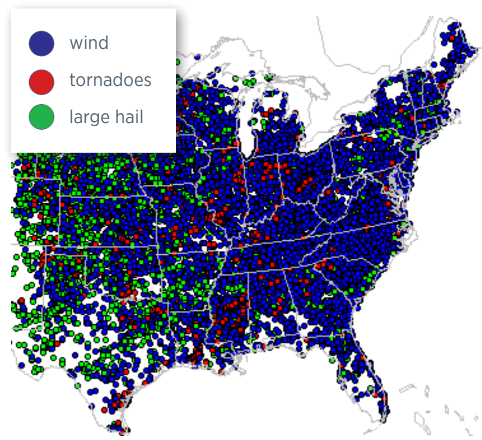
If a community adopts and enforces adequate floodplain management regulations, FEMA will make flood insurance available within the community. Title 44 of the U.S. Code of Federal Regulations (CFR) contains the National Flood Insurance Program (NFIP) criteria for floodplain management, including design and construction standards for new and substantially improved buildings located in special flood hazard areas (SFHAs) identified on the NFIP's FIRMs. An SFHA is an area that has a 1% chance of being flooded in a given year. [CFR Title 44, Section 60.3(a)(3) requires that all new construction in a flood-prone area be constructed with materials resistant to flood damage.] The lowest floor of a residential building must be elevated to or above the base flood elevation (BFE). All construction below the BFE is susceptible to flooding and must consist of flood damage-resistant building materials, for example brick; cement board; concrete; non-paper faced gypsum; steel or solid-wood preservative-treated studs, trusses, and joists; and ceramic tile.

Average Annual Precipitation



(Source: U.S. Geological Survey)

Severe Weather Reports 2010



(Source: National Weather Service)

For More Information on Weather and Precipitation

National Climatic Data Center. 2005. Climate Maps of the United States. National Oceanic and Atmospheric Administration (NOAA) http://hurricane.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl

NOAA. 2010. *Normal Daily Mean Temperature, Degrees F*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, www1.ncdc.noaa.gov/pub/data/ccd-data/nrmavg.txt

U.S. Geological Survey. 2005. "The National Atlas of the United States of America: Precipitation," U.S. Department of the Interior, www.nationalatlas.gov.

U.S. Geological Survey. 2010. "Natural Disasters," www.usgs.gov/hazards/

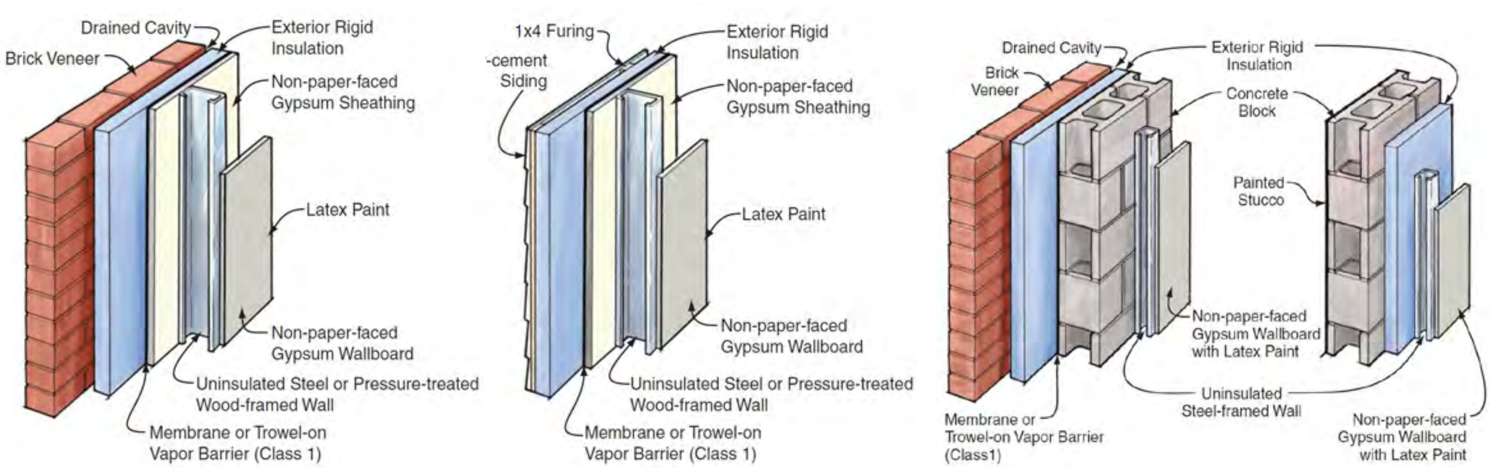
Portions of the mixed-humid climate region are prone to flooding, tornadoes, hail, and hurricanes. *(Photo Source: USGS)*

Flood-resistant materials are described in *"Flood Damage-Resistant Materials Requirements,"* one of a series of Technical Bulletins that FEMA has produced to provide guidance concerning the building performance requirements of the NFIP (available at www.fema.gov/plan/prevent/floodplain/techbul.shtm). **[Code requirements for flood-resistant construction are detailed in the 2009 IRC R322.]**

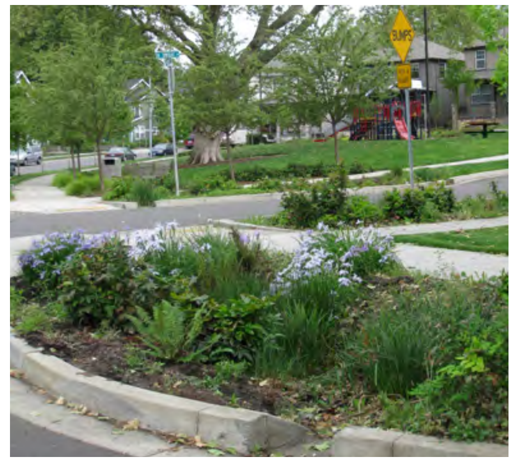
In "Designing for Flood Levels Above the BFE" (FEMA 2009), FEMA noted that floods more severe than the base elevation flood, also known as the 100-year flood, do occur. For example in a 30-year period, there is a 14% chance that a 200-year flood will occur. FEMA reports that "up to 25% of NFIP flood insurance claims are paid on buildings that are outside of the mapped SFHA. This occurs for many reasons, including out-of-date maps and local drainage problems" (FEMA 2008). Therefore, all builders should be aware of flood-safe construction practices, regardless of location designation.

FEMA (2009, 2011) and Building America (Lstiburek 2006) recommended that home builders do the following:

- Design homes on elevated foundations.
- Use strong connections between the foundation and the elevated building to prevent buildings from floating or washing off their foundations.
- Design drainable, dryable interior wall assemblies using non-water-sensitive building materials such as masonry, spray foam, rigid fiberglass insulation, metal or pressure-treated lumber framing, and non-paper-faced gypsum, as shown in the figures below.



Constructing with moisture-resistant materials, such as brick or fiber-cement siding *(left and middle)* or masonry block *(right)* will limit moisture damage in exterior walls. *(Figure Source: FEMA from Coastal Contractor Magazine and Building Science Corporation)*



(top) S&A Homes practices good water runoff management to control sediment during construction and to ensure that stormwater drains away from the house after construction.

(bottom) Vegetated swales, pervious pavers, pocket parks, and retention of existing trees all help to minimize runoff and lessen impacts on municipal sewer systems.

For More Information on Construction in Flood Zones

Algan, H. and Wendt, R. 2005. *Pre-Standard Development for the Testing of Flood-Damage-Resistant Residential Envelope Systems*, Oak Ridge National Laboratory.

FEMA. 2011. Home Builder's Guide to Coastal Construction Technical Fact Sheets Series, Federal Emergency Management Agency, (www.fema.gov/rebuild/mat/mat_fema499.shtm)

FEMA. 2009. FEMA 550: Recommended Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations, Federal Emergency Management Agency, (www.fema.gov/library/viewRecord.do?id=1853).

FEMA. 2009. Designing for Flood Levels Above the BFE. www.fema.gov/library/file?type=publish edFile&file=757_apd_3designabovebfe_rev1.pdf&fileid=388b4fb0-34e6-11de-baca-001185636a87

FEMA. 2008. *Flood Damage-Resistant Materials Requirements for buildings located in special flood hazard areas in accordance with the National Flood Insurance Program*, August 2008, FEMA Technical Bulletin, Federal Emergency Management Agency, www.fema.gov/library/viewRecord.do?id=1580

Lstiburek, Joseph. 2006. *Flood and Hurricane Resistant Buildings*, Building Science Digest 111, Building Science Press, www.buildingscience.com

Zoeller, William. 2006. Designing and Building Hurricane-Resistant Homes, *Home Energy Magazine*, Fall 2006, www.carb-swa.com/articles/in%20the%20news/HomeEnergy_Designing%20and%20Building%20Hurricane%20Resistant%20Homes.pdf

Stormwater Management

Builders are increasingly being called upon to manage surface runoff water onsite during and after construction because stormwater runoff carries with it sediment and pollutants that negatively impact water quality and high levels of runoff tax municipal sewer systems. Builders should check local requirements and guidelines regarding site water runoff control. For long-term stormwater management, builders can minimize impervious surface areas by designing smaller building footprints, clustering developments, and adding green space areas; installing onsite rain-water harvesting systems; and using pervious paver materials. Other recommendations include planting vegetated buffers around parking areas; planting new trees and shrubs and retaining existing trees to minimize erosion; constructing swales, drywells, soakage trenches, planter boxes, vegetated infiltration basins, and flow-through planters; and installing drywells under streets to handle overflow from large storm events.

Tornadoes, Hurricanes, and High Winds

Every state in the mixed-humid climate includes areas in wind zone 4 (the highest risk zone on FEMA's scale of four U.S. wind zones) or areas designated as special wind regions. The mixed-humid climate is vulnerable to catastrophic high-wind, heavy-rain events, such as tornadoes. Proper structural fastening and impact-resistant windows, doors, and skylights are critical to surviving high winds. Proper use

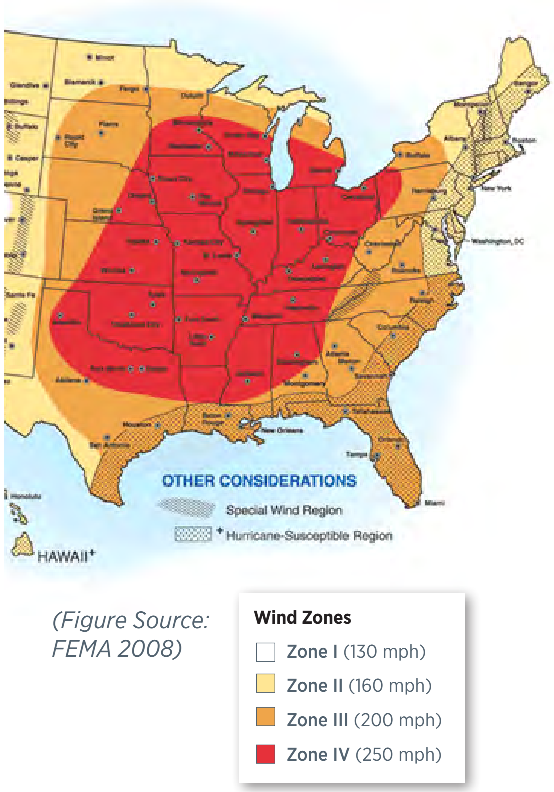
For More Information About Stormwater Management

EPA. 2010. Stormwater Program. U.S. Environmental Protection Agency. http://cfpub.epa.gov/npdes/home.cfm?program_id=6

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

City of Cleveland. 2004. *Guidance Document: Erosion and Sediment Control Best Management Practices for Home Builders*, Cleveland, Tennessee.

Wind Zones in the United States



(Figure Source: FEMA 2008)

For More Information on Construction in Coastal and High Wind Areas

FEMA. 2011. "Safe Rooms," Federal Emergency Management Agency, updated June 23, 2011, www.fema.gov/plan/prevent/saferoom/index.shtm

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

IBHS. 2011. "FORTIFIED Communities of Scale," Insurance Institute for Business and Home Safety, accessed 8-4-11, www.disastersafety.org.

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

of roofing materials can help roofs withstand high winds and protect against severe rains. The following sources provide guidance for construction in high-wind areas.

The Federal Emergency Management Agency (FEMA), the National Association of Home Builders Research Center (NAHBRC), and the U.S. Department of Housing and Urban Development (HUD) have produced a series of 37 fact sheets for building homes in high-wind, high-rain coastal environments www.fema.gov/rebuild/mat/mat_fema499.shtm). 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.

The Insurance Institute for Business and Home Safety provides structural details, guidance, and a list of building materials acceptable for hurricane, high-wind, floods and other natural disasters. The Institute also sponsors a Fortified for Safer Living program that certifies homes that meet a package of "code-plus" upgrades that greatly increase a new home's resistance to natural perils, including hurricanes, tornadoes, wildfires, floods, freezing weather, hail and earthquakes, as well as fires and interior water damage (IBHS 2008). Insurance credits for certified homes are available in some states. See the Institute's website for more details, www.disastersafety.org.

New requirements in the **2009 IRC R301** address some of these high-wind concerns with increased wall bracing requirements for homes built in high-wind and high-seismic actvity areas. The 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 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 requirements include prescriptive blocking details for these conditions. These changes may require revisions to stock plans and standard detailing practices.

For builders and homeowners in tornado-prone areas, FEMA has prepared a guide for building safe rooms—rooms with reinforced walls where occupants can safely take shelter during a tornado or hurricane (FEMA 2011).

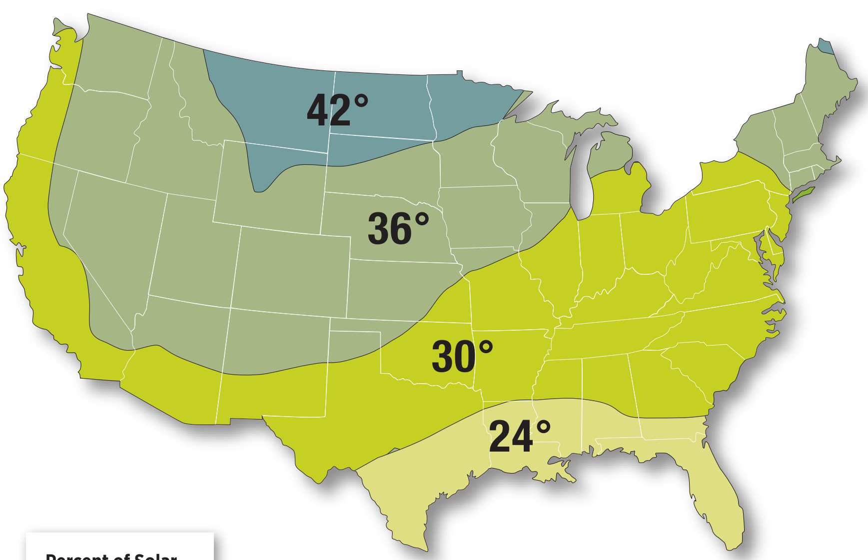
Considering Solar Gain in Siting and Design

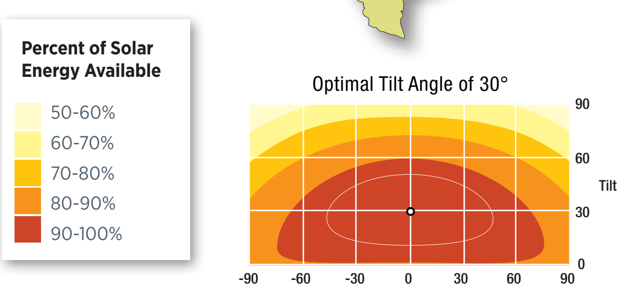
Passive and active solar design elements can be incorporated into homes throughout the mixed-humid climate. Design considerations include lot orientation, roof tilt, overhangs, windows, and shading.

Even if the builder does not plan to put solar panels on the roof at initial construction, homes should be designed and sited with solar panels in mind so that homeowners can take advantage of this energy resource in the future. Significant amounts of unobstructed roof area are needed. Roof space that faces due south is ideal but not necessary. In the mixed-humid climate, the optimal tilt angle or roof pitch for solar panels is 30 degrees. However, more than 90% of the solar energy available can still be collected even when the panels face nearly due east to nearly due west at roof pitch angles of 0 to 60 degrees (DOE 2007).

Optimal Tilt Angles

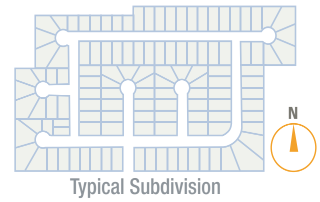
In areas where the optimal tilt angle is 30 degrees, if the roof is facing due south, the tilt angle (roof pitch) can actually vary from 0 degrees to 60 degrees and the roof can still collect 90% to 100% of the available energy. If the roof pitch is at 30 degrees, the direction of the roof can actually vary about 65 degrees to the east or west and still gain 90% to 100% of the available sun energy (Christensen and Barker 2001).

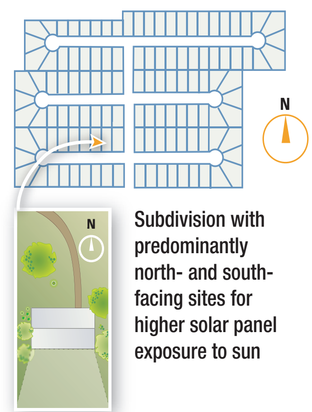




Lot Orientation

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





Subdivision with predominantly north- and south-facing sites for higher solar panel exposure to sun

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.

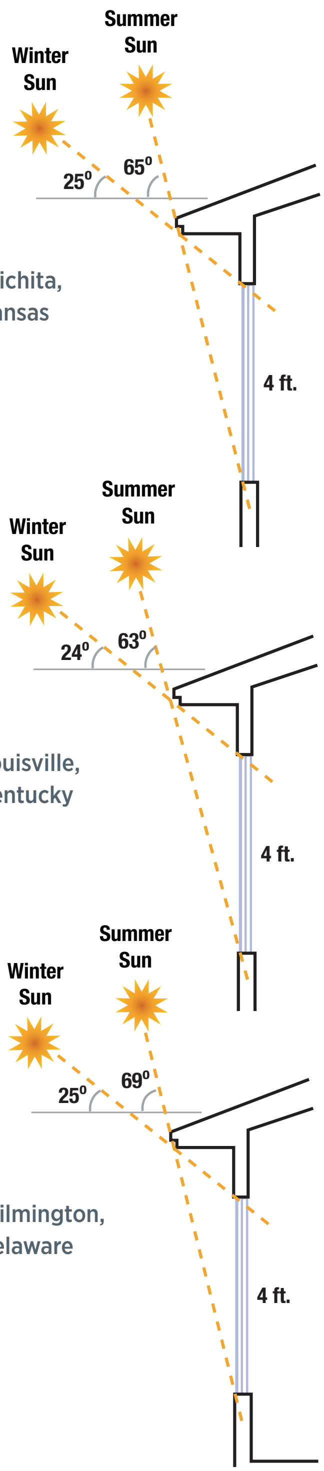
DOE. 2007. *Building America Best Practices Series Volume 6. Solar Thermal and Photovoltaic Systems*. Prepared for the U.S. Department of Energy Building America Program by Pacific Northwest National Laboratory. www.eere.energy.gov/buildings/publications/pdfs/building_america/41085.pdf

Roberts, Bill. 2008. *Solar Maps*, produced by the National Renewable Energy Laboratory for the U.S. Department of Energy. 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.

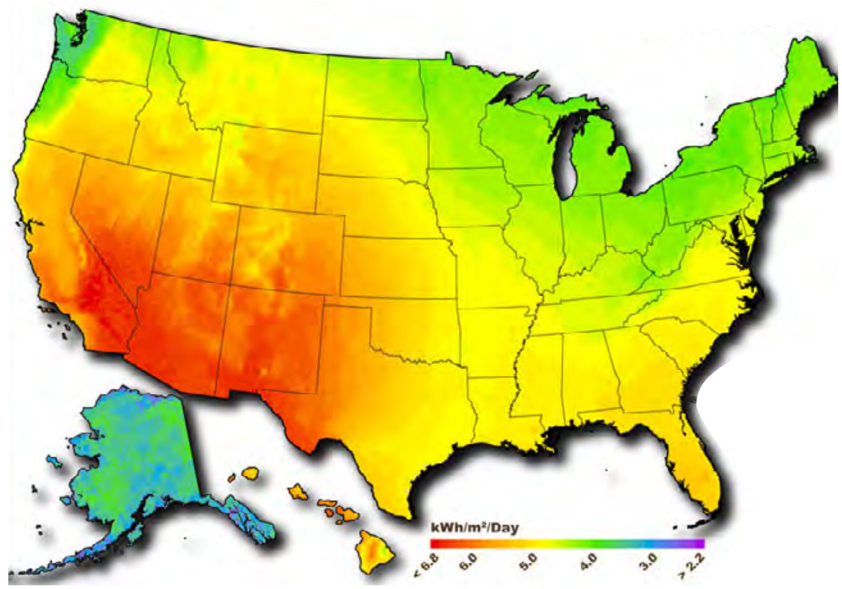
Sun angles vary by latitude



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: Sustainable by Design, www.susdesugn.com/sunangle)*

U.S. Solar Resource

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, the mixed-humid climate has 5 or more kWh/m²/day of solar resource available. *(Figure Source: Roberts 2008)*



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 Wichita, Kansas, a 3-ft high by 4-ft wide window positioned 2 feet below the overhang would need an overhang extending 1 foot to provide full shade at mid-summer at 2 pm.

Windows

Windows should be selected to manage the quantity of heat loss and solar gain, which are indicated by the U-value solar heat gain coefficient (SHGC). The U-value is a measure of heat transfer. The lower the U-value, 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 2009 IECC Table 402.1.1 requires a window U-factor of ≤0.50 in IECC climate zone 3 (or ≤ 0.65 for impact-rated glass complying with IRC 2009 R301.2.1.2) and 0.35 for IECC climate zone 4. The maximum skylight U-factor requirement in 2009 IECC Table 402.1.1 is 0.65 in IECC climate zone 3 and 0.60 in IECC climate zone 4. The 2009 IECC Table 402.1.1 requires a maximum SHGC of 0.30 in IECC climate zone 3 and no requirement is given for IECC climate zone 4. For more information about windows including 2012 IECC requirements, see Chapter 8 of this guide and also see the Efficient Windows, Collaborative website at www.efficientwindows.org.

Pine Mountain Builders retained original native trees to provide shade and erosion control on home sites at its Longleaf Community at Callaway Gardens in Georgia. *(Photo Source: Pine Mountain Builders)*

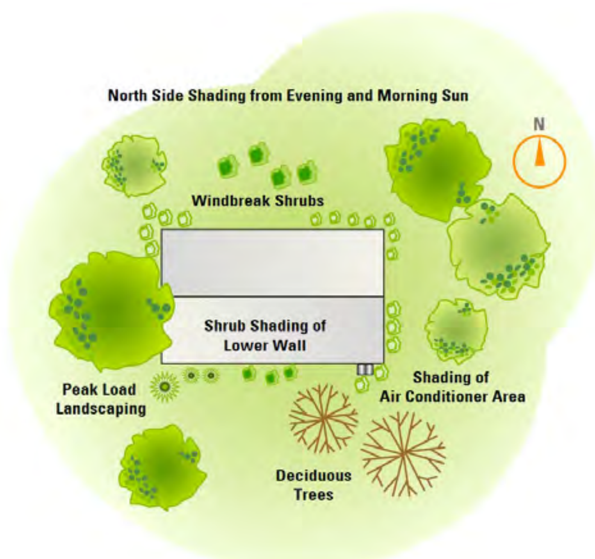
Shading

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.

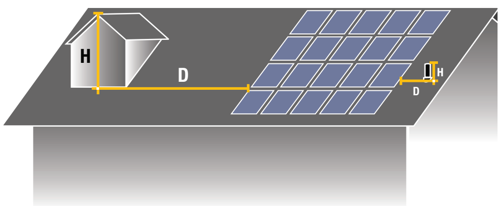
Truly cool neighborhoods have trees. A study in Florida has shown that a subdivision with mature trees had cooler outside air with less wind velocity than a nearby development without trees (Sonne and Viera 2000). The development with a tree canopy had peak afternoon temperatures during July that were 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).

Trees reduce cooling requirements, particularly when located on the south, east and west side of the home to block low-angle, morning and late-afternoon, peak solar-gain sun. Medium and large trees should be planted 16 to 22 feet from the side of the house, smaller trees can be planted 10 to 16 feet from the side of the house. (Miami-Dade County. 2010. "Cool Your Home" www.miamidade.gov/derm/tips_cool_your_home.asp). Trees more than 35 feet from the structure are too far away to provide shade. Planting trees that provide shade to your air conditioning compressor unit will help it work more efficiently.

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



Large deciduous shade trees on the south and west sides of the home provide welcome relief from summer afternoon sun while allowing desirable winter sun to warm the house. *(Figure Source: Viera et al. 1992)*



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

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.

For More Information on Shading

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

Parker, D., Sonne, J., and J. Sherwin. 2002. "Comparative Evaluation of the Impact of Roofing Systems on Residential Cooling Energy Demand in Florida," Prepared by the Florida Solar Energy Center, In *Proceedings of ACEEE 2002 Summer Study*, American Council for an Energy Efficient Economy, Washington, DC, August 2002. www.fsec.ucf.edu/en/publications/html/FSEC-CR-1220-00/index.htm

Sonne, J.K. and R.K. Viera. 2000. "Cool Neighborhoods: The Measurement of Small Scale Heat Islands." Prepared by the Florida Solar Energy Center, In *Proceedings of ACEEE 2000 Summer Study*, American Council for an Energy Efficient Economy, Washington, DC. www.fsec.ucf.edu/en/publications/html/FSEC-PF-363-01/

Walker, L. and S. Newman. 2009. *Landscaping for Energy Conservation*. No 7.225, Colorado State University Extension. www.ext.colostate.edu/pubs/garden/07225.html

Viera, RK, KG Sheinkopf, and JK Sonne. 1992. *Energy-Efficient Florida Home Building*, third printing. Florida Solar Energy Center, FSEC-GP-33-88, Cocoa Beach, Florida.

New roofs are not immune to moss, which can spread quickly under favorable conditions like constant shade and low roof pitch.

Moss

In climates with high humidity, unwanted moss and algae can grow on roofs, especially on north- and east-facing surfaces, and can stain and damage most roofing types. To inhibit moss and algae 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 planting and 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, Oregon, www.portlandonline.com/BES/index.cfm?c=50367

Chapter 6.

Building Science and the Systems Approach

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.

"The energy-efficient features of these homes really begin to shine after the homeowners move in. Then, we hear them saying things like, 'We love our new house; we can't believe how comfortable it is; we can't believe how low the utility bills are!"

Mike Guinan, co-owner, Pine Mountain Builders, Pine Mountain, Georgia

CHAPTER TOPICS

The Systems Approach

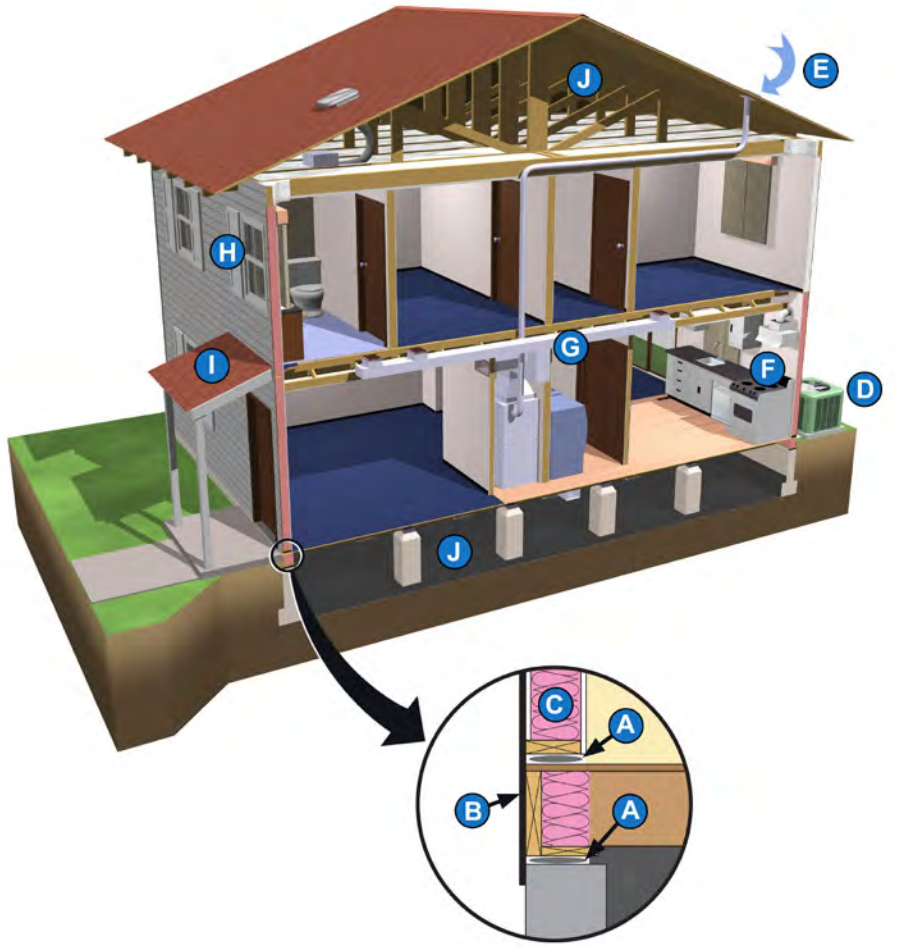
Building America takes a systems approach to home design recognizing that, as buildings become increasingly efficient, one must take into account the interactions of all of the home's components and subassemblies, both to maximize performance and to avoid catastrophe. This "whole-house" approach recognizes 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 affect 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.

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 the home and stops stack effect, limiting drafts and keeping humidity, soil gases, and garage contaminants out of the house. It also 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.

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.

J. **Properly Designed Crawlspaces and Attics:** These and other non-conditioned spaces should either be within the conditioned building envelope or isolated from it by sealed air barriers and insulation.

Water

Rainwater wants to flow down and will take the path of least resistance. To minimize mold and moisture damage in homes, builders must become experts in moisture-management techniques, learning how to guide rainwater 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.

Vapor

Water in its liquid state is not the only problem; water vapor can also be a source of damage. Water vapor causes problems when it is trapped within a building assembly, such as a wall cavity. When warm air touches a cold surface, the water vapor it carries 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.

Water vapor can travel via two means - air movement or vapor diffusion. Of the two, air movement is the far more likely means of vapor transport; research shows 30 times more water vapor is carried through walls by air flow than by diffusion. Warmer air carries more vapor than cold air. Wherever there are air leaks, vapor can be carried, for example into attics or wall cavities. Stopping air leaks by thoroughly air sealing the building envelope is an important step in limiting damage from water vapor.

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 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. One example is inward solar vapor drive, which can occur with "reservoir claddings" such as brick veneer or stucco, that absorb moisture, which is then driven inward by solar heat.

(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 Retarder Definitions

The 2009 IRC R601.3 gives the following definitions and examples for vapor retarder classes:

Class	Definition	Examples
I	≤0.1 perm	Sheet polyethylene, sheet metal, non-perforated aluminum foil
II	>0.1 to <1.0 perm	Kraft-faced fiberglass batts or low-perm paint
III	>1.0 perms	Latex or enamel paint

Perm Ratings of Common Sheathing Materials

A perm is a measure of the permeability of a material. It indicates how much water vapor can pass through a material over a fixed period of time; the higher the number, the more easily water vapor can pass through.

Plywood sheathing	More than 1.0 perm
OSB	More than 1.0 perm
Exterior gypsum	More than 1.0 perm
Fiberboard sheathing	More than 1.0 perm
Extruded polystyrene foam sheathing 1 inch	1.0 perm or less
Expanded polystyrene rigid foam 1 inch	2 – 5 perms
Film-faced extruded polystyrene 0.5 inch thick with perforated facing	More than 1.0 perm
Non-perforated foil-faced rigid insulation	Less than 0.1 perm
Polypropylene-faced rigid insulation	Less than 0.1 perm
Three-coat, hard-coat stucco over 2 layers of Type D asphalt-saturated Kraft paper and OSB	Less than 1.0 perm

Source: Lstiburek 2006. See Building Science Corporation 2006 for an extensive list of building material perm ratings.

Vapor movement through a building component can be impeded by use of a vapor diffusion retarder. Some building scientists will use the terms vapor retarder and vapor barrier interchangeably. Some building scientists refer to vapor retarders as materials with 0.1 to 1.0 perm and vapor barriers as materials with less than 0.1 permeability. The 2009 IRC uses the term vapor retarder to refer to all such materials. Code defines classes of vapor retarders based on their perm ratings (see table at left). Vapor retarder requirements were removed in the 2009 IECC; however, vapor retarder requirements are addressed in the 2009 IRC.

The **2009 IRC R601.3 (2012 IRC R702.7)** requires no vapor retarders in walls in IECC Climate Zones 1, 2, 3, and 4 (except Marine 4). Building scientists recommend against putting a vapor retarder in walls in the hot-humid and mixed-humid climates.

Historically, code has encouraged the use of vapor retarders on the warm-in-winter side of the insulation (2006 IRC R318.1). In warm climates that would be on the exterior side of the thermal barrier; in cold climates, that would be on the interior side of the thermal barrier. In the mixed-humid climate, placement of the vapor retarder based on winter conditions might place the vapor retarder on the "wrong" side during the summer.

Since the 2006 IECC and IRC, code has exempted IECC Climate Zones 1 through 4 (which includes the hot-humid and mixed-humid climates) from the requirement to have a vapor retarder. Even in Climate Zones 5 through 8, the IRC does not require a Class I or II vapor retarder like polyethylene but permits the use of a Class III vapor retarder like latex paint if the wall cavity has a vented cladding or rigid foam sheathing, as defined in the 2009 IRC Table R601.3.1.

Walls in the mixed-humid climate that are properly vented with an air gap and/or walls with insulated foam sheathing should not need a vapor retarder layer. Wall venting behind brick and stone 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 spaces behind brick help to dissipate this vapor before it is injected into the framed cavity. The amount of ventilation gap depends on the cladding used—the gap should be 1 or more inches behind brick or stone veneer, 3/4 inch behind stucco, and 1/16 inch behind lap siding.

To prevent vapor-related moisture accumulation and damage in wall cavities, walls should not have a Class I vapor barrier installed on the interior side of the wall's thermal boundary and should not have vinyl wall coverings installed on the home's interior wall surfaces.

(left) 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)*

(right) Urbane Homes of Louisville, Kentucky, uses XPS rigid foam instead of OSB for the sheathing on their homes' exterior walls. The sheathing (shown here from inside the house) was taped at the seams and covered with housewrap.

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.

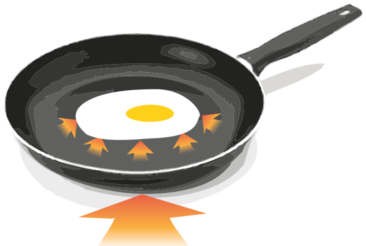
Air movement can affect how well insulation works. When outside air is pushed through insulation in places such as attics, walls, or crawlspaces, it robs the insulation's ability to slow down heat loss. This process is called wind wash or air intrusion. Using baffles, dams, and wind blocks in attics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

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.)

Conduction

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

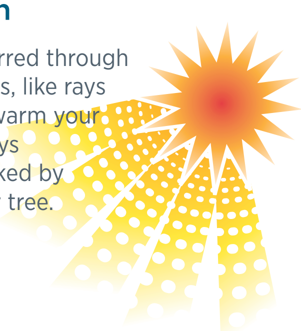


Convection

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 through 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 pulls unfiltered air and soil gases into a home through cracks in the foundation and around doors and windows and it draws conditioned air up and out through air leaks around ceilings, chimneys, flue, and pipe chases.

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. Using supply ventilation provides make up air for combustion appliances and maintains the interior of the home at a slight positive air pressure with conditioned air that will also discourage the infiltration of hot humid air (Lstiburek 2005). Mechanical ventilation and sealed combustion systems are described in Chapter 9.

Heat Transfer

Heat travels via three mechanisms: conduction, convection, and radiation.

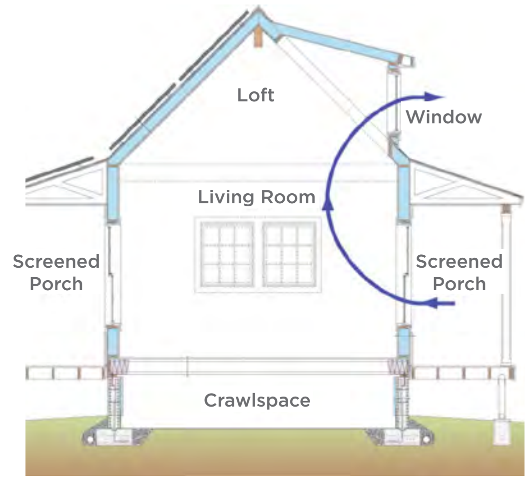
Conduction

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 easier to fill voids using blown-in or sprayfoam insulation than with batt insulation. 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.



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

Convection

Convection is the movement of heat via a gas or liquid. Warm air becomes buoyant, while cold air tends to sink. Convection is the force that draws hot air up a chimney. This force is sometimes called the stack effect.

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 the summer, air-conditioned structures, colder air sinks, drawing in warmer air through leaks in the building envelope. Warmer air carries more moisture than cold air; as it cools, this moisture may condense inside structural assemblies. This outside air 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 when conditioned and unconditioned air mix.

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

"A house is a really complicated set of systems and, as you start to build higher performing houses, the way in which those systems interact requires more detailed analysis. I would encourage others to take the time to do that analysis."

Will Bradshaw, President,
Green Coast Enterprises, New Orleans

Radiation

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

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

Techniques for controlling solar radiation heat gain include tree shading and 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 cold 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.

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 can have an enormous impact on the energy performance of their homes by 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.

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Chapter 7.
The Overall Building Envelope

The building envelope is the boundary that separates interior comfort from exterior conditions. The envelope 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, insulating, 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.

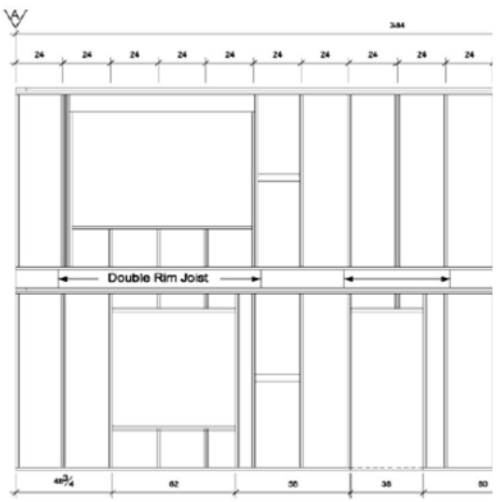
Advanced Framing

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 leaves more room for insulation while saving resources and reducing waste. The recommendations below apply to framed walls using dimensional lumber. Other energy-efficient wall construction materials not described here include structural insulated panels, insulated concrete forms, and steel framing.

"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



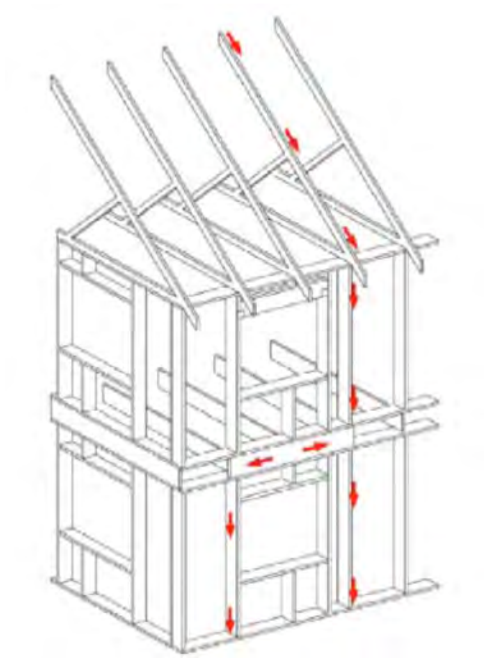
(left) Sheet goods come in 4x8-foot dimensions. Designing and building on a 2-foot grid saves cutting time and reduces lumber and sheet good waste.

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

In one Building America study, 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 (PATH 2005). 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.

Building America research team lead Building Science Corporation helped David Weekley Homes implement advanced framing at its homes in Houston, Texas. Analysis by Building Science Corporation on one home model showed switching from 2x4 16-inch on-center to 2x6 24-inch on-center construction could reduce board feet by 40% (from 5,186 ft to 3,082 ft) and cut costs by 40%, from $2,749 to $1,632. In this analysis, the number of 8-ft studs was cut by 52% from 1,403 to 665.

While lumber savings are significant, there may be added costs for additional insulation, drywall clips and fastening hardware, and supervision time to train subcontractors. In hurricane-prone areas, talk to local code inspectors to determine approval before incorporating advanced framing techniques into your designs. See the advanced framing installer's guide in Chapter 14 for more details on advanced framing and for a sample shear panel to strengthen foam-sheathed walls in hurricane-prone areas.



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

Advanced framing techniques will increase the amount of space in your wall for insulation and will decrease the amount of thermal bridging, but to eliminate thermal bridging completely in a framed wall, consider using rigid foam sheathing insulation, which is described in the next section.

A sample of advanced framing techniques includes the following:

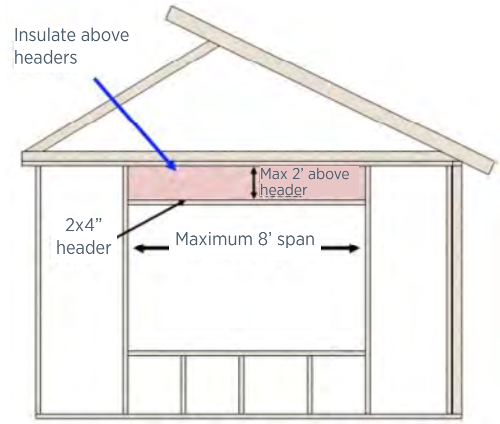
- **TWO-FOOT MODULE DESIGN.** Starting with the foundation, the house exterior dimension footprint should be based on 2-foot increments. Because sheet goods come in 4-foot by 8-foot dimensions, this reduces waste and cuts material costs.

- **FRAME 24-INCH ON-CENTER.** Typical practice is to frame walls, floors, and often roofs at 16 inches 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 construction (PATH 2005).

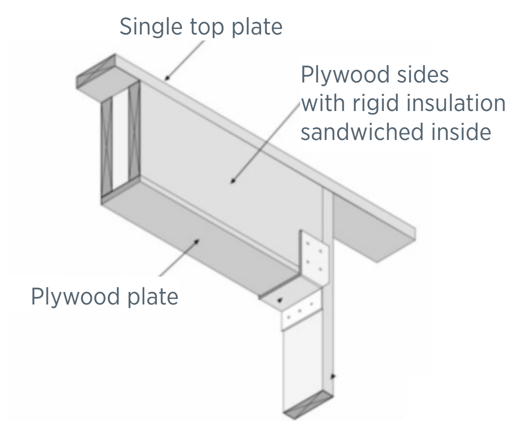
- **ALIGN FRAMING MEMBERS AND USE A SINGLE TOP PLATE.** Double top plates are used to distribute loads from framing members that are not aligned above studs and joists. By aligning framing members vertically throughout the structure, the second plate can be eliminated. Plate sections are cleated together using flat plate connectors [2009 IRC R602.3.2].

- **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.

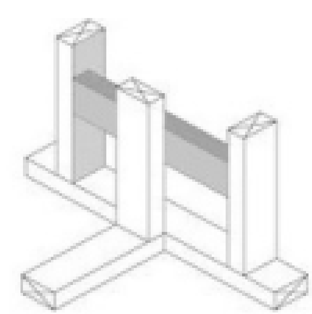
- **LADDER-BLOCK EXTERIOR WALL INTERSECTIONS.** Where interior partitions intersect exterior walls, three-stud "partition post" or stud-block-stud configurations are typically inserted. Except where expressly engineered, these are unnecessary. Partitions can be nailed either directly to a single exterior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



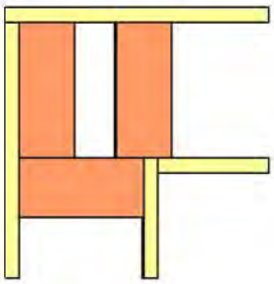
Using single 2x4 headers instead of double 2x6 headers in non-load-bearing walls allows space for insulation.



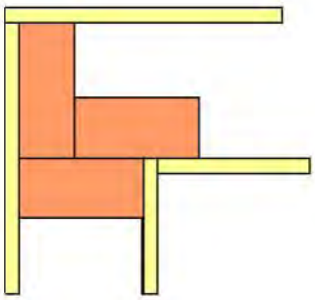
Closed, insulated headers are one advanced framing technique. *(Figure source: CARB)*



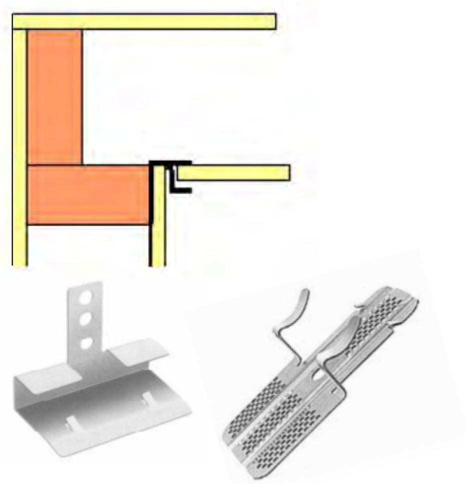
Ladder blocking where exterior walls intersect interior walls provides space for insulation and cuts back on thermal bridging.



Conventional three-stud corner leaves a cavity that must be insulated by the framers—not good.



Improved three-stud corner allows insulation to be installed later, in sequence.



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

- **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 subfloor 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 inches on center or 2x4 "flat studs" at 16 inches on center [2009 IRC R602.5].

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Insulation

Insulation provides the thermal boundary in the home's walls, ceiling, and foundation by blocking heat loss through conduction. Insulation comes in a variety of forms; some of the common options are described below. Average R-values are provided in the table. Vapor retarders are not recommended on the interior of wall assemblies in the hot- or mixed-humid climate (they can trap moisture inside the wall cavity). Therefore, kraft-faced or foil-faced insulation should not be used in framed or masonry walls in the mixed-humid climate.

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		

(1) Batt insulation in ceiling. *(2)* Blown-in insulation. *(3)* Spray foam. *(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.

BLANKETS OR BATTS: Blanket insulation in the form of batts or rolls is a flexible product 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. Proper installation (where the batt fills the full cavity

(top) Masonry walls can be insulated with rigid foam insulation on the interior (shown here) or exterior.

(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.

with no sagging, pinching or gaps) is key to getting full R-value from the batts. 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. They are available with or without vapor retarder facings. Kraft facing forms a Class II vapor retarder. If batts are used for wall insulation in the mixed-humid climate, they should be unfaced.

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 rim 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. 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. Rigid foam insulating sheathing has other significant benefits, particularly in the areas of moisture control. Inwardly driven moisture from reservoir claddings such as brick and stucco can be controlled by rigid foam insulating sheathing. Code permits the use of exterior rigid foam insulating sheathing [2009 IRC 601.3]. If sufficiently braced, walls can use rigid foam as an insulating sheathing in place of oriented strand board (OSB) and plywood sheathings for cost savings.

Rigid foam 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 whose cavities 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. The foil facing is a vapor barrier so, in general, foil-faced insulation should not be used on the interior side of walls in the mixed-humid climate.

- **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. The EPA deadline to switch to a non-ozone-depleting, VOC-free blowing agent was January 1, 2010.

Bob Ward Companies used an exterior wall sheathing consisting of a 1/8-inch layer of laminated fiberboard covered with 1-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 Companies)*

David Weekley Homes uses a radiant barrier product that comes adhered to the underside of the roof sheathing. *(Photo Source: David Weekley Homes)*

- **Expanded Polystyrene (EPS) – 2.3 to 4 R-value per inch**
  EPS foam 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.

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

REFLECTIVE INSULATION AND RADIANT BARRIERS:

Reflective insulation is fabricated from aluminum foil and comes with a variety of backings such as rigid polyisocyanurate foam, kraft paper, plastic film, polyethylene bubbles, or cardboard. It is also available as a roof sheathing product where the reflective surface comes pre-adhered to the OSB sheathing layer. Reflective insulation is used in attics, walls, and floors, usually in combination with other insulation products. Because it is a vapor barrier, it should not be used on the "cold side" (interior) of the thermal envelope in the mixed-humid climate, except as noted above in the description of polyisocyanurate.

A common application in hot climates is the use of radiant barriers in attics to impede radiant heat transfer from the roof into the attic and the rooms below. The radiant barrier can be installed in one of three ways: stapled to the underside of the roof rafters, laid on top of the roof rafters before the roof sheathing is laid, or applied as part of an integrated reflective roof sheathing product. In all cases, the reflective "shiny" side faces down toward the ceiling and there most be an airspace below the radiant barrier for it to work properly. The radiant barrier should not be laid on top of ceiling insulation with the shiny side facing up as dust accumulation will soon inhibit its effectiveness.

Studies show that radiant barriers can cut cooling costs between 8% and 12% in hot climates. The savings will be greatest if you have cooling equipment or duct work in the attic. For more on radiant barriers and their installation, see the radiant barriers primer by Building America research partner the Florida Solar Energy Center (FSEC 2005).

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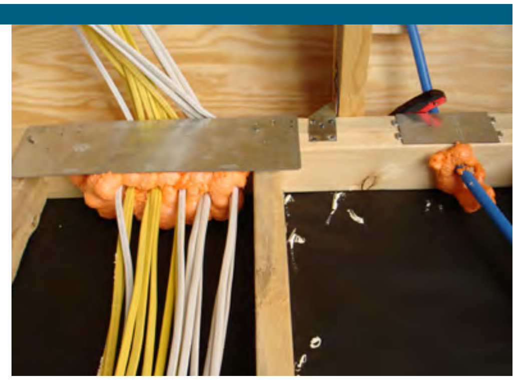

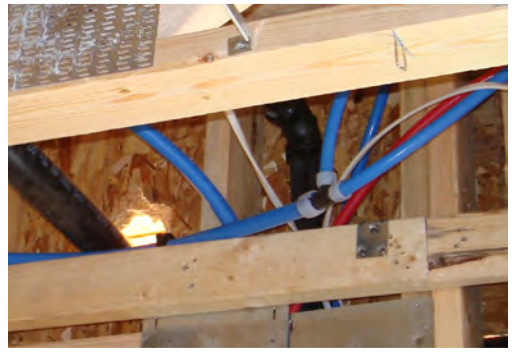

(top) Holes in the top plate for wiring are sealed with foam.

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

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

(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.

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. Air sealing is required 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 14).

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 9.

ENERGY STAR Thermal Enclosure Checklist

As part of the qualifications for ENERGY STAR for Homes Version 3.0, ENERGY STAR has developed a new Thermal Enclosure System Rater Checklist that guides builders and raters through verification of several points in the home's thermal boundary. These include windows, insulation, air barriers in walls, floors, and ceilings, reduced thermal bridging, and air sealing. The checklist can be seen on the following pages. See the ENERGY STAR website more information about this checklist and other criteria for ENERGY STAR for Homes Version 3.0, which will become effective for all new homes January 1, 2012.

For More Information on Air Sealing

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(top) Pine Mountain Builders spray foams their unvented attics with R-30 of low-density spray foam to provide a conditioned space for the high-efficiency heat pump and ducts. *(Photo Source: IBACOS)*

(bottom) Rigid foam wall sheathing is taped at seams and all holes are taped as well to provide a continuous air barrier. These measures help Imagine Homes achieve whole-house air leakage of less than 2.5 air changes per hour at 50 Pascals. *(Photo Source: IBACOS)*

ENERGY STAR Qualified Homes, Version 3 (Rev. 04) Thermal Enclosure System Rater Checklist

Home Address: ______________________________ City: ______________________________ State:________

Inspection Guidelines	Must Correct	Builder Verified [1]	Rater Verified	N/A
1. High-Performance Fenestration				
1.1 *Prescriptive Path:* Fenestration shall meet or exceed ENERGY STAR requirements [2]	☐	☐	☐	☐
1.2 *Performance Path*: Fenestration shall meet or exceed 2009 IECC requirements [2]	☐	☐	☐	☐
2. Quality-Installed Insulation				
2.1 Ceiling, wall, floor, and slab insulation levels shall meet or exceed 2009 IECC levels [3,4,5]	☐	☐	☐	☐
2.2 All ceiling, wall, floor, and slab insulation shall achieve RESNET-defined Grade I installation or, alternatively, Grade II for surfaces with insulated sheathing (see Checklist Item 4.4.1 for required insulation levels)	☐	☐	☐	☐
3. Fully-Aligned Air Barriers [6]				
At each insulated location noted below, a complete air barrier shall be provided that is fully aligned with the insulation as follows: • At interior or exterior surface of ceilings in Climate Zones 1-3; at interior surface of ceilings in Climate Zones 4-8. Also, include barrier at interior edge of attic eave in all climate zones using a wind baffle that extends to the full height of the insulation. Include a baffle in every bay or a tabbed baffle in each bay with a soffit vent that will also prevent wind washing of insulation in adjacent bays • At exterior surface of walls in all climate zones; and also at interior surface of walls for Climate Zones 4-8 [7] • At interior surface of floors in all climate zones, including supports to ensure permanent contact and blocking at exposed edge [8,9]				
3.1 Walls [10]				
3.1.1 Walls behind showers and tubs	☐	☐	☐	☐
3.1.2 Walls behind fireplaces	☐	☐	☐	☐
3.1.3 Attic knee walls	☐	☐	☐	☐
3.1.4 Skylight shaft walls	☐	☐	☐	☐
3.1.5 Wall adjoining porch roof	☐	☐	☐	☐
3.1.6 Staircase walls	☐	☐	☐	☐
3.1.7 Double walls	☐	☐	☐	☐
3.1.8 Garage rim / band joist adjoining conditioned space	☐	☐	☐	☐
3.1.9 All other exterior walls	☐	☐	☐	☐
3.2 Floors				
3.2.1 Floor above garage	☐	☐	☐	☐
3.2.2 Cantilevered floor	☐	☐	☐	☐
3.2.3 Floor above unconditioned basement or unconditioned crawlspace	☐	☐	☐	☐
3.3 Ceilings [10]				
3.3.1 Dropped ceiling / soffit below unconditioned attic	☐	☐	☐	☐
3.3.2 All other ceilings	☐	☐	☐	☐
4. Reduced Thermal Bridging				
4.1 For insulated ceilings with attic space above (i.e., non-cathedralized ceilings), uncompressed insulation extends to the inside face of the exterior wall below at the following levels: CZ 1 to 5: ≥ R-21; CZ 6 to 8: ≥ R-30 [11]	☐	☐	☐	☐
4.2 For slabs on grade in CZ 4 and higher, 100% of slab edge insulated to ≥ R-5 at the depth specified by the 2009 IECC and aligned with thermal boundary of the walls [4,5]	☐	☐	☐	☐
4.3 Insulation beneath attic platforms (e.g., HVAC platforms, walkways) ≥ R-21 in CZ 1 to 5; ≥ R-30 in CZ 6 to 8	☐	☐	☐	☐
4.4 Reduced thermal bridging at above-grade walls separating conditioned from unconditioned space (rim / band joists exempted) using one of the following options: [12,13]				
4.4.1 Continuous rigid insulation, insulated siding, or combination of the two; ≥ R-3 in Climate Zones 1 to 4, ≥ R-5 in Climate Zones 5 to 8 [14,15], **OR**;	☐	☐	☐	☐
4.4.2 Structural Insulated Panels (SIPs), **OR**;	☐	☐	☐	☐
4.4.3 Insulated Concrete Forms (ICFs), **OR**;	☐	☐	☐	☐
4.4.4 Double-wall framing [16], **OR**;	☐	☐	☐	☐
4.4.5 Advanced framing, including all of the items below:				
4.4.5a All corners insulated ≥ R-6 to edge [17], **AND**;	☐	☐	☐	☐
4.4.5b All headers above windows & doors insulated [18], **AND**;	☐	☐	☐	☐
4.4.5c Framing limited at all windows & doors [19], **AND**;	☐	☐	☐	☐
4.4.5d All interior / exterior wall intersections insulated to the same R-value as the rest of the exterior wall [20], **AND**;	☐	☐	☐	☐
4.4.5e Minimum stud spacing of 16" o.c. for 2x4 framing in all Climate Zones and, in Climate Zones 5 through 8, 24" o.c. for 2x6 framing unless construction documents specify other spacing is structurally required [21]	☐	☐	☐	☐

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ENERGY STAR Qualified Homes, Version 3 (Rev. 04) Thermal Enclosure System Rater Checklist

Inspection Guidelines	Must Correct	Builder Verified [1]	Rater Verified	N/A
5. Air Sealing				
5.1 Penetrations to unconditioned space fully sealed with solid blocking or flashing as needed and gaps sealed with caulk or foam				
5.1.1 Duct / flue shaft	☐	☐	☐	☐
5.1.2 Plumbing / piping	☐	☐	☐	☐
5.1.3 Electrical wiring	☐	☐	☐	☐
5.1.4 Bathroom and kitchen exhaust fans	☐	☐	☐	☐
5.1.5 Recessed lighting fixtures adjacent to unconditioned space ICAT labeled and fully gasketed. Also, if in insulated ceiling without attic above, exterior surface of fixture insulated to ≥ R-10 in CZ 4 and higher to minimize condensation potential.	☐	☐	☐	☐
5.1.6 Light tubes adjacent to unconditioned space include lens separating unconditioned and conditioned space and are fully gasketed [22]	☐	☐	☐	☐
5.2 Cracks in the building envelope fully sealed				
5.2.1 All sill plates adjacent to conditioned space sealed to foundation or sub-floor with caulk. Foam gasket also placed beneath sill plate if resting atop concrete or masonry and adjacent to conditioned space.	☐	☐	☐	☐
5.2.2 At top of walls adjoining unconditioned spaces, continuous top plates or sealed blocking using caulk, foam, or equivalent material	☐	☐	☐	☐
5.2.3 Sheetrock sealed to top plate at all attic / wall interfaces using caulk, foam, or equivalent material. Either apply sealant directly between sheetrock and top plate or to the seam between the two from the attic above. Construction adhesive shall not be used.	☐	☐	☐	☐
5.2.4 Rough opening around windows & exterior doors sealed with caulk or foam [23]	☐	☐	☐	☐
5.2.5 Marriage joints between modular home modules at all exterior boundary conditions fully sealed with gasket and foam	☐	☐	☐	☐
5.2.6 All seams between Structural Insulated Panels (SIPs) foamed and / or taped per manufacturer's instructions	☐	☐	☐	☐
5.2.7 In multifamily buildings, the gap between the drywall shaft wall (i.e. common wall) and the structural framing between units fully sealed at all exterior boundaries	☐	☐	☐	☐
5.3 Other openings				
5.3.1 Doors adjacent to unconditioned space (e.g., attics, garages, basements) or ambient conditions gasketed or made substantially air-tight	☐	☐	☐	☐
5.3.2 Attic access panels and drop-down stairs equipped with a durable ≥ R-10 insulated cover that is gasketed (i.e., not caulked) to produce continuous air seal when occupant is not accessing the attic [24]	☐	☐	☐	☐
5.3.3 Whole-house fans equipped with a durable ≥ R-10 insulated cover that is gasketed and either installed on the house side or mechanically operated [24]	☐	☐	☐	☐

Rater Name: ______________________ Rater Pre-Drywall Inspection Date: _________ Rater Initials: ________

Rater Name: ______________________ Rater Final Inspection Date: ____________ Rater Initials: ________

Builder Employee: ____________________ Builder Inspection Date: ______________ Builder Initials: _______

Notes:

1. At the discretion of the Rater, the builder may verify up to eight items specified in this Checklist. When exercised, the builder's responsibility will be formally acknowledged by the builder signing off on the checklist for the item(s) that they verified.
2. *For Prescriptive Path:* All windows, doors, and skylights shall meet or exceed ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights – Version 5.0 as outlined at www.energystar.gov/windows. *For Performance Path:* All windows, doors and skylights shall meet or exceed the component U-factor and SHGC requirements specified in the 2009 IECC – Table 402.1.1. If no NFRC rating is noted on the window or in product literature (e.g., for site-built fenestration), select the U-factor and SHGC value from tables 4 and 14, respectively, in 2005 ASHRAE Fundamentals, Chapter 31. Select the highest U-factor and SHGC value among the values listed for the known window characteristics (e.g., frame type, number of panes, glass color, and presence of low-e coating). Note that the U-factor requirement applies to all fenestration while the SHGC only applies to the glazed portion. The following exceptions apply:
   a. An area-weighted average of fenestration products shall be permitted to satisfy the U-factor requirements;
   b. An area-weighted average of fenestration products ≥ 50% glazed shall be permitted to satisfy the SHGC requirements;
   c. 15 square feet of glazed fenestration per dwelling unit shall be exempt from the U-factor and SHGC requirements, and shall be excluded from area-weighted averages calculated using a) and b), above;

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ENERGY STAR Qualified Homes, Version 3 (Rev. 04) Thermal Enclosure System Rater Checklist

d. One side-hinged opaque door assembly up to 24 square feet in area shall be exempt from the U-factor requirements and shall be excluded from area-weighted averages calculated using a) and b), above;

e. Fenestration utilized as part of a passive solar design shall be exempt from the U-factor and SHGC requirements, and shall be excluded from area-weighted averages calculated using a) and b), above. Exempt windows shall be facing within 45 degrees of true south and directly coupled to thermal storage mass that has a heat capacity > 20 btu / ft^3x^oF and provided in a ratio of at least 3 sq. ft. per sq. ft. of south facing fenestration. Generally, thermal mass materials will be at least 2 in. thick.

3. Insulation levels in a home shall meet or exceed the component insulation requirements in the 2009 IECC - Table 402.1.1. The following exceptions apply:

   a. Steel-frame ceilings, walls, and floors shall meet the insulation requirements of the 2009 IECC – Table 402.2.5. In CZ 1 and 2, the continuous insulation requirements in this table shall be permitted to be reduced to R-3 for steel-frame wall assemblies with studs spaced at 24 in. on center. This exception shall not apply if the alternative calculations in d) are used;

   b. For ceilings with attic spaces, R-30 shall satisfy the requirement for R-38 and R-38 shall satisfy the requirement for R-49 wherever the full height of uncompressed insulation at the lower R-value extends over the wall top plate at the eaves. This exemption shall not apply if the alternative calculations in d) are used;

   c. For ceilings without attic spaces, R-30 shall satisfy the requirement for any required value above R-30 if the design of the roof / ceiling assembly does not provide sufficient space for the required insulation value. This exemption shall be limited to 500 square ft. or 20% of the total insulated ceiling area, whichever is less. This exemption shall not apply if the alternative calculations in d) are used;

   d. An alternative equivalent U-factor or total UA calculation may also be used to demonstrate compliance, as follows:

      An assembly with a U-factor equal or less than specified in 2009 IECC Table 402.1.3 complies.

      A total building thermal envelope UA that is less than or equal to the total UA resulting from the U-factors in Table 402.1.3 also complies. The insulation levels of all non-fenestration components (i.e., ceilings, walls, floors, and slabs) can be traded off using the UA approach under both the Prescriptive and the Performance Path. Note that fenestration products (i.e., windows, skylights, doors) shall not be included in this calculation. Also, note that while ceiling and slab insulation can be included in trade-off calculations, the R-value must meet or exceed the minimum values listed in Items 4.1 through 4.3 of the Checklist to provide an effective thermal break, regardless of the UA tradeoffs calculated. The UA calculation shall be done using a method consistent with the ASHRAE Handbook of Fundamentals and shall include the thermal bridging effects of framing materials. The calculation for a steel-frame envelope assembly shall use the ASHRAE zone method or a method providing equivalent results, and not a series-parallel path calculation method.

4. Consistent with the 2009 IECC, slab edge insulation is only required for slab-on-grade floors with a floor surface less than 12 inches below grade. Slab insulation shall extend to the top of the slab to provide a complete thermal break. If the top edge of the insulation is installed between the exterior wall and the edge of the interior slab, it shall be permitted to be cut at a 45-degree angle away from the exterior wall.

5. Where an insulated wall separates a garage, patio, porch, or other unconditioned space from the conditioned space of the house, slab insulation shall also be installed at this interface to provide a thermal break between the conditioned and unconditioned slab. Where specific details cannot meet this requirement, partners shall provide the detail to EPA to request an exemption prior to the home's qualification. EPA will compile exempted details and work with industry to develop feasible details for use in future revisions to the program. A list of currently exempted details is available at: www.enegystar.gov/slabedge.

6. For purposes of this Checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers.

   Open-cell or closed-cell foam shall have a finished thickness $\geq$ 5.5 in. or 1.5 in., respectively, to qualify as an air barrier unless the manufacturer indicates otherwise.

   If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads $\geq$ 1 in. diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be $\geq$ 6 mil.

7. EPA highly recommends, but does not require, inclusion of an interior air barrier at band joists in Climate Zone 4 through 8.

8. Examples of supports necessary for permanent contact include staves for batt insulation or netting for blown-in insulation. Batts that completely fill a cavity enclosed on all six sides may be used to meet this requirement without the need for supports, even though some compression will occur due to the excess insulation, as long as the compressed value meets or exceeds the required insulation level. Specifically, the following batts may be used in six-sided floor cavities: R-19 batts in 2x6 cavities, R-30 batts in 2x8 cavities, R-38 batts in 2x10 cavities, and R-49 batts in 2x12 cavities. For example, in a home that requires R-19 floor insulation, an R-30 batt may be used in a six-sided 2x8 floor cavity.

9. Fully-aligned air barriers may be installed at the exterior surface of the floor cavity in all Climate Zones if the insulation is installed in contact with this exterior air barrier and the perimeter rim and band joists of the floor cavity are also sealed and insulated to comply with the fully-aligned air barrier requirements for walls.

ENERGY STAR Qualified Homes, Version 3 (Rev. 04) Thermal Enclosure System Rater Checklist

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.
11. The minimum designated R-values must be achieved regardless of the trade-offs determined using an equivalent U-factor or UA alternative calculation. Note that if the minimum designated values are used, they must be compensated with higher values elsewhere using an equivalent U-factor or UA alternative calculation in order to meet the overall insulation requirements of the 2009 IECC. Also, note that these requirements can be met by using any available strategy, such as a raised-heel truss, alternate framing that provides adequate space, and / or high-density insulation. In Climate Zones 1 through 3, one option that will work for most homes is to use 2x6 framing, an R-21 high-density batt, and a wind baffle that only requires 0.5 in. of clearance.
12. Up to 10% of the total exterior wall surface area is exempted from the reduced thermal bridging requirements to accommodate intentional designed details (e.g., architectural details such as thermal fins, wing walls, or masonry fireplaces; structural details, such as steel columns). It shall be apparent to the Rater that the exempted areas are intentional designed details or the exempted area shall be documented in a plan provided by the builder, architect, designer, or engineer. The Rater need not evaluate the necessity of the designed detail to qualify the home.
13. Mass walls utilized as the thermal mass component of a passive solar design (e.g., a Trombe wall) are exempt from this item. To be eligible for this exemption, the passive solar design shall be comprised of the following five components: an aperture or collector, an absorber, thermal mass, a distribution system, and a control system. For more information, see: http://www.energysavers.gov/your_home/designing_remodeling/index.cfm/mytopic=10270.

    Mass walls that are not part of a passive solar design (e.g., CMU block or log home enclosure) shall either utilize the strategies outlined in Section 4.4 or the pathway in the assembly with the least thermal resistance shall provide ≥ 50% of the applicable component insulation requirement in the 2009 IECC – Table 402.1.1.
14. If used, insulated siding shall be attached directly over a water-resistive barrier and sheathing. In addition, it shall provide the required R-value as demonstrated through either testing in accordance with ASTM C 1363 or by attaining the required R-value at its minimum thickness. Insulated sheathing rated for water protection can be used as a water resistant barrier if all seams are taped and sealed. If non-insulated structural sheathing is used at corners, advanced framing details listed under Item 4.4.5 shall be met for those wall sections.
15. Steel framing shall meet the reduced thermal bridging requirements by complying with Item 4.4.1 of the Checklist.
16. Double-wall framing is defined as any framing method that ensures a continuous layer of insulation covering the studs to at least the R-value required in Section 4.4.1 of the Checklist, such as offset double-stud walls, aligned double-stud walls with continuous insulation between the adjacent stud faces, or single-stud walls with 2x2 or 2x3 cross-framing. In all cases, insulation shall fill the entire wall cavity from the interior to exterior sheathing except at windows, doors and other penetrations.
17. All exterior corners shall be constructed to allow access for the installation of ≥ R-6 insulation that extends to the exterior wall sheathing. Examples of compliance options include standard-density insulation with alternative framing techniques, such as using three studs per corner, or high-density insulation (e.g., spray foam) with standard framing techniques.
18. Header insulation shall be ≥ R-3 for wall assemblies with 2x4 framing, or equivalent cavity width, and ≥ R-5 for all other assemblies (e.g., with 2x6 framing). Compliance options include continuous rigid insulation sheathing, SIP headers, other prefabricated insulated headers, single-member or two-member headers with insulation either in between or on one side, or an equivalent assembly, except where a framing plan provided by the builder, architect, designer, or engineer indicates that full-depth solid headers are the only acceptable option. The Rater need not evaluate the structural necessity of the details in the framing plan to qualify the home. Also, the framing plan need only encompass the details in question and not necessarily the entire home. R-value requirement refers to manufacturer's nominal insulation value.
19. Framing at windows shall be limited to a maximum of one pair of king studs and one pair jack studs per window opening to support the header and window sill. Additional jack studs shall be used only as needed for structural support and cripple studs only as needed to maintain on-center spacing of studs.
20. Insulation shall run behind interior / exterior wall intersections using ladder blocking, full length 2x6 or 1x6 furring behind the first partition stud, drywall clips, or other equivalent alternative.
21. Vertical framing members shall either be on-center or have an alternative structural purpose (e.g., framing members at the edge of pre-fabricated panels) that is apparent to the Rater or documented in a framing plan provided by the builder, architect, designer, or engineer. The Rater need not evaluate the structural necessity of the details in the framing plan to qualify the home. Also, the framing plan need only encompass the details in question and not necessarily the entire home. No more than 5% of studs may lack an apparent or documented structural purpose, which is equivalent to one vertical stud for every 30 linear feet of wall, assuming 16 in. o.c. stud spacing.
22. Light tubes that do not include a gasketed lens are required to be sealed and insulated ≥ R-6 for the length of the tube.
23. In Climate Zones 1 through 3, stucco over rigid insulation tightly sealed to windows and doors shall be considered equivalent to sealing rough openings with caulk or foam.
24. Examples of durable covers include, but are not limited to, pre-fabricated covers with integral insulation, rigid foam adhered to cover with adhesive, or batt insulation mechanically fastened to the cover (e.g., using bolts, metal wire, or metal strapping).

Effective for homes permitted starting 10/1/2011 Revised 8/29/2011 Page 6 of 16

Chapter 8.

Building Envelope Sub-Assemblies

Most home designs today are far more complicated than four walls and a roof. Builders need to pay attention to the details of each assembly to deliver energy performance *(Photo Source: Urbane Homes)*.

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

Foundation Assemblies

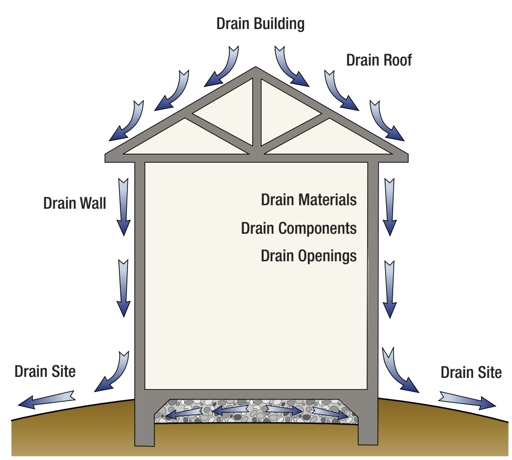
Slabs, crawlspaces, and basements are all common foundation types in the mixed-humid climate. Slabs can be monolithic or poured inside stem walls on footers. The foundation forms the solid underpinning for a house's structural integrity. It also provides the boundary between the house and the ground, 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 14 for examples of detailed foundation drawings that show measures for controlling moisture, air, and heat flow.

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.

In vented crawlspaces, the dominant source of moisture is bulk water, not water vapor from indoor or outdoor air condensing in the crawlspace. Water enters the crawlspace because of improper

Drain all water away from the structure



(Figure adapted from Building Science Corporation)

(top) Make sure the downspouts are continuous to the ground and extend 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)*

(bottom) Insight Homes in Seaford, Delaware, uses a sealed conditioned crawlspace. The exterior below-grade surface is waterproofed. The crawlspace walls are insulated on the interior side with R-10 extruded polystyrene rigid foam. The floor is covered with two layers of polythylene sheeting that is sealed to the perimeter walls.

irrigation practices, ground slope, rain runoff, high groundwater tables, rain 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 described below.

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 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 and 2012 IRC R703.1 and R703.8].
- Slope top soil to drain away from the house. [2009 and 2012 IRC R401.3 require 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. [2009 and 2012 IRC R401.3 require 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 the ground surface.
- Install a protective shield such as a plastic L bracket, gasket, or water-proof membrane between the foundation wall stem and sill plate to keep water from wicking into the wall from the foundation. Metal flashing can also serve this function and serve as a termite shield [2009 and 2012 IRC R318.3].
- Damp-proof or water-proof all below-grade portions of the exterior concrete foundation walls [2009 and 2012 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. [The 2009 IECC 402.2.9 and 2012 IECC 402.2.10 and the 2009 and 2012 IRC 408.3 require a vapor retarder over exposed earth in unvented crawlspaces.]

- Damp proof the exposed portion of the foundation with latex paint or other sealants.
- 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 under the slab and footings up to grade.
- 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.
- Place a 4-inch-deep, ¾-inch gravel bed directly beneath the polyethylene sheeting to act as a capillary break and drainage pad.
- Ensure that the lowest excavated site foundation level is above the local groundwater table at its maximum elevation [per 2009 and 2012 IRC R408.6].
- 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.
- Place drainage systems below basement floors.
- In flood-prone areas, build homes on piers with floors one foot above the base flood elevation.

David Weekley Homes, Houston, Texas Division, uses a slab foundation including a 4-in.-thick post-tensioned monolithic slab with turned-down edges poured over 6-mil polyethylene, which serves as a capillary break. Slab edge insulation is not used due to termite risk.

Unvented, insulated crawlspaces are recommended in the eastern and midwestern United States, where high humidity levels can cause moisture problems in vented crawlspaces.

Frost Heave and Adfreeze

Frost heave occurs when ice crystals form from water at the freezing plane of soil that is saturated. As the water is pulled up into ice crystals, the ground below dries drawing in more water from the surrounding soil, which is in turn drawn up into ice crystals, thus creating an upward thrust of soil and ice. The concern is that this expanding soil and ice, or frost heave, will push against building foundations causing them to crack and buckle. However, frost expansion always follows the direction of heat loss. So expansion will be up and away from the building foundation if the basement is heated. According to Joseph Lstiburek at Building Science Corporation, several years of investigative work by the Canadian Department of Energy, Mines, and Resources found no evidence of frost-damaged foundations in homes with heated basements, regardless of whether the walls were insulated or uninsulated, and regardless of whether the insulation was on the interior or exterior of the wall (Lstiburek 2011). In insulated basements heat loss is greatly reduced but the direction of heat loss remains outward, and frost direction will follow the direction of heat loss. Another concern is adfreeze, or adhesion freezing, where saturated soil freezes against a foundation wall, adhering to it and lifting the wall when it heaves upward. Fortunately water molecules also migrate in the direction of heat loss so, in cold soil, water will migrate away from the foundation wall of a heated basement, reducing the strength of adhesion bonds and the likelihood of damage. Lstiburek notes that this is again true in insulated as well as uninsulated basements as long as they are heated (Lstiburek 2011).

If you don't want to heat the basement, you can lay a skirt of R-10 rigid insulation around the perimeter of the building laid several inches below ground that extends horizontally a distance equal to the average frost depth. A better option is to avoid frost-susceptible soils and water saturation at the foundation. Use granular soil, not fine or silty soil for backfill along the foundation and provide good site grading and perimeter drainage as described above (Lstiburek 2011).

- Place footings below frost depth.
- Use gravel with no more than 3% grains finer than 0.02 mm. Don't use clays, silts, tills, or very fine-grained sand as a backfill because they are susceptible to frost action.
- Prevent saturation of soil at foundation by grading the site away from the house and providing perimeter drainage at the footing.

Controlling Water Vapor in Foundations

Water vapor from basement and slab foundations can be controlled using a vapor barrier under the slab as described above. Properly constructed slab foundations will avoid the moisture issues that are sometimes problematic in crawlspace foundations.

If a crawlspace foundation is to be used, the traditional method for building them is a vented crawlspace with vents cut in the foundation walls and insulation installed under the floor above the crawlspace. Building science research indicates that unvented, insulated crawlspaces may be preferable in certain climates. Unvented crawlspaces are allowed in the 2009 and 2012 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 (check for any state restrictions).

In areas where summers are humid, some building scientists note that moisture can be carried into the crawlspace in the air drawn through open foundation wall vents. When this warm, moist air reaches cooler structural framing, the moisture can condense onto the framing and cause mold and moisture damage. In winter, cold air is drawn into the crawlspace and does little to dry out crawlspaces, but can lower temperatures, cause condensation on warm floor joists, and freeze exposed water pipes. In these climate conditions, which are common in the mixed-humid climate, researchers recommend sealing, insulating, and conditioning the crawlspace. (See sidebar.)

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

- Install 6-mil polyethylene across the entire ground surface.
- Overlap all seams by 12 inches and tape.
- 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 [2009 IECC 402.2.9; 2012 IECC 402.2.10].

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.

Sealed, conditioned crawlspaces offer non-energy advantages over vented crawlspaces that are worth considering, such as minimizing bulk water intrusion, and pest intrusion. While unvented crawlspaces

To Vent or Not to Vent? Crawlspace Research Looks at Both Sides

Two DOE-funded studies compared vented versus unvented crawlspaces in warm and humid versus dry and cold environments. A study conducted by Advanced Energy of sealed versus unsealed crawlspaces in hot, humid Baton Rouge and cold, dry Flagstaff found that the sealed, insulated crawlspaces were drier than the unsealed crawlspaces. In Baton Rouge average relative humidity was over 80% in the unsealed crawlspaces and under 60% in the sealed crawlspaces; in Flagstaff average relative humidity was just under 70% in unsealed versus under 50% in sealed crawlspaces (Advanced Energy 2009).

A DOE-funded study by Washington State Energy Office found that in the west, where summers are dry and winters are heating-dominated or in dry climates where relative humidity in vented crawlspaces stays low year-round, there is less likelihood of condensation-related moisture problems in the crawlspace so crawlspaces could be vented or unvented, as long as radon is dealt with. The WSU study compared crawlspaces in cold, dry Moses Lake, Washington, and damp Vancouver, Washington. WSU found that even in the marine climate in Vancouver, all of the crawlspaces stayed well below the dew point, although homes with vented crawlspaces had slightly higher relative humidity than those with unvented crawls (Nordeen 2008).

In the cold climate homes, both studies found an energy penalty when installing ducts in the sealed conditioned crawlspaces, due to winter heat loss through the uninsulated floor. Both studies also found elevated radon levels in the sealed, insulated crawlspaces. Among the conclusions drawn from the studies: sealed crawlspaces make sense in humid environments; vented crawlspaces can work in cold and dry climates; best practice is to keep ducts out of crawlspaces; slabs may be preferable; and a passive radon venting system should always be installed as a precautionary measure.

Code/Above Code Foundation Insulation

Code Requirements found in **2009 IECC and 2012 IECC Table R402.1.1**

Code	IECC Climate Zone	
IECC Climate Zone	3	4++
Underfloor Insulation		
2009 IECC	R-19	R-19
2012 IECC	R-19	R-19
Basement Wall Insulation		
2009 IECC	R-5/13+	10/13*
2012 IECC	R-5/13+	10/13*
Slab Edge Insulation		
2009 IECC	R-0	10, 2ft**
2012 IECC	R-0	10, 2ft**
Above Code		
ENERGY STAR Version 3.0	Insulation levels shall meet or exceed 2009 IECC levels and achieve Grade 1 installation per RESNET standards.	

+ *For areas in IECC Climate Zone 3 above the warm-humid line.*

++ *IECC Climate Zone 4, except marine.*

* *R-5 continuous insulated sheathing or R-13 cavity insulation.*

** *Add R-5 slab edge for heated slabs.*

can provide a better environment for HVAC equipment than a vented crawlspace, the best practice is to locate the furnaces and ducts in conditioned space.

Controlling Air Infiltration in Foundations

The greatest challenges for air sealing are at the intersections of different building assemblies. [The **2009 IECC 402.4** requires air sealing of the building thermal envelope at rim joists, utility penetrations, and other areas. In the **2012 IECC**, areas to be air sealed are described in **Table R402.4.1.1**.] 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 air seal and insulate at the rim joist.

Controlling Heat Flow in Foundations

Insulation requirements for the **2009 and 2012 IECC** are found in **Table R402.1.1**. The 2009 and 2012 IECC require zero insulation for slabs in IECC Climate Zone 3. In IECC Climate Zone 4 (except Marine) R-10 insulation is required extending down and/or under or out 2 feet. If the slab floor contains radiant heating elements, then R-5 insulation must be added to the required amount. Both the 2009 and 2012 IECC require a basement wall insulation amount of R-5 continuous insulation on the interior or exterior of the home in IECC Climate Zone 3 above the warm-humid line, or R-10 in IECC Climate Zone 4 (except marine). Alternatively, builders can install R-13 cavity insulation on the inside of the basement walls. Insulated crawlspace R-value requirements are identical to the basement requirements. Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation probability. See the **2009 IRC and the 2012 IRC R318.4** for restrictions on the use of rigid foam for below-grade insulation in areas where the probability of termite infestation is very heavy (which includes parts of some southern states, see map page 8.11).

For More Information on Foundations

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

Slab Foundation Insulation

Where permitted and required by code, slabs in the mixed-humid climate should be insulated at the perimeter with borate-treated foam board or rigid fiberglass insulation approved for below-grade use. Building America recommends that rigid insulation be placed on the interior side of the stem wall from the slab to the top of the footing. Rigid foam insulation can also be laid underneath the slab. This provides additional moisture control and minimizes the likelihood of condensation and mold in carpeting and floor coverings over an uninsulated floor.

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.

For More Information on Slab Foundations

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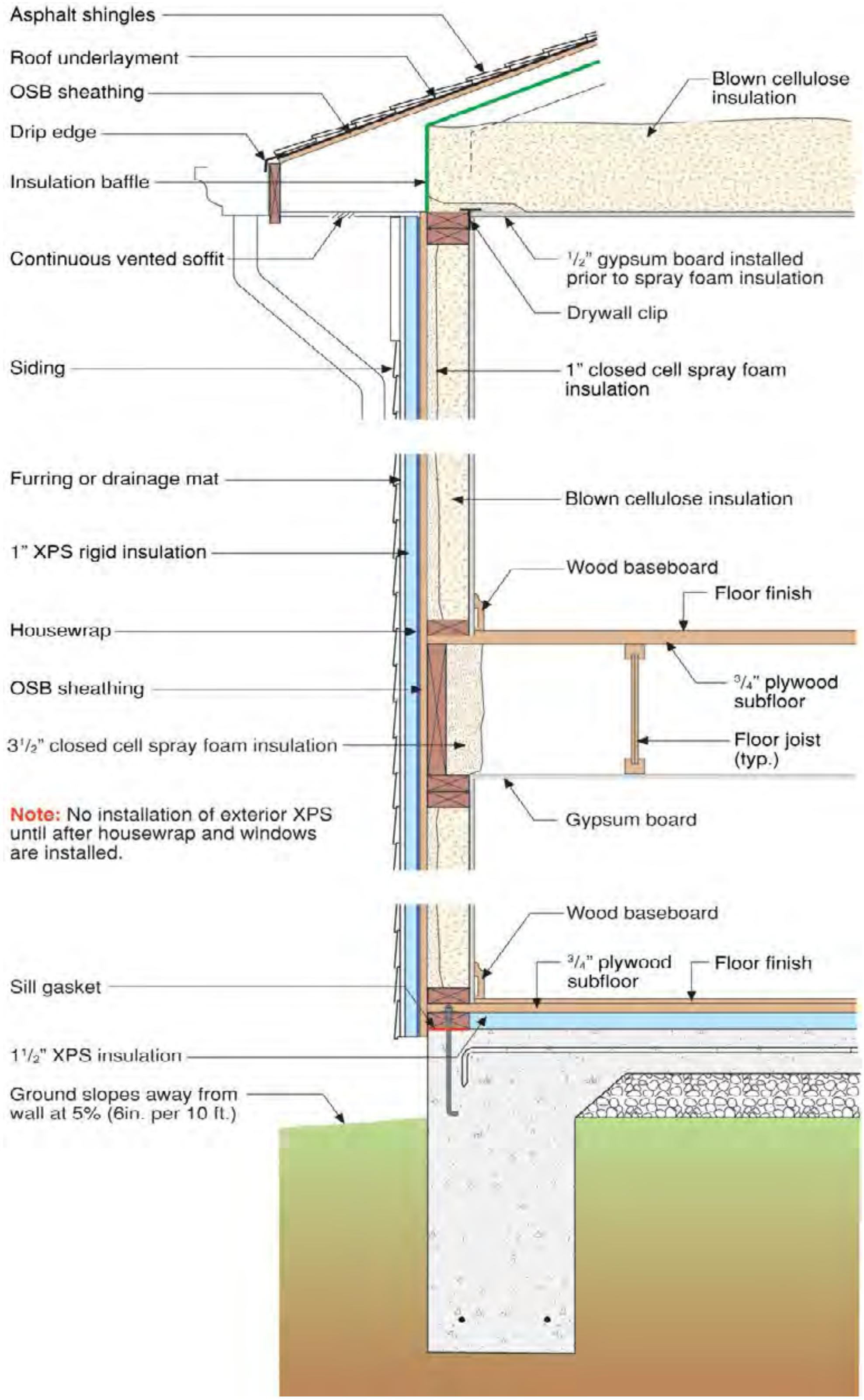
Building Science Corporation. 2009. *Slab Edge Insulation*, Information Sheet 513, www.buildingscience.com/documents/information-sheets/5-thermal-control/slab-edge-insulation/

The American Society of Civil Engineers. Standard 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

One House Design in the Mixed-Humid Climate – Slab Foundation, Blown Cellulose Walls and Ceiling, Exterior XPS Sheathing



Building Science Corporation recommended this wall detail for this home in Montgomery County, Maryland. Additional wall schematics for other mixed-humid climate locations are shown in Chapter 14. *(Figure Source: Building Science Corporation)*

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.

Another approach, referred to above, is sealed, conditioned crawlspaces with foundation side walls insulated on either the interior or exterior. Unvented, conditioned crawlspaces can provide a conditioned space for furnaces and ducts, although best practice is to not locate furnaces and HVAC equipment in the crawlspace.

If you have a vented crawlspace or basement (not recommended in the mixed-humid climate), here are recommendations for insulating the floor (Advanced Energy 2005):

- Install batt insulation at the sub-floor without gaps or compression and in full contact with the sub-floor to achieve the nominal R-value. Insulating open-web floor truss systems with batt insulation is discouraged due to the difficulty in insulating the openings in the truss structure. Better options for insulating open-web floor truss systems include using spray foam or netting the bottom of the trusses and completely filling the cavity with blown insulation. These strategies would likely also improve insulation performance in wooden I-beam floor structures.

If you install an unvented crawlspace or basement, here are recommendations for insulating the walls (Advanced Energy 2005):

- Place insulation on either the interior surface, the exterior surface, or inside of the perimeter wall (for example, use insulated concrete form foundation wall).
- Use a rigid foam or other non-porous insulation material. Rigid fiberglass is not eaten by termites.
- Provide a termite inspection gap of at least 3 inches (or as required by local code officials) between the top of the insulation and the top of the stem wall and between the bottom of the insulation and the floor of the crawlspace (Dastur et al. 2009).
- Seal the top of the vapor retarder to the wall with duct mastic or equivalent sealant. The mastic or a light colored paint can be continued up over the inspection gap to improve inspectability by pest control professionals.
- Insulate the band joist with batt insulation, which can be removed and repositioned easily for termite inspections.

For More Information on Basement Insulation

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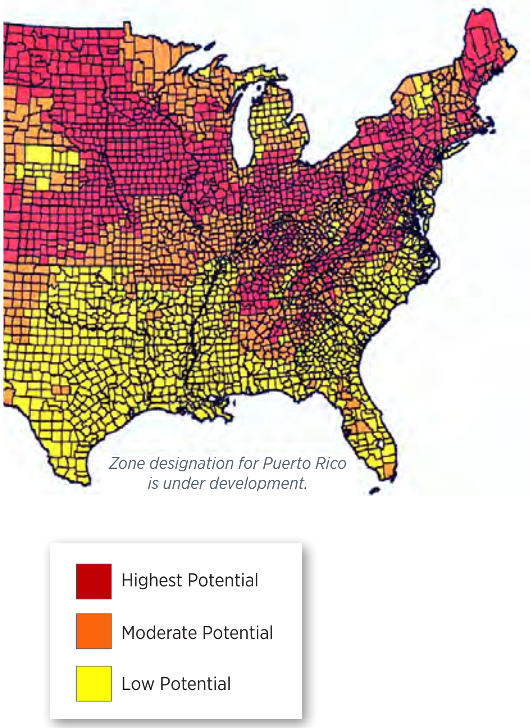
EPA Radon Zone Map



EPA recommends consulting the *EPA Map of Radon Zones* document (EPA-402-R-03-071) when using this map. Radon levels in individual homes can vary. All homes should be tested regardless of geographic location. Passive radon strategies should be employed *(Image source: www.epa.gov/radon/zonemap.html).*

Basement Insulation

Basements are a common foundation system in the mixed-humid climate. Wall insulation in basements is similar to that described for crawlspaces. Basement floors are insulated in the same way as slabs. 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.

Controlling Other Foundation Issues

Radon Control

The mixed-humid climate includes counties in the lowest to highest potential regions for radon gas emissions (see EPA map). Regardless of what county you are building in, the EPA cautions that local radon levels may vary and recommends that all homes be tested. As it is impossible to predict radon accumulation levels in houses prior to construction, Building America recommends that inexpensive radon-control measures be incorporated when building new homes.

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.

One measure recommended by the EPA to control radon 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. This system is often installed as a precaution even when no evidence of radon has been shown, because 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 EPA radon map at www.epa.gov/radon/zonemap.html. [Many of these radon control recommendations can be found in the **2009 and 2012 IRC, Appendix F**.]

For More Information on Radon Control

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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, thus, 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.

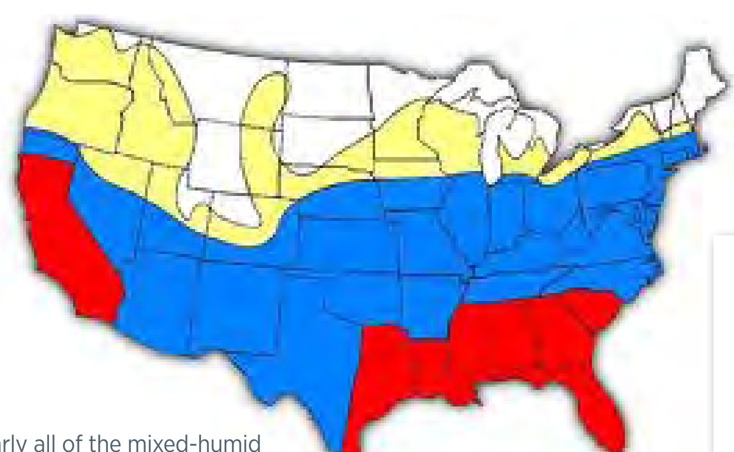
Pest Control

The Termite Infestation Probability Map, **Figure R301.2(6) in the 2009 IRC and 2012 IRC**, shows the probability of termite infestation across the mixed-humid climate. The **2009 IRC and 2012 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:

- Keep all wood (including siding, decking, and fencing that attaches to the house) from soil contact to minimize the presence of wet wood.
- Use termite flashing.
- Keep plants at least 18 inches from house.
- Maintain at least 8 inches between the ground and wood siding.

Termite Probability Map



Nearly all of the mixed-humid climate is subject to a moderate to heavy probability of termite infestation.

(Figure Source: 2009 and 2012 IRC R301.2(6))

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

(middle) Preventive measures by builders can reduce the likelihood that termites will cause large-scale destruction later on. *(Photo source: Jody Green)*

(bottom) Green Coast Enterprises uses termite-resistant borate pressure-treated lumber throughout its homes in New Orleans.

Drainage Plane Choices (House Membrane or Rain Barrier)

None of these are waterproof but they serve to shed rainwater that penetrates exterior cladding while remaining vapor permeable. *(Adapted from Straube 2001)*

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 100 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.

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 mixed-humid climate zone.

Controlling Liquid Water in Walls

Nearly all walls leak. Builders should assume some rainwater will get through the outer surface of the wall (i.e., the rain screen layer) and plan for it by including a drainage gap and a drainage plane to stop this water and direct it down and out of the building assembly. The drainage plane layer can be housewrap, building paper, asphalt impregnated felt, or taped insulated sheathing.

Care should be taken to overlap all wall layers to provide an exit pathway for rain 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 and kickout flashing.
- Back prime and back vent siding.
- Use housewrap.
- Elevate the bottom of the wall enough to prevent rain from splashing up on the siding.

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 [2009 and 2012 IRC R703.2] (also called a house membrane or rain barrier). 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).

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. If felt is used, install it half-lapped to create two layers.

Installation is key for all types of housewraps. See the Installers Guide on installing housewraps in Chapter 14. 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 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. Provide a drainage space to prevent wetting of the housewrap or use two layers of textured building paper. Apply shingle fashion and install a weep screed at the bottom of the wall sheathing beneath the first layer of housewrap (Lstiburek 2008).

Drainage Gaps

It is essential to provide an air gap or air space between cladding and housewraps to reduce the 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 spacer. 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. An air gap of 1 inch or more is needed behind brick and stone veneer [as required by 2009 IRC R703.7.4.2 or 2012 IRC Table R703.7.4].

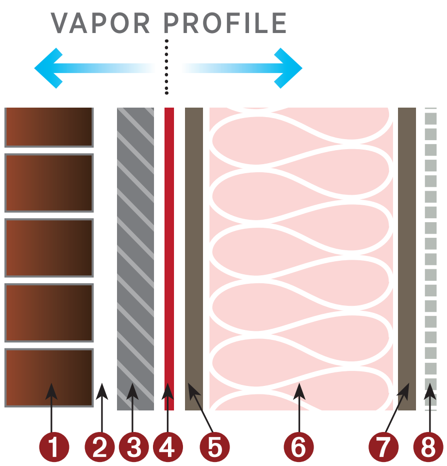
Flashing

Details should be provided for flashing for all windows and doors; around chimneys, 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 14 for instructions on installing window flashing. [Flashing should be specified in accordance with the 2009 IRC R703.8. 2012 IRC R703.8 adds the requirement that windows be installed per the window manufacturer's or flashing manufacturer's

(top) Taped rigid foam insulation can serve as a drainage plane, air barrier, and vapor barrier as well as a thermal boundary behind cladding. David Weekley Homes' uses XPS rigid foam insulation that is taped at seams to form a drainage plane. Windows are pan flashed to the exterior of the XPS sheathing. All roof-to-wall transitions have flashing and kick-out diverters. *(Photo Source: Building Science Corporation)*

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

(bottom) This display shows flashing covering the bottom edge of the wall sheathing. Housewrap is then layered over the top edge of the flashing. *(Photo Source: PNNL)*



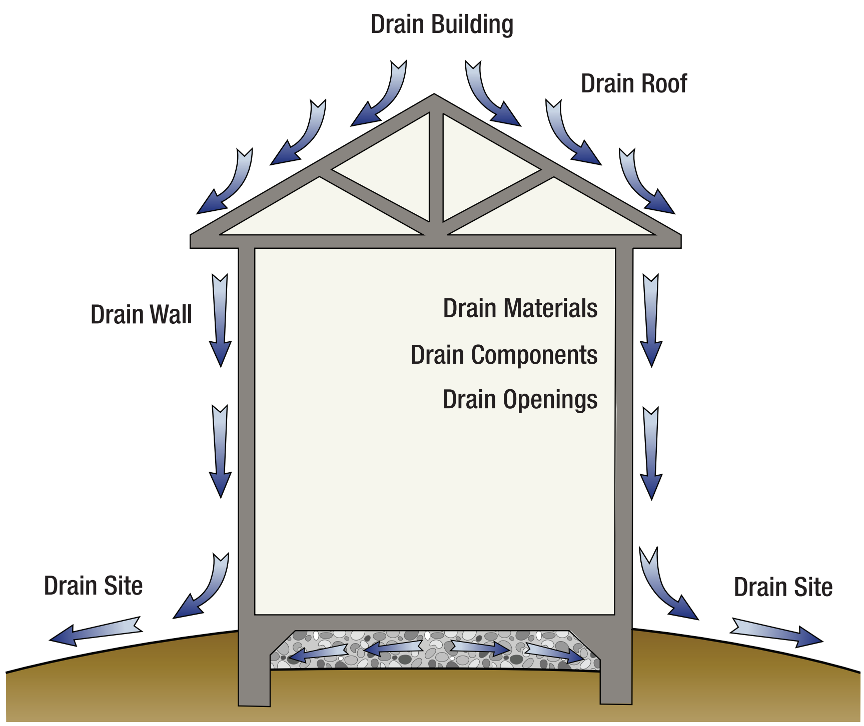
1. Brick veneer/stone veneer/ ship-lapped siding
2. Drainage cavity
3. Exterior rigid insulation – extruded polystyrene, expanded polystyrene, rigid fiberglass
4. Housewrap, membrane, trowel-on, or spray-applied drainage plane; air barrier; and vapor retarder.
5. Non-paper-faced exterior gypsum sheathing, 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 (no polyethelene sheeting, no vinyl wallpaper)

This assembly can work in all climates except extreme cold. The house wrap serves as the drainage plane. The air barrier can be the interior gypsum wall, the exterior gypsum wall, or the rigid foam. For other wall profiles, see Lstiburek 2009a. *(Figure Source: Adapted from Lstiburek 2009b).*

instructions or, if they are not provided, that pan flashing must be installed at the sill of exterior window and door openings to direct water outside.] Additional guidance can be found in the *EEBA Water Management Guide* (Lstiburek 2006a) and ENERGY STAR Qualified Homes Version 3 Water Management System Builder Checklist (EPA).

Drain all water away from the structure

(Figure adapted from Building Science Corporation)



Controlling Water Vapor in Walls

As discussed in Chapter 6, most vapor transmission through building assemblies is via air flow so stopping air leaks is an important way to prevent water vapor from getting into walls. Water vapor can also move via diffusion. Vapor pressure moves water vapor from indoors to outdoors during cold-dry weather and from outdoors to indoors during hot-humid weather. Water vapor that is trapped in walls or condenses in walls due to temperature differences can cause moisture problems like mold. Vapor retarders will stop this vapor diffusion.

Vapor Retarders

The 2009 IRC R601.3 does not list any requirement for vapor retarders in the hot-humid or mixed-humid climates (IECC Climate Zones 1, 2, 3, and non-Marine 4). In the 2012 IRC, the vapor retarder discussion was moved to Section R702.7 but no requirement was added for vapor retarders in the hot-humid or mixed humid climates. See Chapter 6 for more about vapor retarders.

Building scientists generally do not recommend putting a vapor retarder in walls in the mixed-humid climate. In the mixed-humid climate, walls should be able to dry to both the interior and exterior. Thus, the exterior assembly might include structural rigid foam sheathing taped at the seams to serve as an air flow retarder and drainage plane between the framing and lap siding or between the masonry and stucco. Interior building components should be vapor permeable. For example if batt wall insulation is used, it should be unfaced. Vinyl wall paper should not be used on exterior walls and paints should be latex not oil-based. Extra attention should be given to making sure the exterior air barrier is continuous. Using supply ventilation to maintain the interior of the home at a slight positive air pressure with conditioned air will also discourage the infiltration of hot-humid air. (See ventilation discussion in Chapter 9; see also Lstiburek 2005).

Drainage Spaces

Cladding should have a drainage space behind it of 1 or 2 inches for brick and stone veneer, 3/4 inch for stucco, and 1/16 inch for siding. Bricks and other masonry absorb water from 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 and 2012 IRC Table R703.7.4] allows the vapor to dissipate before entering the wall cavity. An air space stops capillary movement of moisture, discourages vapor diffusion, stops the contamination of the drainage plane via contact with the cladding,

Windows

One critical point of concern is water leakage around windows. The *EEBA Water Management Guide* (Lstiburek 2006a) offers examples of many window flashing applications. See Chapter 14 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).

Vapor Retarder Recommendations:

- Design walls to dry to the interior or both the interior and exterior.
- Avoid use of a less permeable vapor retarder where a more permeable retarder will provide satisfactory performance, to encourage drying.
- Avoid installing vapor barriers on both sides of assemblies, i.e., double vapor barriers, to facilitate assembly drying in at least one direction.
- Avoid installing Class I vapor barriers (polyethylene sheet, foil-faced batt) on the interior of air conditioned assemblies.
- Avoid vinyl wall coverings on the inside of air conditioned assemblies.

(Source: Lstiburek 2006c)

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. See Straube (2009b) for information about the performance of drainage spaces with different wall types.

Dry Building Materials

Building with wet or green materials can be a source of vapor in walls. Damp lumber should be allowed to dry before use to less than 18% moisture content or as required by local code. The Forest Products Laboratory recommends 12% mositure content (FPL 2010). Interior relative humidity should be kept to less than 50% during the cooling season.

Air Sealing

Water vapor is far more likely to be transported into walls by air movement than by diffusion. Therefore, air sealing is an important method for preventing water vapor movement into walls. Air sealing is further described in the next section.

Controlling Air Infiltration in Walls

The **2009 IECC 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 junctions; and other sources of infiltration. These air sealing items are listed in the **2012 IECC in Table R402.4.1.1.** The 2009 IECC allows for air leakage to be tested with a blower door or visual inspection. The **2012 IECC R402.4.1.2** requires that air leakage be tested with a blower door test, to confirm that air leakage does not exceed 5 air changes per hour at 50 Pascals in IECC climate zones 1 and 2, or 3 ACH at 50 Pa in climate zones 3-8. To be effective the air barrier must be continuous, meaning that it extends over the entire envelope of the structure, although it 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.

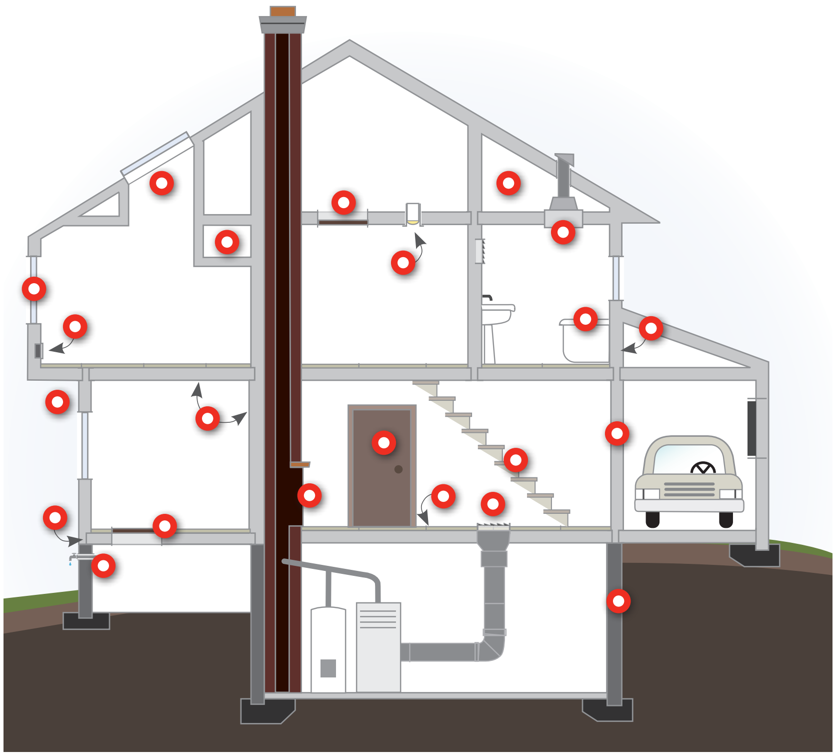
A comprehensive air-sealing strategy begins with indicating on the house plans the location of the conditioned space by outlining the building envelope. The plans should show the location of complex details like chases, stairwells, dropped ceilings, fireplace penetrations, balconies, and knee walls, so that they can easily be identified as

(top) When rigid foam insulation is applied to the exterior side of the wall cavity under the cladding, with seams taped and an air gap provided, 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. *(Photo Source: S+A Homes)*

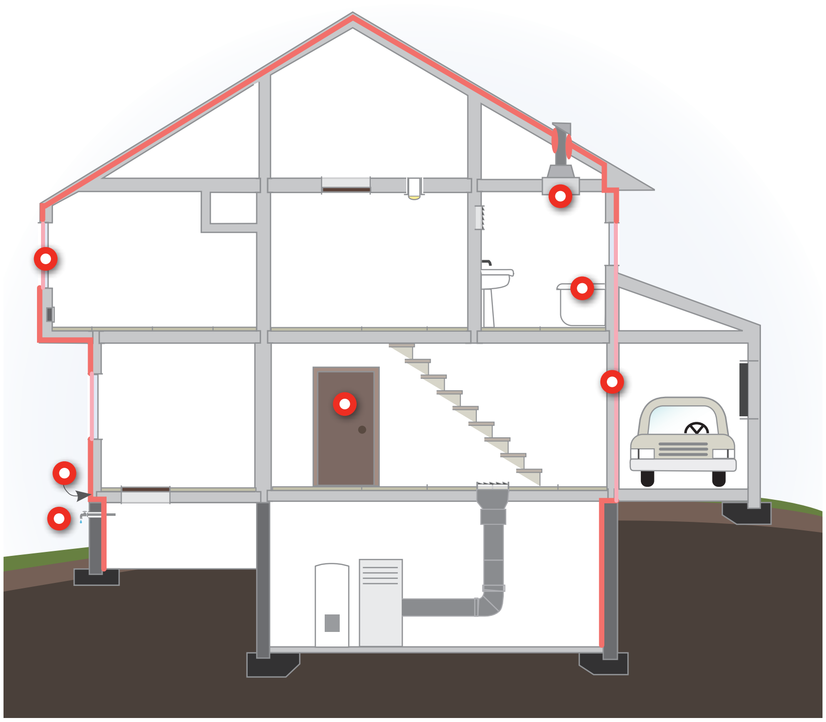
(middle) Window flashing is overlapped to provide a continuous drainage plane.

(bottom) Water should not be directed to flow into the wall. This could soon lead to water intrusion inside the wall.

Interior Air Barrier – Points to Seal



Exterior Air Barrier with Rigid Foam Sheathing – Points to Seal



Interior vs. Exterior Air Barrier

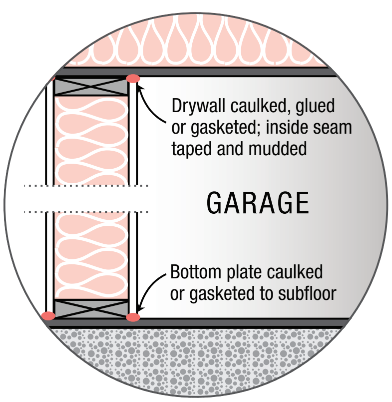
(see house figures at right) Air sealing is needed on the top, bottom, and sides of the house to ensure an airtight shell. The house on top uses a conventional approach where the interior drywall and subfloor serve as the air barrier. Every hole through these surfaces (for wiring, pipes, etc.) must be caulked. The house on the bottom uses external rigid foam sheathing, which provides a continuous air barrier with fewer air sealing steps. Foam sheathing can also serve as a drainage plane, vapor barrier, and thermal barrier. (Detailed drawings are in Chapter 14.)

Cladding should have a drainage space behind it:

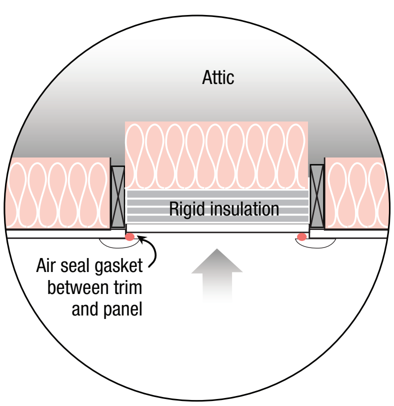
- 1 inch for brick [2009 IRC R703.7.4.2]
- 3/4 inch for stucco, and
- 1/16 inch for siding.

Wood or rigid foam filler blocking is cut to fit the gaps between floor joists and caulked or foamed in place to form an air break between conditioned and unconditioned spaces.

Garage common wall air sealing



Attic access panel air sealing



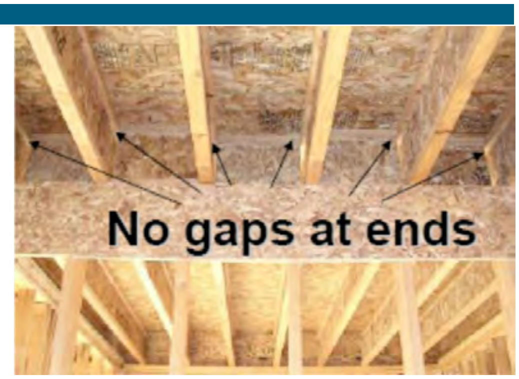
being inside or outside the conditioned space. The plans also should show where insulation and draft stopping should be installed.

If the air barrier will be on the interior side of the walls, 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; 2012 IECC Table R402.4.1.1].
- Use blocking material to airseal floor joists under cantilevered floors and kneewalls and behind staircases on exterior walls.
- 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 14.
- Caulk, foam, or seal with gaskets all penetrations for electrical boxes, outlets, switches, and plumbing.

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



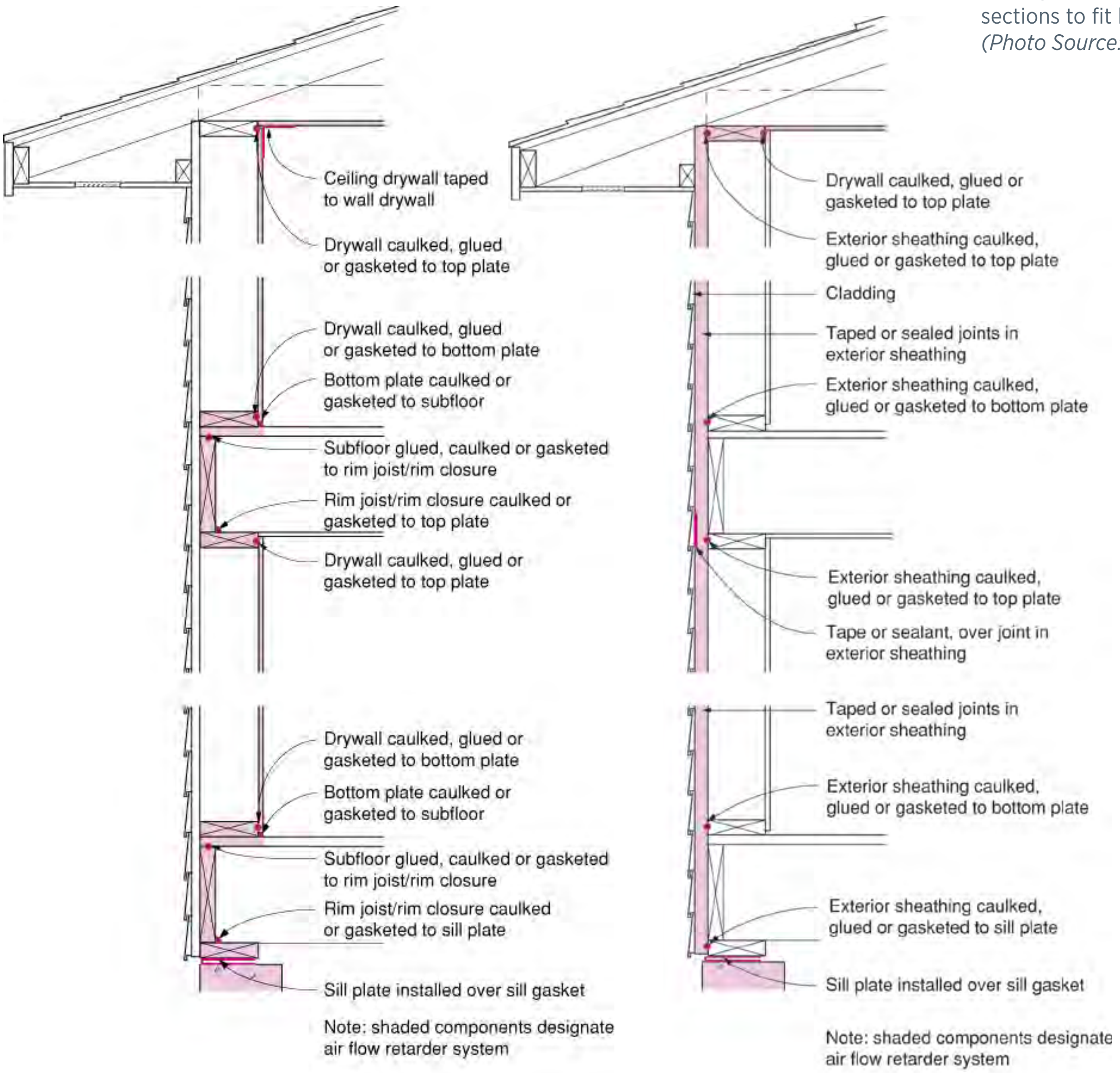
Gaps between the garage and conditioned space are properly sealed by carefully cutting and then caulking wood sections to fit between trusses. *(Photo Source: EPA 2008)*

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.

Envelope Air Sealing

INTERIOR -
Using gypsum and flooring

EXTERIOR -
Using rigid foam sheathing



(Figure Source: Building Science Corporation)

Rigid foam insulates the interior of masonry walls behind the fireplace in this Building America home by Castle and Cooke in Winter Garden, Florida. *(Photo Source: BAIHP)*

Code/Above Code

Wall Insulation Above Grade

Code Requirements found in **2009 IECC and 2012 IECC Table R402.1.1**

Code		
2009 IECC	Wood Framed	Mass Wall***
IECC CZ 3	R-13	R-5/R-8
IECC CZ 4	R-13	R-5/10
2012 IECC	Wood Framed	Mass Wall***
IECC CZ 3	R-20/ R-13+R-5**	R-8/R-13
IECC CZ 4	R-20/ R-13+R-5**	R-8/R-13
Above Code		
ENERGY STAR Version 3.0	Insulation levels shall meet or exceed 2009 IECC levels and achieve Grade 1 installation per RESNET standards.	

**The second R value applies when more than half the insulation is on the interior of the mass wall.*

***R-13 cavity insulation + R-5 Rigid foam sheathing.*

Controlling Heat Flow in Wall Assemblies

The control of heat flow in the building is managed by the type, thickness, location, and proper installation of insulation. The **2009 IECC Table 402.1.1** requires a wall R value of R-13 for wood-framed walls for IECC climate zones 3 and 4. For mass walls (concrete block, concrete, ICF, brick, etc.), the requirement is R-5 for climate zones 3 and 4. If more than half the insulation is on the interior of the mass wall, the requirements is R-8 for climate zones 3 and 4. In the **2012 IECC (Table R402.1.1)**, the insulation requirement increases for IECC climate zones 3 and non-marine 4. The requirement for a wood-framed wall increases to R-20 (or R-13 cavity insulation plus R-5 insulated sheathing) and the requirement for a mass wall increases to R-8 (or R-13 if more than half the insulation is on the interior). Window selection and design are also important.

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.
- Specify that taped rigid foam insulating sheathing be used on the exterior side of studs 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 STAR-labeled doors.
- Design roofs and overhangs to shade and protect windows, doors, and walls.

Masonry walls may be finished with stucco, wood, or other claddings. Best practices to improve thermal efficiency include the following:

- Semi-vapor permeable rigid insulation should be installed on the interior or exterior of wall assemblies and should be unfaced.
- Wood furring should be installed over rigid insulation. The rigid insulation should be continuous over the surface of the wall, except for a 2x4 furring at the intersection with the ceiling. This blocking attaches directly to the masonry block and serves as a draft and fire stop. The rigid insulation abuts the blocking but does

not cover it or extend behind it. Foam seal or caulk all top plate penetrations and exterior wall penetrations.

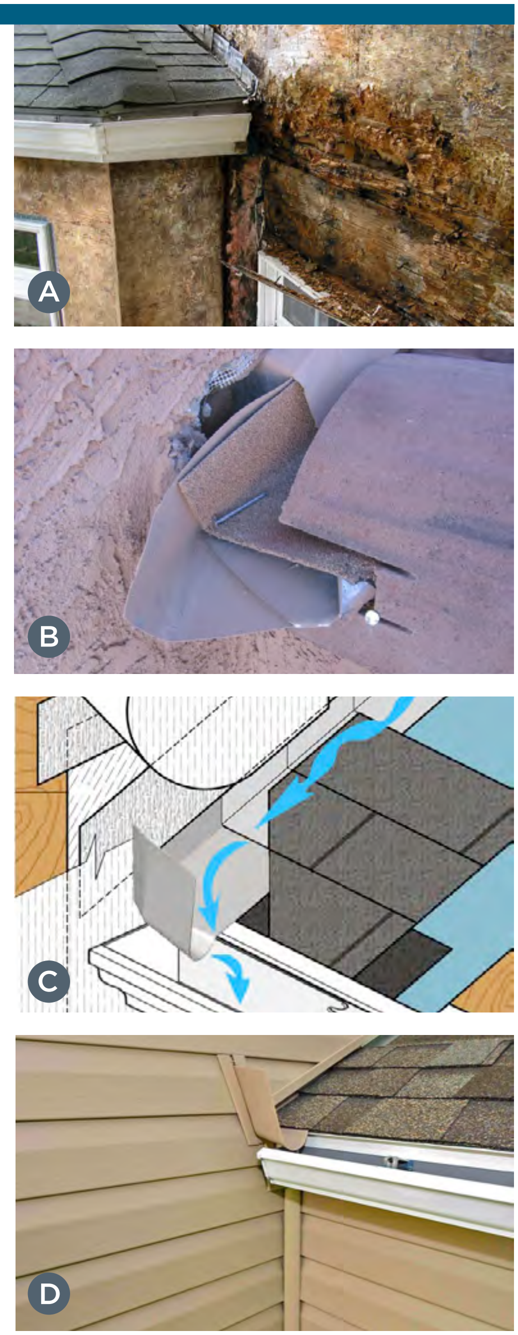
- Use pressure-treated lumber to frame out sub-jambs and spacers within window and door rough openings.
- As with other walls, penetrations to the exterior or through top and bottom plates should be foam sealed or caulked. Also air seal penetrations to garages and porches.
- Mud, tape, and caulk seams and corners of gypsum board and use sill sealer at top plates and bottom plates to control air leakage through the walls.
- When pouring the slab, take care to create a seat in the concrete to accept the block and seats in the concrete to act as drain pans where exterior doors and sliding doors will be located.

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 [2009 and 2012 IRC R703.8; R903.2].
- 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.
- Use kick-out diverters properly integrated with flashing to direct water away from the side of the house [2009 and 2012 IRC R703.8, R903.2].
- 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.



(**A**) Deluging rains in the hot-humid climate can overwhelm gutters. Improper flashing can allow water into walls, causing significant damage. (**B**) Improvised deflectors that are improperly integrated into the wall flashing and gutter are rarely sized to handle the volume of water that can run off the roof in a large downpour and they may contribute to water entry into the wall. (**C**) To keep the water out, flashing should be integrated with the house wrap, siding, and shingles or roof tiles and (**D**) the diverter should be seamless and adequately sized to direct all of the water volume away from the wall and into the gutter. See Chapter 14 for details. *(Photo Sources: A, C, D - DryFlekt Products, Inc., B - Steve Easley)*

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

Code/Above Code
Ceiling Insulation

Code Requirements found in 2009 IECC and 2012 IECC Table R402.1.1

Code	2009 IECC	2012 IECC
IECC CZ 3	R-30	**R-38*/****
IECC CZ 4	R-38	**R-49**
Above Code		
ENERGY STAR Version 3.0	Insulation levels shall meet or exceed 2009 IECC levels and achieve Grade 1 installation per RESNET standards. Radiant barrier or ENERGY STAR roof product are required if more than 10 feet of ductwork is located in an unconditioned attic.	

** R-30 if cathedral but cathedral must be limited to 500 ft² or 20% of total insulated ceiling area, whichever is less.*

***R-30 permitted if raised heel trusses used.*

Controlling Water Vapor in Roof/Attic Assemblies

While ventilation and an interior vapor retarder are recommended to deal with water vapor in cold climates, most of which is coming from inside the home, in the mixed-humid climate, the greatest source of water vapor during warm months is hot, humid outside air.

Moisture in attics has traditionally been addressed with ventilation by providing soffit, ridge, and/or gable vents at a ratio of typically 1:300 free vent area to insulated ceiling area. However, with the complex roof designs of modern homes where attics are blocked by dormers, hips, skylights, cathedral sections, etc., it is difficult to achieve adequate cross ventilation. In vented cathedral ceiling assemblies, a minimum 2-inch clear airspace is recommended between the underside of the roof deck and the top of the cavity insulation (Lstiburek 2006d). In a vented attic, the air barrier is provided by the ceiling gypsum. Latex paint provides an adequate, Class III vapor retarder because the primary transport mechanism for vapor is air movement, which is stopped by ceiling drywall if it is adequately sealed at all penetrations. Class I and Class II vapor retarders are not recommended in vented attic assemblies in IECC climate zones 1-5 due to the potential for top side condensation in summer months during air conditioning periods (Lstiburek 2006d).

Unvented attics are another option that is recommended. A sealed attic reduces the infiltration of hot, humid outside air into the home, provides a conditioned space for HVAC and ducts, increases structural resistance to high winds, increases fire resistance by limiting air supply (Rudd 2003), reduces infiltration of wind-driven rain, and provides conditioned storage. The key to moisture control in an unvented roof assembly is to keep the condensing surface, the underside of the roof deck, sufficiently warm throughout the year to prevent condensation or to prevent interior moisture-laden air from accessing it. The local climate may be warm enough year-round that the roof deck stays warm or rigid insulation can be installed above the roof deck. Or, to keep humid air from touching the underside of the roof deck, it can be sprayed with air-impermeable spray foam insulation (Lstiburek 2006d).

Controlling Air Flow in Roof/Attic Assemblies

The ceiling is air sealed with techniques similar to those used for the walls including mudding and taping of dry wall seams and caulking of cracks. 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. The **2012 IECC** lists air sealing requirements in **Table R402.4.1.1**.

Air sealing details to consider include:

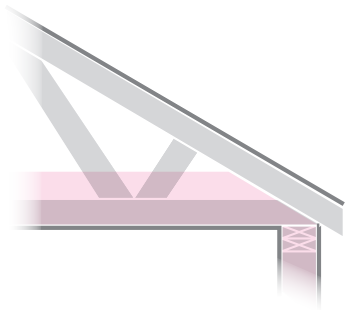
- Provide details on plans for air sealing and insulating complex structures like kneewalls, gable windows, porch-attic interfaces, and cathedral ceilings.
- Seal all penetrations and seams in ceiling gypsum board so that it functions as a continuous air barrier.
- Draft-stop soffits with rigid air barrier 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; 2012 IECC 402.2.4].
- Install recessed lighting fixtures that are airtight insulation-contact (IC) rated, and caulk or gasket the housing to the ceiling drywall [per 2009 IECC 402.4.5; 2012 IECC 402.4.4].
- Provide a weather-stripped cover for whole-house fans.
- Ensure that windows, doors, and skylights have a labeled infiltration rate of no more than 0.3 cfm/ft^2 [per 2009 IECC 402.4.4; 2012 IECC 402.4.3].

Two Building America builders in the hot-humid climate chose to insulate their attics by spray foaming the underside of the roof decking providing an insulated conditioned space for HVAC. Green Coast Enterprises *(top)* chose high-density closed-cell spray foam for its homes in New Orleans. Imagine Homes chose low-density spray foam for its attics.

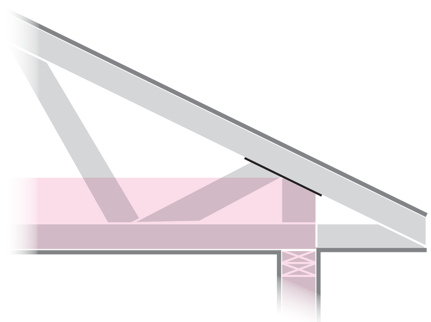
Controlling Heat Flow in Roof/Attic Assemblies

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. [See the ceiling insulation table above for 2009 and 2012 ceiling insulation requirements. Also see 2009 and 2012 IECC Table 402.1.1 and sections 402.2.1 and 402.2.2.]

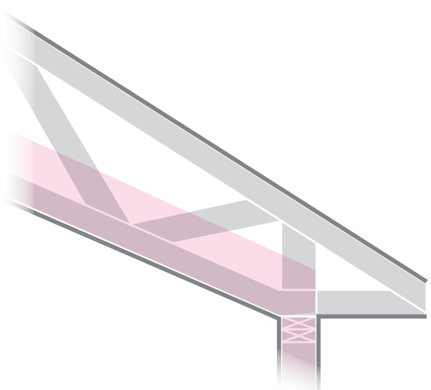
Research by Building America research partner the Florida Solar Energy Center showed that sealed attic construction with an R-19 spray-foam-insulated roof deck would reduce cooling energy consumption by 6% to 11% and lower attic temperatures to an average of 83°F compared to 110°F for the control home (Parker et al. 2002).



Traditional roof trusses pinch insulation where the roof meets the walls



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.



Some builders use cantilevered trusses to get full height insulation over the exterior wall.

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

Window and Door Assemblies

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

Code/Above Code
Window U Factor and Solar Heat Gain Coefficient

A comparison of the 2009 IECC and 2012 IECC Climate Zone 3 and 4 Requirements and Building America Recommendations

Code	U-Factor		SHGC	
	2009 IECC	2012 IECC	2009 IECC	2012 IECC
CZ 3	0.5	0.35	0.30	0.25
CZ 4	0.35	0.35	NR	0.40
Above Code				
ENERGY STAR Version 3.0	U-Value: CZ 3 - ≤0.60 CZ 4 - ≤0.32		SHGC: CZ 3 - 0.30 CZ 4 - 0.40	

less solar heat the window transmits. This rating is expressed as a fraction between 0 and 1. The **2009 and 2012 IECC Table 402.1.1** lists U-factor and SHGC requirements. See the table on page 8.25 for U-factor and SHGC requirements for IECC climate zones 3 and 4.

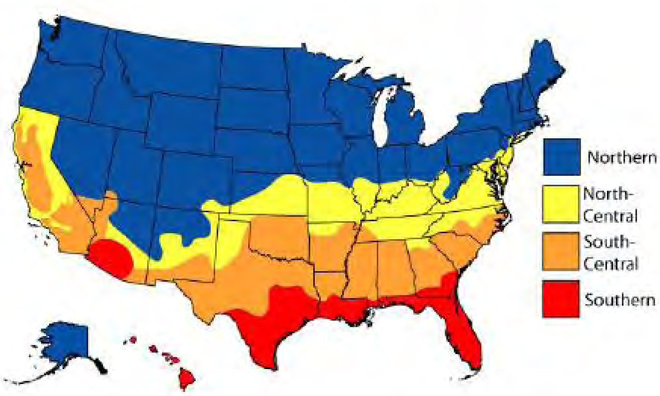
- Visible transmittance (VT) measures how much light comes through a window. VT is expressed as a number between 0 and 1 —the bigger the number, the more clear the glass.

- 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 (2012 IECC 402.4.3)**, 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.

ENERGY STAR qualifies windows based on climate zones and divides the United States into four climate zones. See the charts and map below for U-factor and SHGC guidelines by climate.

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.

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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Chapter 9.

Mechanical, Plumbing, and Electrical Systems

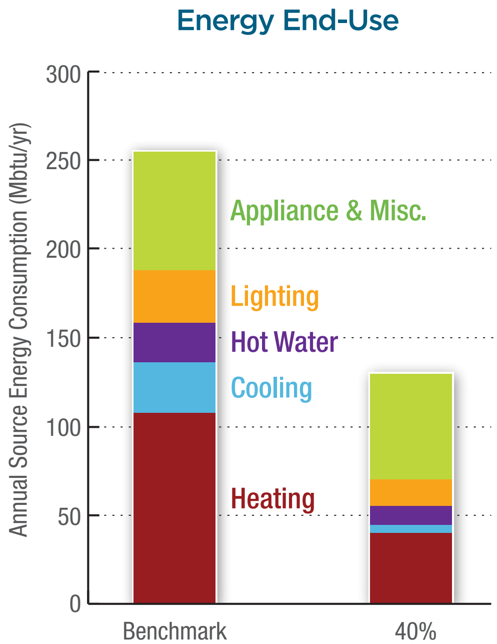
High-efficiency, sealed-combustion HVAC equipment increases savings and works well with the tighter building envelope of Building America homes. *(Photo Source: BSC)*

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.

CHAPTER TOPICS

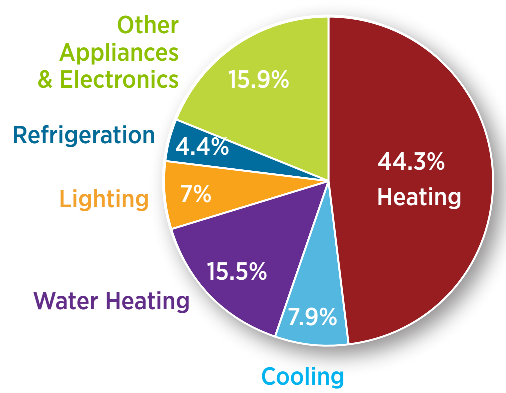
Heating and Cooling

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 reduced 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 the Building America benchmark and a home built to the 40% energy savings target in the mixed-humid climate. *Example based on a 2,140 ft²-house in Seaford, Delaware. Analysis by IbACOS.*

Typical Residential On-Site Energy Consumption by End Use in the United States



(Figure source: DOE. 2008 Buildings Energy Data Book, *based on delivered energy end-uses for an average U.S. household.)*

Efficiency Measures for Air Conditioners, Heat Pumps, and Furnaces

Seasonal Energy Efficiency Ratio (SEER) is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air-conditioner or heat pump (in Btu) during the normal cooling season as compared to the total electric energy input (in watt-hours) consumed during the same period. Heat pumps and air conditioners must have a SEER of 13 or higher (per Federal requirements that went into effect in 2006).

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. Heat pumps and furnaces must have an HSPF of 7.7 or higher (per Federal requirements that went into effect in 2006).

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) is 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.

DOE is mandated by Congress to continually review and update appliance efficiency standards. For a schedule of appliance standards updates, see www.standardsasap.org/federal.htm

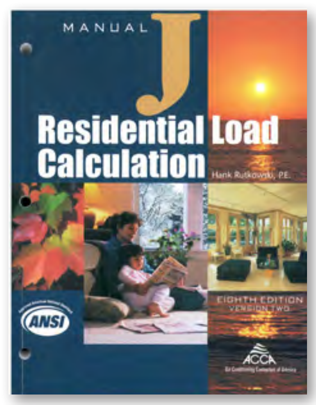
For the best results in comfort, efficiency, and durability, HVAC and duct design must be integrated in the overall architectural design. Builders should work closely with their HVAC engineer to properly size and select the HVAC equipment, design and install ducts, and provide appropriate ventilation. These steps will go a long way toward improved energy efficiency, comfort, and cost savings. [The 2009 and 2012 IECC 403.1 and ENERGY STAR Version 3.0 require that forced air furnaces come with a programmable thermostat and that heat pumps with electric resistance backup heat be equipped with controls that prevent the supplemental heater from coming on when the heat pump compressor can meet the load.]

Look for ENERGY STAR-qualified furnaces, heat pumps, and air conditioners. See the Building America HVAC guide for more information on selecting energy-efficient heating and cooling equipment (DOE 2011).

Heating and Cooling Equipment Sizing

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 ACCA and the American National Standards Institute have produced several ANSI/ACCA standards on HVAC equipment installation and maintenance (ACCA 2010):

- #4 Maintenance of Residential HVAC Systems
- #5 HVAC Quality installation Specification
- #6 Restoring the Cleanliness of HVAC Systems
- #9 Quality Installation Verification.

[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. The 2012 IECC 403.6 references ACCA Manuals S and J directly.]

One estimate states that a Manual J calculation takes about 30 to 60 minutes for an average home, using the software and measurements from construction drawings. Manual S calculations require an additional 15 to 30 minutes (SBIC 2003). A single calculation can work for multiple uses of the same plans.

Central Gas-Fired Furnaces

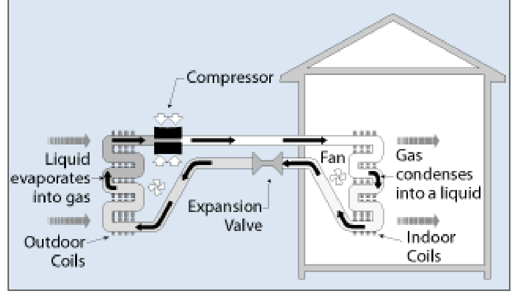
For central gas-fired heating systems, high-efficiency (≥90% AFUE) sealed combustion gas furnaces should be installed. Sealed combustion means that an appliance acquires all air for combustion through a dedicated sealed passage from the outside to a sealed combustion chamber, and all combustion products are vented to the outside through a separate, dedicated sealed vent. Sealed-combustion, condensing appliances eliminate the potential for back-drafting. Variable speed motors, also known as electrically commutated motors (ECMs), are more efficient than regular furnace blower motors because they can operate at variable speeds allowing the speed to adjust to the heating and cooling needs of the house. Instead of repeatedly blasting on and shutting off, the variable speed motor runs the blower for longer periods at lower speeds, providing quieter operation, and more even heat and cooling. They can be more effective at reducing humidity levels in a home than a central HVAC with a single-stage blower.

Electric Heating and Heat Pumps

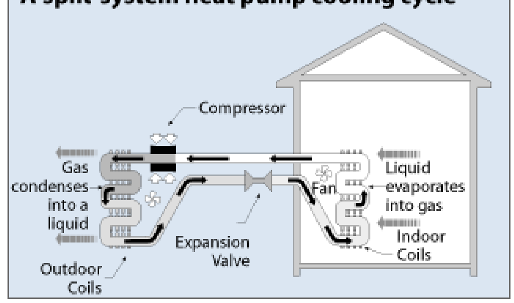
Electric furnaces, electric baseboard heating, and electric resistance wall units are used in all climates but, from a fuel-cost perspective, they are an expensive method for heating. One recent study reported electric furnace heating costs of $2.56/100,000 Btus and electric resistance heating costs of $2.05/100,000 Btus, compared to $1.49/100,000 Btus for gas heat and $0.82 /100,000 Btus for ductless heat pumps (based on fuel costs of $0.07/kWh electric, and $1.10/ therm gas) (Pratt 2008).

Heat pumps are more efficient than electric resistance heating. A standard heat pump unit with a Heating Seasonal Performance Factor (HSPF) of 7.7 or more (the minimum HSPF required by law as of 2006), can reduce electricity consumption for heating by 30% or more relative to electric resistance heating systems. In colder areas, when temperatures fall below 30°F, standard air-source heat pumps typically use electric resistance or gas furnaces to provide backup

How Air Source Heat Pumps Work



In heating mode, an air-source heat pump evaporates a refrigerant in the outdoor coil. As the liquid evaporates, it pulls heat from the outside air. After the gas is compressed, it passes into the indoor coil and condenses, releasing heat to the inside of the house. The pressure changes caused by the compressor and the expansion valve allow the gas to evaporate at a low temperature outside and condense at a higher temperature indoors. In cooling mode, the reverse happens.



In cooling mode, an air-source heat pump evaporates a refrigerant in the indoor coil; as the liquid evaporates it pulls heat from the air in the house. After the gas is compressed, it passes into the outdoor coil and condenses, releasing heat to the outside air. The pressure changes caused by the compressor and the expansion valve allow the gas to condense at a high temperature outside and evaporate at a lower temperature indoors.

(top) Ductless heat pumps mount to the wall to provide zoned heating and cooling with exceptional energy performance.

(bottom) The outside unit of a ductless heat pump can be mounted on the wall or on a concrete pad on the ground.

heat to the home. Heat pumps also provide cooling; per Federal requirements since 2006, heat pumps and air conditioners must have a Seasonal Energy Efficiency Ratio (SEER) of 13 or higher. ENERGY STAR Version 3.0 criteria for heating equipment are climate specific. See the table on the next page for requirements.

Ductless Heat Pumps

Unlike central air source heat pumps, which use ducts and a large blower to distribute the hot or cool air throughout the house, ductless heat pumps use no ducts and directly heat and cool the area where they are located. Ductless heat pumps are sometimes referred to as mini-split heat pumps because they consist of a single outside compressor/condenser unit connected to one or more wall- or ceiling-mounted indoor air handler units. The indoor air handlers have dimensions of approximately 12x9x31 inches and weigh as little as 25 pounds. The outdoor units are approximately 25x12x31 and weigh about 88 pounds. The outdoor units are mounted on a concrete pad or on the outside wall of the house. Tubing connects the two units through a small hole in the wall.

Ductless heat pumps have been used in Asia and Europe since the 1970s and in U.S. commercial buildings since the 1980s, but they are not yet well known in the U.S. residential market. They are 25% to 50% more efficient than electric baseboard or wall heaters (NEEA 2009).

Ductless heat pumps provide increased energy savings over standard heat pumps in several ways—because they are ductless and mounted inside conditioned space, there are no losses to the attic or crawlspace or through leaky ducts; they provide zoned heating and cooling; and advances in technology in recent years have increased performance to the point that HSPF 12/SEER 26 units are now available. These high-performing heat pumps also perform at a much wider temperature range than standard heat pumps: some models can operate at an outdoor temperature range of 5°F to 75°F for heating and 14°F to 115°F for cooling, eliminating or significantly reducing the need for backup heat sources in many locations.

These ductless heat pumps use an inverter technology with a variable-speed compressor that can vary the refrigerant flow. They also have linear expansion valves rather than open-close valves and multi-speed rather than single-speed fans to continuously match the heating/cooling load. Unlike conventional air conditioning/heating systems that stop and start repetitively, the inverter technology adjusts the motor speed, allowing the system to adapt more smoothly to shifts in demand with less temperature variation and much lower energy use. When maximum capacity isn't needed, compressor revolution and power decreases, increasing energy efficiency. For example, one model reports a capacity range of 3,100-24,000 Btus in heating mode and 3,800-14,500 Btus in cooling mode.

For more information on ductless heat pumps, including installation tips, production selection recommendations, and performance details, see the website for the Northwest Ductless Heat Pump Project (www.nwductless.com), conducted by Bonneville Power Administration and Northwest Energy Efficiency Alliance (NEEA) (Bonneville Power Administration 2010; NEEA 2009). Begun in 2008, the project included 12,047 ductless heat pumps installed in Northwest homes, 91 participating utilities, and 833 participating contractors by September 2011. Research results on energy savings will be out in 2012.

Ground-Source Heat Pumps

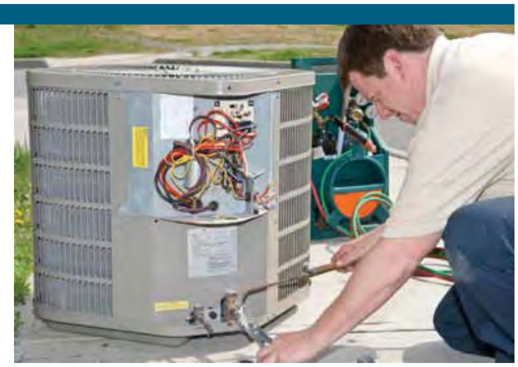
Geothermal or ground-source heat pumps can be very efficient for heating and cooling in this climate because they use the constant temperature of the earth as the exchange medium instead of the outside air temperature. This allows the system to reach fairly high efficiencies (200% -300%) on the coldest winter days, compared to 100%-175% for central air-source heat pumps on cool days. The disadvantages are their initial installation cost and the need for yard space to install the piping. For more information on various HVAC technologies, see www.energysavers.gov.

Cooling Equipment

Mechanical cooling options in the mixed-humid climate include central air conditioning and air source heat pumps.

Central air conditioners are typically installed with central furnaces and use the same ducts and blower. Refrigerant is piped to the evaporator coil in the air handler unit where it cools the distribution air. Air conditioners have become much more efficient over the past few decades. Technology improvements include variable-speed motors that allow more control over air distribution, which can lower energy consumption and increase comfort. The majority of systems rated SEER 15 or higher incorporate variable-speed motors to achieve this efficiency. Advanced compressors and micro-channel heat exchangers are other advancements that have improved efficiency.

Central air conditioning systems are rated according to their seasonal energy efficiency ratio (SEER). Since 2006 the federal government has required new air conditioners sold in the United States to have a



(top) The newest models of air conditioners have efficiencies as high as SEER 20. Follow the manufacturer's recommendations for charging to ensure that high efficiencies are achieved.

(bottom) Green Coast Enterprises is working with Building Science Corporation to study the cost-effectiveness of dehumidifiers that are ducted to the air handler in affordable homes in New Orleans. *(Photo Source: Building Science Corporation)*

ENERGY STAR Version 3.0 HVAC Requirements

(2009 IECC Climate Zones 3 and 4)

Heating Equipment	IECC CZ 1-3	IECC CZ 4-8
Gas Furnace	≥ 80 AFUE	≥ 90 AFUE
Oil Furnace	≥ 80 AFUE	≥ 85 AFUE
Boiler	≥ 80 AFUE	≥ 85 AFUE
Air Source Heat Pump with Electric Back-Up	≥ 8.2 HSPF/ 14.5 SEER/ 12 EER	≥ 8.5 HSPF/ 14.5 SEER/ 12 EER (for CZ 4)
Air Source Heat Pump with Dual-Fuel Backup	CZ 1-8: ≥ 8.2 HSPF/ 14.5 SEER/12 EER	
Ground Source Heat Pump	Any ENERGY STAR–qualified model	
Cooling Equipment	**IECC CZ 1-3**	**IECC CZ 4-8**
Air Conditioner	≥ 14 SEER/ 12 EER	≥ 13 SEER
Heat Pump	See above	

Beach house builders have been using passive cooling techniques for decades, including deep overhangs, covered porches, awnings, openable windows that face prevailing breezes, and upper story windows that allow convective currents to draw air in through the first-floor porches and pull hot air out of second- and third-floor windows. Another beach house technique is to install shower stalls outside the house, either on the ground level or under the house if the first floor is raised up on stilts, to keep sand, heat, and humidity out of the house.

SEER rating of 13 or higher. Split-system air conditioners (the type most common in homes) can use the ENERGY STAR label if they have a SEER of 14.5 or greater in IECC climate zones 1-3 or SEER 13 or greater in IECC climate zones 4 through 8. The best available air conditioning units can have SEER ratings of over 20.

Correct installation and commissioning can have a big impact on air conditioner performance in the mixed-humid climate. The time-delay relay on many newer air conditioning units is set to keep the fan running for about two minutes after the compressor shuts off. The relay can help boost efficiency in dry climates, but allows some of the moisture on the evaporator coil to evaporate back into the air stream, contributing to increased indoor humidity in humid climates. The time-delay relay is typically jumper selectable and should be set to 30 seconds or less in humid climates. Also, the fan on central air conditioning systems should always be set to “Auto” rather than “On” for most efficient humidity control. Some air conditioners allow the compressor to start about 30 seconds before the blower starts and this is also recommended in humid climates to reduce “hot” blow and provide better dehumidification. Make sure the drain pans are correctly installed and drain all the condensate water rather than creating a puddle. 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).

Heat pumps are more efficient than standard electric air conditioning. Central air source heat pumps use ducts. Ductless heat pumps can provide zoned cooling. The highest performing models of ductless heat pumps offer SEER ratings as high as 26 at outside temperatures as high as 115°F. In very hot climates, their efficiency may need to be balanced against cost-effectiveness in comparison to other cooling technologies such as ductless heat pumps.

Evaporative cooling is not recommended in the mixed-humid climate because it depends on low humidity to perform. Radiant cooling is not recommended in humid climates due to condensation issues on flooring. Ground source heat pumps can provide heating and cooling at high efficiencies in the mixed-humid climates, although their efficiency may need to be balanced against cost-effectiveness in comparison to other cooling technologies such as ductless heat pumps.

Dehumidifiers

In the mixed-humid climate, there are times of the year, especially in the spring and fall, when the temperature is not high enough to call for air conditioning, but the humidity level is high enough to make conditions inside the home uncomfortable. At times like these, a dehumidifier can bring the humidity down to a comfortable level, without the need for air conditioning.

One study done by Building America partner Building Science Corporation in Houston, Texas (Rudd et al. 2005) indicated that separate dehumidification is even more necessary in energy-efficient homes because efficiency measures like better insulation, air sealing, and energy-efficient windows reduce the home's temperature but don't reduce humidity. Also, in an energy-efficient home, a central air conditioning system does not have to operate as much to bring the indoor temperature down. Therefore, the air conditioner may not operate long enough to reduce the humidity, especially in the spring and fall when outdoor temperatures are not much higher than indoor temperatures.

The Building Science Corporation study compared six different dehumidification and ventilation systems in 20 homes and found that supplemental dehumidification, in addition to that provided by the central cooling system, was required to maintain indoor relative humidity below 60% throughout the year. All of the energy-efficient homes that had additional dehumidifiers kept their homes below 60% relative humidity at least 90% of the time. All of the homes that only had dehumidification as part of their air conditioning system experienced relative humidity higher than 60% for about 20% or more of the monitored hours. The study also compared six dehumidifier technologies, including expensive, integrated systems, and found that the dehumidifier system providing the best overall value, including humidity control, first cost, and operating cost, used a standard dehumidifier located in a hall closet with a louvered door and central-fan-integrated supply ventilation with fan cycling (Rudd et al. 2006).

Pine Mountain Builders incorporated covered porches, deep overhangs, numerous windows, shade trees, and ceiling fans into its designs as passive cooling strategies in its Georgia homes. The builder also incorporated 14 SEER/8 HSPF 8.0 air source heat pumps and, in some units, ground-source heat pumps, to provide heating and cooling. *(Photo Source: Pine Mountain Builders)*

Natural Cooling Strategies

Design strategies, fans, and shading are among the natural cooling strategies builders can employ. While these options don't reduce humidity, they can help occupants to feel cooler and thus they may reduce air conditioning bills.

Design strategies include siting on the lot to take advantage of natural breezes. In coastal environments, openable windows can be located on the side of the home that receives prevailing breezes and on the opposite side of the home to encourage cross ventilation. Porches and two-story designs with open interiors can take advantage of the stack effect to draw air through the home during the shoulder seasons. Shading options include planting trees, designing in overhangs, especially over south-facing glass, and adding awnings, pergolas, and covered porches (see Chapter 5). Studies show ceiling fans can allow occupants to raise the thermostat 4°F in an air-conditioned room with no noticeable reduction in comfort.

If the attic is unsealed, properly sized and placed roof vents (including soffit, ridge, and gable end vents) can help reduce heat in the attic. Motorized attic fans are not necessarily recommended because, if the ceiling is not air-tight, air conditioned air can be pulled out of the home and into the attic. Whole house fans are also not recommended in humid climates; because they require windows to be open for proper operation, they pull in significant amounts of humid outside air, and they push conditioned air into the attic.

Low-emissivity, high-performance windows, which are described in the following sections, can help reduce solar heat gain. Radiant barriers (described in Chapter 7) and cool roofs (described in Chapter 5) are other passive strategies for minimizing heat gain in cooling-dominated parts of the mixed-humid climate.

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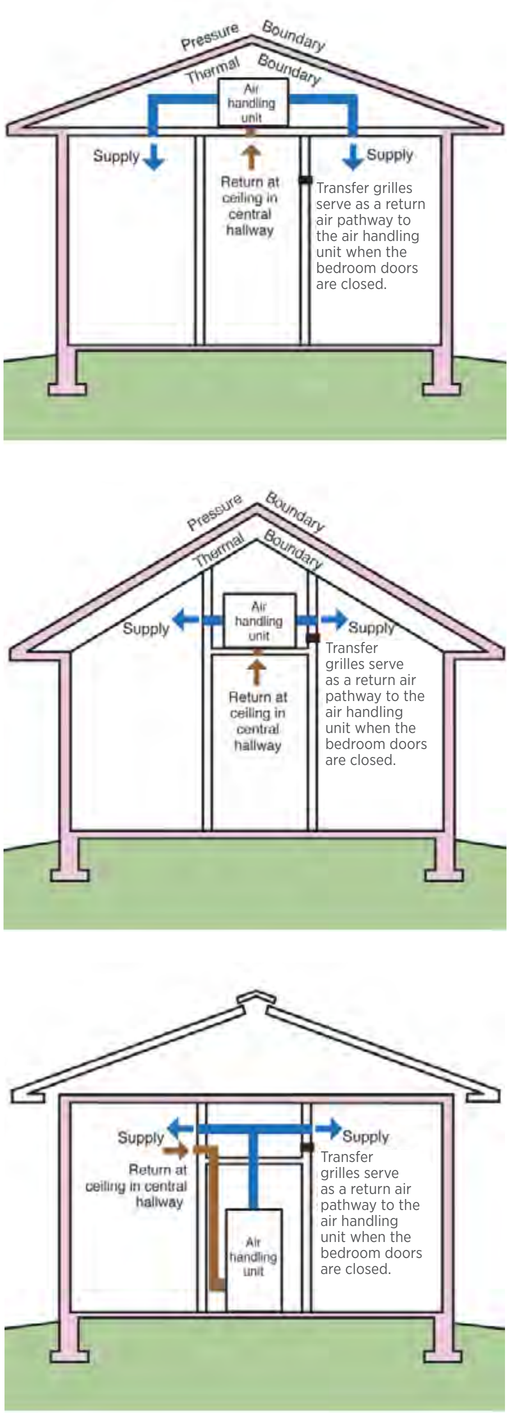
Duct Run Configurations

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



(Source: Building Science Corporation)

Ducts and Air Handlers

Duct System Design and Layout

With central forced-air systems, the gas or electric furnace and ducts are often located in unconditioned space in the attic, garage, or crawlspace. As typically installed, this "default" design is assumed in codes to reduce system efficiency by about 20%, while placing ducts in conditioned space is assumed to cut air loss to about 4% (ICC 2006 as reported in Lubliner et al. 2008). Numerous studies have shown significant savings from moving the ducts and air handler into conditioned space. In a modeling study conducted in Spokane, Washington, by Building America research partner Washington State Energy Office, using a home built to the current Washington State Energy code, moving ducts out of a vented crawlspace and into the home resulted in heating energy savings of 28.4% and cooling savings of 17% (Hales et al. 2010).

As 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. 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 and 2012 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 or return ducts [2009 and 2012 IECC 403.2.3].

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.

All four of the Building America builders described in the case studies in this guide locate their ducts in conditioned space. Two put the ducts in open-web floor joists between floors. One puts ducts in sealed, insulated crawlspaces, and one puts ducts in insulated attics.

Another Building America builder, Quadrant Homes, in Seattle, Washington, moved the furnaces out of the attic into conditioned space in a second-floor utility closet, and located the ducts in open-web floor trusses between the first and second floor. Quadrant's HVAC contractor, Wade Craig of Bob's Heating, noted several advantages to the move. When ducts are installed between floors, they are clearly visible to the general contractor and inspector, encouraging better installations. They are less likely to suffer from "trade damage" from electrical or plumbing subcontractors who step on or squish the ducts when installing wires or pipes. Putting the air handler in a closet on the second floor makes equipment servicing easier and improves worker safety during installation and retrofits. Craig said his firm can lower its bid when the HVAC system is moved inside. "It is a lot easier for installers to do a quality job when they are not lying in the mud, deep in a corner of the crawlspace," said Craig. Quadrant is aware of the potential for air leakage pathways between floors at rim joists so all ducts are 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. In humid climates this strategy is not recommended because condensation could occur at the duct exterior surface. Building America researchers have investigated burying ducts in attic insulation above ceilings and based on this research, buried ducts may be permissible but the ducts should be directly insulated to R-8, apart from the piled-on insulation. Building America does not recommend using the buried duct approach in climates where the summertime attic dew point temperature is often above 60°F, or if the Jul-Aug monthly average outdoor dew point temperature is above 60°F (refer to Table 6-3 of ASHRAE Standard 90.2-1993). The mixed-humid and hot-humid climates often exceed this dew point and so buried ducts are specifically not recommended there. In other climates, such as cold climates up through the humid river valleys, builders and designers should be cautious.

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 181B-M-compliant mastic, with a target leakage between the duct system and the garage of 0 CFM @25 Pa.

(Top and Bottom) These Building America builders run ducts through open-web floor trusses to keep the ducts in conditioned space. 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.

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.

(1) 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.

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

(3) This air handler closet is located in the garage space but is isolated with thermal and air barriers.

All ducts, air handlers, and filter boxes should be airsealed 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 181B-M, as appropriate. Duct-drywall connections should be sealed with caulk or foam sealant or mastic. 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 drafts. The double-check inherent in the process of sealing each joint reduces the chances of unconnected ductwork, which is a surprisingly common mistake.

Although mastic is the most reliable duct sealing method, the 2009 IRC M1601.4.1 allows certain approved tapes and DOE research has found that some tapes perform adequately for sealing ducts, particularly fiberglass board ducts (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 attic 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; insulation is not required for ducts located inside the building's thermal envelope [per 2009 IECC 403.2 and 2012 IECC R403.2, and ENERGY STAR Version 3.0].

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 drywall is put up or after drywall is put up. If tested at pre-drywall or rough-in, duct leakage must be ≤ 6 cfm per 100 ft^2 of conditioned floor area at 25 Pa; if tested after construction, then it must be ≤ 8 cfm at 25 Pa. The 2012 IECC R403.2 requires that duct joints be connected and sealed according to the International Mechanical and Residential Codes and that duct leakage be tested with total leakage ≤ 4 cfm per 100 ft^2 of conditioned floor area at 25 Pascals across the entire system including the air handler when tested at rough-in or post-construction. (If the airhandler 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.

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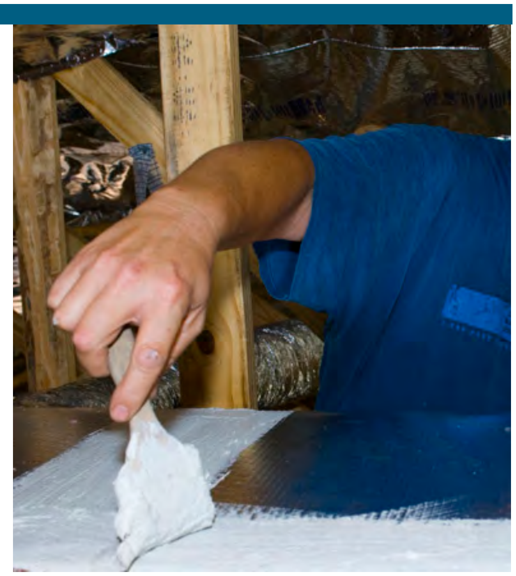


Mastic provides the most reliable duct sealing method. Ducts should be located in conditioned space. *(Photo source: BAIHP)*

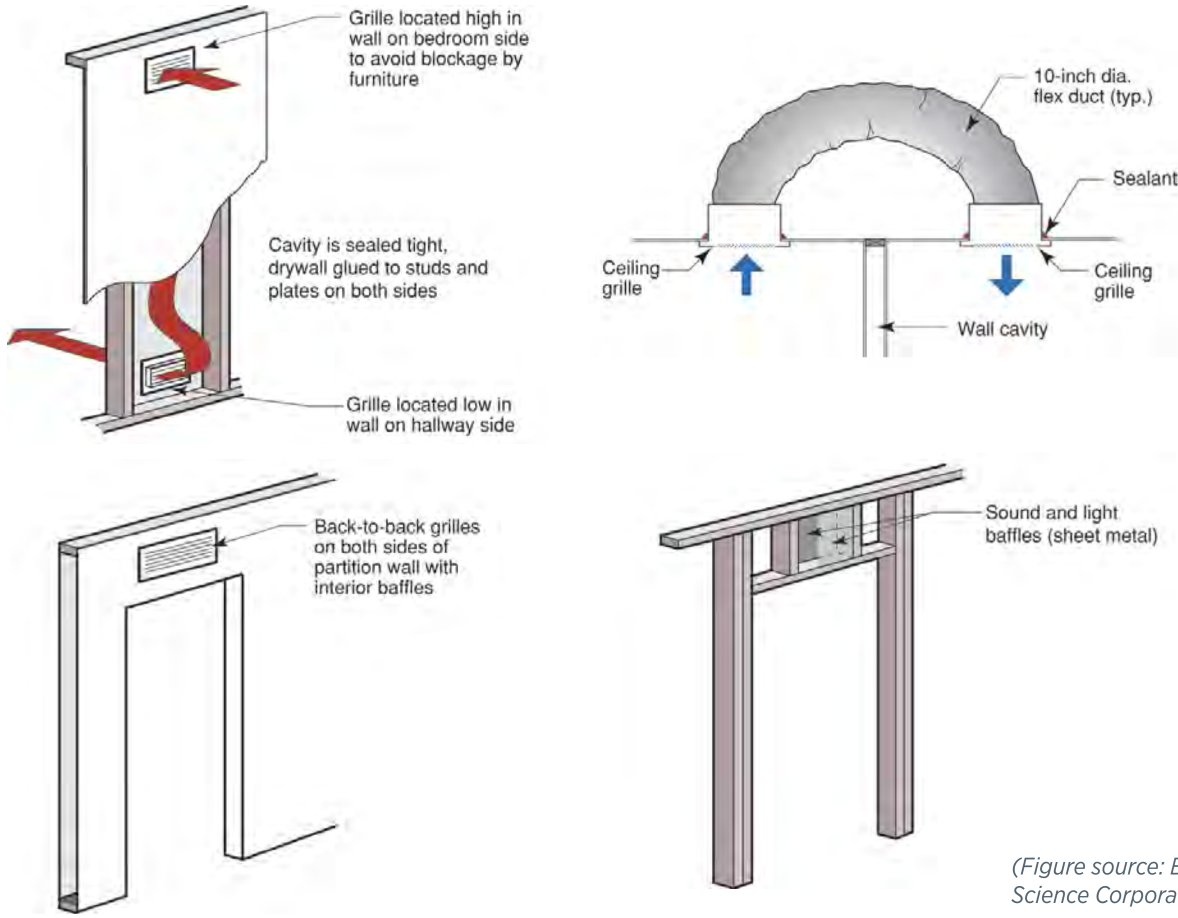
Standards for Duct Sealants

Underwriters 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; UL 181A covers field-assembled duct-board and UL 181B covers 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.

Examples of Jump Ducts and Transfer Grilles for Pressure Balancing



(Figure source: Building Science Corporation)

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 often too small and/or are blocked by the installation of carpeting. Consequently, they should not be relied on to provide adequate return air pathways and should be supplemented by other methods.

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.

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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

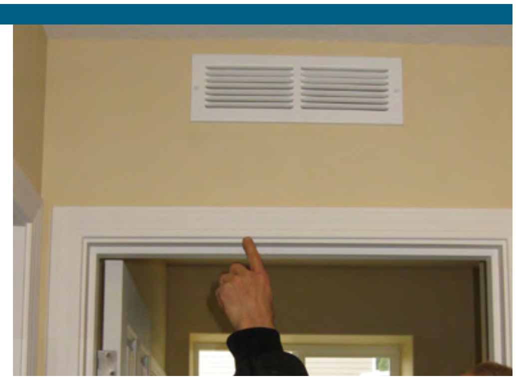
Building America recommends that all new homes be equipped with whole-house mechanical ventilation. Mechanical ventilation systems for indoor air quality include exhaust-only fans, supply-only systems, and balanced systems.

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. An advantage of supply-only ventilation is that it can positively pressurize the house, which is desirable in humid climates as it reduces intrusion of moisture-laden outside air as well as radon. Also 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). Code requires that outdoor air intakes and exhausts should be equipped with automatic or gravity dampers that close when the ventilation system is not in operation [2009 IECC 403.5].

Building America team member Building Science Corporation recommends that electronic controls be added, including a motorized damper and timer to open the damper in sync with operation of the HVAC fan for automatic ventilation of the home at regular intervals throughout the day. This approach would run the central fan on a timer basis, even when the compressor is not running.

Another approach to supply air ventilation is to have a run-time only ventilation system that introduces filtered outdoor ventilation air only when the compressor runs, i.e., only when heating and cooling happens. This approach has been used by several Building America builders (Chandra et al. 2009). The motorized outside air damper



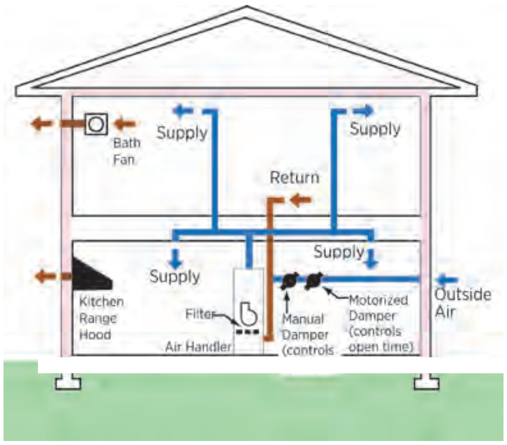
(top) Transfer grilles help balance air pressure between rooms, which helps to minimize drafts and comfort complaints.

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

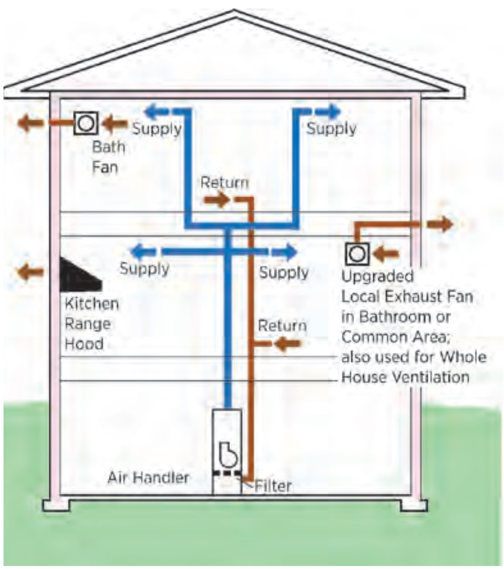
ASHRAE 62.2

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.

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. In hot-humid climates, ASHRAE 62.2 requires supplemental dehumidification systems to control humidity. Builders who do not use supplemental dehumidifiers sometimes choose to provide whole house ventilation rates that are significantly lower than required by 62.2 to avoid over-ventilating the house with unconditioned air.



Supply-only ventilation brings in fresh outside air through a dedicated duct *(Figure Source: Rudd 2011).*



Exhaust fans provide simple, inexpensive ventilation but may depressurize the house, pulling air in from crawlspaces and through cracks in the walls *(Figure Source: Rudd 2011).*

and associated control can be used to limit outside air introduction to a set maximum, regardless of how long the fan operates. Continuous operation of the air handler fan is not recommended as it would consume too much electricity and is detrimental to humidity control in humid climates (Rudd 2011).

Central fan-integrated supply ventilation can be used with a central air handler equipped with an electronically commutated motor (ECM) rather than a permanent split capacitor (PSC) motor and some fan energy consumption savings may be possible (Rudd 2011). The key is that the ducts have been properly designed and installed according to manufacturers' specifications to eliminate excessive airflow resistance. However, there are still concerns that, at the high speed required to draw enough air in through the outside air intake, the ECM is likely to have no savings relative to a PSC blower and at the lower air flows where the ECM performs better, the air flow through the exterior duct will not meet desired ventilation rates.

For homes that don't have a central heating and cooling system, an electric fan, like an exhaust fan, can be installed in or ducted to an exterior wall to draw in outside air. This outside air should be mixed with indoor air before it is delivered into the home (Rudd 2011).

Exhaust-Only Ventilation

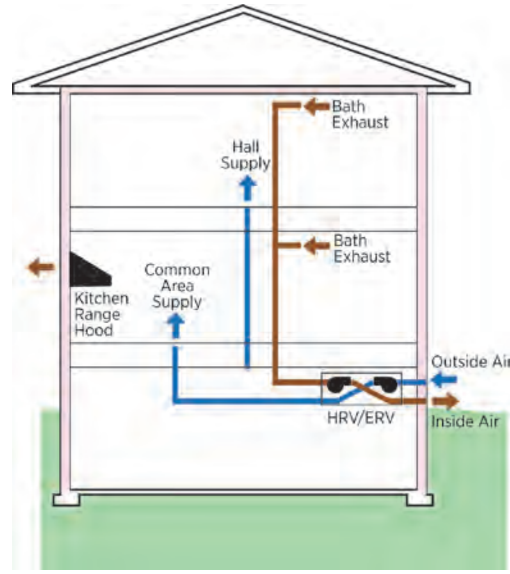
Continuously operating an exhaust fan located in a bathroom or central area of the house provides low-cost ventilation that meets ASHRAE 62.2. High-quality, quiet, efficient fans that have separate speeds for ventilation and exhaust are typically used for this application. A better solution than an isolated 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. 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. Another concern with exhaust-only ventilation systems is that the exhaust fans (when combined with other exhaust systems in the home including kitchen range fans, clothes dryers, fireplaces, and central vacuums) may draw too much 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 combustion (fuel-burning) appliances or fireplaces that may be in the home. Backdrafting occurs when the flue's natural ability to draw combustion fumes out of the house is 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 gases, garage fumes, and pollens.

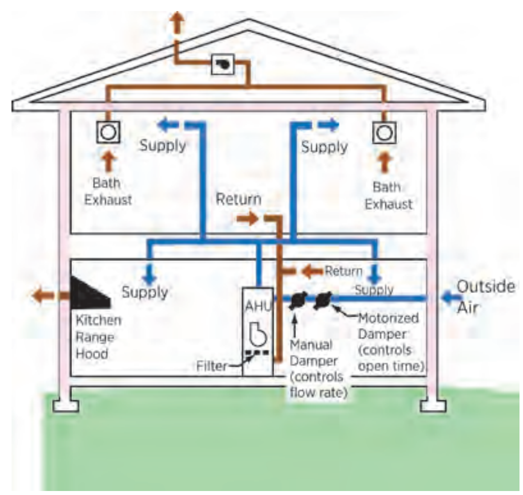
Balanced Systems

Balanced systems intentionally provide both supply and exhaust. The best means for providing this balanced ventilation is with a heat recovery ventilator (HRV) or an energy recovery ventilator (ERV). Both provide a controlled way of ventilating a home while minimizing energy loss because they incorporate a heat exchanger that uses the heat or cooling from the outgoing exhaust air to warm or cool the fresh incoming air. The incoming and outgoing air volumes are balanced and air is evenly distributed throughout the house. ERVs and HRVs can share a central furnace air handler and 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 (also called an enthalpy-recovery ventilator), the heat exchanger transfers water vapor along with heat energy, while an HRV only transfers heat. See the manufacturers' specifications for determining which model is best in which climate and install it according to their directions for best performance, especially in regard to ERVs in humid climates. Most ERVs can recover about 70% to 80% of the sensible energy in the exiting air (Rudd 2011).

Balanced whole-house ventilation systems both exhaust and supply in roughly equal amounts. Inside air is exhausted to the outdoors and outside air is supplied indoors. Balanced ventilation, by definition, should not affect the pressure of the interior space relative to outdoors. HRVs and ERVs are balanced systems. A balanced system can also be made up of any combination of the exhaust and supply ventilation systems described above (Rudd 2011). In reality the balance may never be perfect due to fluctuations in wind and stack pressures. Balanced ventilation can be used effectively in any climate. Rudd 2011 shows several examples of configurations of balanced systems.



Heat and energy recovery ventilators (HRVs and ERVs) bring in fresh air, exhaust stale air, and save energy by transferring heat to incoming air through a heat exchanger *(Figure Source: Rudd 2011)*.



Semi-balanced ventilation systems provide fresh air and exhaust stale air but flow rates may not be balanced *(Figure Source: Rudd 2011)*.

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

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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

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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

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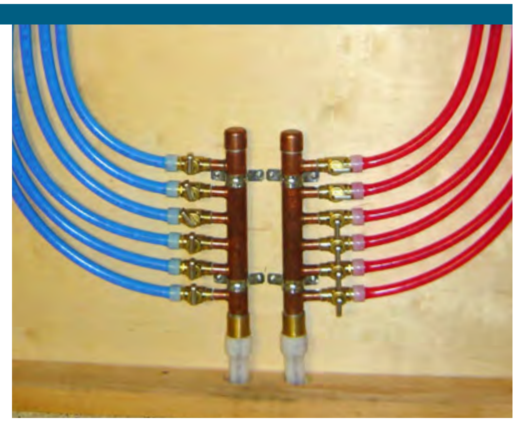
Plumbing and Water Heating

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:

- Install high-efficiency electric or gas water heaters. Specify sealed-combustion, power-vented, or direct-vented gas water heaters. These models save energy and reduce the risk of backdrafting flue gases into the house.
- Consider alternative technologies like tankless gas heaters, solar thermal water heaters, and air-source heat-pump water heaters.
- Insulate hot water supply lines to R-4 and install tanks that have at least R-12. [2009 IECC and 2012 IECC 403.3 require R-3 minimum insulation on pipes.]
- Consolidate bathrooms and other hot water-consuming activities into the same area(s) of the house.
- Place the 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. Locate the pipes in interstitial space between floors for multi-story homes.
- Do not install plumbing in exterior walls.
- Do not oversize piping. Use code-permitted minimums. Bigger isn't better.
- 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.
- 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.



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.

Code/Above Code

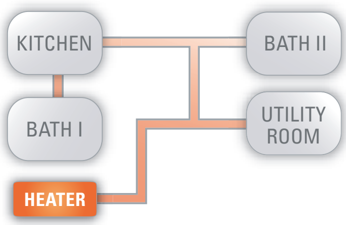
Water Pipe Insulation

A comparison of the 2009 and 2012 IECC and Building America Recommendations

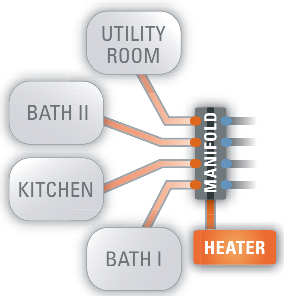
Code	Pipe Insulation for hot and cold water pipes
2009 IECC 403.3	R-3
2012 IECC 403.3	R-3
Above Code	
ENERGY STAR Ver. 3.0	R-4

Hot Water Distribution Systems

Traditional Trunk System



More Efficient Manifold System



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, which 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.

Common plumbing pipe materials are copper and PEX (cross-linked polyethylene). 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 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 an automatic or readily accessible manual control to turn off the hot-water circulating pump when the system is not in use [per **2009 IECC and 2012 IECC 403.4**] and insulate the pipe to R-2. An on-demand system recirculates the water through the hot water tank only when hot water is needed. This system helps eliminate wasted water down the drain 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.

Water Heaters

Performance rating information for conventional storage water heaters, electric heat pumps, and tankless 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 lists of qualifying products, see www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters.)

Conventional Storage Water Heaters

Conventional gas or electric 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 DOE Energy Savers website www.energysavers.gov. Storage heaters work best with steady, continuous use patterns.

Gas combustion storage water 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- or gas-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. Gas-fired tankless water heaters produce higher flow rates than electric tankless heaters. Because of their heat-on-demand nature, electric versions can create

Water Heater Efficiency

The current DOE standard for water heaters went into effect in 2004.

DOE published a final rule for amended standards for residential water heaters on April 16, 2010, which will become effective April 16, 2015, for products manufactured on or after April 16, 2015. The required energy factor (EF) varies depending on the type of water heater and the rated storage volume:

Gas ≤55 gal EF............................0.675

Gas >55 gal EF............................0.8012

Electric ≤55 gal EF.....................0.960

Electric >55 gal EF.....................2.057

Instantaneous Gas EF 0.820

Instantaneous Electric EF 0.930

For the most common sized electric water heater (50 gallons) the new standard will save 4%; for the most common gas water heater size (40 gallons) the new standard will save 3%. For gas-fired and electric storage water heaters that are over 55 gallons, the standards will effectively require electric storage water heaters to be air source heat pump water heaters and gas storage water heaters will have to use condensing technology (DOE 2011; ASAP 2011).

(top) Building America builder Tommy Williams Homes installs tankless gas-fired water heaters to save energy by eliminating the stand-by losses inherent with storage tank water heaters.

(bottom) Air-source heat pump water heaters are now commercially available like this one seen at the 2010 International Builders Show.

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 used 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.

Air Source Heat Pump Water Heaters

Air source heat pump water heaters use electric compressors and pumps to move heat from the environment to the water tank. Although they use electricity, they can be two to three times more energy efficient than conventional electric resistance water heaters. One manufacturer estimates $320 savings per year in water heating costs when comparing their ENERGY STAR heat pump water heater, which uses 1,856 kWh/yr, to a standard 50-gallon electric tank water heater, which uses 4,881 kWh/yr.

Because the heat pump water heater draws in air from the room to heat water, some manufacturers recommend that the room the water heater is located in be at least 10 ft x 10 ft x 7 ft (700 cubic feet). If the room is smaller than 700 cubic feet, the room must have a louvered door or a door that has vents installed near the top and bottom. Each of these vents should have an area of 240 square inches. The units themselves are approximately 63 inches tall by 24 inches wide.

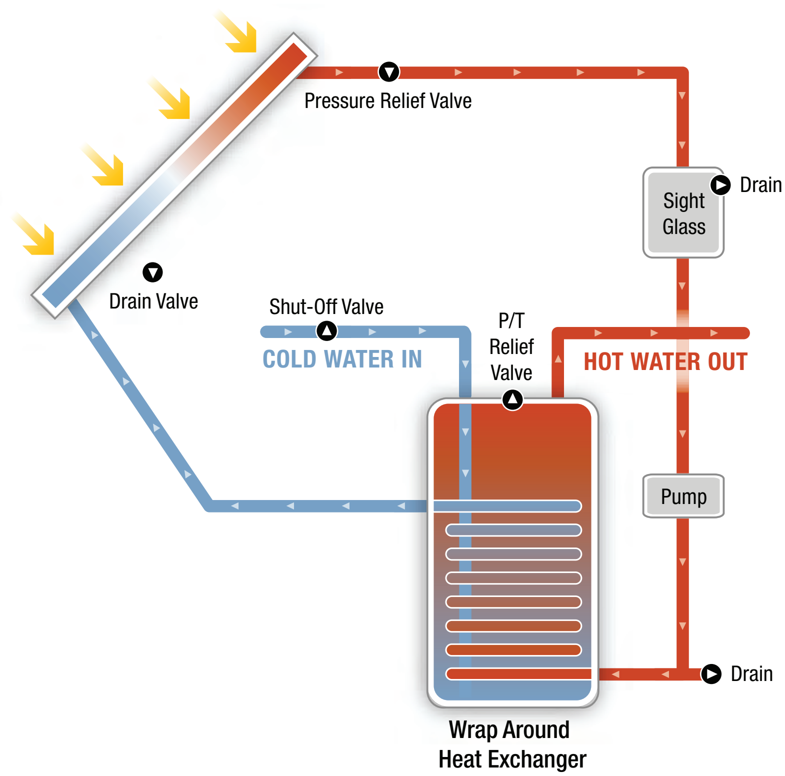
Because they have a fan, heat pump water heaters do make some noise; noise is related to fan speed, the faster the fan speed the more sound is likely. Fans speeds will increase when ambient temperatures are colder and when tank temperature is lower. In parts of the mixed-humid climate that are cooling-dominated, the best location for a heat pump water heater is in the garage. In heating-dominated regions, it can be located in a heated basement or utility room. The water heater pulls heat from the air and may help reduce cooling loads in the summer in the area of the home where it is located.

One concern with heat pump water heaters is their recovery rate. The water heater industry typically measures the recovery rate of a water heater by its first hour delivery (FHD) of hot water. Natural gas and liquid propane water heaters are capable of heating water more quickly than electric water heaters (standard electric or heat pump), and therefore, have quicker recovery rates. A 50-gallon gas water heater has an FHD of 80-90 gallons. A 50-gallon electric standard or heat pump water heater has an FHD of 58-65 gallons. Many heat pump water heaters are hybrid models that use electric elements to provide back-up heat. These can assist with recovery rates. Another solution is to get a slightly larger tank than you would typically size, for example a 50-gallon rather than 40-gallon tank.

(top) Flat plate collector-style solar water heaters are shown mounted on the roof along with solar photovoltaic panels. *(Photo Source: Florida Solar Energy Center)*

Solar Water Heaters

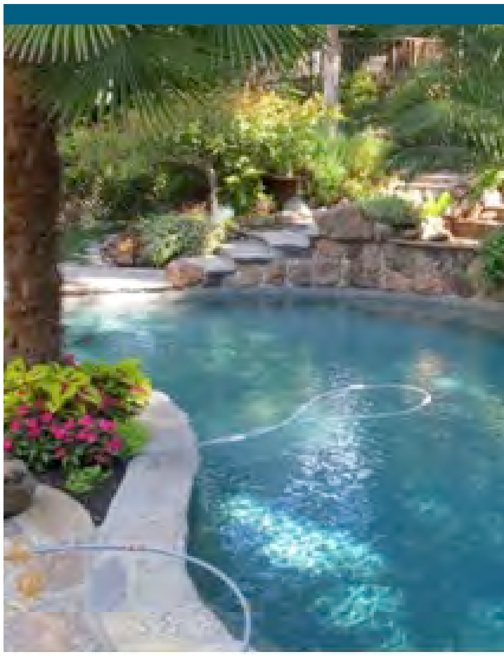
Solar thermal water heaters use the sun's heat to provide hot water. These systems usually include one or two collectors that typically sit on a house's roof and resemble skylights.



(left) This solar water heater is a drainback active, indirect system that uses water or a water and propylene–glycol mixture as the heat transfer fluid. Fluid in the roof-top collector and pipes drains into a reservoir inside the house when the hot water tank has reached the desired temperature or when the pump shuts off; thus protecting the system from both overheating or freezing. This feature makes this system a suitable option for the mixed-humid climate.

There are four main types of solar water heating systems:

- 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.



(top) If you are installing a swimming pool, consider energy saving features like a high-efficiency pump, solar water heating, and LED lighting.

(bottom) Pool pumps equipped with variable-speed motors can reduce electricity use 75% compared to standard single-speed pool pumps.

(Photo Source: Steve Easley)

- 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.

Swimming Pools

There are more than 5 million in-ground pools in the United States and many of them are located in the hot-humid climate. The typical in-ground swimming pool can consume up to 25% of a home's electricity use, canceling out the savings of energy-efficient construction. There are several steps you can take to improve pool efficiency. First replace the standard pool pump motor with a high-efficiency model. Standard models typically draw 2,000 to 2,200 watts of electricity, consuming about 12 kWh per day. New variable-speed pumps, which cost about $1,200 to $1,500 installed can cut energy use by 75% compared to single-speed models. While single-speed pool pumps consume about 10 to 12 kWh per day of electricity, variable-speed pumps usually draw about 120 to 180 watts on low speed and consume about 2 kWh per day (Easley 2010). These high-efficiency pumps tend to last longer, reduce peak demand, are more quiet, put less stress on the pool's plumbing system, and provide better filtration. They can also be configured to accommodate cleaners that can run without a booster pump, which can save an additional 1,000 kWh per year (Easley 2010). Other ways to save energy with pools include installing a solar thermal water heater, installing LED pool lights, and providing a pool thermal blanket to retain heat in cooler seasons. To save water, cartridge filters should be installed rather than sand or diatomaceous earth filters which require periodic flushing with large amounts of water.

For More Information on Plumbing and Water Heating

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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.

Residential lighting controls represent a significant opportunity for energy savings. Lighting controls generally refer 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.

CFLs and LEDs

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.

[The 2009 IECC 404.1 requires that at least 50% of the lamps in permanently installed lighting fixtures be high-efficacy lamps. The 2012 IECC R404.1 increases this requirement to 75%. ENERGY STAR Version 3.0 requires 80% of fixtures to contain



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

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

ENERGY STAR-qualified CFLs, LEDs, or pin-based lamps.] 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 reflector, and mercury vapor lamps do not qualify as high efficacy.

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.

DOE partners with lighting organizations to host two CFL and LED lighting design competitions. Next Generation Luminaires (www.ngldc.org) and the L-Prize (www.lightingprize.org). The American Lighting Association, the Consortium for Energy Efficiency, and Underwriters Laboratory host a third competition, Lighting for Tomorrow (www.lightingfortomorrow.com). Visit the competition websites to see competition winners, including some of the most energy-efficient, eye-catching designs on the market.

Recessed Can Lights

Recessed "can" ceiling fixtures, or downlights, that are recessed into insulated ceilings are required [by the **2009 IECC 402.4.5 and the 2012 IECC 402.4.4**] 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 and the 2012 IECC 402.4.4**] 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.

Example of Recessed Downlight Performance Using Different Lighting Sources

MEASURE	INCANDESCENT*	FLUORESCENT*		LED**
	65W R-30 Halogen	13W triple tube Spiral CFL	15W R-30 CFL	LED downlight
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 products available July 2010. Actual downlight performance depends on reflectors, trims, lamp positioning, and other factors. Assumptions available from PNNL.

**LED fixture was the LR6 model by Cree. It was tested through the DOE CALiPER light testing program. For more information about CALiPER, see 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.

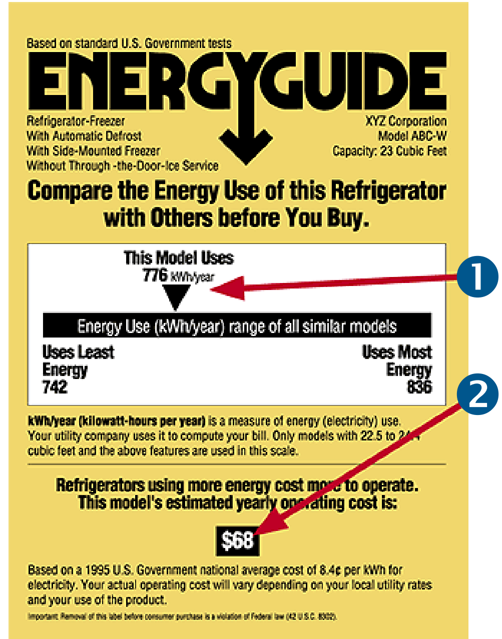
EnergyGuide Label

The Federal Trade Commission requires EnergyGuide labels on most home appliances (except for stove ranges and ovens, and home electronics, such as computers, televisions, and home audio equipment). EnergyGuide labels provide an estimate of the product's energy consumption or energy efficiency. They also show the highest and lowest energy consumption or efficiency estimates of similar appliance models.

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.

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.

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/

Chapter 10.

Occupant Health and Safety

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

(bottom) Several low-VOC adhesives are now available.

As houses become tighter, indoor air quality becomes a more important issue. To address occupant health and safety, the EPA has developed the Indoor airPlus label. The Indoor airPlus checklist is shown at the end of this chapter. The EPA 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) a properly engineered HVAC system including sealed ducts, and whole-house and spot ventilation; 5) combustion venting including installing sealed combustion heating equipment and carbon monoxide detectors, and sealing and ventilating attached garages; and 6) choosing low-chemical-content materials, keeping materials dry during construction, and airing out the home prior to move in. Many of these recommendations are addressed in this guide; see Chapter 8 for actions 1, 2, and 3; see Chapter 9 for actions 4 and 5.

Best practices for health and safety include the following:

- Use only sealed-combustion or power-vented appliances in the conditioned space. Specifically, Building America recommends that any combustion 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.
- Choose high-efficiency water heaters. Don't install atmospheric-venting water heaters inside the home. These appliances draw air from the room in which they are located and depend on the stack effect to establish an exhaust draft, but the stack effect can be overcome by dryers, exhaust fans, supply duct leakage, or other conditions that depressurize the house, causing back drafting of exhaust gases.

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

(top) This fresh air intake has a mechanical damper to control the intake of fresh outside air into the air handler for distribution via the central HVAC system.

(bottom) Atmospheric venting water heaters, like the one shown here, can backdraft through the opening at the base of the flue. Use of closed-combustion appliances eliminates this risk.

- 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 crawl spaces. 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.]

- Vent all exhaust fans directly to the outside, not into the attic. Equip outdoor air intakes and exhaust vents 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]. 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 energy-efficient and quiet fans (see Chapter 9, ventilation section).

- 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 dryer duct length. Avoid sags in ducts. Insulate ducts to avoid condensation; flash and caulk wall penetrations. Vinyl, nylon, and foil ducts do not meet code [2009 IRC M1502].

- 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.

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

- Install a central (also known as "whole-house") vacuum system that exhausts to the outdoors, to facilitate cleaning and minimize reintroduction of vacuumed dust.

- Provide occupants with information on safety and health related to HVAC equipment, 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 air-tight with weather stripping.

- Install an exhaust fan in attached garages with a minimum installed capacity of 70 cfm that is rated for continuous operation. Vent the fan 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. The fan carries pollutants outside and creates a negative pressure that helps stop garage air from migrating into the house.

- If gas or wood fireplaces are included, install units that have a dedicated outside air intake for combustion air, directly vent effluents outside, and are equipped with tight-fitting glass doors.

- 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 (like those shown in lower photo) to meet local green building guidelines.

For More Information on Healthy Homes and Combustion Safety

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

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DOE. 2011. [draft] *Workforce Guidelines for Home Energy Upgrades.* Prepared by the National Renewable Energy Laboratory for the DOE. www.eere.energy.gov/wip/retrofit_guidelines.html

American Lung Association: Nine Features of a Healthy House

- Foundation waterproofing and moisture control
- Advanced framing techniques
- Air sealing and advanced insulation techniques
- Energy-efficient, high-performance windows
- Energy-efficient and sealed combustion appliances
- High-efficiency air filtration
- Whole house ventilation
- Humidity control
- Low-VOC interior finishes.

(Source: Health House, American Lung Association of the Upper Midwest, www.healthhouse.org/build/components.cfm)

(top) Insight Homes meets the strict requirements of the American Lung Association Healthy House program, which include a whole-house dehumidifier and central vacuum system. Its homes also meet the requirements of ENERGY STAR's Indoor AirPlus Package.

(bottom) Pine Mountain Builders builds detached garages, which keeps fumes out of the house. Inside the homes, the builder uses low-VOC paints and carpets and installs carbon monoxide detectors. Houses sit on raised slabs to protect the home from water damage and avoid crawlspace moisture issues.

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

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The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Top Ten Things that homeowners can do to provide good indoor air quality. www.contractorconnect.net/GoodAir.html

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

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U.S. Environmental Protection Agency. "Wood Coating Case Studies by Company," www.epa.gov/ttn/atw/wood/low/casebyco.html

U.S. Green Building Council, LEED for Homes. 2008. www.greenhomeguide.org/documents/leed_for_homes_rating_system.pdf

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:

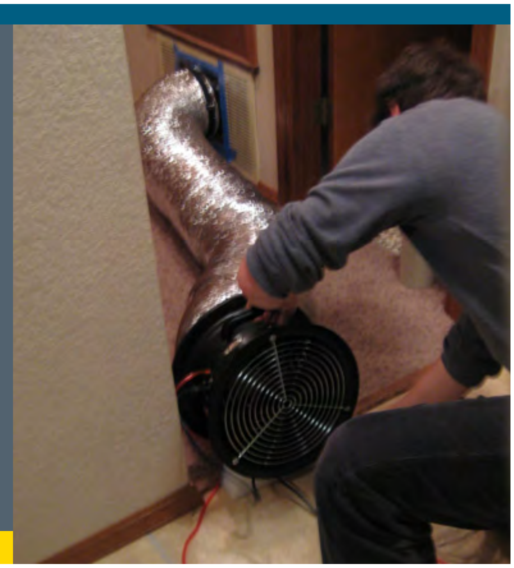
For further information on the Indoor airPLUS program, visit epa.gov/indoorairplus.

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 11.

Inspecting, Testing, and Commissioning



Duct blaster testing confirms that ducts are well sealed *(Photo source: PNNL)*.

Building America believes in real results. The only way to confirm results is to test for them. Therefore, in addition to required inspections by the code inspector, Building America recommends that site supervisors conduct systematic inspections during the course of construction, and that a formal commissioning be conducted before handing the keys to the new homeowners. The steps described in this chapter will confirm your workmanship, giving you peace of mind while reducing the likelihood of costly callbacks. Some of the activities recommended here are now required by the 2009 IECC, as noted in green in this section.

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

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

Building America recommends that every home be tested for air tightness. The four builders featured in this guide each had all of their homes inspected and tested for duct tightness and whole-house air leakage, which puts them ahead of the code. In the 2012 IECC, blower door and duct blaster testing of every home is a requirement.

CHAPTER TOPICS

Walk-Throughs during Construction

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. If the whole-house approach 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

Before the drywalling starts, you should conduct a pre-drywall inspection to test ducts and make sure insulation is properly installed and test moisture levels in framing.

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

Nat Hodgson, vice president of construction, Pulte Homes Las Vegas Division

and pre-job/post-job checklists filled out by the subcontractor can help solve recurring problems. These are both described in Chapter 12. A checklist for designers in Chapter 13 contains many of the provisions that site supervisors should look for and work to include.

Building Commissioning

Basic commissioning of the house and its mechanical systems is vital for high-performance housing and should be completed before the home is considered ready for the homeowner to take possession. Commissioning activities include verifying the installation and operation of HVAC equipment, especially for advanced systems like combination water/space heating systems, ground-source heat pumps, solar thermal systems, and photovoltaic arrays. Combustion safety testing should be conducted if any combustion appliances (including fireplaces) are installed. Additional testing recommended by Building America includes whole-house air leakage testing with a blower door test, duct air tightness testing, and pressure balance testing of each room. These activities are described below.

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 tested at pre-drywall or rough-in, duct leakage must be ≤6 cfm per 100 ft^2 of conditioned floor area at 25 Pa; if 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.) The **2012 IECC 403.2.2** requires that ducts be tested at rough-in and have total leakage that is ≤4 cfm/100 ft^2 of conditioned floor area at 25 Pascals including the air handler enclosure, or ≤3 cfm/100 ft^2 of conditioned floor area at 25 Pa if the air handler is not installed at the time of the test. If the duct leakage is tested after construction is complete, total leakage must be ≤4 cfm/100 ft^2 at 25 Pa. Duct leakage testing is not required if the ducts and air handler are located entirely within the building thermal envelope.]

Building America recommends performing a duct pressure test ("duct blaster" test) 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 any zone dampers are operating correctly and that bypass dampers are properly adjusted. The pre-drywall inspection is also a good time to visually inspect that insulation and draft-stopping have been properly installed.

Whole-House Pressure Testing and HERS Rating

After completion of the home, including all interior and exterior finishes but before occupancy, 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 ACH at 50 Pa. Or, the 2009 IECC allows an extensive visual inspection of all of the areas listed in the 2009 IECC 402.4.2.2. The 2012 IECC R402.4.1.2 eliminates the visual inspection and requires that all homes be blower door tested. Homes in IECC climate zones 1 and 2 must show air leakage rates of ≤5 ACH when tested at 50 Pa. Homes in IECC climates zones 3 through 8 must show air leakage rates of ≤3 ACH at 50 Pa. The testing may need to be conducted by an approved third party, if required by the code official.] Building America also recommends a blower door test. In addition, 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. The HERS rater should conduct a combustion safety test of all fuel-fired equipment as part of the rating certification. The HERS rating itself can be a valuable marketing tool for an energy-efficient house. Homes built to the recommendations in this guide would achieve a HERS score of 70 or lower. Homes built to the 2006 IECC would score 100 on the HERS index.

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

SNAPSHOT Form

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-0413b-snapshot-form/view?topic=doctypes/reports. 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-2010, which is available at www.acca.org/industry/quality/quality-installation.

Homeowner Education

Homeowners should also be given information on maintenance and operation of the HVAC equipment in their new home. Building Science Corporation 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.

For More Information

ACCA. 2010. *ANSI/ACCA Standard #5 HVAC Quality installation Specification*, Air Conditioning Contractors of America, Arlington, Virginia, www.acca.org/industry/quality/quality-installation

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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

Chapter 12.

Construction Site Documents, Scheduling, and Training

Getting a high-performance home requires having good plans; the proper contracts, permits, and materials; and properly trained and competent installers, who are scheduled at the right time and whose work is verified with testing.

Construction and Contract Documents

Builders should use construction and contract documents **[in compliance with 2009 IECC 103]** including plans and specifications, scopes of work, and job-ready and job-complete checklists, to describe and define exactly what you want from your subcontractors.

PLANS AND SPECIFICATIONS – Elevations, floor plans, and equipment layout should clearly identify all details related to energy efficiency, such as duct layout, advanced framing techniques, moisture management techniques, and air sealing details. Plans and specifications should include sufficient building and equipment details for the code inspector **[as required by the 2009 IECC 103]**.

SCOPES OF WORK – Scopes of work define expectations and explain unfamiliar sequences of work. The Building America research teams have put together an extensive set of sample scopes of work that builders can include with contract documents, covering the foundation, framing, walls/drainage plane, windows, HVAC, and air sealing. See Appendix E of *Achieving 30% Whole-House Energy Savings Level in Marine Climates* (DOE 2006).

JOB-READY CHECKLIST – Signed by the site supervisor and trade contractor, the job-ready checklist includes all items that must be installed or prepared on the job site, by other trade contractors, before the contractor's work can begin.

JOB-COMPLETE CHECKLIST – Signed by the site supervisor and trade contractor, it confirms that the contractor's work was completed as specified.

"Keys to success are commitment from the final decision maker; scopes of work for subcontractors with specific performance criteria; clear communication with the trades often accompanied by training and education activities; independent third party testing, commissioning and feedback to the builder; ongoing training, and marketing...If the above process is followed, the results are going to be increased sales and profits for the home builders, satisfied homeowners and significant energy savings with its attendant economic and environmental benefits for all."

Ken Fonorow, Florida HERO,
a Building America research partner

CHAPTER TOPICS

(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 pre-construction 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.

Site supervisors should review construction documents before they are folded into contracts and should 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 back to designers and managers so that documentation can capture those improvements. Although individual improvements may seem small, capturing these in construction documents helps you achieve superior building in the field.

"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

Contract Documents

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 be able to communicate with the builder's 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 (see HotSpots example at the end of this chapter).

- Trades must self-inspect each phase of work before reporting the work complete to the site supervisor. 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 job site.

Change Orders

Change orders occur when changes have to be made to the original plans, because of a change in equipment or materials, or because a design change was made, or because the original plans didn't provide correct details. Change orders and their impacts on building performance can be minimized by providing detailed plans including a site plan, assembly sequence drawings, framing layout with mechanical layout, and mechanical system equipment and distribution layout. Equipment schedules can be integrated into these plans. The detailed drawings should address structural connections (load transfer paths), movements and tolerances, and continuity of water, air, vapor, and heat control layers. With these drawings it is important to convey both the sequence of each step and the intent of these steps to achieve high performance. The plans should be reviewed by the architect to make sure they are complete. The builder's team (including the site supervisor and subcontractors) should review the plans together before construction starts so the builder can convey the design intent, proposed methods, and required performance level. These quality control steps will greatly minimize change orders and, if changes do need to be made, all team members will have a clear understanding of what is being changed (Lukachko et al. 2011).

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 unconstricted access and pathways than it is for wires or pipes. However, be sure needs for other systems, such as drain pitch, are coordinated.

"It took us awhile to get to where we could build our homes as tightly as we needed to, to train our air conditioning contractors to where their duct work was as tight as it needed to be, and our insulation contractors to air seal in the way they needed to. This [energy-efficient building] isn't something that a builder can do just by flipping a switch or spending more money. You have to fail a lot of blower door tests and duct blaster tests first."

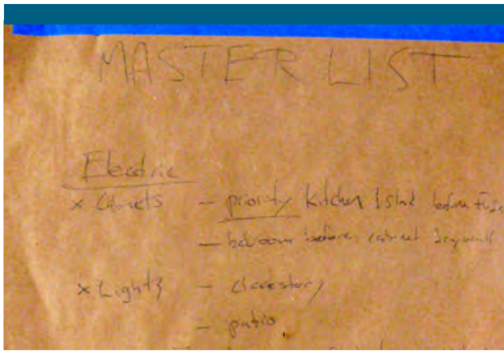
David Weekley, president,
David Weekley Homes

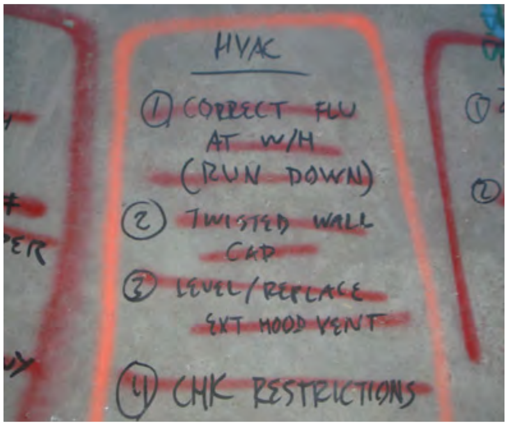
For More Information on Construction and Contract Documents

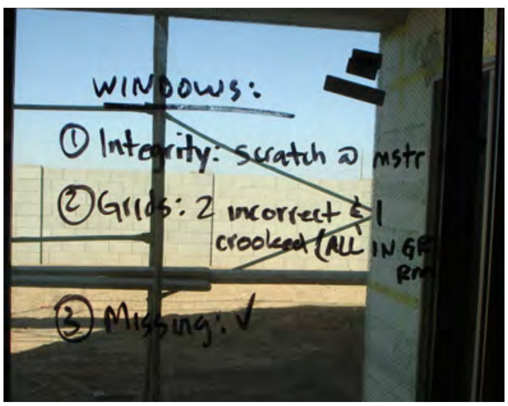
DOE. 2006. *Achieving 30% Whole-House Energy Savings Level in Marine Climates.* Prepared for the U.S. Department of Energy by the Building America Research Teams (BAIHP, BIRA, BSC, CARB, DEG, IBACOS, NAHBRC, and NREL), http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/39743.pdf.

Lukachko, Gates, and Straube. 2011. 3.1.1 Construction Documents for High-Performance Homes, Building Science Corporation, www.BuildingAmerica.gov

NAHBRC. 2006. "Quality Matters: Six Ways to Improve Trade Contracts." *ToolBase News*, Summer 2006: Volume 11, Issue 3.







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

- If using an insulated, conditioned attic, schedule insulating under the roof deck before HVAC is installed. 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.
- 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 subcontractors, 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 14 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 foam insulation). Open headers may be left for the insulation contractor. Pre-fabricated, insulated headers are another alternative.

"You can expect what you inspect."

Dr. W. Edwards Deming, the originator of total quality management

- Draftstops must be installed behind bathtubs and stairwells on exterior framed 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.

Training Installers

High-performance home construction does not just happen. Training is essential. Training need not involve days off the work site 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 job site 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 14 of this guide, or the DOE Building Energy Code Program's Code Notes (see examples in Appendix 2).
- 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 Tips from Mixed-Humid Climate Builders

All of the builders who work with Building America mention the importance of training to meet their energy efficiency goals.

Urbane Homes holds pre-construction meetings so the site superintendent can coordinate schedules with the trade contractors. Urbane provides training sessions for their subcontractors on the use of newer products like exterior rigid foam and they have developed a framing manual for the special techniques they expect their framers to use. David Weekley Homes' Houston division employs a full-time quality coach. Building America research partner Building Science Corporation worked with the coach to train several groups of Weekley employees, including site supervisors, sales agents, and

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

"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.

"Our framers do the majority of our air sealing, so when we make changes to our process, they get an updated manual and do a great job with it."

Abe Gilbert, co-owner, Urbane Homes, Louisville, Kentucky

Cooling the HotSpots

The NAHB Research Center recommends using HotSpots inspection forms. HotSpot inspection forms are used by supervisors on every job:

- Distribute and discuss HotSpot inspection forms in weekly production meetings.
- Identify quality issues through job inspections, builder feedback, and comprehensive quality reviews. Include the problems that show up often on your punch lists.
- Add HotSpot checkpoints to the inspection form where improvement is needed.
- Train site supervisors in procedures to prevent identified problems.
- Develop one-page diagrams that address specific problem areas and use these in toolbox talks to train crews.
- Monitor the use of the new processes and the quality of installations. Results provide feedback on the effectiveness of the improvements.
- Celebrate success. When a HotSpot is no longer an issue, remove it from the HotSpot list and put it in a reminder section. In time, items may leave the inspection form altogether.

Adapted from the ToolBase Resources Website at www.toolbase.org/Best-Practices/Business-Management/Hot-Spot-Inspections. This website includes examples of HotSpot inspection forms.

subcontractors involved in advanced framing, enclosure air sealing, duct sealing, and HVAC system sizing. Building Science Corporation noted that one of the most difficult things to train was the advanced framing techniques. They repeatedly pointed out unnecessary framing pieces to contractors, only to see them installed on the next home. When site supervisors began making the contractors go back and remove extra pieces of lumber, then the contractors started consistently using the advanced framing techniques. David Weekley Homes was so pleased with the advanced framing they implemented it in other divisions as well.

Building America's team lead IBACOS took an active role in subcontractor training on a Building America project in Pittsburgh. IBACOS prepared mockups of field assemblies at its warehouse and provided hands-on training sessions. "We had the actual crew who would be performing the work in the field practice by working on the mockups. If they had any questions or suggestions for improving the process, we could work this out before we got into the field," said Kevin Brozyna, an IBACOS building performance specialist.

Training Opportunities

Building America's research partners represent some of the world's leading building scientists. In addition to providing training to the builders with whom they work, Building America research partners provide training and national certifications to builders and contractors across the country. For a current list of research partners and links, see the Building America website, www.eere.energy.gov/buildings/building_america/research_teams.html.

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 Training to correct recurring problems. Builders can use "HotSpot" forms like the sample on the following page to note problem areas that need to be inspected and signed off by the site supervisor.

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

Chapter 13.

Durability and Energy-Efficiency Checklist

CHAPTER TOPICS

This checklist summarizes the measures presented in Chapters 6–12. Measures from the ENERGY STAR Qualified Homes, Version 3 (Rev 4.0) National Program Requirements are included as well; see the Requirements document for more specific details (www.energystar.gov/ia/partners/bldrs_lenders_raters/ES_Combined_Path_v65_clean_508.pdf). The 2009 and 2012 IECC and IRC code requirements for the measures listed below can be found with descriptions of these measures in Chapters 6 through 12 of this guide.

Designers, use this checklist as a reminder to investigate these measures throughout the design process. It is important to develop specifications and drawings to ensure that selected features are included in construction documents.

Site supervisors, use this list to develop customized onsite pre-job and post-job inspection checklists for each trade contractor.

Foundation Assemblies

Slabs, crawlspaces, and piers are all common foundation types in the mixed-humid 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 1/2 inch per foot for at least 10 feet around and away from the entire structure.
- ☐ Slope impervious surfaces such as driveways, garage slabs, patios, stoops, and walkways away from the structure at least 1/4-inch per foot to edge of surface or 10 feet, whichever is less.

- ☐ Design the house structure with overhangs, gutters, drainage planes, and flashing to shed rainwater and conduct it away from the house.
- ☐ Slope top soil to drain away from the house. Building America recommends a surface grade of at least 5% for at least 10 feet around and away from the entire structure.
- ☐ 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 between foundation wall stem and sill plate 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.
- ☐ 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. 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 of 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.
- ☐ In flood-prone areas, build homes on piers with floors one foot above the base flood elevation.
- ☐ Ensure sump pump cover is mechanically attached and has a full gasket seal or equivalent.
- ☐ In all crawlspaces, install 6-mil polyethylene across the entire ground surface. Overlay all seams by 12 inches and tape. Seal the polyethylene at least 6 inches up the walls or to a height equal to ground level.
- ☐ 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).

Controlling Heat Flow in Slab Foundations

- ☐ Follow local code requirements regarding termite inspection of foundation walls.
- ☐ 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.

Controlling Heat Flow in Crawlspace Foundations

- ☐ Follow local code requirements regarding termite inspection of foundation walls.
- ☐ 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 the exterior side of the beam to R-5.6.
- ☐ 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 IECC climate zones 5 and 6, R-38 in climate zones 7 and 8 (or sufficient to fill the framing cavity, at least R-19).

Controlling Heat Flow in Basement Foundations

- ☐ Follow local code requirements regarding termite inspection of foundation walls.
- ☐ Wall insulating in basements is similar to the approaches described for crawlspaces. Basement floors are insulated similarly to slabs.
- ☐ 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 frame wall with additional insulation is added, 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.

Controlling Air Infiltration in All Foundation Types

- ☐ Install a sill gasket between the foundation and the bottom plate of the exterior framed wall to prevent air leaks and 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 caulk, spray foam, and blocking material to air seal all penetrations through the sill plate and subfloor for plumbing, wiring, and ducts.
- ☐ Weatherstrip basement and crawlspace doors and access hatches.

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.
- ☐ Include a sub-slab-to-roof vent system to vent radon and soil gases.
- ☐ Install a fan on the vent stack if testing of the house shows high radon levels.

PEST CONTROL

- ☐ Use termite treatments, bait systems, and treated building materials for assemblies that are near soil or have ground contact.
- ☐ Provide roof drainage to carry water at least 3 feet away from the building.
- ☐ Apply decorative ground cover no more than 2 inches deep within 18 inches of the foundation.
- ☐ Keep plantings at least 30 inches from the foundation with supporting irrigation directed away from the finished structure.
- ☐ Install a metal termite shield at the sill plate.

Wall Assemblies

Controlling Liquid Water in Wall Assemblies

- ☐ Install flashing and kickout diverters at all intersections of the wall with roofs and other building elements.
- ☐ Install flashing at the bottom of exterior walls with weep holes included for masonry veneer and weep screed for stucco cladding systems.
- ☐ Properly flash and seal windows, doors, and other penetrations through the wall.
- ☐ Specify and show in elevations building paper, housewrap, or taped insulating sheathing (rigid foam insulation) behind the exterior cladding to serve as a fully sealed, continuous drainage plane.
- ☐ Provide an air space between the cladding and the drainage plane of 1 to 2 inches for brick and stone veneer, 3/4 inch for stucco, and 1/16 inch for lap siding.
- ☐ For the drainage plane behind stucco cladding, include two layers of building paper or housewrap 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 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 to provide shade.
- ☐ In slab foundations, form a stepped-down shelf at the slab edge to seat doors so that any water that gets in under them is directed outside.

Controlling Water Vapor in Wall Assemblies

- ☐ Back-prime wood and fiber cement cladding to avoid water saturation and migration.
- ☐ Do not install vapor barrier (e.g., polyethylene sheeting, foil-faced batt insulation, reflective radiant-barrier foil insulation) on the interior side of walls in air-conditioned structures. Wall assemblies should be able to dry to at least one side and in many cases both sides of the assembly.
- ☐ Do not use impermeable coverings, such as vinyl wallpaper, on exterior walls.
- ☐ Use a Class 3 vapor retarder (latex paint) on interior side of walls with vented cladding over wall sheathing.
- ☐ Leave a drainage space of at least 1/16-inch behind lap siding and ¾ inch between stucco and plastic housewraps to control liquid phase water penetration. A 1- to 2-inch air gap is needed behind brick veneer.

- ☐ Use a non-paper-faced backerboard such as cement board on walls behind tub and shower enclosures that are composed of tile or panel assemblies with caulked joints.
- ☐ Do not use building materials that show signs of water damage or mold.
- ☐ Use dry lumber that has a moisture content <18%.
- ☐ Follow manufacturers' drying recommendations for wet-applied insulation.

Controlling Air Infiltration in Wall Assemblies

- ☐ Install insulation and an air barrier that is in full contact with the insulation at all exterior walls, and behind showers and bathtubs, behind fireplaces, at attic kneewalls and skylight shaft walls, at walls adjoining porch roofs, at staircase walls, at double walls, and at garage rim or band joists adjoining conditioned space.
- ☐ Use interior gypsum board as the interior air infiltration barrier. Tape and mud gypsum board at all joints and the intersections of the wall with the floor and the ceiling.
- ☐ 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.
- ☐ Use the ENERGY STAR Thermal Enclosure System Rater Checklist (ENERGY STAR Qualified Homes, Version 3).
- ☐ Seal all exterior wall penetrations (exterior lights, phone lines, vents, faucet pipes, cables, etc…) with caulk, gaskets, or other sealants.
- ☐ For occupant health and safety, verify air sealing at all shared walls and ceilings between attached garages and living spaces.

Controlling Heat Flow in Wall Assemblies

- ☐ Reduce thermal bridging at exterior walls by insulating with rigid insulation, insulated siding, structural insulated panels, or insulated concrete forms.
- ☐ If using stud-framed walls, use advanced framing techniques to maximize insulation.
- ☐ Meet or exceed 2009 IECC insulation requirements.
- ☐ Properly install wall insulation to ensure the cavity is completely free of voids.
- ☐ Use spray foam to insulate and seal rim joists (and where the wall connects to the roof in non-vented attics).
- ☐ Install ENERGY STAR-labeled doors and windows that meet ENERGY STAR requirements for the mixed-humid climate.
- ☐ Use roof overhangs, porches, and awnings to provide shade and protect windows, doors, and walls. Plant trees to provide shade.

Roof Assemblies

Controlling Liquid Water in Roof/Attic Assemblies

- ☐ In areas with potentially high winds and heavy rains, apply 4-inch to 6-inch "peel and seal" self-adhering water-proofing strips over joints in roof decking before installing the roof underlayment and cover.
- ☐ Install roofing materials shingle-fashion to provide a continuous drainage plane over the entire surface of the roof.
- ☐ Properly flash roof valleys and edges and use step and kick-out flashing where roof edges abut walls.
- ☐ Install self-sealing bituminous membrane or equivalent at all valleys and roof deck penetrations.
- ☐ 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/Attic Assemblies

- ☐ Install roof, ridge, and soffit 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/Attic Assemblies

- ☐ Tape and seal all ceiling gypsum board seams so that the gypsum board functions as an air barrier. Ensure an air seal at the intersection between the walls and ceilings in attics, cathedral ceilings, and knee walls.
- ☐ Use spray foam for tight sealing of the wall-roof intersection in non-vented attics.
- ☐ Caulk all intersections of ceiling with other components (soffits, ceiling fans, duct registers, light fixtures, etc.).
- ☐ Use draftstopping in dropped ceiling areas.
- ☐ Use ceiling light fixtures that are rated for insulation contact and airtight (ICAT); install with proper trim and caulk cracks around light fixtures.
- ☐ Air seal all penetrations through top plates.
- ☐ Weatherstrip and insulate attic access hatches or doors.
- ☐ Seal all penetrations through the ceiling and the roof, including holes for flue stacks, wiring, fans, etc.

Controlling Heat Flow in Roof/Attic Assemblies

- ☐ Consider a non-vented attic.
- ☐ Install insulation amounts that meet or exceed the requirements of the 2009 IECC.
- ☐ Use insulation contact rated recessed can lights and insulate over them.

- ☐ Use raised-heel energy trusses to maintain the thickness of ceiling insulation directly above the top plates of the exterior wall framing. 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.
- ☐ Construct insulation dams around chimneys and flues to allow full attic insulation depth around them.
- ☐ Insulate attic doors and hatches. Provide insulation dams around horizontal access doors to allow full depth attic insulation.
- ☐ Insulate kneewalls and walls adjoining porch ceilings.
- ☐ In vented attics, install baffles to prevent blocking of soffit vents and wind washing.

Whole-House Air Leakage

- ☐ Have building envelope tested for air leakage by a HERS rater who uses a blower door test to confirm leakage rates do not exceed code maximums.

Mechanical Systems

Heating and Cooling Equipment

- ☐ Size heating and cooling equipment using ACCA Manuals J and S.
- ☐ 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.
- ☐ If installing a gas furnace, install a sealed-combustion, condensing furnace that exceeds 90 AFUE and install it in conditioned space if possible.
- ☐ 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 Minimum Efficiency Reporting Values (MERV) 8 normal-thickness filter. Make the filter easy to access for cleaning or replacement and design the filter slot so there is no air bypass around the filter when the HVAC system is operating. The maximum air velocity through the filter should not exceed 400 fpm.
- ☐ Keep air 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.
- ☐ Consider alternative energy-efficient equipment such as high-efficiency ductless heat pumps.

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.
- ☐ Size ducts using ACCA Manual D.
- ☐ 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.
- ☐ Use ducts made of galvanized sheet metal, duct board, or flex duct, not building cavities.
- ☐ Air seal insulated ducts running outside conditioned spaces, by use of proper duct-sealing techniques. 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.
- ☐ 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" (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 an air-sealed, insulated closet. Ducts located in the garage may not have any openings in the garage and furnaces and air handlers that supply air to living spaces shall not supply air to or return air from a garage. The air handler and any return-air ductwork should be thoroughly sealed with UL 181B-M-compliant mastic, with a target leakage between the duct system and the garage of 0 CFM @ 25 Pa.
- ☐ Verify duct air tightness with a duct blaster pressure test. Test at rough-in when leaks can be easily accessed and sealed.

Ventilation

- ☐ 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 MERV 8 normal-thickness filter. Make the filter easy to access for cleaning or replacement and design the filter slot so there is no air bypass around the filter when the HVAC system is operating.
- ☐ Install ENERGY STAR-qualified low-sone exhaust fans in bathrooms and kitchens. Sone ratings should not exceed 1.5.
- ☐ Seal bathroom and kitchen fans to drywall with caulk or gaskets.
- ☐ Equip outdoor air intakes and exhausts with automatic or gravity dampers that close when the ventilation system is not in operation.
- ☐ Consider installing a night ventilation cooling system in appropriate subclimates.

Plumbing

- ☐ Locate bathrooms and other hot water-consuming activities near each other in house layout.
- ☐ Centrally locate 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.
- ☐ Insulate tanks to at least R-12.
- ☐ Use a central manifold (home-run) water distribution system.
- ☐ Use PEX (high-density polyethylene) piping. Use approved connectors so PEX pipes are not 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.
- ☐ If gas water heaters, use closed-combustion or power-vented models.
- ☐ Consider alternative technologies like on-demand gas or electric water heaters, solar thermal water heaters, and air-source heat pumps for water heating.
- ☐ Use solar water heaters for pools and spas; use high-efficiency pool pumps.

Electrical

- ☐ Use ENERGY STAR-qualified compact fluorescent lights (CFLs or LEDs) in all fixtures expected to be on more than 2 hours per day.
- ☐ Use recessed ceiling lights that are ICAT rated (approved for insulation contact and airtight).
- ☐ 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.
- ☐ Use sealed-combustion gas fireplaces to eliminate the threat of harmful combustion gases entering the house.
- ☐ Install CO detectors and smoke alarms.
- ☐ Use filtration systems for forced air systems that provide a minimum atmospheric dust spot efficiency of 30% or MERV 8 or higher.
- ☐ Maintain indoor humidity in the range of 30% to 60% by controlled mechanical ventilation, mechanical cooling, or dehumidification.
- ☐ 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 about the operation and maintenance of the building systems that provide 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.
- ☐ Vent clothes dryers and central vacuum cleaners directly outdoors.
- ☐ Use low-VOC paints, finishes, varnishes, and adhesives whenever possible.

Commissioning

- ☐ Test ducts for air leakage at rough-in.
- ☐ Test whole-house air leakage with a blower door.
- ☐ Do combustion safety testing if combustion appliances are installed in the home.
- ☐ Provide homeowners with operation and maintenance guidance to HVAC and mechanical systems.

Chapter 14.

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 job site, 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
- Ductless Heat Pump Installers Guide
  (from Northwest Energy Efficiency Alliance www.ductless.com)
- Roof Fascia/Soffit Vent Detail
- Ice Dam Prevention

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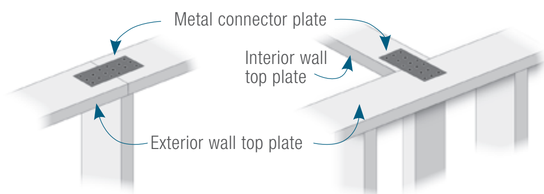
Advanced Framing

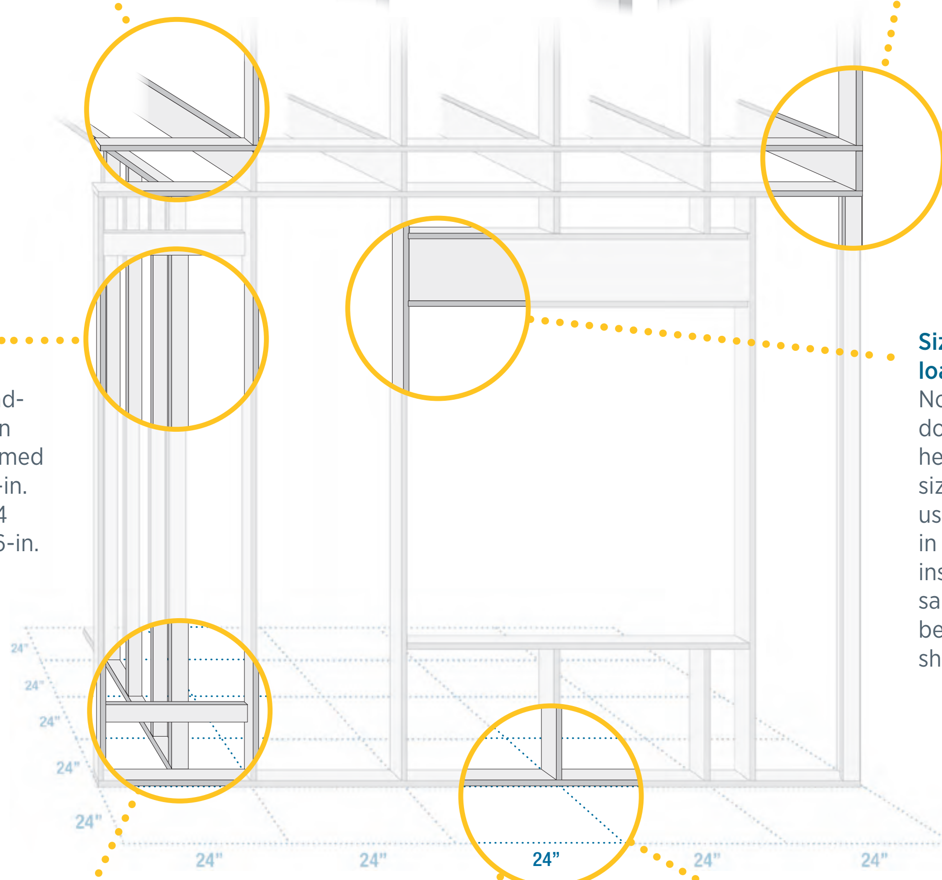
The following tips show examples of framing techniques that can create more open space to hold insulation while reducing framing costs and waste. The following page shows an example of a detailed framing plan. Such detailed plans should be included in construction documents.

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.

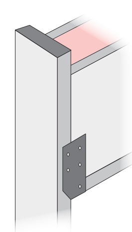


Use two-stud corners: Rather than using a third stud as a nailing edge for interior gypsum board, use drywall clips, a 1x nailer strip, or a recycled plastic nailing strip. Using drywall clips also reduces drywall cracking and nail popping.



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 sheathing.



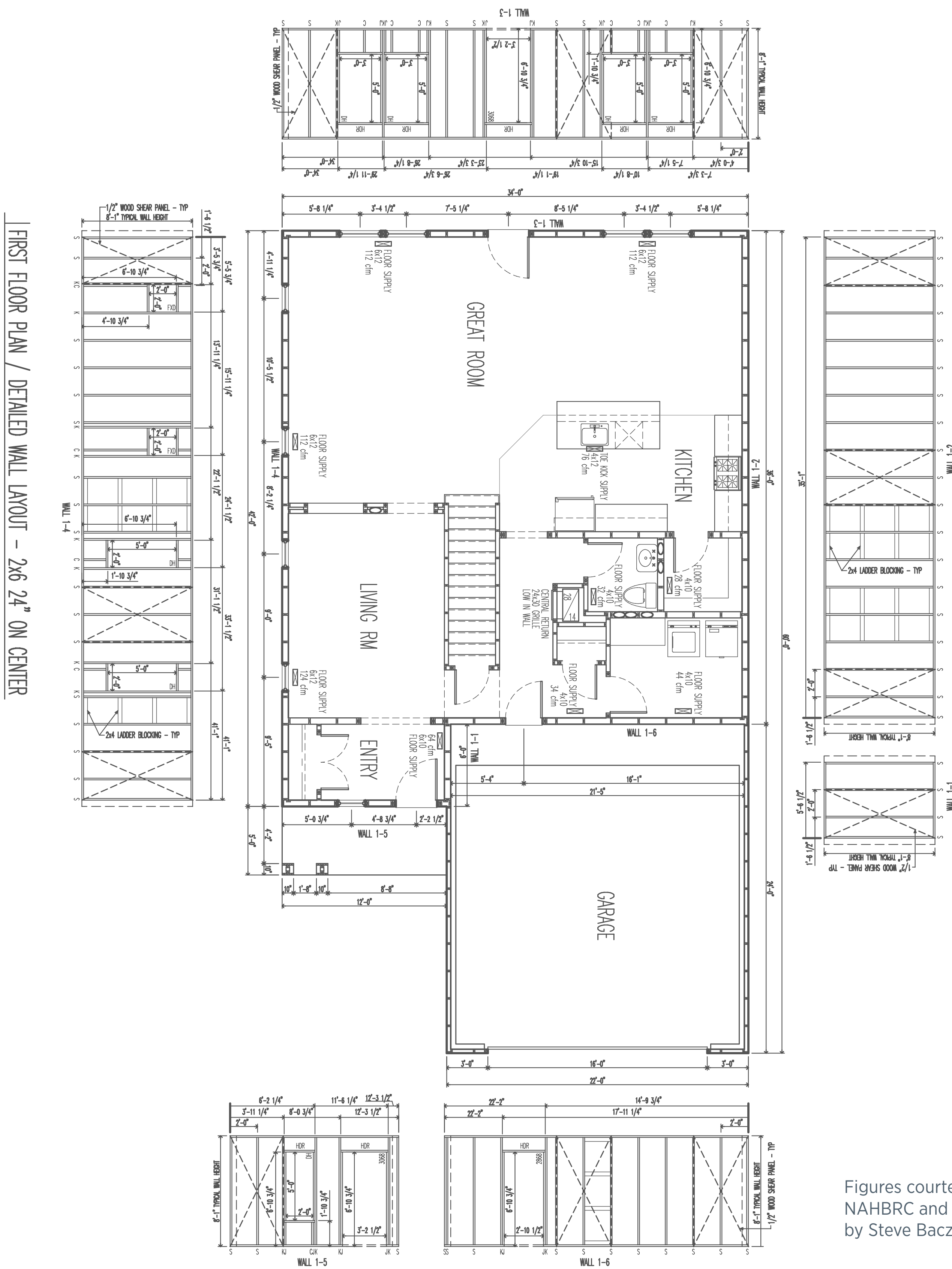
Ladder-block exterior wall intersections: Partitions can be nailed either directly to a single exterior wall stud or to flat blocks inserted between studs.

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.

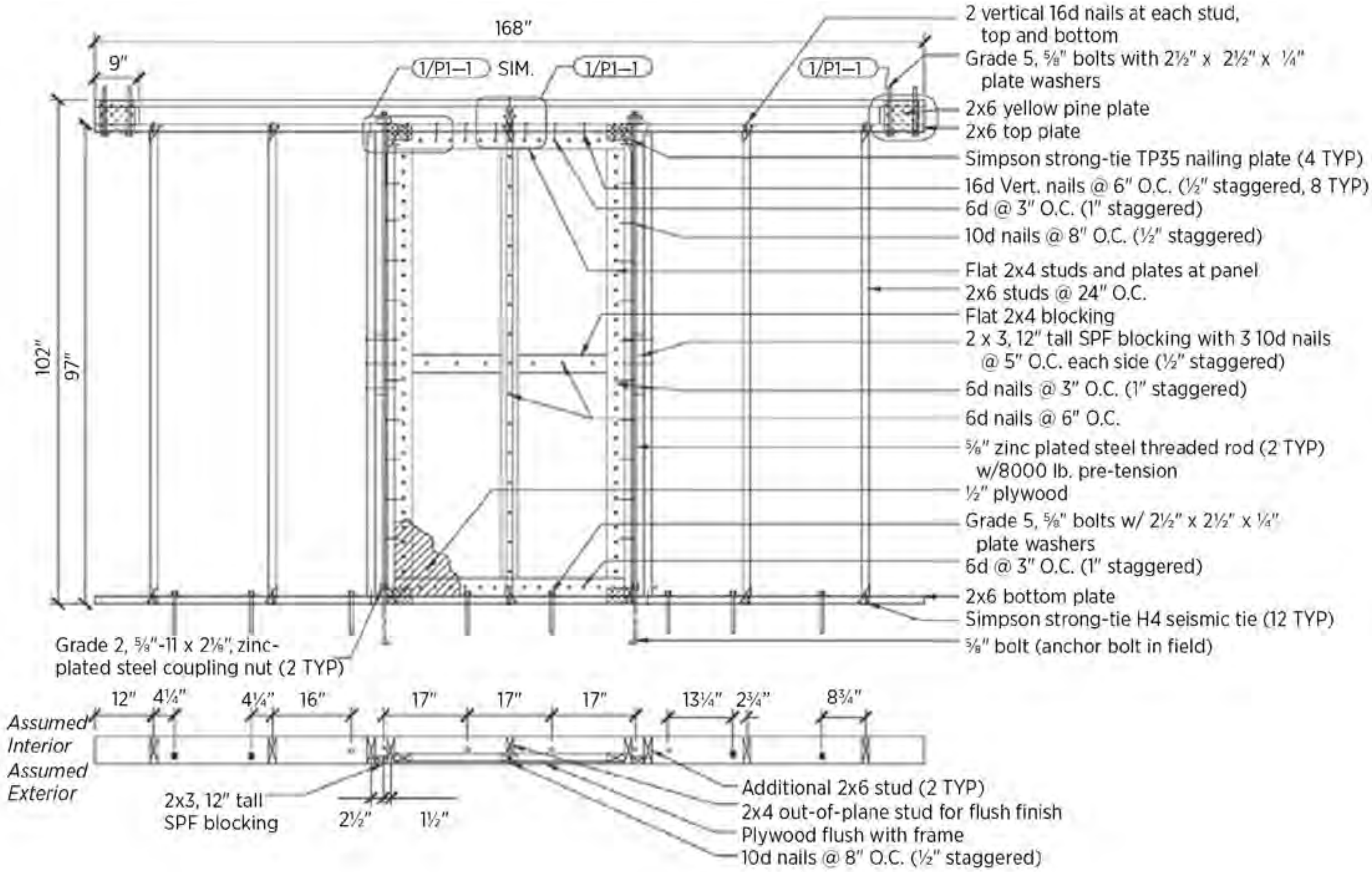
Detailed Wall Framing Layout

Use detailed layouts like this to make sure studs align from first floor to second floor to roof and design on a 24-inch grid.



Figures courtesy of the NAHBRC and prepared by Steve Baczek.

Wall Design for Seismic and Hurricane Regions



This advanced framing wall shear panel for seismic and hurricane regions was designed and tested by Building Science Corporation and the U.S. Army Construction Engineering Research Laboratory (CERL) with funding from 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. *(Figure Source: Building Science Corporation)*

Sources and Additional Information

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

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

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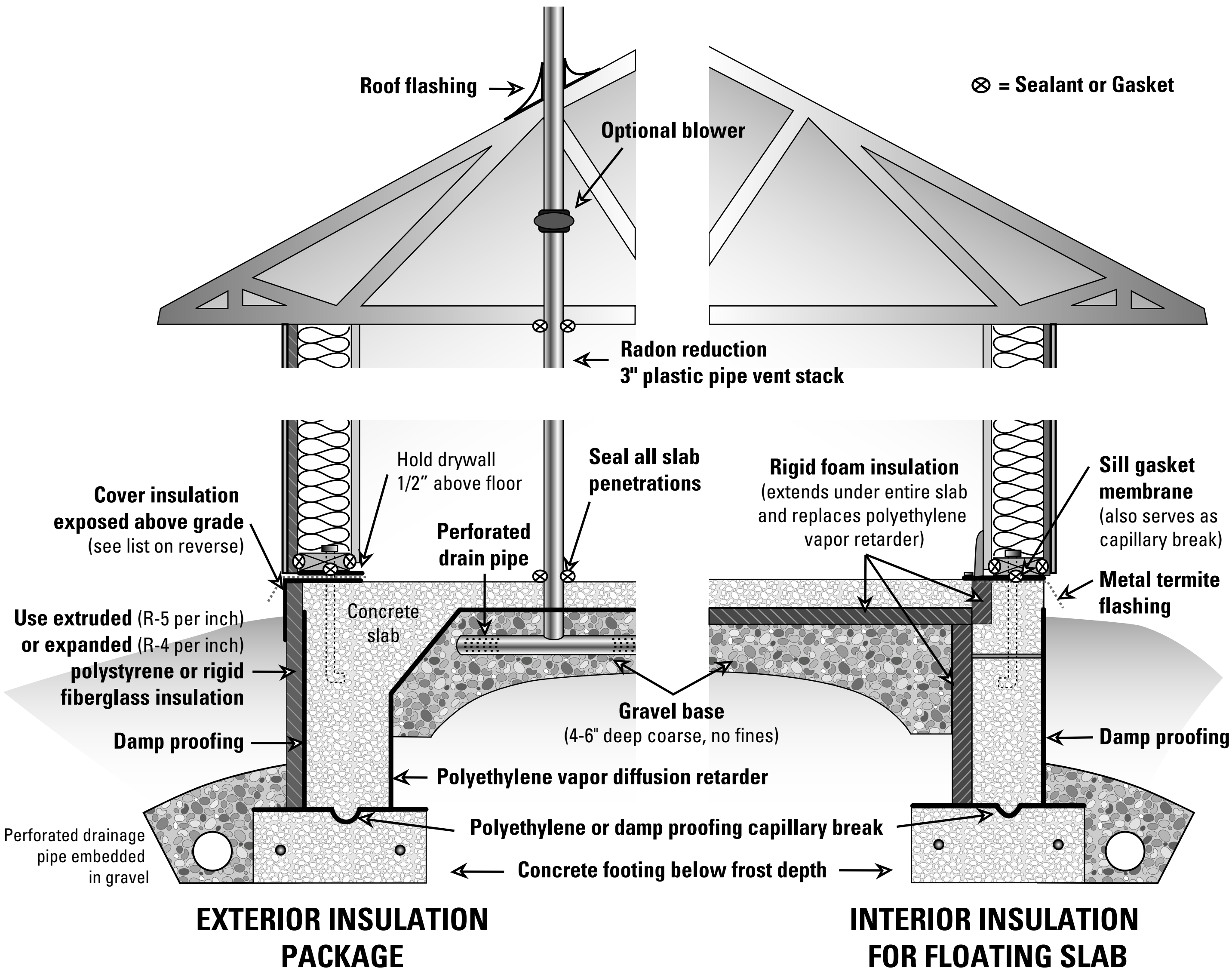
Foundation System Insulation, Moisture, and Air Leakage Control



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 = Ethylene Propylene Diene Monomer.*

Sources & Additional Information

U.S. DOE, *Technology Fact Sheet on Slab Insulation.*

U.S. EPA, *Building Radon Out: A Step-By-Step Guide oni How to Build Radon Resistent Homes.*

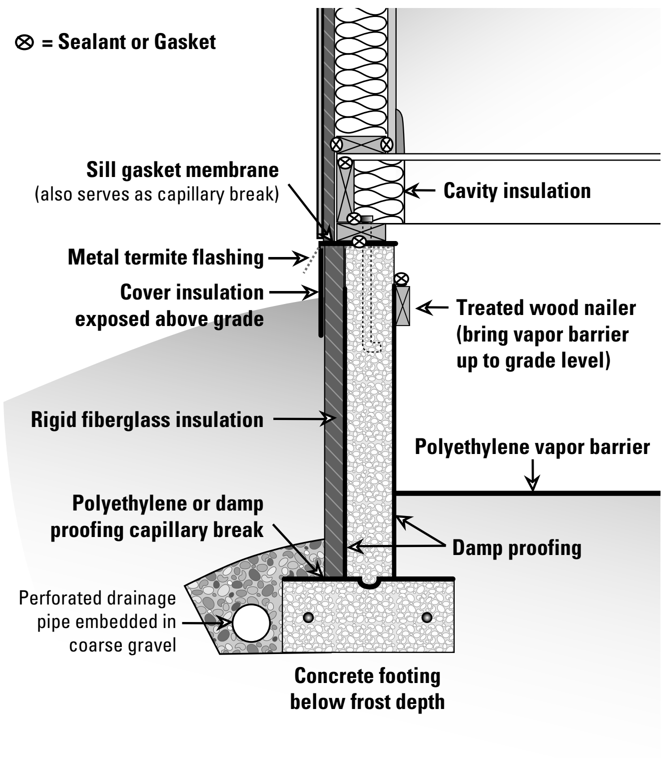
Southface Energy Institute. 2002. *Fact Sheets #29: Insulating Foundation and Door*s. www.southface.org/factsheets/29_insulatefloors4PDF.pdf

Southface Energy Institute. 2002. *Fact Sheets #30: Radon-Resistant Construction for Builders.* www.southface.org/default-interior/Documents/30_radonresistantconst.pdf

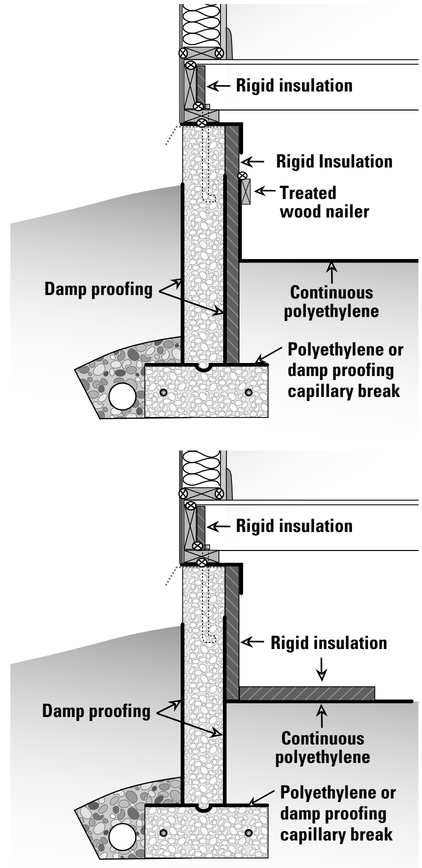
Building Science Consortium. *"Profiles: Hot-Humid Climate,"* www.buildingscience.com/documents/profiles

Basement & Conditioned Crawlspace Insulation, Moisture, and Air Leakage Control

EXTERIOR CRAWLSPACE INSULATION

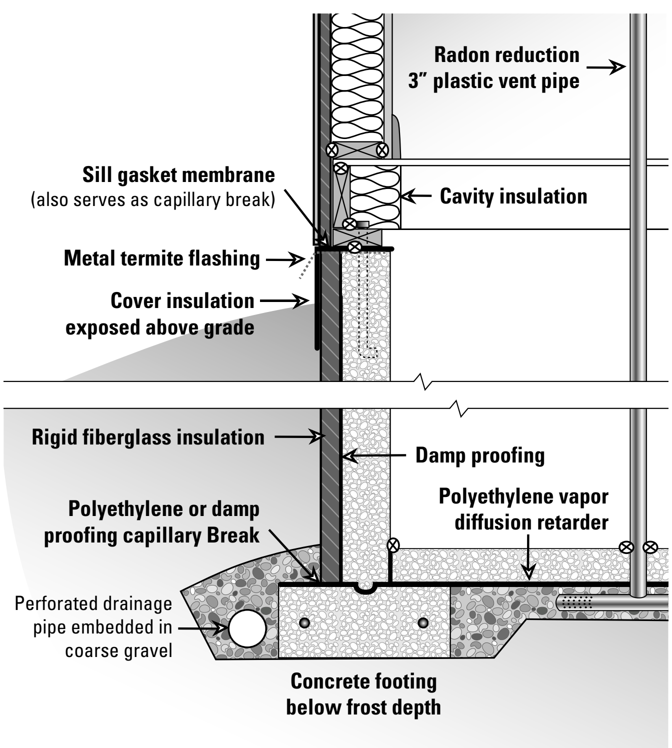


INTERIOR CRAWLSPACE INSULATION

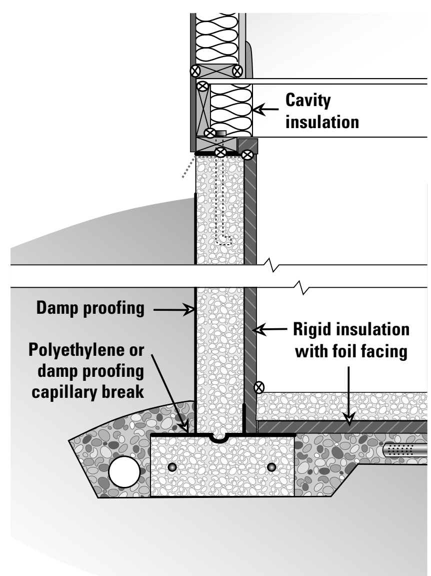


If depth does not extend two feet below grade, place remaining insulation horizontally along the ground.

EXTERIOR BASEMENT INSULATION



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 interior rigid foam insulation (extruded polystyrene is more moisture tolerant than expanded polystyrene) so that the foam is sandwiched between the nailing strip and the basement wall.
- When interior foam insulation is applied directly to foundation walls, seal joints in the foam panels with adhesive or mastic.
- 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. In a conditioned basement, the insulation should be covered with drywall that is tightly air sealed to keep interior moist air from condensing on the foundation wall.

Crawlspace and Basement 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.
- 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, a 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 from 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 = 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)

Building Profiles: Mixed-Humid Climate – Charlotte, North Carolina

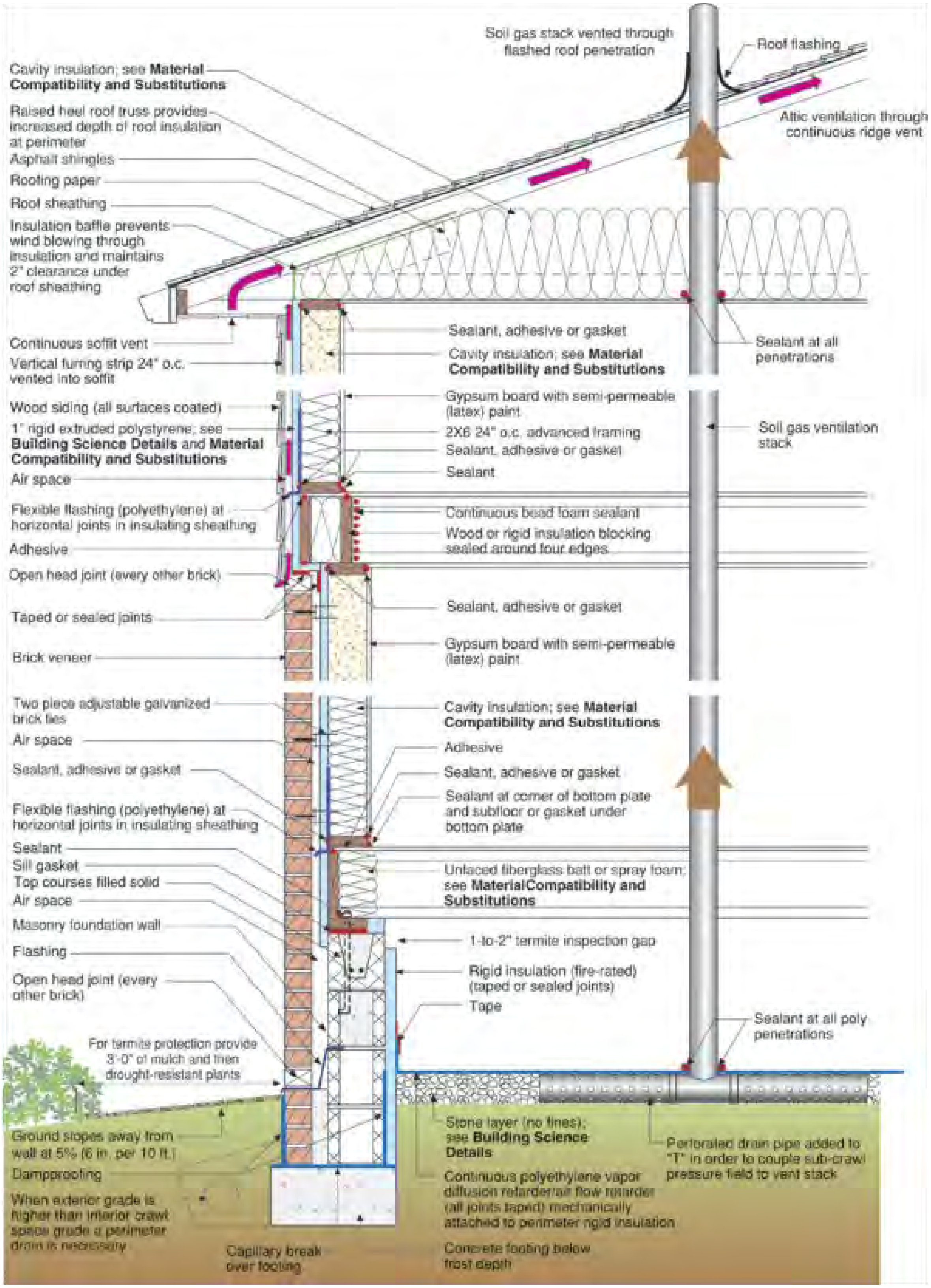


Figure Source: Building Science Corporation.
For technical details, see www.buildingscience.com/documents/profiles/etw-charlotte-profile

Building Profiles: Mixed-Humid Climate – Atlanta, Georgia

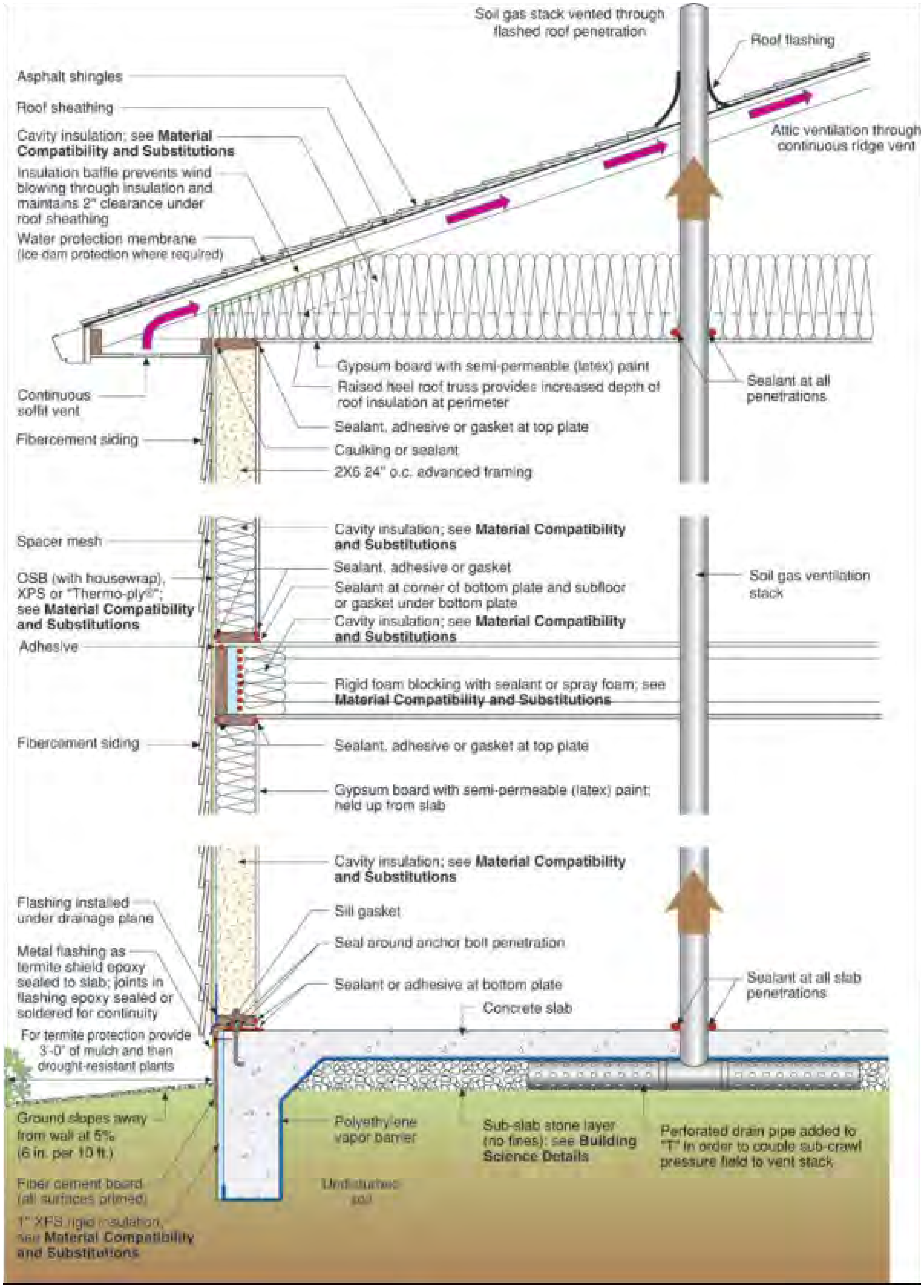


Figure Source: Building Science Corporation.
For technical details, see www.buildingscience.com/documents/profiles/etw-atlanta-profile

Building Profiles: Mixed-Humid Climate – Louisville, Kentucky

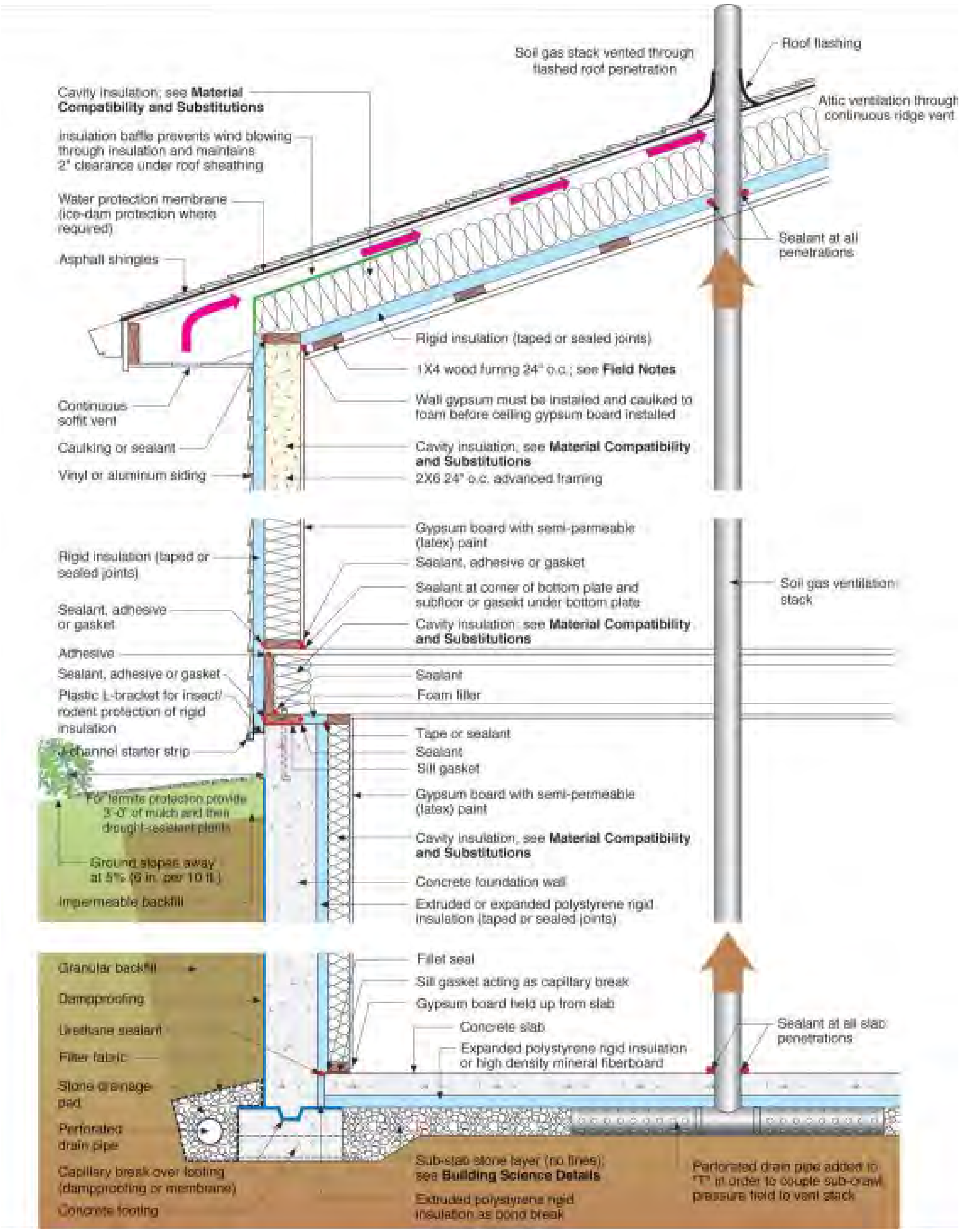


Figure Source: Building Science Corporation.
For technical details, see www.buildingscience.com/documents/profiles/etw-louisville-profile

Building Profiles: Mixed-Humid Climate – Montgomery County, MD

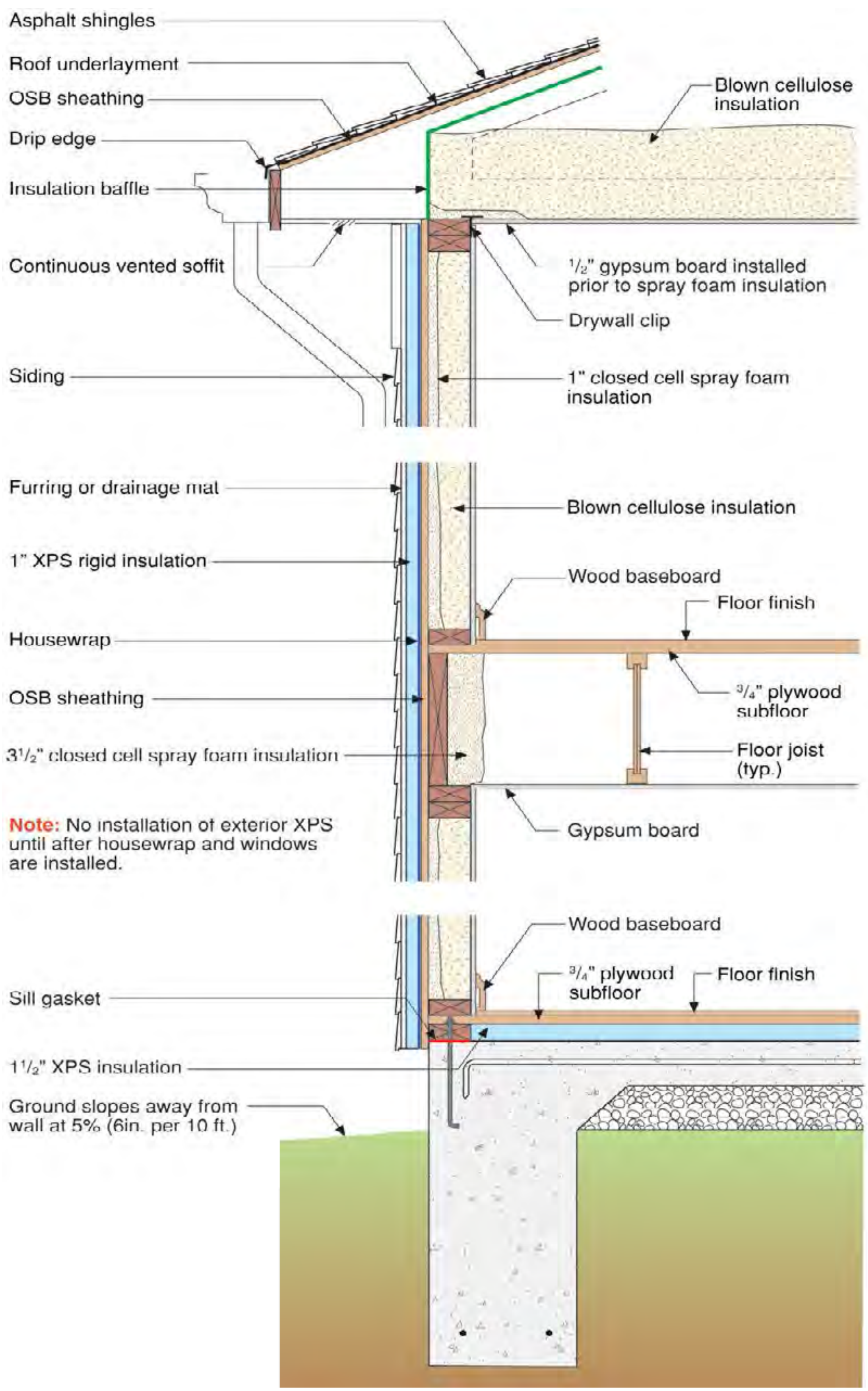
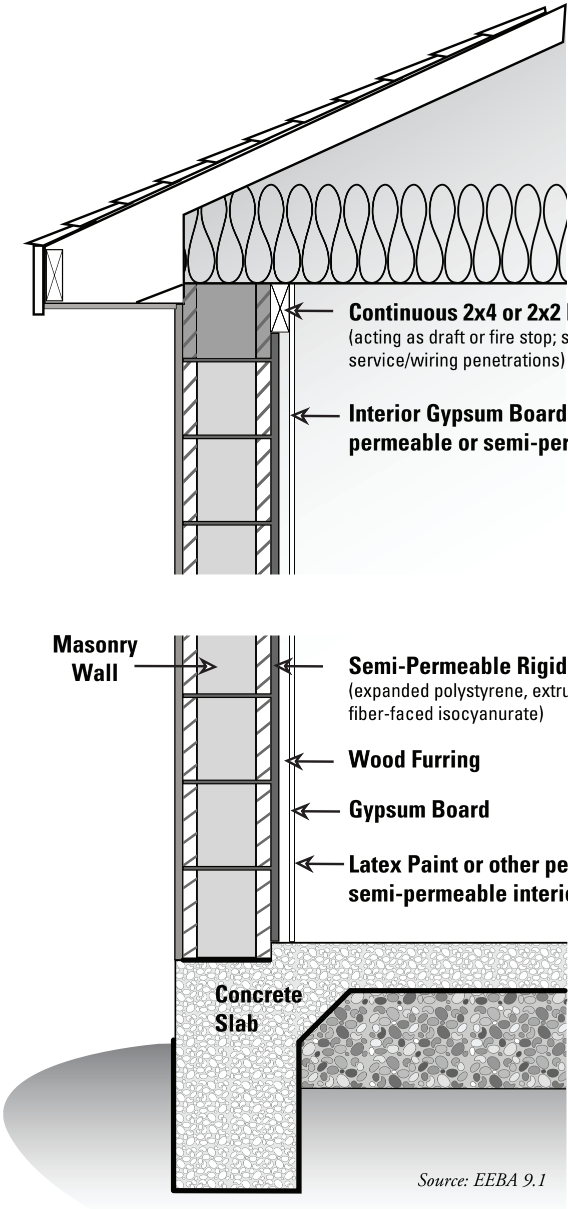


Figure Source: Building Science Corporation.
For technical details, see www.buildingscience.com/documents/profiles/etw-montgomery-profile

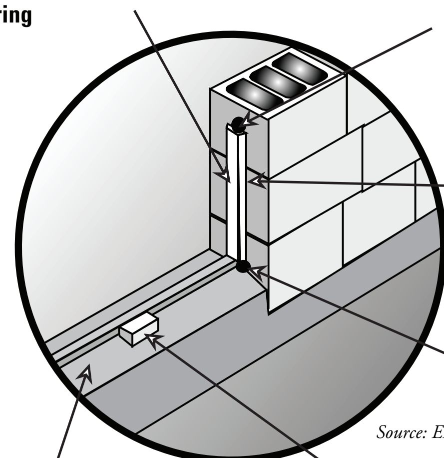
Masonry Construction

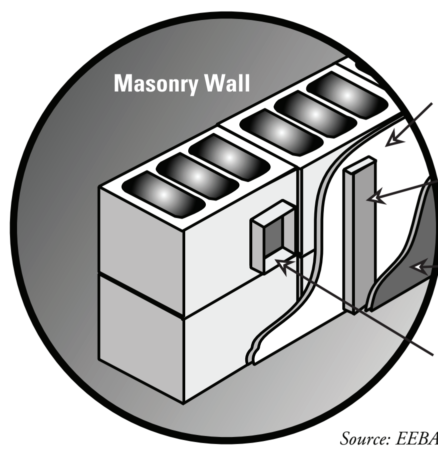
- Semi-vapor permeable rigid insulations used on the interior of wall assemblies should be unfaced or faced with permeable skins. Foil facings and polypropylene skins should be avoided.

- 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 or chipping masonry

ELECTRICAL BOX

Sources & Additional Information

Building Science Corporation. 2010. "Enclosures That Work: Building Profiles," Building Science Corporation, www.buildingscience.com/doctypes/enclosures-thatwork/etw-building-profiles

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

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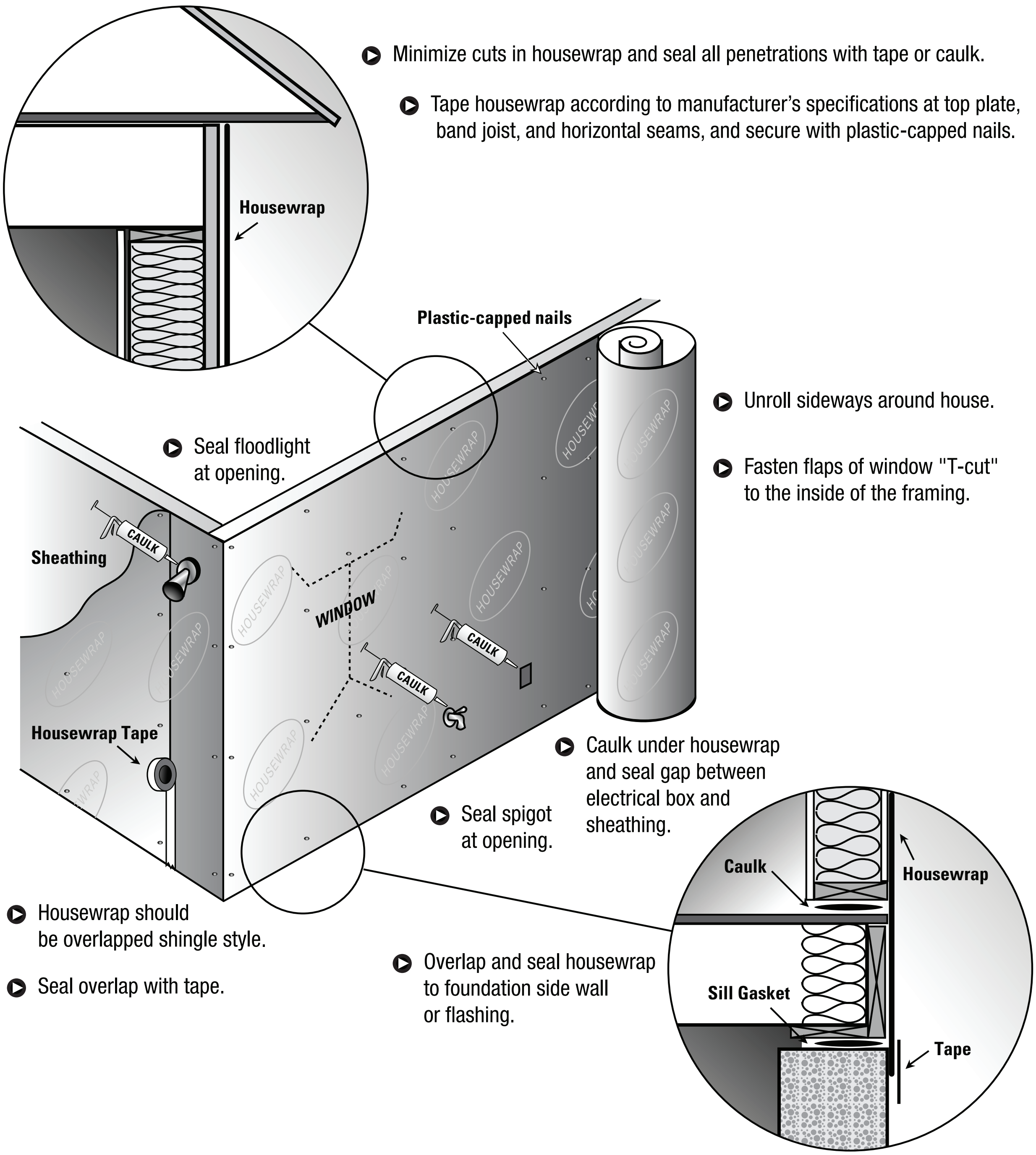
Housewrap

Example of housewrap strategies



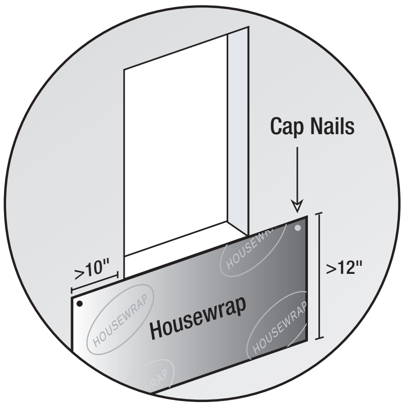
DO's and DON'Ts of Housewrap

- **Do** follow manufacturer's 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.
- 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).
- **Do** integrate wrap correctly with window flashing so that wrap goes over top edge of flashing.
- **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 to 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.
- **Don't** rely on caulk or self-sticking tape to "fix" improper lapping of housewrap. Caulk will fail over time.

Window Flashing

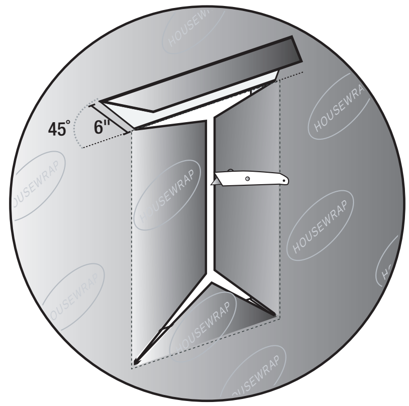
Window flashing details for home with housewrap and plywood or OSB wall sheathing

STEP 1 - IF HOUSEWRAP HAS NOT YET BEEN INSTALLED



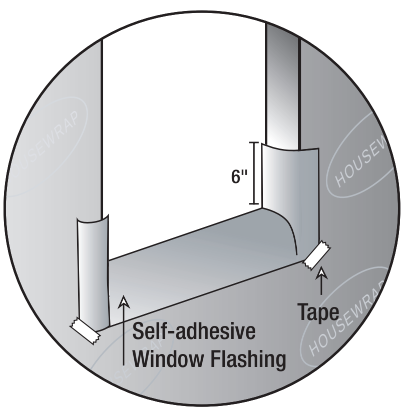
- Apply at least a 12-inch flap, or apron, of building paper or housewrap just below the window sill.
- If the window sill is close to the sill plate, the apron can extend all the way to the sill plate.
- The apron should extend at least 10 inches past the sides of the window opening, or to the first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

STEP 1 - IF HOUSEWRAP HAS BEEN INSTALLED



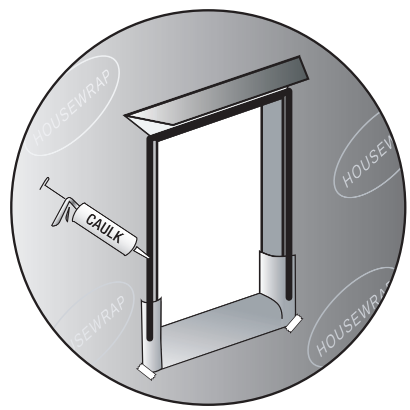
- Cut the housewrap covering the rough opening in the shape of a modified "Y."
- Fold the side and bottom flaps into the window opening and secure.
- Above the window opening, cut a head flap and flip it up to expose sheathing, and loosely tape in place out of the way.

STEP 2 - SILL FLASHING



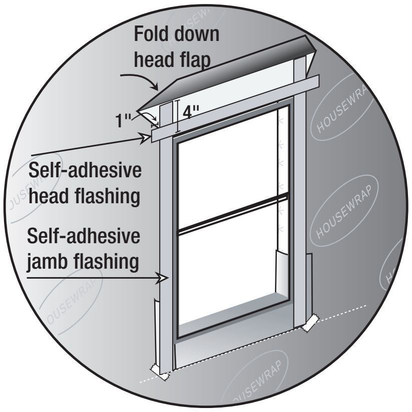
- Install self-adhesive flashing to the sill, ensuring that the flashing extends up jambs at least 6 inches.
- One commercial product comes with two removable strips over the adhesive. Remove the first strip to expose half of the adhesive and apply this area to the sill. Begin pressing in the middle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



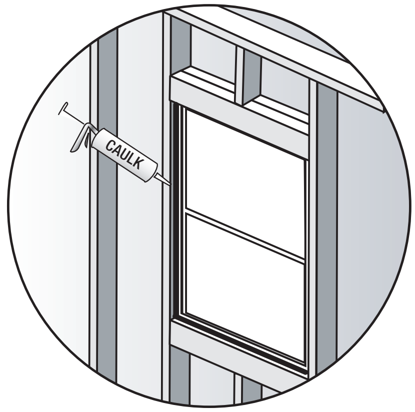
- Caulk the outside edges of the head and side jambs.
- Do not caulk across the sill.
- Install the window using corrosion-resistant nails and following manufacturer's specifications.

STEP 4 - JAMB AND HEAD FLASHING



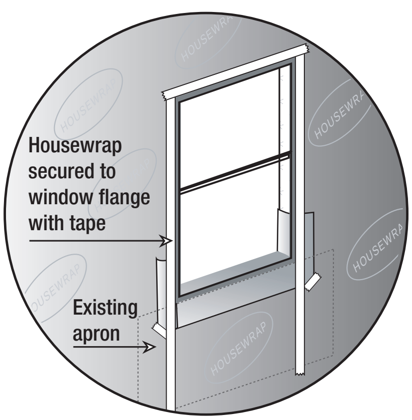
- Install self-adhesive jamb flashing extending 4 inches above the top of the head flange and even with the bottom of the sill flashing.
- Install self-adhesive head flashing extending 1 inch beyond the jamb flashing.
- If housewrap has been installed, be sure that the head flap, when it is folded down,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

STEP 5 - SEAL ROUGH OPENING GAP



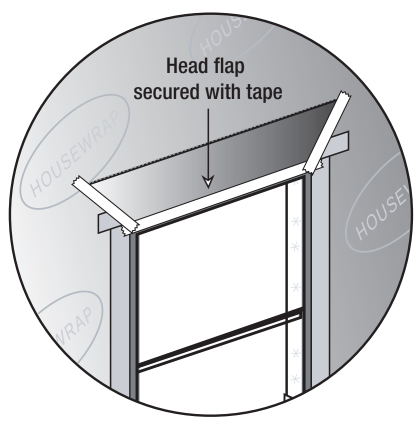
- On the interior side of the window, seal the gap between the window and the rough opening with a backer rod or non-expanding foam and caulk.

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

Wall-to-Roof Flashing

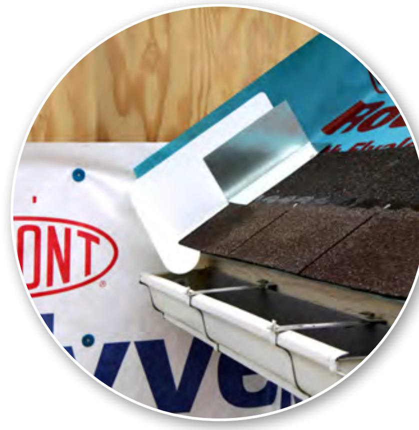
Kick-Out Diverter Flashing Details – Housewrap Installed Over OSB or Plywood as Water-Resistive Barrier

Water runoff from rain storms can run along roof-wall intersections and spill over gutters to flow down exterior walls. If flashing is lacking or inadequate, this water runoff can get inside the wall and cause serious damage. Anywhere roof sections adjoin wall sections, side-wall flashing should be used to keep water from entering the walls and kick-out diverters should be used to direct the rain water into rain gutters where it can be carried down and away from the structure. The kick-out flashing should be seamless and sized (as shown in the photos below) to effectively manage large volumes of water run-off associated with torrential rains from a variety of roof pitches, with an appropriate expected service life to avoid premature failures. *(Photos Source: DryFlekt Products, Inc.)*

STEP 1 Apply drip edge and roof underlayment over roof deck. Continue lapping up the sidewall and over the water-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 of 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.
- The 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 the 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, diverter, and housewrap.

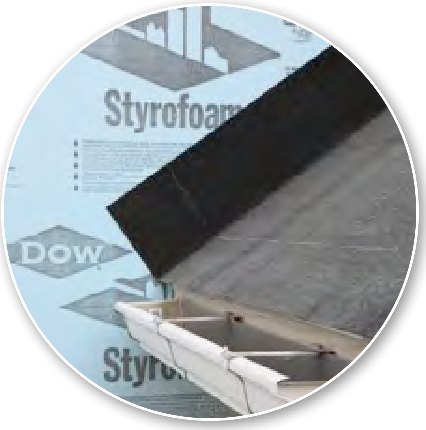
STEP 6 Install house wrap; cut the house wrap to fit over the self-adhesive flashing and sidewall flashing.

STEP 7 Apply siding over housewrap.

Wall-to-Roof Flashing

Kick-Out Diverter Flashing Details - Rigid Foam Insulation Installed as a Water-Resistive Barrier

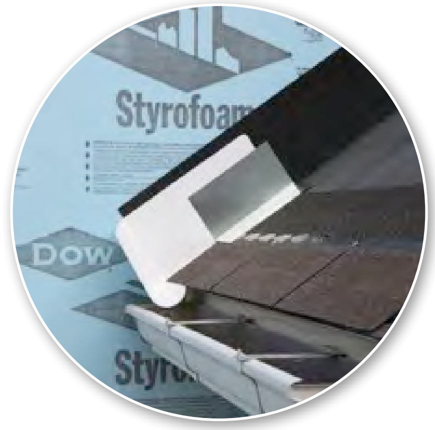
Water runoff from rain storms can run along roof-wall intersections and spill over gutters to flow down exterior walls. If flashing is lacking or inadequate, this water runoff can get inside the wall and cause serious damage. Anywhere roof sections adjoin wall sections, side-wall flashing should be used to keep water from entering the walls and kick-out diverters should be used to direct the rain water into rain gutters where it can be carried down and away from the structure. The kick-out flashing should be seamless and sized (as shown in the photos below) to effectively manage large volumes of water run-off associated with torrential rains from a variety of roof pitches, with an appropriate expected service life to avoid premature failures. *(Photos Source: DryFlekt Products, Inc.)*



STEP 1 Apply drip edge and roof underlayment over roof deck and continue lapping up the sidewall and over the water-resistive barrier (in this case rigid foam insulation) a minimum of 7 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.)

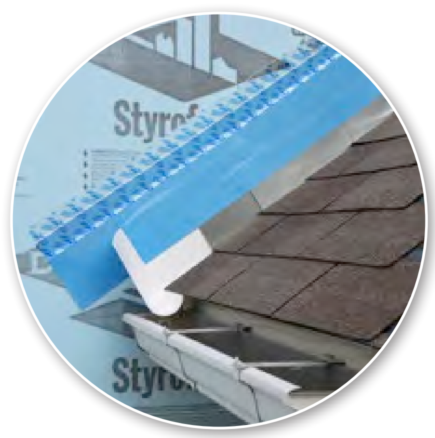


STEP 3 Place first shingle and next section of sidewall flashing over up-slope edge of diverter, lapping a minimum of 4" over diverter.

(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, diverter and rigid foam insulation.



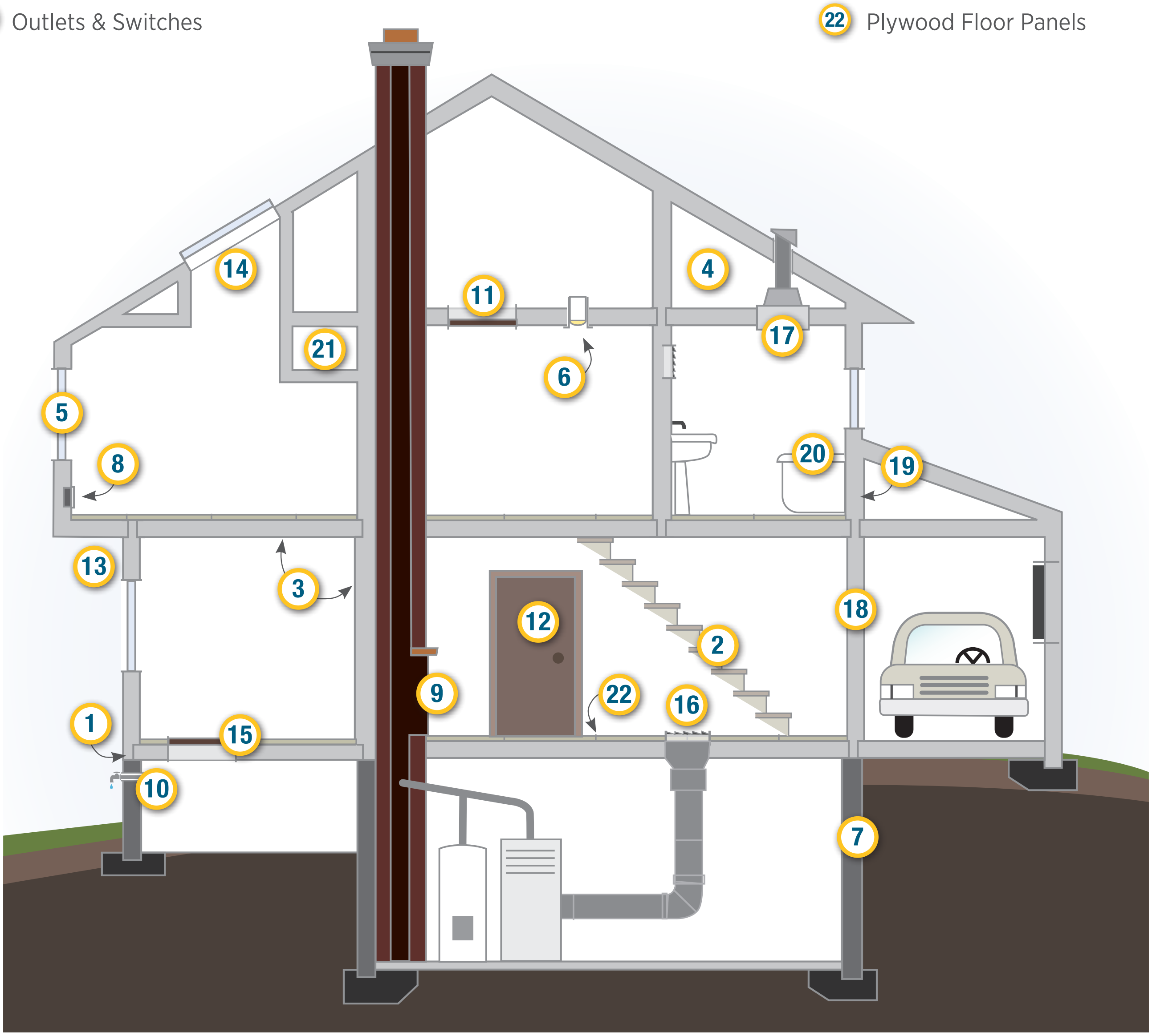
STEP 6 Apply construction tape over the self-adhered flashing.

STEP 7 Apply siding over rigid foam insulation.

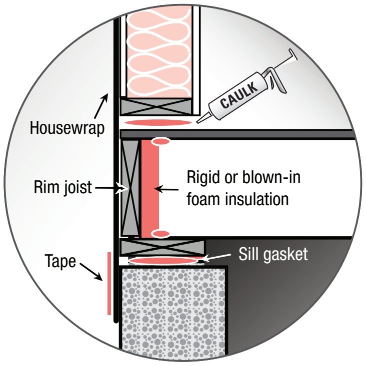
Interior Air Sealing

Conventional construction requires tracking down and sealing multiple air leaks that ultimately lead to or through the exterior shell.

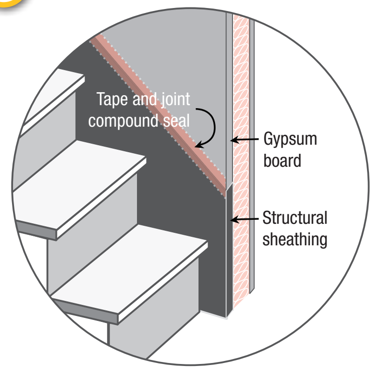
1. Sill Plate & Rim Joist
2. Stairs
3. Wall & Ceiling Drywall
4. Kneewalls
5. Windows
6. ICAT Can Light
7. Electric Circuit Box
8. Outlets & Switches
9. Fireplace
10. Plumbing Penetrations
11. Attic Access
12. Doors
13. Cantilever
14. Skylight
15. Crawlspace Access
16. Registers
17. Exhaust Fan
18. Garage Common Wall
19. Wall Adjoining Cavity
20. Tub
21. Interior Soffit
22. Plywood Floor Panels



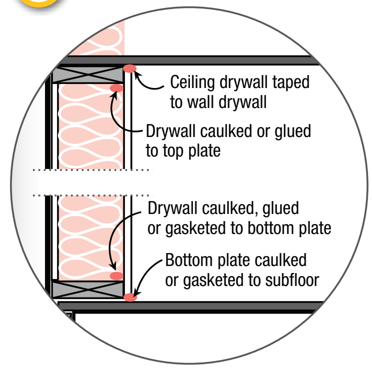
1 Sill Plate & Rim Joist



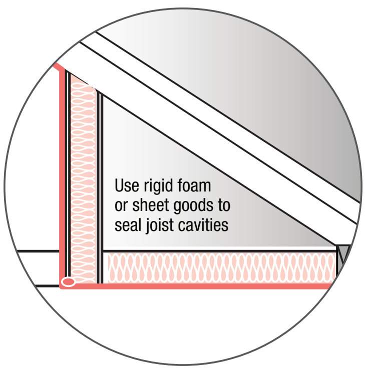
2 Stairs

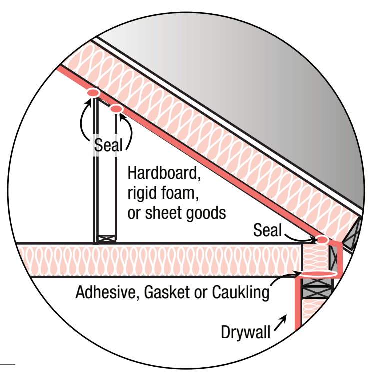


3 Wall & Ceiling Drywall

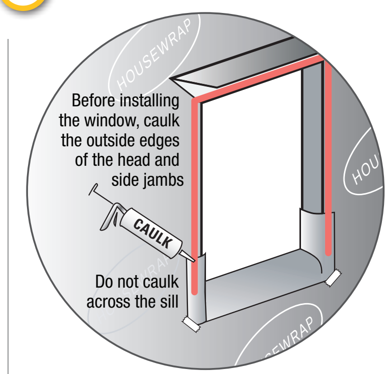


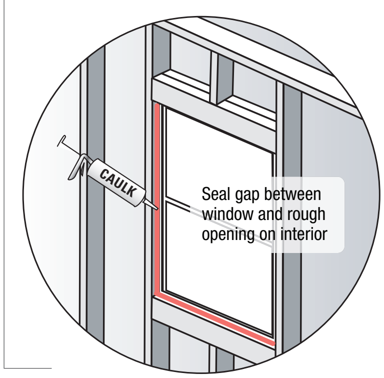
4 Kneewalls



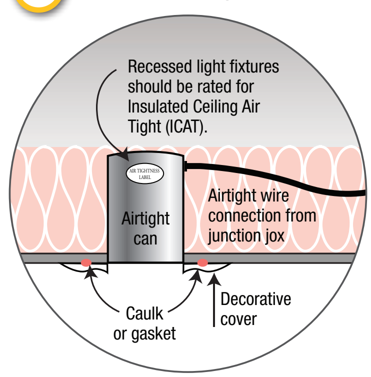


5 Windows

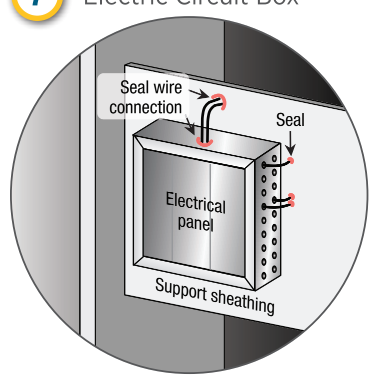




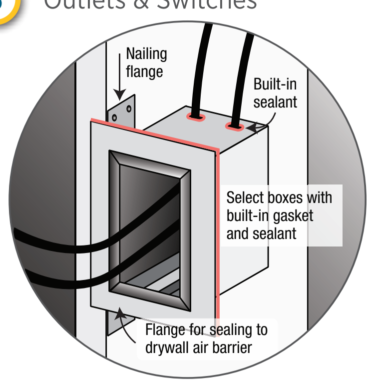
6 ICAT Can Light



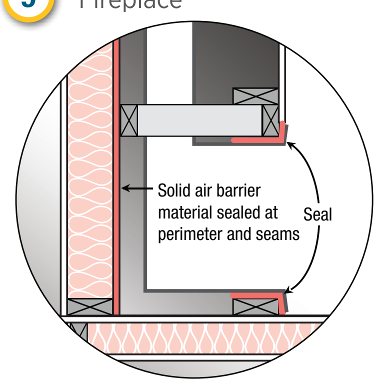
7 Electric Circuit Box



8 Outlets & Switches

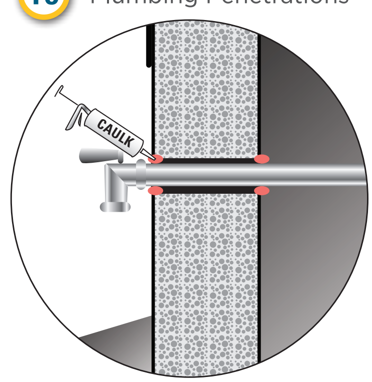


9 Fireplace

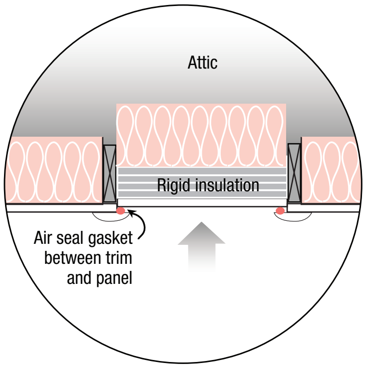


Direct vent fireplace through outside wall;
no chimney needed, but seal fireplace alcove.

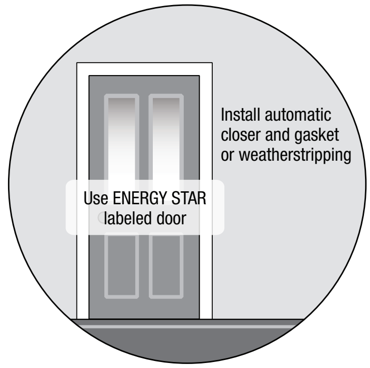
10 Plumbing Penetrations



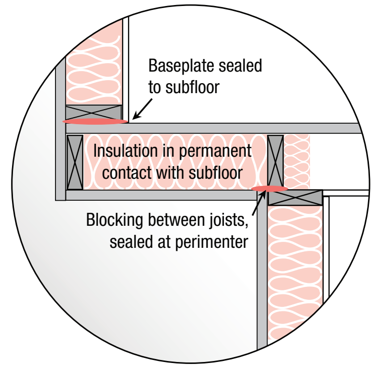
11 Attic Access



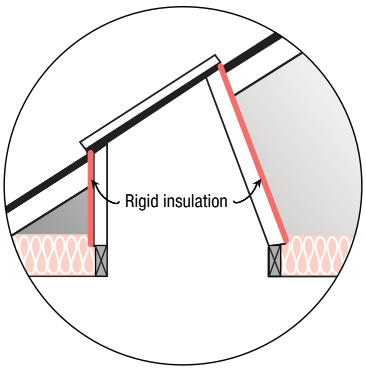
12 Doors



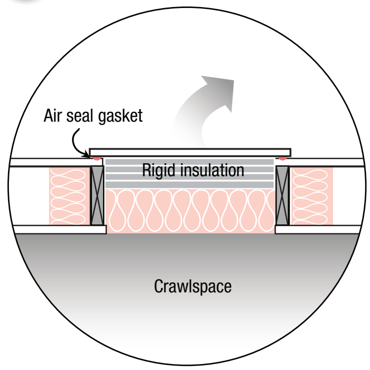
13 Cantilever



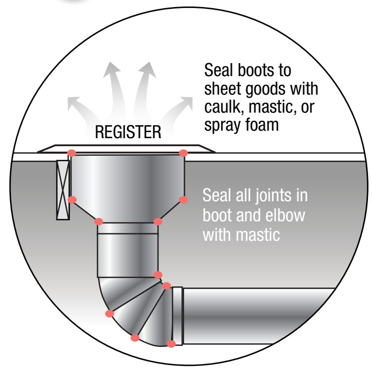
14 Skylight



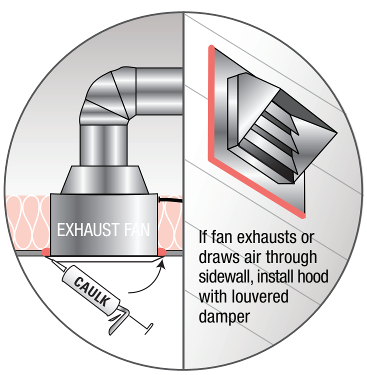
15 Crawlspace Access



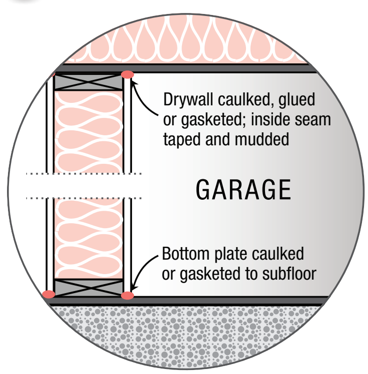
16 Registers



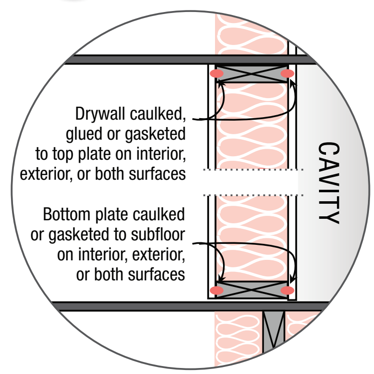
17 Exhaust Fan



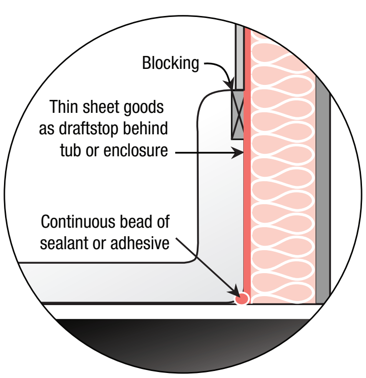
18 Garage Common Wall



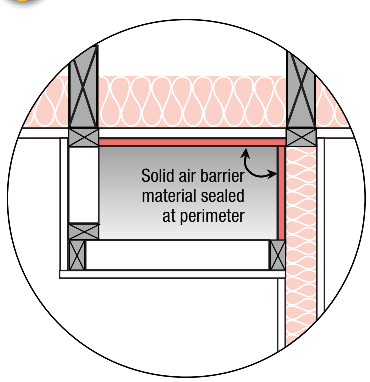
19 Wall Adjoining Cavity



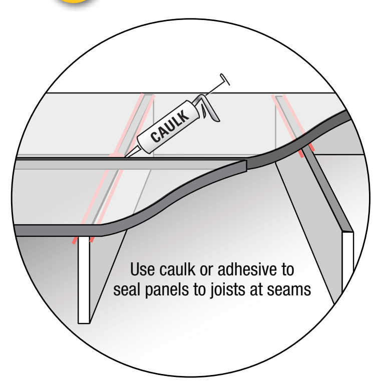
20 Tub



21 Interior Soffit



22 Plywood Floor Panels



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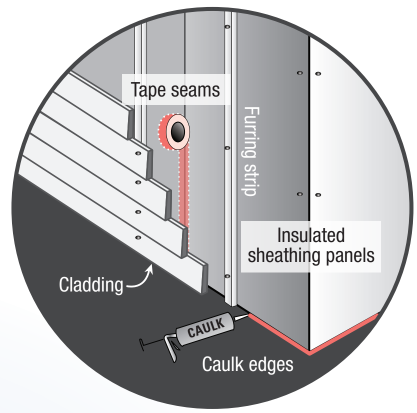
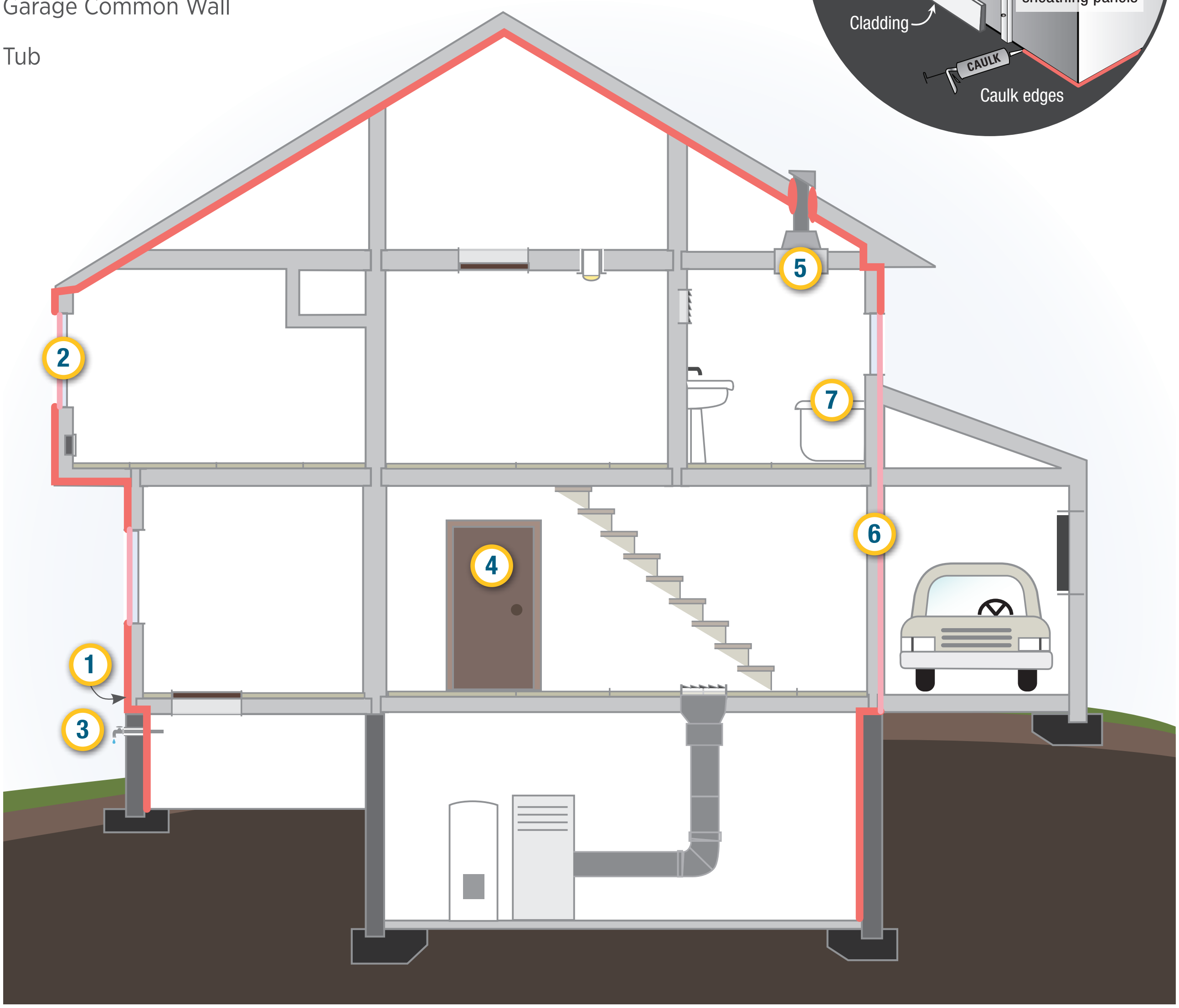
Exterior Air Sealing with Insulating Sheathing Panels

This figure shows an approach to construction used in some Building America homes. The red line represents the thermal boundary, which is provided here by rigid foam insulation that is on the external side of the walls and the interior side of the foundation walls and roof. This exterior insulating sheathing provides both an air and thermal barrier for the walls. The non-vented attic is sealed and insulated along the roofline. Particular attention is paid to the intersection of the foundations, walls, and roof.

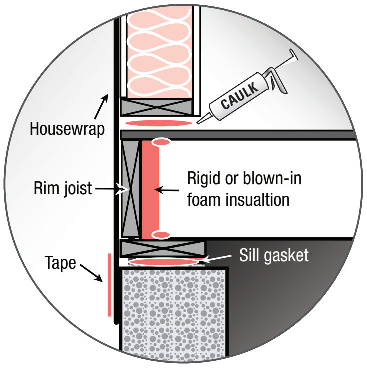
1. Sillplate & Rim Joist
2. Windows
3. Plumbing Penetrations
4. Doors
5. Exhaust Fan
6. Garage Common Wall
7. Tub

Insulating Sheathing Detail

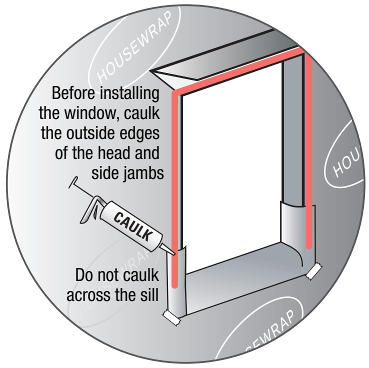


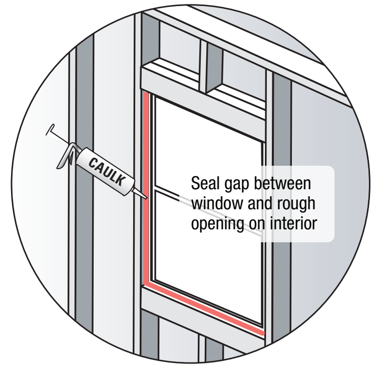


1 Sill Plate & Rim Joist

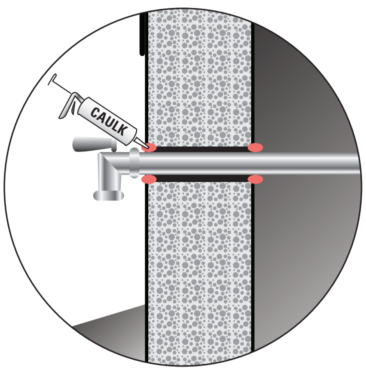


2 Windows

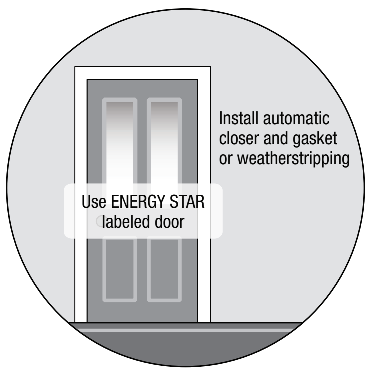




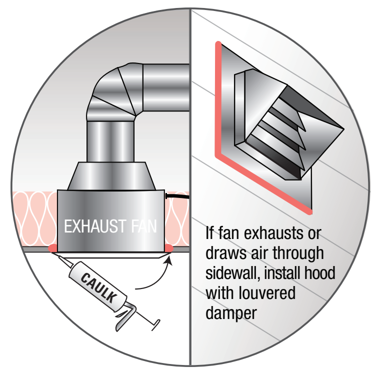
3 Plumbing Penetrations



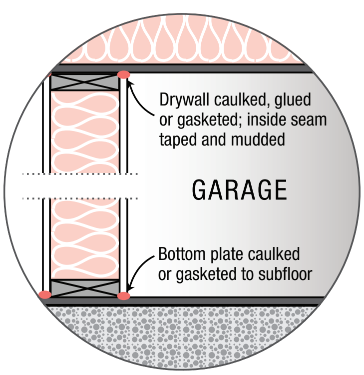
4 Doors



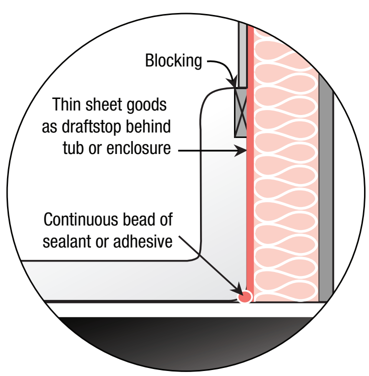
5 Exhaust Fan



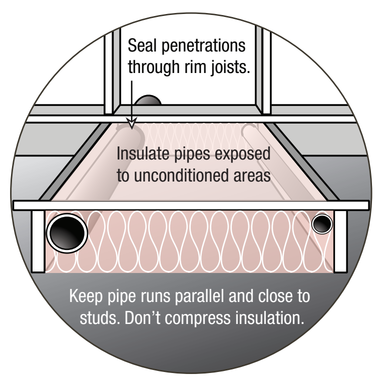
6 Garage Common Wall



7 Tub

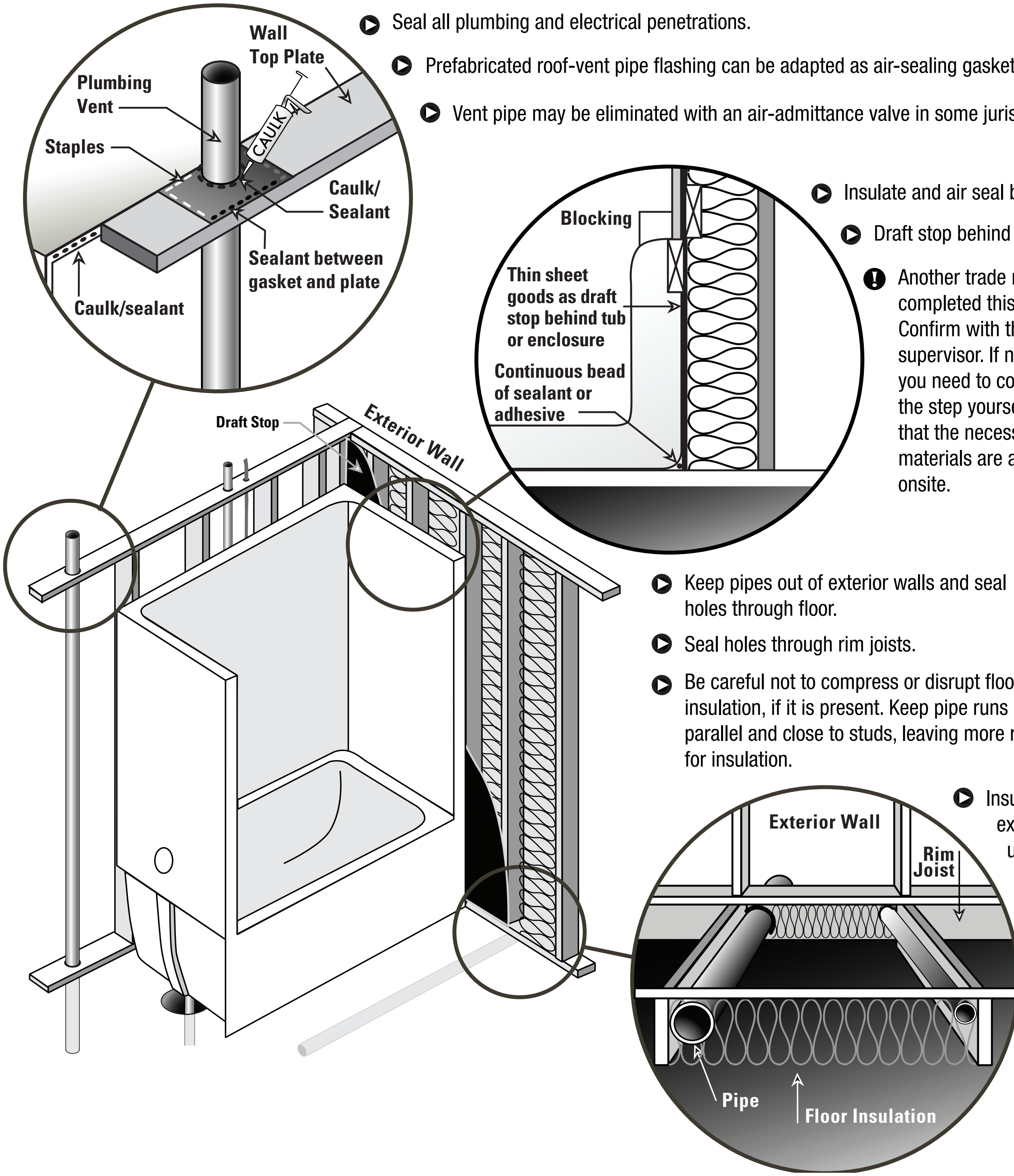


Plumbing Floor Penetrations



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 air seal 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 onsite.

- Keep pipes out of exterior walls and seal holes through floor.
- Seal holes through rim joists.
- Be careful not to compress or disrupt floor insulation, if it is present. Keep pipe runs parallel and close to studs, leaving more room for insulation.

- Insulate pipes exposed to unconditioned areas

Sources & Additional Information

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

U.S. DOE. *Technology Fact Sheet on Air Sealing*.

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

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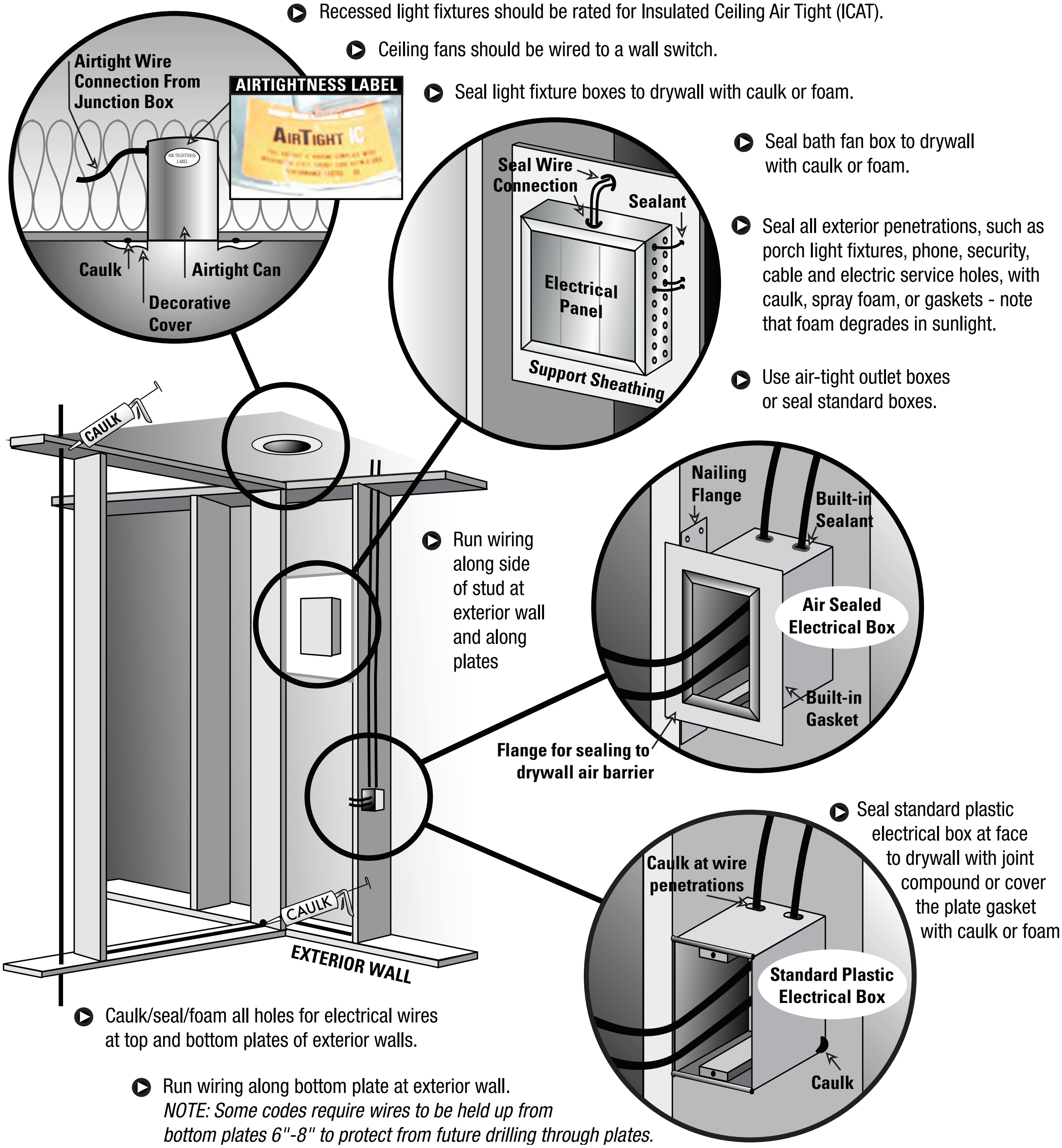
Electrical Air Sealing



- 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 caulk or foam.
- Caulk/seal/foam all holes for electrical wires at 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).

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Installing Fiberglass Batt Insulation

Always:

- [ ] Avoid gaps, tight turns, and compressions.
- [ ] 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 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 and fireplaces.

Walls:

- [ ] Friction-fit the batts in place until covered by drywall or sheathing.
- [ ] Insulate before installing stairs, tubs, and other features that will block access.

Knee Walls:

- [ ] Seal knee wall to create a continuous air barrier. Close air gaps between floor joists under attic rooms. 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 between attic rafters in vented attics.

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:

- [ ] An insulated, unvented crawlspace is preferred rather than insulating under the floor. If under-floor 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 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.

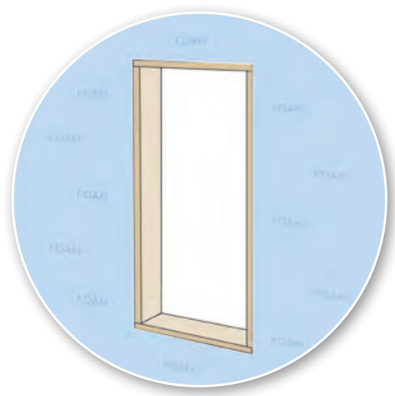
The following apply to any window installation:

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 + width of foam (the plywood should be flush on the interior surface and extend to the anticipated outside face of the foam).



STEP 3 Install the exterior foam. The outer face of the foam should be flush with the outer edge of the plywood frame.

Continued on following page

Interior Ledge Window Installations - *Continued*

STEP 4 Install housewrap. Cut modified “I” over window.

STEP 5 Fold in housewrap at jambs and sill. Fold back temporarily at jamb. Install backdam on sill.

STEP 6 Install adhesive-backed sill flashing and corner flashing patches at sill. Apply sealant at jambs, head, and sill.

STEP 7 Install window; plumb, level, and square as per manufacturer’s instructions.

STEP 8 Install jamb flashing first; install a drip cap (if applicable); install head flashing.

STEP 9 Fold down head housewrap; apply corner patches at head; air seal window around the entire perimeter on the interior with sealant or non-expanding foam.

STEP 10 Install vertical wood strapping on top of the foam and housewrap to use when attaching siding.

Sources & Additional Information

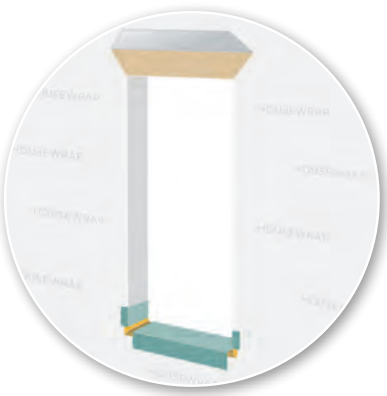
Building Science Corporation. 2007. *Guide to Insulating Sheathing*, Building Science Corporation, www.buildingscience.com/documents/guides-and-manuals/gm-guide-insulating-sheathing

Exterior Ledge Window Installations:

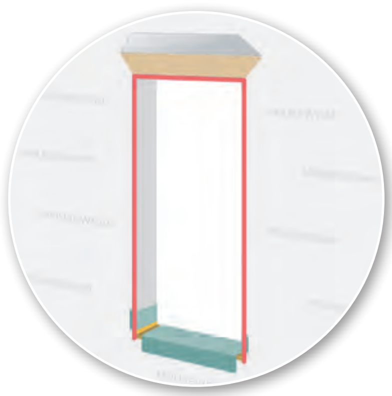
STEP 1 Install OSB and housewrap on wood frame wall.

STEP 2 Cut modified "I" in housewrap

STEP 3 Fold housewrap in at jambs and sill. Temporarily fold up housewrap at head. Install backdam.



STEP 4 Install adhesive-backed sill flashing and corner flashing patches at sill.

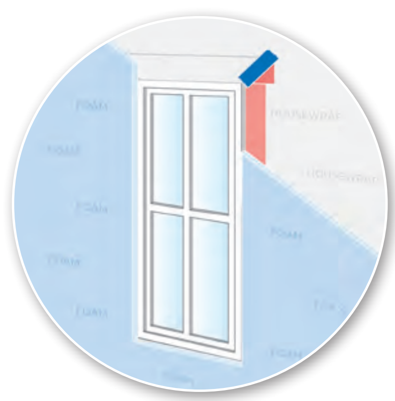


STEP 5 Apply sealant at jambs, head, and sill.

STEP 6 Install window; plumb, level, and square as per manufacturer's instructions.

STEP 7 Install jamb flashing first; install a drip cap (if applicable); install head flashing.

STEP 8 Fold down head housewrap.



STEP 9 Apply corner patches at head; air seal window around entire perimeter on the interior with sealant or non-expanding foam; install foam sheathing over housewrap.

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Duct Location – Dropped Ceiling Soffit

Ducts can be placed in a dropped ceiling soffit to keep them in conditioned space.

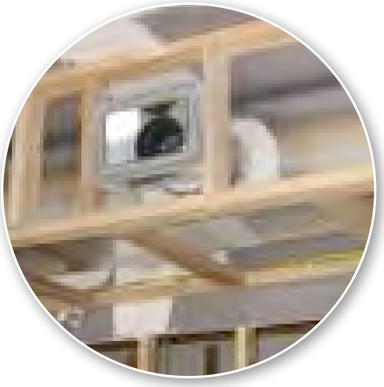
STEP 1 Use Manual J to determine appropriate HVAC size.

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 installer, framer, sheetrocker, other pertinent trades to discuss approach, if this is a new method.

STEP 4 Install sheetrock above chase. One method is to keep top plate of non-load bearing interior walls ¾ inch from bottom cord of roof trusses. Slip drywall in this space.

STEP 5 Fabricate and seal ducts 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

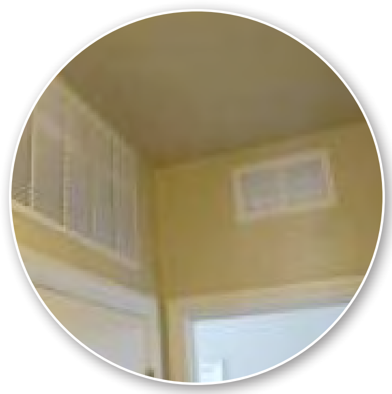
Hard ductwork is used wherever possible.

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 Between Floors

Ducts can be placed in open web trusses between floors to keep them in conditioned space. Rim joists must be thoroughly air sealed.

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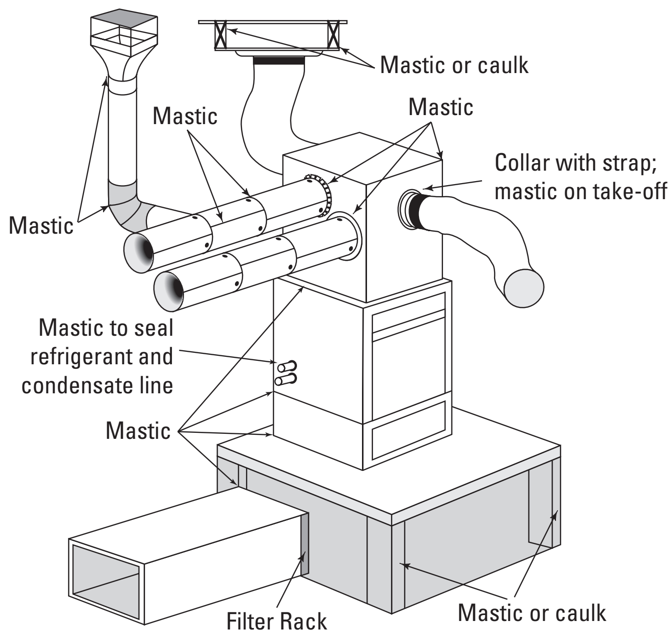
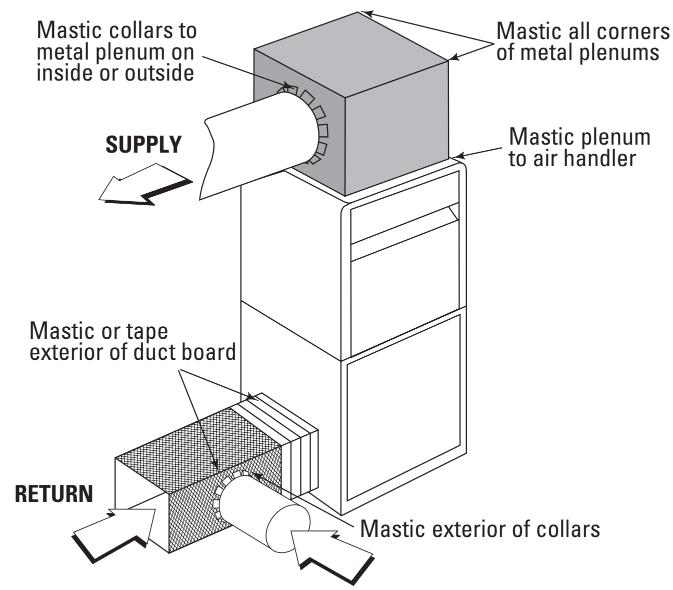
Air Handler and Duct Sealing

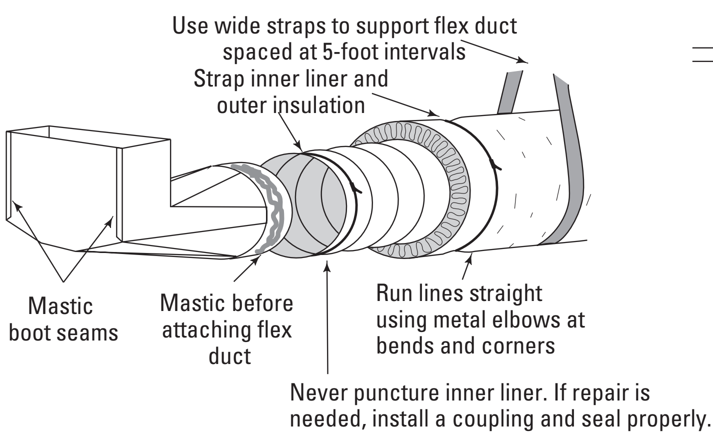
AIR HANDLER



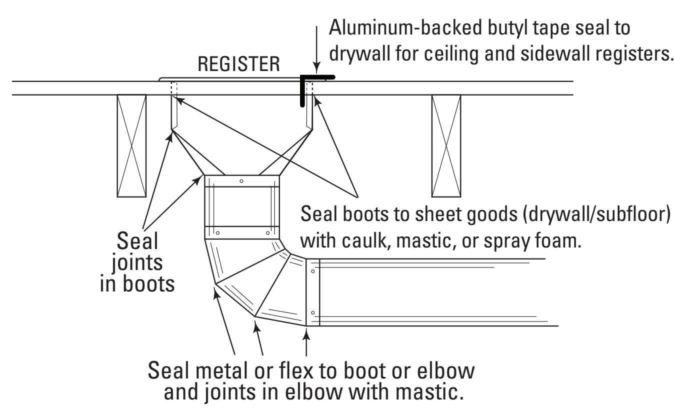
SUPPLY AND RETURN PLENUMS



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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Ductless Heat Pump Installers Guide

(Source: Northwest Energy Efficency Alliance Ductless Heat Pump Project, www.nwductless.com)

Best Practices for Ductless Heat Pump Installations *A Contractor's Guide*

A quality ductless heat pump installation results from attention to details including: tools, installation and homeowner education. This guide provides information and suggestions to help you achieve successful ductless heat pump installations. Quality installations result in minimal call backs, more customer referrals, and increased awareness of ductless heat pump technology.

Required Tools

R410A Specific Flaring Tools

Programmable Refrigerant Charging Scale

Torque Wrench

R410A Gauge and Hose Set

Installation Best Practices

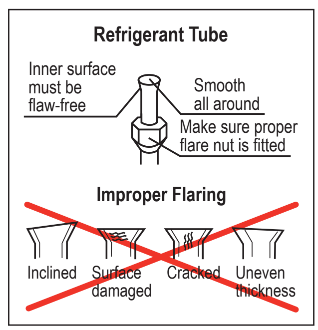
- Follow manufacturers' installation instructions. This guide is not intended to replace manufacturers' specifications.

Outdoor Unit (Compressor):

- Set the unit on a stable, level surface.
- Risers are essential to prevent snow and debris build-up and should be installed to allow better drainage of defrost water.
- Outdoor units should be secured to the pad, risers, and/or surface on which they are set using bolts and/or adhesive.

Refrigerant Tubing:

- Factory tubing flares and fittings are NOT TO BE REUSED.
- Create new flares using appropriate R410A flaring tool & measurement gauge.
- Apply refrigerant oil to the end of each flare.
- Connect tubing with R410A nuts (supplied with indoor and outdoor units) using a torque wrench tightened to manufacturer's specifications.



Refrigerant Charge:

- Adjust refrigerant charge ONLY IF NECESSARY. Most installations do not require adjustment from pre-charge levels.
- Gauges are not needed to verify refrigerant levels. (A scale should be used when adding or removing refrigerant.)
- Consult the manufacturer's installation manual to verify refrigerant protocols, specifications can often change.

Line Set Insulation and Protection

- Insulation must cover entire line set length to avoid condensation and decreased efficiency.
- Once insulated, protect the outdoor portion of line set with rigid line hide to avoid premature degradation damage to the insulation.
- All penetrations through the shell of the home must be sealed with an insulative sealant.

Condensate Drain:

- Must slope downhill and can be routed with line set or run to a different termination point.

Ductless Heat Pump Installers Guide, *Continued*

(Source: Northwest Energy Efficency Alliance Ductless Heat Pump Project, www.nwductless.com)

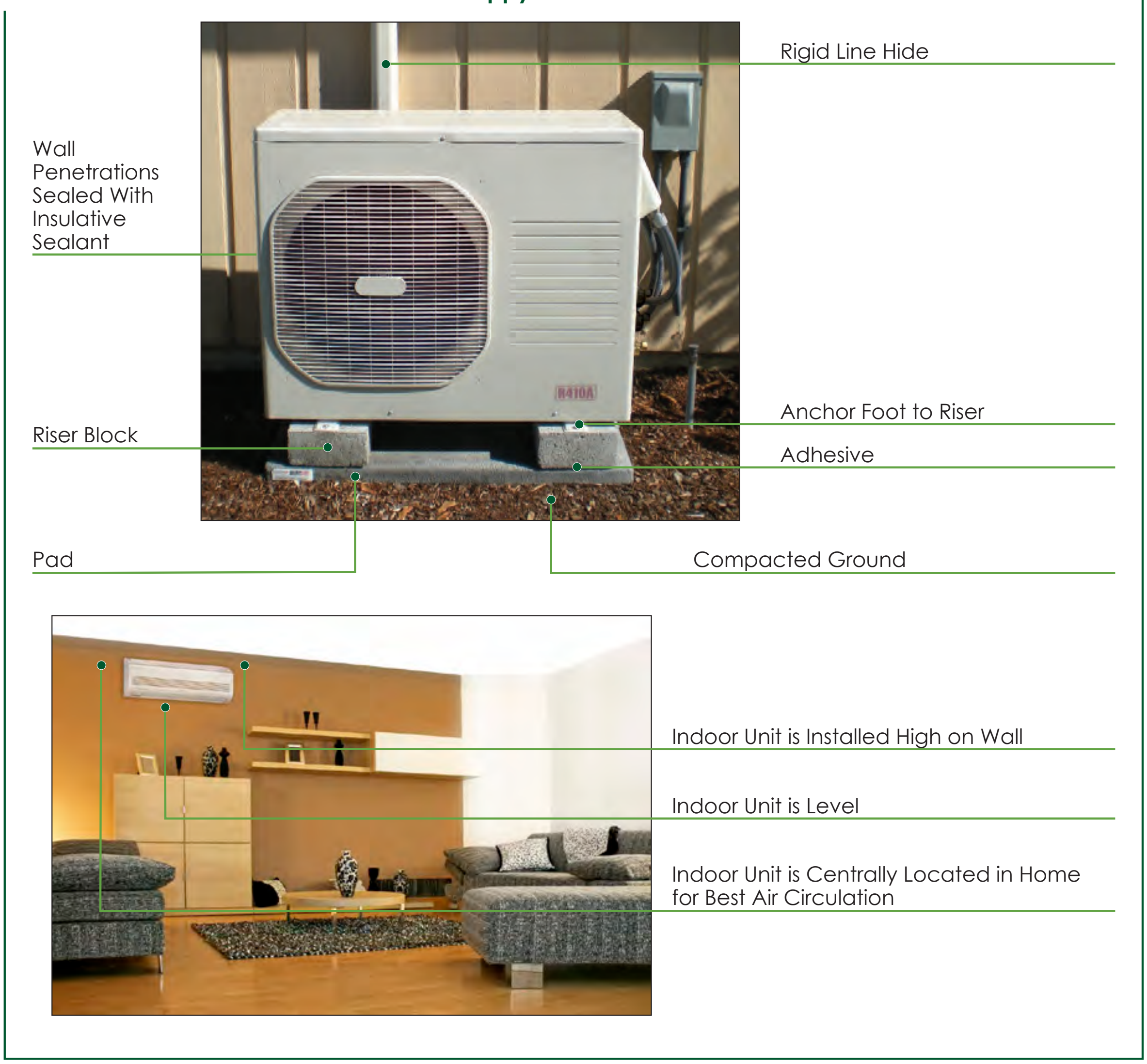
Homeowner Education

- Ensure homeowner has a copy of the Manufacturers Operation Manual that is provided with the indoor unit. Refer to this manual as you perform a walkthrough of unit operation.
- Provide homeowner with a copy of the "Homeowner's Guide" and remind homeowners of www.GoingDuctless.com for more information about ductless heating and cooling systems.
- Educated homeowners reduce call backs and promote your services!

Contractor Resources

- For information on becoming a Project-oriented contractor, visit www.NWDuctless.com or call (503) 808-9003. Project-oriented contractors are eligible to perform installations that receive utility rebates of up to $1,500!

Well Installed Outdoor and Indoor Unit = Happy Homeowner



Disclaimer: This document is only to be used as a general guide for providing quality installations. For complete information regarding installation requirements, features, benefits, operation, and maintenance, review the manufacturer's installation manual of the product being installed. Images of specific manufacturer product lines are not placed as endorsements, nor does this guide guarantee their quality.

An initiative of the Northwest Energy Efficiency Alliance, an alliance of NW Utilities and energy efficiency partners.

Roof Fascia/Soffit Vent Detail

The soffit detail for vented attics discourages water draining off the roof from coming into the soffit vent openings. The detail was designed by Building America's Consortium for Advanced Residential Buildings (CARB) team (led by Steven Winter Associates) for Mercedes Homes of Melbourne, Florida,

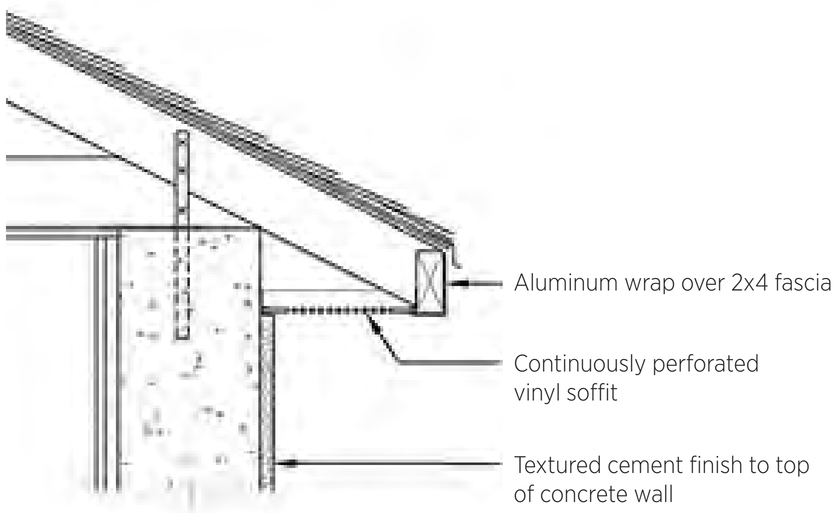


Figure 1.

The typical soffit design for new home construction in Florida is susceptible to water intrusion from direct wind pressure, suction on the lee-ward side of the house, and from surface tension as the water sheets off the roof and clings to the fascia and soffit.

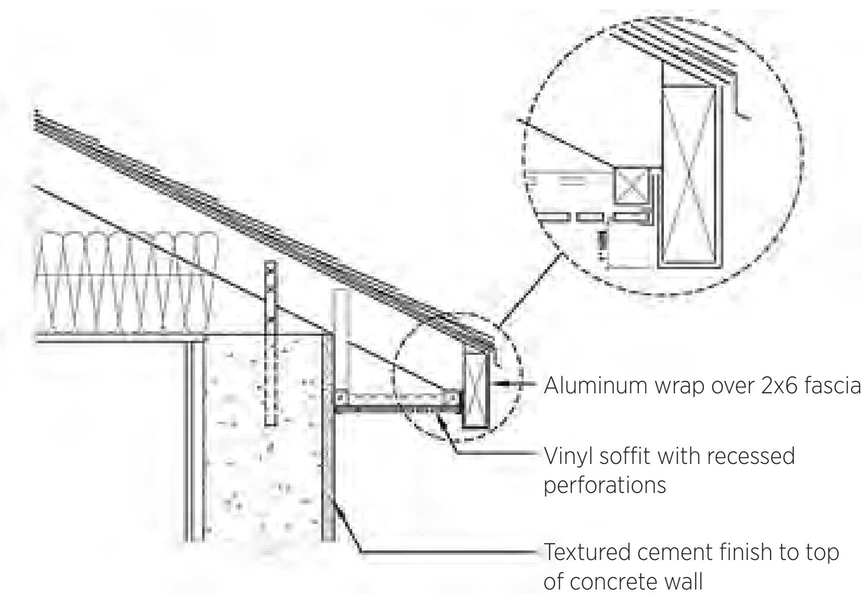


Figure 2.

The fascia was redesigned to extend 1 inch below the soffit to form a drip edge, directing water down and away from the house. A perforated soffit board product with recessed rather than surface openings was installed to limit water intrusion while encouraging greater air circulation and faster drying within the eave assembly The improved eave design has a fascia that is extended one inch below the soffit to form a drip-edge to defeat the rain water's surface tension. The vented soffit is reconfigured with recessed perforations arranged along the top of perpendicular ridges. Additional blocking is also installed to prevent soffit blow-out.

Detail of old soffit showing bottom of assembly is flat with vent perforations facing downward.

Detail of new soffit design showing extended fascia, providing drip edge.

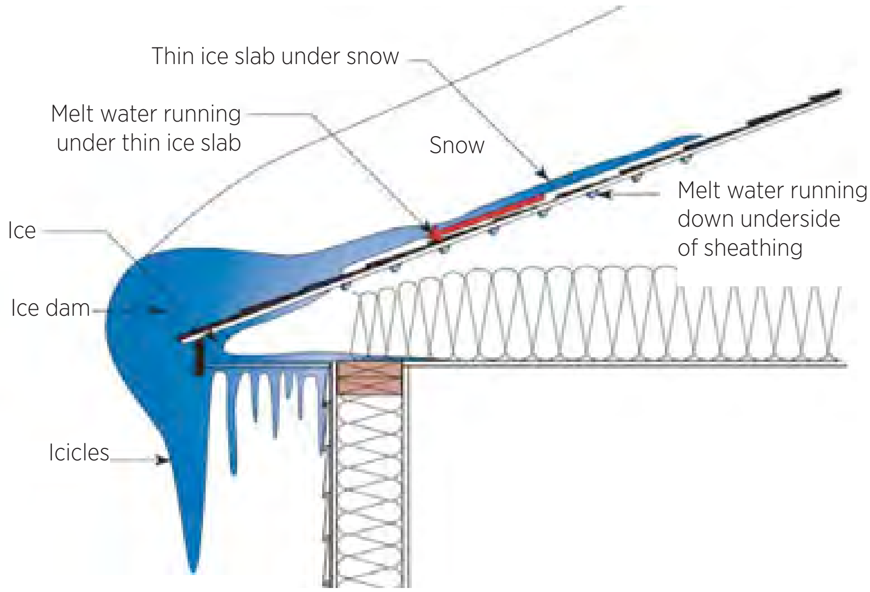
Detail of new soffit design showing fascia and recessed vent perforations.

Sources & Additional Information

Zoeller, William. 2006. "Designing and Building Hurricane-Resistant Homes," prepared by Steven Winter Associates, published in *Home Energy Magazine*, Fall 2006, www.carb-swa.com/articles/in%20the%20news/HomeEnergy_Designing%20and%20Building%20Hurricane%20Resistant%20Homes.pdf.)

Ice Dam Prevention

Ice dams are hazardous for buildings and people. Use the following guidance to minimize chances of ice dams forming on your homes.

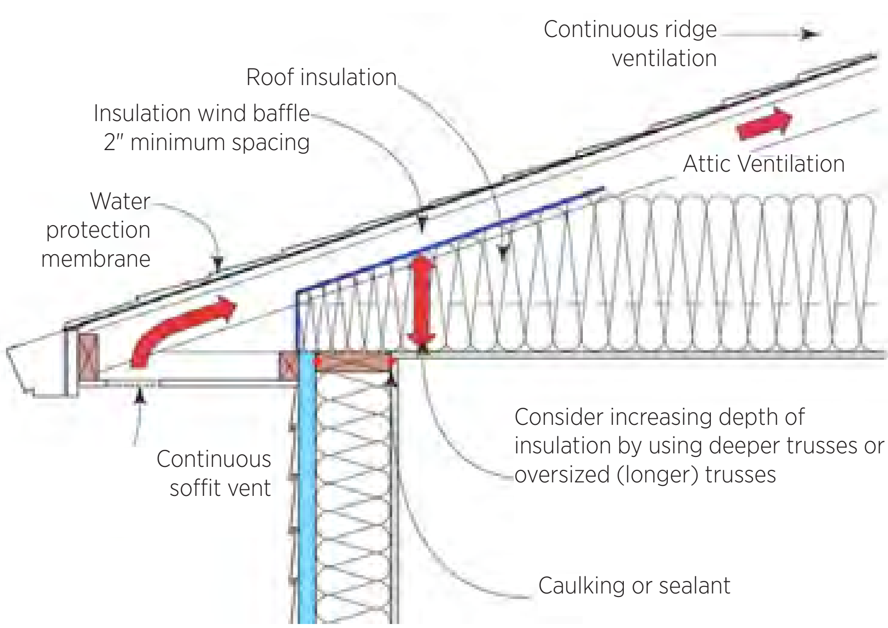


Ice Dam Formation -

Ice dams can form when the roof deck temperature is above freezing and the air is below freezing.

Melted snow eventually reaches the colder edge of the roof where it refreezes, creating an ice dam that collects more water and ice. The ice dam is often not visible under the snow layer on the roof except for the telltale icicles, which indicate melting is occurring somewhere on the roof.

(Source Lstiburek 2011, Building Science Corporation)



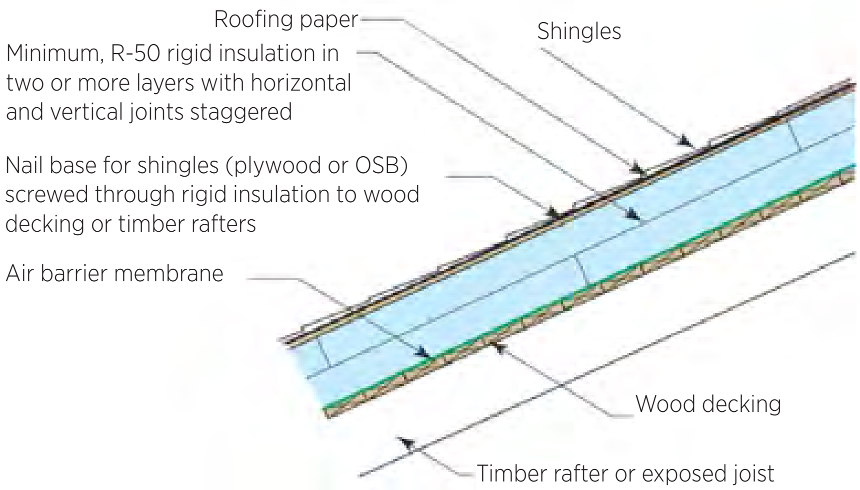
Three Steps to Ice Dam Control in a Vented Attic –

1) Construct an airtight ceiling plane. Limit the number of holes through the ceiling and air seal every one.

2) Insulate well, especially over the top plates, use raised heel trusses if needed to get full insulation coverage.

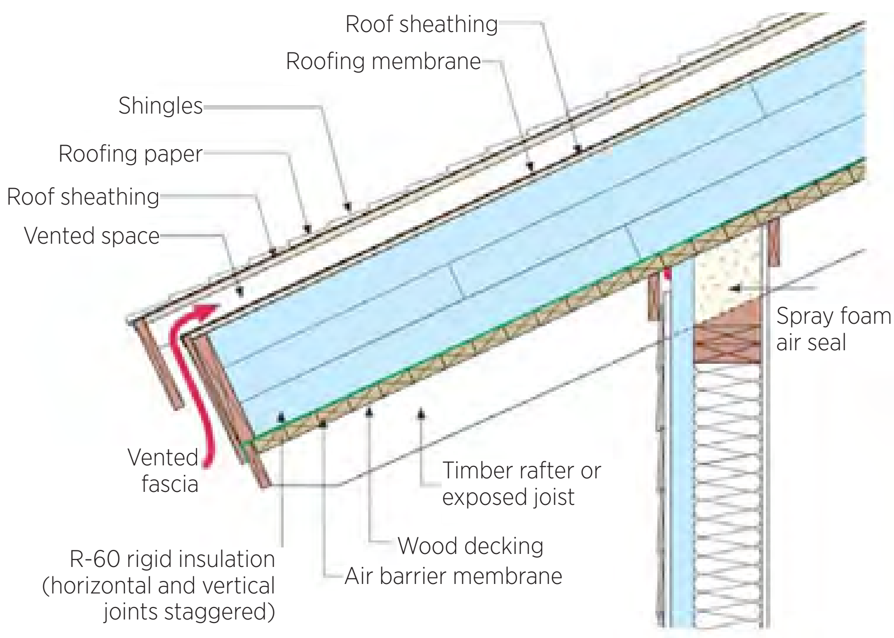
3) Vent the underside of the roof deck, with vent screens at every rafter bay and a 2-inch airspace under the sheathing where ground snow loads are greater than 30 lb/ft^2.

(Source Lstiburek 2011, Building Science Corporation)



Ice Dam Control in an Unvented Attic with Insulation above Roof Deck –

Cover roof sheathing with a fully adhered air barrier membrane. Install two layers (to R-50 or greater) of rigid insulation over air barrier, stagger the seams. Note there is no vented space under the roof cladding to compensate for the insulation value of the snow layer. This roof should be used where the ground snow load is less than 50 lb/ft^2. With ground snow loads greater than 50 lb/ft^2, provide a ventilation space under the roof cladding as shown in Figure 4 *(Source Lstiburek 2011, Building Science Corporation).*



Ice Dam Control in an Unvented Attic with Insulation above Roof Deck in High-Snow-Load Areas –

In regions with snow loads greater than 50 lb/ft^2, the snow can provide enough thermal resistance to allow the roof cladding to be above freezing even when the air temperature is below freezing (one foot of snow = R-10 to R-15). To prevent ice damming with an unvented attic in these conditions, construct a "vented over-roof" over the top of the "unvented compact roof" as shown above *(Source Lstiburek 2011, Building Science Corporation)*.

Sources & Additional Information

Lstiburek, Joseph. 2011. *Dam Ice Dam*, Insight 046, Feb. 2011, Building Science Corporation, www.buildingscience.com/documents/insights/bsi-046-dam-ice-dam/

40% Whole-House Energy Savings in the Mixed-Humid Climate

Case Studies

Several builders are building energy-efficient homes in the mixed-humid climate. The following case studies showcase four mixed-humid climate builders who have worked with Building America research teams to build homes that exceeded the Building America benchmark by 40% or more. The energy-efficient measures they incorporated in their homes are summarized in the table below.

Table 1. Summary of Energy-Efficient Measures Incorporated in Case Study Homes in the Mixed-Humid Climate

Measure	Insight Homes Seaford, DE	Tindall Homes Princeton, NJ	Urbane Homes Crestwood, KY	Pine Mountain Builders Pine Mountain, GA
Project	54 homes at Deep Creek in Seaford, DE, at Windstone in Milton, DE; and at Ridings of Rehoboth in Lewes, DE. 1,400 to 3,300 ft^2	20 homes in The Legends at Mansfield, Columbus, NJ. 3,800 to 6,000 ft^2	10 homes in first community, plus 5/year since, Louisville, KY. 1,484 to 2,996 ft^2	Approximately 14 in Callaway Gardens' Longleaf Community in Pine Mountain, GA. 1,929 ft^2 to 3,124 ft^2
HERS	50-56	58	57-62	59-85
Walls	Advanced 2 x 6 framing at 24-inches on center	Advanced 2 x 6 framing at 24 inches on-center	Advanced 2 x 6 at 24-inch on center framing	2x4 16-inch on-center framing
Wall Insulation	Dense-packed netted and blown-in fiberglass to R-23	R-18 polyurethane spray foam; R-12.5 foam insulated foundation walls	R-5 XPS foam sheathing with R-19 fiberglass batts	R-3 XPS foam sheathing R-13 low-density spray foam
Attic Insulation	R-38 with loose-blown fiberglass	Vented R-49 with R-30 kraft-faced fiberglass batts and R-19 blown-in cellulose	R-50 blown fiberglass	R-30 low-density spray foam
Radiant Barrier	No	No	No	No
Ducts	In sealed conditioned crawlspace. R-6 insulated flexible branches	In open web floor joists in conditioned space	In sealed conditioned space	In sealed semi-conditioned space. Mastic sealed

Measure	Insight Homes Seaford, DE	Tindall Homes Princeton, NJ	Urbane Homes Crestwood, KY	Pine Mountain Builders Pine Mountain, GA
Air Handler	Within main living space	Largest unit in basement. Secondary unit in living space on second floor	Within main living space	Within sealed attic
Air Sealing	3.0 ACH at 50 Pa.	1.5 ACH at 50 Pa.	3.6 ACH at 50 Pa.	1.8 ACH at 50 Pa.
HVAC	Right-sized 16 SEER air conditioner; 96% AFUE gas furnace	Right-sized 13.5 SEER air-conditioner; two 92% AFUE gas furnaces. Four independent temperature zones	Right-sized 14.5 SEER/8.4 HSPF heat pump	Right-sized 14 SEER/8.0 HSPF heat pump; some homes have ground-source heat pump
Windows	Vinyl-framed, double-glazed, low-e, argon-filled; U=0.26, SHGC=0.19	U=0.16, SHGC=0.61	Vinyl-framed, double-glazed, low-e, argon filled; U=0.32, SHGC=0.31	Wood-framed, double-glazed windows, argon filled; U=0.38, SHGC=0.35
Water Heating	0.87 EF tankless gas water heater	Tankless gas water heater	0.92 EF electric tank water heater	0.93 EF electric 40 gallon tank heater
Ventilation	Integrated exhaust fans with run time to satisfy ASHRAE 62.2	Heat recovery ventilator (HRV) connected to the return plenum on both furnaces	Fresh air intake with damper timed to exhaust ventilation	Fresh-air ducted to air cycler
Moisture Management Features	Conditioned crawlspace has R-10 continuous XPS on the interior of the walls; two layers of poly sheeting, taped and sealed at all penetrations and to the foundation floor and walls	A drainage plane layer is used over insulating foam sheathing and is correctly integrated with flashing which was properly applied around windows and door areas to promote shedding of water	XPS rigid foam board for sheathing on walls and concrete	R-13 closed-cell with spray polyurethane foam insulation, R-3 XPS insulation
Green features	Low-or-no VOC paints and flooring	Open-web floor joists use less lumber than solid joists	Low-or-no VOC paints and flooring	Mature trees. Low- or no-VOC paints, flooring. Low-flow plumbing fixtures. Erosion control and on-site recycling during construction
Lighting and Appliances	100% hardwired CFL	100% CFL, ENERGY STAR appliances	100% hardwired CFL, ENERGY STAR appliances	75% CFL, ENERGY STAR appliances
Solar	No	Optional upgrade; 2.64-kW photovoltaic system on garden shed roofs	No	No
Verify	All homes third-party tested and inspected. ENERGY STAR certifications	All homes third-party tested	All homes third-party tested and inspected. ENERGY STAR certifications	All homes third-party tested and inspected. Builders Challenge, EarthCraft House and ENERGY STAR certifications

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

BUILDING TECHNOLOGIES PROGRAM

Building America Best Practices Series

Volume 16. 40% Whole-House Energy Savings in the Mixed-Humid Climate

Case Study: Insight Homes

Deep Creek | Seaford, DE

Insight Homes' Jerry model showed that the builder's standard specification package exceeds the 40% level of energy savings relative to the Building America benchmark, achieving 50% energy savings and a HERS index score of 50. The 2,140 ft² home sells for around $196,000.

BUILDER PROFILE

Builder: Insight Homes

Contact: Rob Lisle, President
(302) 337-0400 (main office)
www.itsjustabetterhouse.com

Founded: 2007

Where: Bridgeville, DE

Employees: 8 to 14

Number of homes per year: 40 to 70

Development:
Deep Creek, Seaford, DE
Windstone, Milton, DE
Ridings of Rehoboth, Lewes, DE

Size: 1,400 to 3,300 ft², 3 to 4 bedrooms, 2 to 3.5 baths

Price Range: $220,000 to $280,000

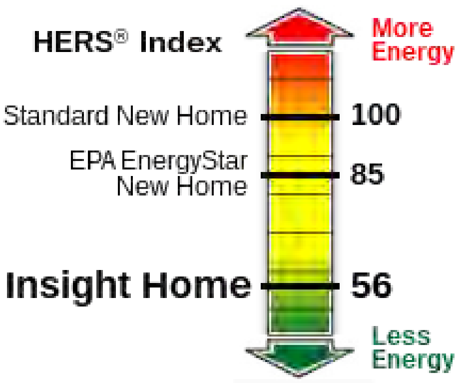
Building America® U.S. Department of Energy

Rob Lisle, a businessman who owns multiple companies in Delaware, initially founded Insight Homes in 2007 as an experimental company. His goal was to build 36 identical houses, three at a time. Energy efficiency would improve with each generation while the sales price remained the same as a comparable home in Delaware.

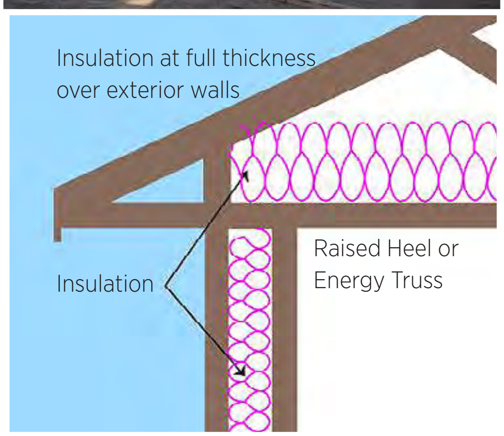
"After experimenting with seven generations of a single home plan we were able to achieve our goal of a HERS score of 56," said Lisle. To further refine his building specifications, Lisle began working with the U.S. Department of Energy's Building America program.

Lisle worked with Integrated Building and Construction Solutions (IBACOS), a Building America research partner, to evaluate building durability and bulk water management details. IBACOS also helped develop duct designs and system layouts for several of Insight Homes' models to address recurring comfort issues with the heating, ventilation, and air conditioning system (HVAC). IBACOS continues to work with Insight Homes to establish quality assurance measures that will help the company consistently deliver high-quality production houses as they build homes in greater volume.

While Insight Homes has been in business for just four years, the company's increasing number of home sales indicates that offering energy-efficient homes at the same cost as any comparable home in the Delaware area is a good way to beat a down market. In addition, Insight markets their homes exclusively based on their energy efficiency rather than the great locations or design. They advertise their homes as "the top 1% in the nation for energy efficiency" with an average monthly power bill of $92.68 for the years 2009 to 2010.



The HERS Index scores for Insight Homes are significantly lower than the new code-built homes. They range from 49 to 56, depending on the model.



(Top) The above-grade walls are constructed with 2"x6" wood framing spaced 24" on center, providing space for R-23 of dense-pact blown fiberglass.

(Bottom) Insight Homes are built with raised-heel energy trusses, which can accommodate a full 14 inches of insulation over the whole ceiling deck including the top plate, eliminating cold spots along the tops of outside walls.

One of Insight Homes' volume projects is a 30-home community called Deep Creek in Seaford, DE. The Deep Creek homes achieved 50% whole house energy savings compared to the Building America benchmark (a home built to the 1993 Model Energy Code). The Jerry model has a HERS score of 50.

Insight Homes is now building 40 to 70 homes per year. They range in size from 1,400 to 3,300 ft², at a price range of $220,000 to $280,000.

Lisle is a frequent speaker at building conferences on the topic of energy efficiency. In 2009, he began hosting a local weekly radio show where he answers callers' questions about green and energy-efficient building.

"Our company's mission is to develop systems and approaches that demonstrate to other builders how they can also build energy-efficient, healthy, and durable homes at cost-competitive prices," said Lisle.

Energy-Efficiency Features

All Insight Homes are built using the energy-efficiency package that Lisle developed through his experimental home building and the refinements developed with IBACOS.

Insight Homes' standard energy-efficiency features start with a conditioned crawlspace insulated with continuous R-10 extruded polystyrene rigid foam (XPS) on the interior of the walls.

Insight achieves airtight construction and an improved thermal envelope with advanced 2 x 6 framing at 24-inches on center. Walls are insulated with dense-packed netted and blown-in fiberglass to R-23. The attic is insulated to R-38 with loose-blown fiberglass. Blower door tests show a maximum of 3.0 air changes per hour at 50 Pascals of pressure.

The high-efficiency HVAC system includes a 96% AFUE two-stage propane-fired furnace and a 16 SEER air conditioner. The ducts are located in the sealed, conditioned crawlspace and consist of a sheet metal trunk and R-6 insulated flex duct branches. There are two central returns for the main living space with door undercuts at enclosed rooms. The duct blaster test shows less than 3% total system leakage and less than 1% leakage to the exterior.

Integrated bathroom exhaust fans coordinate run time to satisfy ASHRAE 62.2 ventilation requirements. Insight Homes explored several whole-house ventilation strategies before settling on an exhaust-only system. The previous supply strategies required the use of a filter to limit the influx of particles in incoming air. Homeowners who were not replacing the filters according to schedule complained of performance issues. Insight Homes made an effort to teach homeowners the importance of replacing filters during new homeowner orientations, but the problem persisted.

The 0.87 EF tankless gas water heater uses a homerun distribution system, which uses a multiport manifold to deliver water to each fixture through PEX tubing.

The low-e windows are vinyl-framed, double-glazed, and argon-filled, with a U value of 0.26 and an SHGC of 0.19. Flashing tape is used to keep out any air and moisture that gets past the house wrap. Rain troughs built into the window sills are a further precaution.

Lighting is a combination of screw-in and hardwired compact fluorescent lighting.

Insight Homes has a third party perform blower door, duct blaster, and flow hood tests on 100% of its homes. Each home is ENERGY STAR®-certified and subject to additional third-party inspections.

The poured concrete wall foundation is coated with an asphalt-based moisture blocker. The conditioned crawlspace has R-10 XPS insulation continuous on the interior of the walls, and the earthen floor is covered with two layers of polyethylene sheeting that is taped and sealed at all penetrations and to the foundation walls.

Innovation

Insight Homes is currently working with IBACOS to build and test two side-by-side houses—one with Insight's standard energy-efficiency features and the other with an advanced HVAC system that includes a super-efficient heat pump paired with a tankless water heater that can provide backup heating.

"This system does not exist anywhere else in the market," said Kevin Brozyna, an IBACOS researcher. "We are working with Rob Lisle and manufacturers to develop it as a new product."

Health, Durability, Sustainability

Insight Homes uses poured concrete wall foundations with an asphalt-based coating to ensure that the crawlspace stays moisture free. The earthen floor of the crawlspace is covered in two layers of poly sheeting, taped and sealed at all penetrations and to the foundation walls. French drains are used to further keep the foundation dry. Downspouts for the gutters are located at the front of the house and piping attached to the downspouts is buried underneath the sidewalks, carrying rain water away from the house and releasing it into the yard, far away from the foundation.

All Insight Homes meet the strict requirements of the American Lung Association Healthy House program, which include a whole-house dehumidifier and central vacuum system.

All Insight Homes achieve not only ENERGY STAR certification but also qualify for ENERGY STAR's Indoor Air Package.

Insight Homes uses a dense-pack insulation system that blows loose, dry, formaldehyde-free fiberglass into the walls and attics, eliminating gaps around wiring and fixtures. When the insulation is in place, the fibers adhere to each other to form dense insulation.

Key Features

- Average HERS score: 50
- Basement: Interior of walls insulated with R-10 XPS
- Crawlspace: Unvented earthen floor covered in two layers of poly sheeting, taped and sealed at all penetrations and to foundation walls
- Advanced framing: 2x6, 24-inch on-center walls
- Wall insulation: R-23 dense-packed netted and blown-in fiberglass
- Windows: Vinyl-framed, double-glazed, low-e, argon-filled; U=0.26, SHGC=0.19
- Attic: R-38 loose-fill fiberglass
- Blower door test: 13.0 ACH50
- Ventilation: Integrated exhaust fans with run time to satisfy ASHRAE 62.2
- 96% AFUE two-stage propane-fired furnace
- 16 SEER split system air-conditioning unit
- All-metal ducts within conditioned space
- Duct blaster test: 3% total leakage
- Tankless gas water heater
- 100% screw-in and hardwired CFL

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Dollars and Sense

The representative model for this case study, the 2,140 ft² Jerry, has 3 bedrooms and 2.5 baths. IBACOS analysis showed that the Jerry model uses 50% less energy than the Building America benchmark. The builder estimates that energy-efficiency upgrades cost $7,660 per house, which adds $612 a year to a mortgage (based on a 30-year term and 7% interest). But the homeowner enjoys an estimated $1,405 a year in energy savings, for a net annual gain of $793.

Table 1. Added Costs and Savings of Energy-Efficient Measures for Insight Homes

Total Energy Savings*	50%
Total Added Builder Costs**	$7,660
Annual Mortgage Payment Increase***	$611.55
Annual Utility Savings	$1,405
Annual Net Cash Flow to the Homeowner	$793.45

* For the Jerry model compared to the Building America benchmark.

** Costs are based on builder estimates, and manufacturers' data, plus a 10% markup relative to minimum code. These costs do not reflect rebates, incentives, and subsidies.

***The annual mortgage payment is an estimate based on a 30-year mortgage with a 7% fixed interest rate.

The Bottom Line

One of the keys to Insight Homes' success was their willingness to experiment with various combinations of system solutions until they developed a cost-effective, energy-efficient, and replicable specifications package. Insight's standard home is capable of achieving better than 40% source energy savings, compared to the Building America benchmark.

Marketing homes exclusively on the basis of energy efficiency has paid off in Insight's home sales.

"This may not work for all builders, but it seems to be working well for Insight," said IBACOS researcher Brozyna.

In 2008 and 2009, Insight had 38 closings on homes at Deep Creek as well as other communities in Sussex County, DE. They sold 54 homes in 2010 and expect to finish building and selling 70 homes by the end of 2011. Insight Homes also has a long backlog of orders for new houses that promises to keep their sales numbers growing.

IBACOS has continued its partnership with Insight Homes to research new energy-efficiency technologies and support development of its business processes and practices.

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BUILDING TECHNOLOGIES PROGRAM

Building America Best Practices Series

Volume 16. 40% Whole-House Energy Savings in the Mixed-Humid Climate

Case Study: Tindall Homes

The Legends at Mansfield | Columbus, NJ

Tindall Homes' energy-efficient Morgan model in The Legends at Mansfield community uses 49% less energy than the Building America benchmark (2008).

BUILDER PROFILE

Builder: Tindall Homes

Contact: Mark Bergman (former owner, the company has been sold)

Founded: 1986

Where: Princeton, New Jersey

Employees: 10

Number of homes per year: 20 to 30

Development: Legends at Mansfield, Columbus, New Jersey

Size: 20 homes, 3,800 to 6,000 ft^2, 4 to 5 bedrooms, 3 to 4.5 baths

Price Range: $700,000 to $900,000

Building America U.S. Department of Energy

Swedish native Mark Bergman launched Tindall Homes in Columbus, New Jersey, in 1986 with a mission to build homes with greater durability and energy efficiency than other houses on the market.

Bergman found an ally in Integrated Building and Construction Solutions (IBACOS), a research team in the U.S. Department of Energy's Building America program. With design analysis and advice from IBACOS, Bergman built 20 luxury homes at The Legends at Mansfield community in Columbus, New Jersey. These homes use 40% to 49% less energy than a code-built home and achieve an average HERS score of 58. (A typical new American home has a score of 100—lower scores indicate greater energy efficiency). For the buyers of Tindall Homes' Morgan design, for example, this translates into calculated annual energy savings of $1,541. With the addition of a solar photovoltaic system, the energy efficiency increases another 5% to 8%.

"Over their lifetimes," Bergman predicted, "our houses will save more in energy costs than the purchase price." Bergman said greater durability is another benefit of applying Building America recommendations.

Energy-Efficiency Features

Tindall Homes targeted move-up homebuyers in the luxury housing market by offering large floor plans with two-story spaces and high-end finishes. During the design phase of The Legends of Mansfield houses, IBACOS recommended several above-code options that would work together to create a high-performance home. These included advanced

Tindall Homes installed their optional grid-tied solar photovoltaic systems on backyard garden sheds, situated for maximum solar gain. Wiring for the systems runs underground from the shed to the home's basement.

wood framing, spray foam wall insulation, precast insulated foundation walls, increased attic insulation, a heat recovery ventilator, a tankless gas water heater, and energy-efficient HVAC and lighting.

Advanced framing conserves lumber and provides more space for insulation. By upgrading from the 2" x 4" conventional stud walls located 16" on center to 2" x 6" studs placed 24" on center, the builder was able to significantly decrease conductive heat loss through exterior walls. Three inches of closed-cell polyurethane spray foam within the walls increased the insulation to R-18, sealed penetrations, and improved air tightness.

The precast concrete foundation system with integral R-12.5 insulation board within the wall cavity provides an airtight basement and a more comfortable home year-round than a traditional block or site-poured concrete foundation.

The builder insulated the vented attic to R-49 with a combination of R-30 kraft-faced fiberglass batts and R-19 blown cellulose. The overhanging floors contain 2" of urethane foam (R-12) and R-30 kraft-faced fiberglass batts to equal R-42.

A direct-vent tankless gas water heater provides hot water instantly as needed, which is more energy-efficient than continuously heating a large tank of water.

Since IBACOS' recommendations reduced the houses' energy needs, Tindall Homes was able to reduce the size of the heating and cooling equipment. The two optimally sized 92% AFUE direct vent natural gas furnaces and two 13.5 SEER air conditioners are of smaller capacity than standard, reducing the cost to the builder by $800 and contributing additional energy savings for the homeowner. Due to the large size of the homes, one HVAC unit was located in the conditioned basement and the other was placed on the second floor. There are four thermostats in the homes that control the temperature for four independent zones. This

Insulated precast concrete foundation walls, spray foam-filled frame walls, and R-49 of attic insulation keep the Tindall homes in Columbus, New Jersey, warm in winter and cool in summer.

option gives the homeowner more control of the comfort levels in the home, where needed, and provides opportunities to use less energy. All of the ductwork is located within conditioned space.

Innovation

Fourteen of the 20 Legends of Mansfield homes are equipped with a 2.64-kilowatt solar photovoltaic (PV) system that is tied to the grid. Since some of the houses with solar systems could not be oriented for optimal solar collection, Tindall used an innovative solution. They built specially designed garden sheds in the back yards of those homes and mounted the PV panels on the shed roofs. The sheds have a short pitched roof in the front and a long, 40-degree sloped back roof oriented to the south for the PV panels. Wiring for the system runs underground from the shed to the house, and the inverter is in the basement.

Health, Durability, Sustainability

To improve indoor air quality, Tindall Homes replaced the standard ventilation system with a heat recovery ventilator (HRV), connecting it to the return plenum on both furnaces. This upgrade provides a way to bring in fresh air and capture much of the heat contained in outgoing air before it exhausts to the outside.

"Incoming air in the winter may be only 30 degrees. If you warm it 20 degrees with exhaust air, then you are enjoying this heat virtually free," said John Clark, construction supervisor for The Legends at Mansfield. The HRV system provides improved ventilation, better air quality, and enhanced occupant comfort.

Dollars and Sense

Tindall Homes had planned to build 39 houses in The Legends of Mansfield community, but due to the downturn in the market for luxury homes, only 20 houses were completed. The houses are two-story, single-family dwellings ranging in size from 3,800 to 6,000 ft^2, with 3 to 5 bedrooms and 2.5 to 3.5 bathrooms. Prices ranged from $700,000 to $900,000.

The representative model for this case study, the 4,700 ft^2 Morgan, has 4 bedrooms and 3.5 baths. Analysis by IBACOS showed the Morgan model used 49.2% less energy than the 2008 Building America Benchmark without PV, and 55.9% less energy when PV is included. The energy efficiency upgrades (not including PV) cost nearly $18,000 per house, which adds $1,699 a year to a mortgage (based on a 30-year term and 7% interest). But the homeowner enjoys an estimated $3,240 a year in energy savings, for a net annual gain of $1,541.

Key Features

- Basement insulation: Integral R-12-5 insulation board
- Advanced framing, 2 x 6, 24-inch o.c. walls
- Wall insulation: R-18 closed-cell spray polyurethane insulation
- Windows: U-value=0.36, SHGC=0.33
- Attic: Vented, R-30 fiberglass batt and R-19 blown cellulose insulation
- Blower door test: 3.2 ACH50
- Ventilation: 50 cfm heat recovery ventilator
- Two 92% AFUE natural gas furnaces
- 13.5 SEER air-conditioner
- Ducts in conditioned space
- Duct blaster test: <6% total leakage
- Two tankless gas water heaters, 85 EF
- 95% CFLs
- 2.64 kW grid-connected photovoltaic system available
- Average HERS score: 58

Table 1. Added Costs and Savings of Energy-Efficiency Measures for Tindall Homes

Total Energy Savings*	49%
Total Added Builder Costs**	$17,630
Annual Mortgage Payment Increase***	$1,699
Annual Utility Savings	$3,240
Annual Net Cash Flow to the Homeowner	$1,541

* Compared to the Building America benchmark.

** Costs are based on builder estimates and manufacturers' data. These costs do not include solar photovoltaic systems and do not reflect rebates, incentives, and subsidies.

*** The annual mortgage payment is an estimate calculated by CARB and is based on a 30-year mortgage with a 7% fixed interest rate.

The Bottom Line

"If all builders built to save 50% on energy use, we could make a big difference," Bergman said. "We all want to make money, but at some point, as a society, we have to evaluate what we are doing. We take seriously our responsibility to the surrounding community, to the environment, and most importantly to our buyers."

"It's important to recognize that many of the things that make our houses more energy efficient will also make them last longer," said Bergman, who noted that features like aggressive air sealing help keep out humidity and dampness.

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BUILDING TECHNOLOGIES PROGRAM

Building America Best Practices Series

Volume 16. 40% Whole-House Energy Savings in the Mixed-Humid Climate

Case Study: Urbane Homes

Various Locations | Greater Louisville, KY

Urbane Homes won an Energy Value Housing Award in 2009 for their energy-efficient prototype. They built the house in 2008 for just $36 per ft² using materials and techniques available to all builders and achieved an energy savings of 44% compared to the Building America benchmark.

BUILDER PROFILE

Builder: Urbane Homes

Contact: Abe Gilbert and Zane Underwood, Co-Owners
(502) 509-7373
www.myurbanehome.com

Founded: 2007

Where: Louisville, KY

Employees: 2 to 3, not including subcontractors

Number of homes per year: 5 plus

Size: 1,484 to 6,000 ft², 3 to 5 bedrooms, 2 to 3.5 baths

Price Range: $150,000 to $450,000

Building AMERICA U.S. Department of Energy

When Abe Gilbert and Zane Underwood founded Urbane Homes in 2007, their goal was to build bigger, better, and more affordable houses than any other builder in the area. They are now one of the top 10 production home builders in Louisville.

At the time Gilbert and Underwood started Urbane, they could see the beginning of a downturn in the housing market and knew that their survival depended on building the most affordable houses in Kentucky. By working with the U.S. Department of Energy's Building America program, they discovered how to make their houses not just affordable but energy efficient—their homes achieve HERS scores of 57 to 62.

Gilbert says Urbane Homes sells every house they build, and they don't do any formal advertising.

"We just list the house about two weeks before it's done so people can come and see it. The longest we've had a house listed is 3 weeks. The last one we sold was on the market for just 2 weeks."

As they launched Urbane Homes, Gilbert researched ways to reduce costs by making their building practices efficient. This led him to Steve Bazek, a Boston architect who pioneers in efficient and green housing designs.

"Bazek said, 'Why don't you build really good homes that are also energy efficient and green?'" Gilbert remembers. He and Underwood were skeptical. How could they keep costs low while adding energy-efficiency upgrades? But Bazek thought they could do both.

Bazek worked with the builders to design their first house and introduced them to the National Association of Home Builders

Urbane Homes worked with the researchers from the National Association of Home Builders, a Building America partner, to develop a frost-protected shallow foundation that can reduce the cost of excavation and amount of concrete needed. The bottom of the footings can be placed 12″ to 16″ below grade instead of digging below the frost line (up to 48″) because the foundation is protected from freezing by rigid insulation. Insulation used for below-grade application must be in compliance with ASTM C 578 Standard.

(Top) The walls use advanced framing with 2x6 studs at 24 inches on center and XPS rigid foam sheathing on exterior walls instead of OSB.

(Bottom) Ceiling trusses are designed to span the entire home. There are no bearing walls for the roof in the interior of the home. All ducts are located within conditioned space. The duct shown here is the fresh air intake for the house.

(NAHB) Research Center, a Building America research partner. The partnership helped them incorporate energy-efficient features and green building practices. The NAHB Research Center provided technical support for a frost-protected shallow foundation and for code approval of their prototype house.

"We set out to prove that we could build a really good house for an affordable price, and we built that first house for $36 per square foot," said Gilbert. The remarkably low cost per square foot of Urbane's prototype model was verified by both the NAHB and DOE. A typical home in Louisville costs between $55 and $85 per ft² to build, not including the lot.

Urbane Home's prototype model won three major building awards in 2009, including two NAHB Energy Value Housing Awards (for affordability and production), and it was runner-up for the NAHB's Green Project of the Year.

By 2010, Urbane Homes built 10 production homes on custom lots in scattered locations within greater Louisville. Urbane's six model home designs are one- and two-story, single-family dwellings ranging in size from 1,484 to 2,996 ft², with 2 to 5 bedrooms and 2 to 3.5 bathrooms. Prices range from $150,000 to $450,000.

The homes have calculated energy savings of 41% to 44% compared to the Building America benchmark (a home built to the 1993 Model Energy Code), and have HERS scores of 57-62, depending on the model. A typical new American home has a HERS score of 100 (lower scores indicate greater energy efficiency).

Energy-Efficiency Features

Urbane Homes worked with the NAHB Research Center to develop an energy-efficiency package using readily available off-the-shelf products. "We wanted to pick all the low-hanging fruit for green and energy-efficient design and put it in a standard package that made sense and was affordable," said Gilbert.

Urbane's standard package begins with the frost-protected shallow foundation. This method allows footing or foundation depth to be reduced from 48″ to 12″ to 16″, saving about two-thirds the amount of concrete needed. Traditionally, foundations are protected from frost-heaving damage by placing the footing below the frost line, but the shallow foundation is protected from freezing by placing rigid insulation around the outside of the foundation. Urbane Homes uses 1″ of R-5 extruded polystyrene (XPS) foam below the entire slab. The exterior foundation is protected by 2″ (R-10) of recycled expanded polystyrene (EPS) foam, and the interior slab edge is insulated with 1¼″ (R-5) of EPS foam.

The attic is insulated with R-50 blown fiberglass.

The advanced wood framing (2x6 at 24-inch on center) uses less lumber and leaves more room for the R-19 fiberglass batts on the interior walls. One-inch (R-5) XPS rigid foam is used for sheathing instead of OSB on the exterior walls. The sheathing is taped at the seams and braced at the corners and then covered with a water-resistant barrier (house wrap) that is fastened and taped. The exterior is finished with vinyl siding. Blower door tests show air tightness of less than 3.6 air changes per hour at 50 Pascals of pressure (~0.15 ACHnat infiltration).

The heating, ventilation, and air-conditioning (HVAC) system includes an 8.4 HSPF, 14.5 SEER heat pump. A runtime positive ventilation system is dampered with programmable exhaust ventilation. Ducts are installed within the conditioned space in open-web floor trusses and are tested for leakage to achieve less than 5%.

The hot water system uses a 0.92 energy factor (EF) electric tank hot water heater. All other appliances are ENERGY STAR. Windows are vinyl-framed, double-glazed low-e with argon fill (U-value=0.32, SHGC=0.31), and the lighting is 100% hardwired compact fluorescent lighting.

The XPS rigid foam sheathing is taped at the seams and covered with house wrap to provide a drainage, air barrier, and thermal barrier.

Innovation

Urbane Homes incorporates improvements to its energy-efficiency package on a yearly basis.

To ensure adherence to quality standards, Urbane Homes holds pre-construction meetings to coordinate trade contractors and ensure buy-in from the site superintendent. They provided training sessions for their subcontractors on the use of newer products like exterior rigid foam and they developed a framing manual for the special techniques they expect their framers to use.

"Our framers do the majority of our air sealing, so when we make changes to our process, they get an updated manual and do a great job with it," said Gilbert.

All of Urbane's houses meet the Building America 40% savings standard and are five-star ENERGY STAR certified. ENERGY STAR provides third-party testing for energy efficiency.

Health, Durability, Sustainability

Greater Louisville gets 44 inches of rain annually. Moisture and mold are a common problem for homes in the area. Urbane Homes builds from the ground up to keep moisture from getting into their houses. Instead of the oriented strand board (OSB) that many builders use, Urbane uses XPS rigid foam sheathing for exterior walls. OSB can absorb and trap moisture in a mixed-humid climate.

Key Features

- Advanced 2″x 6″ wood framing at 24″ on center
- Attic insulation: R-50 blown fiberglass
- Wall insulation: 1″ (R-5) XPS foam sheathing with R-19 fiberglass batts
- Foundation insulation: 1″ (R-5) XPS below slab, 2″ (R-10) EPS exterior foundation, 1¼″ (R-5) EPS interior foundation
- Homes with basements: 2″ (R-10) EPS exterior, R 13 fiberglass batts in interior walls
- Windows: Vinyl-framed, double-glazed, low-e with argon fill (U-0.32, SHGC=0.31)
- Blower door test: Less than 3.6 ACH@50PA (~0.15 ACHnat infiltration)
- 8.4 HSPF, 14.5 SEER heat pump
- Runtime positive ventilation system
- 0.92 EF electric tank hot water heater
- Ducts in conditioned space with less than 5% leakage
- 100% hardwired CFLs
- ENERGY STAR appliances
- HERS scores: 57-62

For More Information

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Dollars and Sense

The energy-efficiency upgrades cost about $1,465 per house, which adds about $129 a year to a mortgage (based on a 30-year term and 7% interest). But the homeowner enjoys an estimated $713 a year in energy savings, for a net annual gain to the homeowner of $584.

Urbane Homes is working with the NAHB Research Center to design a building envelope with a much higher level of insulation. They are also researching alternative HVAC strategies. These should help Urbane Homes achieve 50% savings over the Building America benchmark while maintaining affordability.

Table 1. Added Costs and Savings of Energy-Efficient Measures for Urbane Homes' 2,184 Slab Model

Total Energy Savings*	44%
Total Added Builder Costs**	$1,612
Annual Mortgage Payment Increase***	$129
Annual Utility Savings	$713
Annual Net Cash Flow to the Homeowner	$584

*Compared to the Building America benchmark.
**Costs are based on builder estimates and manufacturers' data. These costs do not include solar photovoltaic systems and do not reflect rebates, incentives, and subsidies.
***The annual mortgage payment is an estimate based on a 30-year mortgage with a 7% fixed interest rate.

The Bottom Line

Urbane Homes has become a leader in high-performance homes in a remarkably short time, receiving industry honors for design and construction approaches that raise the level of energy efficiency and green building beyond the typical practices of the area.

Urbane has built five or more homes per year since their original community of 10. Urbane Homes' dollar sales volume has doubled every year since they started building, and they've already had repeat buyers who sold their original Urbane homes at a significant profit.

The builders admit that most of their customers initially are more interested in price and location, but as homeowners learn how much money the house will save them on energy costs, they get excited about the energy-efficiency features.

"We're very passionate about what we do and people can see that," said Gilbert. "We just keep getting busier and busier."

Building America Best Practices Series

Volume 16. 40% Whole-House Energy Savings in the Mixed-Humid Climate

Case Study: Pine Mountain Builders

Pine Mountain, Georgia

Pine Mountain Builders worked with IBACOS, a DOE Building America research partner, to come up with designs that use off-the-shelf parts to build homes that look conventional but are both environmentally sustainable and energy efficient.

BUILDER PROFILE

Builder: Pine Mountain Builders

Contact: Mike Guinan, Manager
(706) 663-8443
www.callawaygardensliving.com/pine-mountain-builders.html

Founded: 2004

Where: Pine Mountain, Georgia

Employees: 5

Development: Callaway Gardens (140 lots) and Blalock Lakes

Square Footage: 1,192 to 3,124 ft^2

Size: 2-4 bedrooms

Price Range: $300,000 to $450,000

Pine Mountain Builders, a partnership between the owners of Fortress Construction and Cousins Properties, has teamed up with the U.S. Department of Energy's Building America program to build homes that achieve HERS scores as low as 59. (A typical new American home has a score of 100.)

Since 2005, Pine Mountain Builders has been working with Integrated Building and Construction Solutions (IBACOS) and Southface Energy Institute, both Building America research partners, to improve the energy efficiency of their homes. With the help of IBACOS and Southface, Pine Mountain Builders has used innovation to overcome technical challenges to meet and exceed the high standards of Callaway Gardens' Longleaf sustainable resort community. Located in western Georgia near the non-profit Callaway Gardens Wetlands Preserve, this community was designed to serve as an example of sustainable development practices that are energy efficient and protect area wilderness.

With help from Building America, Pine Mountain Builders completed its first 11 homes of 140 at Callaway Gardens in 2007. "We love the program," said co-owner Mike Guinan. "We learn and improve every day. With IBACOS we can experiment with new systems and products," explains Guinan.

Although homebuyers may initially be drawn by the development's proximity to nature, they soon find that their homes perform extraordinarily well and can reduce their electricity bills to as little as $50 a month, or about half of the state average.

Unvented attics insulated with R-30 low-density spray foam provide a semi-conditioned space for the high-efficiency heat pump and ducts.

Framing is covered with XPS foam structural insulated sheathing instead of OSB. The foam sheathing provides R-3 of insulation and protection against moisture. The wall cavities are filled with an additional R-13 low-density spray foam insulation, which provides air sealing as well as insulation.

Energy-Efficiency Measures

The homes are located in western Georgia's mixed-humid climate, approximately 70 miles southwest of Atlanta, and range from one story, 3 bedrooms, and 1,929 ft² at approximately $355,000 to two stories, 4 bedrooms, and 3,124 ft², at a cost of up to $450,000.

Pine Mountain Builders first worked with IBACOS to design homes that used 30% less energy than the Building America Benchmark (a home built to the 1993 Model Energy Code). These designs became their standard homes. Now further work with IBACOS has enabled them to reach the 40% savings mark. Using off-the-shelf technologies, Pine Mountain offers a suite of energy-saving features designed for high-performance in Georgia's mixed-humid climate. These features include low-emissivity windows, passive design to reduce heat gain, tightly sealed thermal envelope, an efficient HVAC equipment and duct system design, efficient appliances, and independent testing.

Because the mixed-humid climate requires a great deal of cooling, the builders chose low-emissivity, wood-framed, double-glazed windows filled with argon and rated U=0.38 and SGHC=0.35. Solar gain is also mitigated through the use of architectural shading, such as low overhangs, and the preservation of mature trees to provide shade.

The thermal envelopes of Pine Mountain's homes are built to be airtight. Blower-door tests show 1.0 to 1.8 air changes per hour at 50 Pascals of air pressure. A cathedralized, sealed attic with R-30 low-density spray foam insulation is indirectly conditioned by the HVAC system. The walls are 2x4 16-inch on-center and the cavities are filled with R-13 low-density spray foam. Above grade, 75% of the exterior walls are covered with a ½-inch R-3 extruded polystyrene (XPS) rigid foam insulation. Instead of oriented strand board sheathing, the builders recently began using structural XPS foam insulated sheathing panels. The structural panels provide extra insulation and resist moisture to protect the home from the humid climate.

The HVAC system is designed to achieve ASHRAE 62.2 whole house ventilation requirements by placing the ventilation, heat pump, and ducts within the semi-conditioned space of the sealed attic. An air cycler provides fresh air to the house at an average of 20 cfm, while a 14 SEER/HPSF 8.0 heat pump provides cooling and heating. All air ducts are sealed with mastic at the joints. Some homes employ a ground source heat pump for heating, cooling, and water heating, pushing overall home energy savings to the 50% savings level compared to the Building America benchmark (a home built to the 1993 Model Energy Code). The homes achieve 30% energy savings compared to homes built to the Georgia construction code.

The builder installed only ENERGY STAR appliances, and 75% of the light fixtures are CFL.

Health, Durability, Sustainability

Pine Mountain Builders has set aggressive environmental performance measures that go beyond energy efficiency. The builder uses low-VOC paints and installs carbon-monoxide monitors and low-VOC carpets in each home. Pest controls are applied externally around the perimeter of the home to reduce human exposure. Garages are detached, which keeps fumes out of the house. The slab-on-grade foundation is raised to protect the home from water damage and sits on 4-ft-deep stemwalls that extend below the frostline.

To improve water efficiency, the builders have included low-flow showerheads, dual-flush toilets, high-efficiency washing machines, and rainwater harvesting for drip irrigation.

The builder grinds organic construction debris on site to use for mulch blankets that absorb rainfall to minimize runoff. Other erosion control measures include silt fences, permeable driveways and walkways, planting native species, and preservation of existing trees. The builder is registered in the NAHB's Building With Trees program. Each home is framed with sustainably harvested lumber.

Innovation

The company works with EarthCraft House, a regional program developed by the Southface Energy Institute that grades and certifies homes based on energy efficiency, indoor air quality, water efficiency, and other metrics for sustainability throughout the construction process. The builder also works with Callaway Gardens' Design Review Committee to ensure that the construction of its homes causes minimal impact to area habitat and water resources. Beyond providing third-party testing for energy efficiency, homes earning an EarthCraft House certification are also built to ENERGY STAR levels of efficiency. Certification requires builders to provide documentation of design goals and third-party verification before, during, and after the construction process to ensure overall building performance is as designed. This arduous process ensures that the finished building performs as it was designed. Furthermore, the builders take each home's alignment with the sun into consideration, both to adjust the amount and location of windows and doors and to properly determine the home's heating and cooling loads.

Pine Mountain Builders has worked with IBACOS and Southface over the past few years to reach both the 30% and 40% targets. Pine Mountain Builders have also begun working toward the 50% energy savings level in future designs. With more than 10 years of experience in building homes, Pine Mountain Builders has longstanding relationships with its trade partners that ensure its performance standards are met with the use of conventional building materials.

Key Features

- HERS scores: 59 to 85
- Foundation: Slab on grade, perimeter slab-edge insulation
- Siding: Wood shake cladding with R-3 XPS structural insulated foam sheathing
- Walls : 2x4 16-inch on center, R-13 low-density spray foam insulation
- Attic: Cathedralized, sealed, R-30 low-density spray foam insulation
- HVAC: ACCA Manual J-sized 14 SEER/HPSF 8.0 heat pump
- Ventilation: Air-cycler fresh-air supply with 20 cfm per hour
- Duct system: ACCA Manual D sized, located in semi-conditioned attic space, mastic sealed at joints
- Water heating: 40 gallon electric, 0.93 EF
- Windows: Low-E, double-pane, wood-framed windows, U=0.36, SHGC=0.30
- Lighting: 75% CFL
- Appliances: All ENERGY STAR

With help from IBACOS, Pine Mountain Builders has improved its energy efficiency from 30% to 40% savings over the Building America benchmark and HERS scores of 59. They are now working toward 50% energy savings in future designs.

"We like to build the most energy-efficient and best-performing home with off-the-shelf parts," explains manager Mike Guinan of Pine Mountain Builders. "We don't have any solar or PV arrays. It looks like an ordinary house but it performs way better."

Dollars and Sense

The builders have calculated that their efficiency measures add $917 per year (based on a 30-year mortgage at 7% interest), compared to a home built to Georgia code. IBACOS calculated the energy improvements can save homeowners up to $1,180 per year on their utility bills for a net gain to the homeowners of $263 per year.

Table 1. Calculated Costs and Savings of Energy-Efficiency Features for Pine Mountain Builders, Pine Mountain, Georgia

Total Energy Savings[1]	41%
Total Added Builder Costs[2]	$2,564
Annual Utility Savings	$1,180
Annual Mortgage Payment Increases[2,3]	$917
Annual Net Cash Flow to the Homeowner	$263

1 Savings are in comparison to the Building America benchmark (a home built to the 1993 Model Energy Code)
2 Builder costs were estimated by builders and Building America team. Costs include a 10% markup. Incentives and rebates are not included.
3 Mortgage costs are based on a 30-yr fixed mortgage at 7% interest; inflation is not considered.

The Bottom Line

With the downturn in the housing market, Pine Mountain Builders' construction rate has dropped from 50-75 homes per year to 15 homes in 2010. Guinan sees a need for builders to help homebuyers understand the role efficient and sustainable design plays in the overall quality of their home. "The demand side, that's where I think we need to put a lot of our attention," he said.

Homebuyers may begin the process focusing on amenities such as garage size and swimming pools, according to Guinan but energy-efficient features really begin to shine after the home is built. "After they move in, they're saying, 'Wow, this is great! I can't believe how well all this stuff works!" explains Guinan.

"We try to do the extreme best with what is available to us today," explains Guinan. "We think that our greatest success is our overall customer satisfaction. Our consumers are enjoying greater overall indoor air comfort and lower utility costs."

For More Information

www.buildingamerica.gov
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
eere.energy.gov/informationcenter

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

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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, showers, stairs, fireplaces, etc.	Yes			
Insulation fills entire cavities—no voids or compressed batts—Attic insulation level without gaps and covers entire attic floor	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			
MOISTURE MANAGEMENT (take a look at a house under construction before exterior siding is installed)				
Ground slopes away from house on all sides or drainage is addressed	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. Diverter flashing is used where roofs touch walls to direct water away from wall and into gutter.	Yes			
Air gap between stucco, brick, or masonry cladding and housewrap	Yes			
Overhangs for shade and to direct water away from walls	Yes			
No polyethelyene in interior side of wall assembly. No vinyl wallpaper on interior face of exterior 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 minimum 8 in. clearance	Yes			
AIR BARRIERS				
Follow ENERGY STAR Version 3.0 thermal boundary guidelines	Yes			
All penetrations through exterior walls sealed	Yes			
Careful sealing of sheetrock or exterior sheathing	Yes			
Recessed can lights rated for insulation contact and airtight (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 tested with blower door test	Yes			
Draft stops installed behind tubs, showers, stairs, and fireplaces, under kneewalls and cantilevered floors, and in floor joist bays spanning garages and living spaces	Yes			
Garage completely sealed from conditioned areas of house	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			
Slab or open web foundation preferred. If crawlspace, then unvented and insulated on interior walls.	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 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) as permitted by local code: - 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 - Hurricane strapping and rods - Borate-treated lumber	Yes			
OTHER				
Low VOC interior coatings	Yes			
Low VOC adhesives	Yes			
Low VOC 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.

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 Crawl Spaces
- Ventilation Requirements for Condensing Clothes Dryers
- Drywall Clips
- Rigid Board Insulation Installed as Draft Stop in Attic Kneewall
- Whole-House Mechanical Ventilation
- Residential Heating and Cooling Load Calculation Requirements
- Conditioned Attics.

We have included one of these Code Notes as a sample in this document, the Code Note for *Rigid Board Insulation Installed as Draft Stop in Attic Kneewall*. You will find it on the pages that follow.

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

The R-value of the kneewall sheathing insulation should equal the R-value of the exterior wall insulation.

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 III.

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

Air flow retarders are used to form a home's pressure boundary. They retard air flow through the home's walls, floors, and ceiling. Common air flow retarder materials include drywall that is taped and mudded at seams; OSB or plywood subflooring that is caulked at seams; plastic sheets placed between drywall and framing (should not to be used in hot and humid climates); exterior rigid foam insulating sheathing that is taped at seams; and building paper that is taped at seams.

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 Index

The HERS Index is a scoring system established by the Residential Energy Services Network (RESNET) in which a home built to the specifications of the HERS Reference Home (based on the 2006 International Energy Conservation Code) scores a HERS Index of 100, while a net zero energy home scores a HERS Index of 0. The lower a home's HERS Index, the more energy efficient it is in comparison to the HERS Reference Home.

Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference Home. Thus a home with a HERS Index of 85 is 15% more energy efficient than the HERS Reference Home and a home with a HERS Index of 70 is 30% more energy efficient.

Housing Expense-to-Income Ratio

The ratio, expressed as a percentage, which results when a borrower's total monthly housing expenses (P.I.T.I.) are divided by their gross monthly income. This is one of two ratios (debt-to-income ratio being the other) used by the mortgage industry to determine if a prospective borrower qualifies (meets the underwriting guidelines) for a specific home mortgage. Fannie Mae, Freddie Mac and FHA underwriting guidelines set an upper limit of 28% on this value for conventional loans but increase ("stretch") the ratio by 2% for qualifying Energy-Efficient Mortgages (EEM).

Housewrap

Any of several spun-fiber polyolefin rolled sheet goods for wrapping the exterior of the building envelope.

HSPF (Heating Season Performance Factor)

A measurement of the seasonal efficiency of an electric heat pump using a standard heating load and outdoor climate profile over a standard heating season. It represents the total seasonal heating output in Btu divided by the total seasonal electric power input in watt-hours (Wh). Thus, the resultant value for HSPF has units of Btu/Wh.

Infrared Imaging

Heat sensing camera which helps reveal thermal bypass conditions by exposing hot and cold surface temperatures revealing unintended thermal flow, air flow, and moisture flow. Darker colors indicate cool temperatures, while lighter colors indicate warmer temperatures.

Insulated Concrete Forms (ICFs)

Factory-built wall system blocks that are made from extruded polystyrene insulation. Steel reinforcing rods are added and concrete is poured into the voids, creating a very air-tight, well insulated and sturdy wall as the insulation is inherently aligned with the exterior and interior air barriers.

Insulation Contact, Air-Tight (ICAT) Lighting Fixture

Rating for recessed lights that can have direct contact with insulation and constructed with air-tight assemblies to reduce thermal losses.

Jump Duct

A flexible, short, U-shaped duct (typically 10-inch diameter) that connects a room to a common space as a pressure balancing mechanism. Jump ducts serve the same function as transfer grilles.

Load

The quantity of heat that must be added to or removed from the building (or the hot water tank) to satisfy specific levels of service, such as maintaining space temperature or hot water temperature at a specified thermostat setting (see also the definitions of energy and thermostat).

Low-E

Refers to a coating for high-performance windows, the "E" stands for emissivity or re-radiated heat flow. The thin metallic oxide coating increases the U-value of the window by reducing heat flow from a warm(er) air space to a cold(er) glazing surface. Low-E coatings allow short-wavelength solar radiation through windows, but reflect back longer wavelengths of heat.

MEC (Model Energy Code)

A "model" national standard for residential energy efficiency. The MEC was developed through a national consensus process by the Council of American Building Officials (CABO) and is the accepted national minimum efficiency standard for residential construction. Since MEC is a model code, it does not have the "force of law" until it is adopted by a local code authority. The MEC is used as the national standard for determining Energy-Efficient Mortgage (EEM) qualification, and it serves as the national "reference point" used by Home Energy Rating Systems (HERS) in the determination of energy ratings for homes.

Mechanical Ventilation

The active process of supplying or removing air to or from an indoor space by powered equipment such as motor-driven fans and blowers, but not by devices such as wind-driven turbine ventilators and mechanically operated windows.

Optimal Value Engineering (OVE)

A strategy for reducing thermal bridging by minimizing wall framing needed for structural support. Common techniques include 2x6 framing with 24" on-center spacing, single top plates where trusses align with wall framing below, properly sized headers, two-stud corners, lattice strips at exterior/interior wall intersections, and the elimination of excessive fire blocking and window framing. This results in much more open framing for insulation to improve energy efficiency and comfort.

Performance Test

An on-site measurement of the energy performance of a building energy feature or an energy using device conducted in accordance with pre-defined testing and measurement protocols and analysis and computation methods. Such protocols and methods may be defined by national consensus standards like those of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and the American Society for Test and Measurement (ASTM).

P.I.T.I.

An abbreviation which stands for principal, interest, taxes, and insurance. These generally represent a borrower's total monthly payment obligations on a home loan. The taxes and insurance portion are often paid monthly to an impound or escrow account and may be adjusted annually to reflect changes in the cost of each.

Pressure Boundary

The point in a building at which inside air and outside air are separated. If a building were a balloon, the rubber skin would form the pressure boundary. Where inside and outside air freely mingle there is no pressure boundary.

Pressurization Test

A procedure in which a fan is used to place a house, duct system, or other container, under positive or negative air pressure in order to calculate air leakage.

RESNET (Residential Energy Services Network)

The national association of energy rating providers.

Rated Home

A specific residence that is evaluated by an energy rating.

R-Value

Measures a material's ability to slow down or resist the transfer of heat energy, also called thermal resistance. The greater the R-value, the better the resistance, the better the insulation. The effective R-value of an insulation material will be reduced by gaps, voids, compression or misalignment. R-values are the reciprocal of U-values. See U-values for more information.

Sealed Combustion

Sealed combustion means that a combustion appliance, such as a furnace, water heater, or fireplace, acquires all air for combustion though a dedicated sealed passage from the outside; combustion occurs in a sealed combustion chamber, and all combustion products are vented to the outside through a separate dedicated sealed vent.

SEER (Seasonal Energy Efficiency Ratio)

A measurement similar to HSPF except that it measures the seasonal cooling efficiency of an electric air conditioner or heat pump using a standard cooling load and outdoor climate profile over a standard cooling season. It represents the total seasonal cooling output in Btu divided by the total seasonal electric input in watt hours (Wh). The SEER value are units of Btu/Wh.

Semi-Permeable

The term vapor semi-permeable describes a material with a water vapor permeance between 1 and 10 Perms. Water vapor can pass through a semi-permeable material but at a slow rate.

Shading Coefficient (SC)

The ratio of the total solar heat admittance through a given glazing product relative to the solar heat admittance of double-strength, clear glass at normal solar incidence (i.e., perpendicular to the glazing surface).

Site Energy

The energy consumed at a building location or other end–use site.

Solar Heat Gain Coefficient (SHGC)

SHGC measures how well a window blocks heat caused by sunlight. The lower the SHGC rating the less solar heat the window transmits. This rating is expressed as a fraction between 0 and 1. The number is the ratio of a window's solar heat admittance compared to the total solar heat available on the exterior window surface at normal solar incidence (i.e., perpendicular to the glazing surface).

Sone

A sound rating. Fans rated 1.5 sones and below are considered very quiet.

Source Energy

All the energy used 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 furnace 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 IV.
Acronyms and Abbreviations

AC air conditioner

ACCA Air Conditioning Contractors of America

ACH air changes per hour

ACI Affordable Comfort Incorporated

AFUE Annual Fuel Utilization Efficiency

AHRI Air-Conditioning, Heating, and Refrigeration Institute

AHU air-handler unit

AIA American Institute of Architects

AL air leakage

ALA American Lung Association

ANSI American National Standards Institute

ARRA American Recovery and Reinvestment Act

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

BEES Building Energy Efficiency Standard

BEopt Software developed by NREL for identifying optimal building design

BESTEST A benchmark for building energy simulation: Building Energy Simulation Test and Diagnostic Method

BFE base flood elevation

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

CDD cooling degree days

CEE Consortium for Energy Efficiency

CERL Construction Engineering Research Laboratory

CFL compact fluorescent light

CFM cubic feet per minute

CFR U.S. Code of Federal Regulations

CGSB Canadian General Standards Board

CO carbon monoxide

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)
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
FHA	Federal Housing Administration
FHD	first hour delivery
FIRM	Flood Insurance Rate Map
FSEC	Florida Solar Energy Center
GAMA	Gas Appliance Manufacturers Association
GenOpt	generic optimization program
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
HVAC	heating, ventilating, and air conditioning
HVI	Home Ventilating Institute
IAQ	indoor air quality
IBACOS	Integrated Building and Construction Solutions
IC	insulated ceiling
ICAT	insulation-contact air-tight
ICC	International Code Council
ICF	insulated concrete form
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
LED	light emitting diode
LEED	Leadership in Energy and Environmental Design
mcf	million cubic feet
MEC	Model Energy Code (replaced 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
NAHBRC	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
o.c.	on center
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

NFIP National Flood Insurance Program

NIBS National Institute of Building Sciences

NRDC Natural Resources Defense Council

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

SFHA special flood hazard areas

SHGC solar heat gain coefficient

SHW solar hot water

SLA specific leakage area

SIP structural insulated panels

TIP Termite Infestation Probability

TMY2 typical meteorological year weather data

TOU time of use

TXV thermostatic expansion valve

UA heat loss coefficient

UL Underwriter's Laboratory

USDA U.S. Department of Agriculture

USGBC U.S. Green Building Council

USGS U.S. Geological Survey

U-Value The thermal transmittance of a material, incorporating the thermal conductance of the structure along with heat transfer resulting from convection and radiation.

UV ultraviolet

VOC volatile organic compounds

VT visible transmittance

WUFI modeling program for simulating heat and moisture transfer

XPS extruded polystyrene

ZEH zero energy home

ZNE zero net energy

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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:

- Emerging Technologies Research and development of the next generation of energy-efficient components, materials, and equipment
- Technology Integration of new technologies with innovative building methods to optimize building performance and savings

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