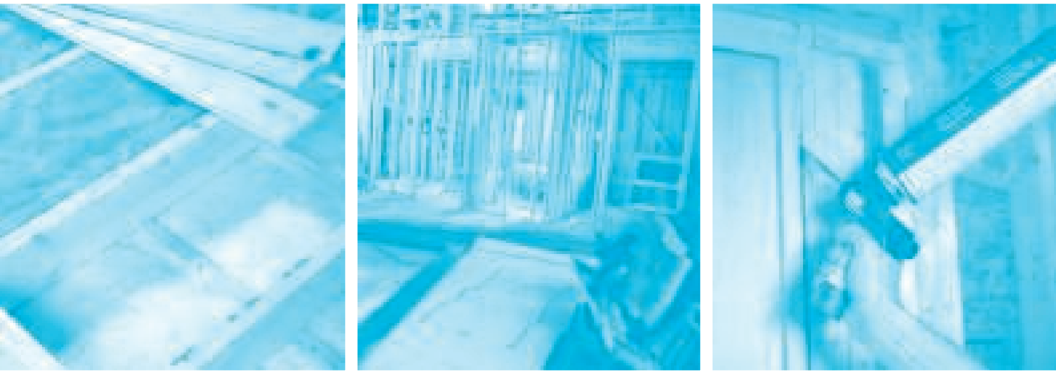
Field Guide

Residential New Construction



New Jersey ENERGY STAR® Homes

- New Jersey Energy Subcode
- Energy Efficient Residential Construction

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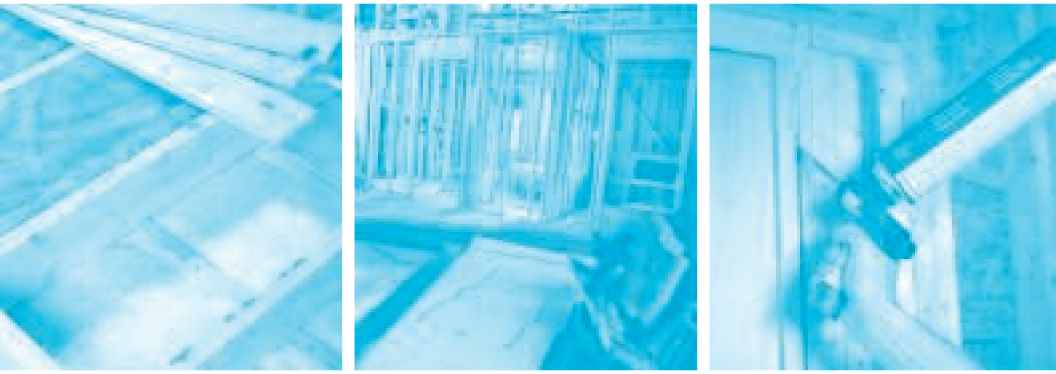
Residential New Construction



New Jersey ENERGY STAR® Homes

- New Jersey Energy Subcode
- Energy Efficient
  Residential Construction

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Acknowledgments

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Thank you!

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Introduction

What is “energy efficient” construction? Many people picture a space-age house, with a wall of south-facing glass. Others think about solar power or heat. Still others think of superinsulation and high-tech windows. Energy efficient construction can include these features, but it does not need to.

Any home design can be energy efficient, and with careful planning additional construction costs can be minimal. Builders who use the “house as a system” concept to plan and build their homes will have happier customers, more referrals and fewer callbacks, which in the long run will more than pay for any added costs. This guide serves as a starting point to help designers and builders understand the system approach, with an emphasis on meeting the requirements of the energy code and the New Jersey ENERGY STAR Homes Program.

About this guide

The purpose of this guide is to provide an overview of energy efficient residential new construction in the Northeast and mid-Atlantic states. The focus of the text and drawings in the guide are on three main subjects:

- **Compliance with the New Jersey residential energy subcode**—New Jersey has adopted a modified version of the 2006 International Energy Conservation Code (IECC). Although there are some state-specific differences, most of the code references in the guide can be used generally for any nearby state with an IECC- or MEC-based energy code.
- **New Jersey ENERGY STAR Homes Program**—New Jersey’s Clean Energy Program™ has established standards for qualification based upon the Environmental Protection Agency’s national benchmark for energy efficient new construction. This guide serves as a summary of the key components of a successful ENERGY STAR project.
- **A systems approach to building**—Understanding the way different components and materials interact in a building can reduce moisture problems, indoor air quality complaints, combustion safety problems, ice dams, and other expensive callbacks. This guide provides an overview of the key components of “house as a system” building, with a focus on energy performance.

Format

This guide is divided into sections that follow a typical construction sequence. Each section has convenient tabs marked on the edge of the page (e.g. foundation, framing, etc.). There are also special sections on the energy code, on ENERGY STAR, and on the "house as a system" approach to building.

The purpose of this guide is to provide an overview of the important issues related to building an energy efficient new home, and also to serve as a handy field reference that designers, builders and trades people can use at every step of the construction process. Each chapter has the following features in common:

- **Energy code**—The opening section of the chapter outlines what parts of the energy code you must pay attention to during that stage in the construction process. References are made to the code document itself so you can find the actual code language that relates to your situation.

  With the exception of Chapter 2 (which is devoted entirely to the New Jersey energy subcode), energy code requirements are highlighted in blue.

  Non-energy code requirements that are cited in the New Jersey version of the International Energy Conservation Code (IECC) (referred to as the New Jersey energy subcode) are both highlighted in blue and outlined in a blue box.

  Other (non-energy) code requirements that may be related to an energy concern are outlined by a blue box. Most of these requirements are drawn from the International Residential Code (IRC) for One- and Two-Family Dwellings, which serves as the basis for the New Jersey edition of the IRC. (see Appendix for ordering information).

- **ENERGY STAR**—Further suggestions are made about what steps you may take to help ensure ENERGY STAR guidelines are met at every step. Included are some suggestions about how costs in one area may be traded off against reduced costs in another area. Note that the ENERGY STAR compliance related information presented in this guide is based on the performance or Home Energy Rating System (HERS) based approach, as opposed to the prescriptive or "BOP" approach (see page 13), in addition to requirements set forth by the EPA, the New Jersey energy subcode and New Jersey's Clean Energy Program™.
- **Going further**—This guide is intended to be a concise reference; there are numerous situations which are beyond its scope. There are many references listed in the Appendix for further reading. One of these

resources stands out as exemplary, thorough, and easy to understand—the Energy and Environmental Building Association (EEBA) *Builder's Guide to Mixed-Humid Climates*. The EEBA *Builder's Guide,* referenced as such throughout this book, is an ideal resource for further reading and more detail drawings. See the Appendix for ordering information.

- **Detail drawings**—Most of the drawings in this guide are found at the end of each chapter. The drawings have shaded notes that refer to code requirements. In all drawings, the dotted line (in color) indicates the location of the primary air barrier.

Remember that this is book is only intended as a *guide*. Make sure any new details are included in your plans, and reviewed and approved by your local building official prior to construction. If instances occur where local code and regulatory requirements and the recommendations in this guide are not in agreement, the authority having jurisdiction should be consulted, and/or the local code and regulatory requirements should prevail. Be aware that the local code official may ask for engineering or other confirmation of the integrity of some of the design examples in this guide.

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The New Jersey ENERGY STAR Homes Program

Participating in the New Jersey ENERGY STAR Homes program helps builders:

- Save energy
- Improve Quality Assurance
- Increase customer satisfaction
- Increase sales
- Reduce callbacks
- Differentiate themselves in the market
- Construct better performing homes
- Obtain assistance with code documentation

This guide contains valuable information to help you build more efficient, healthier, and more durable homes while helping you to gain recognition as a better builder. By incorporating the guidance contained in this book into your construction practices and meeting all program requirements, your customer's energy bills will be lower, you will experience fewer callbacks, and you will gain differentiation in the market as a builder of homes that are certified to be more energy efficient. As an added bonus, significant incentives are available for eligible homes.

The New Jersey ENERGY STAR Homes program, under New Jersey's **Clean Energy** Program™, is sponsored by the New Jersey Board of Public

Utilities (NJ BPU). Participation is open to all builders of residential new construction or gut rehab projects, for all units meeting specific eligibility criteria.

For more information, call New Jersey's **Clean Energy** Program™ at 866-NJ SMART (866-657-6278) or visit www.njcleanenergy.com. Also see www.njenergystarhomes.com and www.energystar.gov to learn more about the state and nationwide ENERGY STAR Homes programs.

The New Jersey ENERGY STAR Homes program is subject to continued regulatory approval by the NJ BPU, and the NJ BPU reserves the right to change, modify, or cancel the program or program offerings without notice. It is the program participant's responsibility to ensure that the program materials they are using represent the most current standards and terms.

Eligible Structures

This program is only for new construction and complete gut rehabs. Homes that have not been enrolled and inspected prior to occupancy will be considered *existing construction* and are not eligible to participate. Multifamily and mixed use (residential/commercial) buildings can qualify if more than 50% of the projected total energy usage can be attributed to the residential units and each unit has its own gas or electric heating system and/or central air conditioning system. Energy analysis and any available incentives are determined by building type (see below). Be sure you know which categories apply to your project:

Building Classification Types

- **Single Family**—A structure containing one or two single family dwelling units. The dwelling unit(s) must have a roof, foundation, exposure on at least three sides, and a separate entrance for each unit. *Includes most single homes, twins and duplexes.*
- **Multiple Single Family**—A structure containing three or more dwelling units. Each unit has a separate entrance. *Includes most townhomes and garden apartments.*
- **Multiple Family**—A structure containing three or more dwelling units that share a common entrance. *Includes most apartment buildings.*

Note: The program has the discretion to determine the building type as necessary. The EPA ENERGY STAR Homes program is for 1-3 story buildings. Buildings over three floors require approval on a case-by-case basis; upgrades and compliance may be determined using an EPA approved methodology based on ASHRAE standard 90.1 (rather than the Home Energy Rating System). Building type and certification method will be determined at the time of enrollment.

New Jersey ENERGY STAR Homes Program Requirements at-a-Glance

At a minimum, all certified homes in New Jersey include the following:

- **Whole house thermal efficiency**—The building must be verified by program staff to achieve efficiency levels defined by the United States Environmental Protection Agency (US EPA), including compliance with the EPA Thermal Bypass Inspection Checklist (see page 14).
- **Energy efficient lighting**—Check www.njenergystarhomes.com for New Jersey specific requirements for incorporating ENERGY STAR lighting.
- **Mechanical ventilation system**—Buildings must include an automatically controlled ENERGY STAR qualified exhaust fan, heat recovery ventilator, or HVAC integrated whole-house ventilation system (see pages 20, 101).
- **High efficiency central heating and cooling systems**—ENERGY STAR qualified systems are required in most instances. Central air conditioning systems and heat pumps must be properly sized per ACCA *Manual J* (see pages 18, 93).
- **Air-tight ductwork**—All joints and seams in ductwork must be sealed with mastic compound (no tapes). Building cavities may not be used as ducts (i.e., panned joist returns are prohibited); the entire system must be fully ducted (supplies and returns).
- **Insulation verified**—Insulation is inspected prior to drywall and assessed a grade level based on installation quality. This assessment is a key factor in determining compliance with the whole house thermal efficiency requirement, described above.

Typical Features

A typical ENERGY STAR Home in New Jersey also includes most of the following energy features (see Table 1.1). Please note that this list is not a prescriptive list of minimum features. We encourage you to work with a Program Technical Representative to develop a package of energy features that will work best for you and your project. A prescriptive "Builder Option Package" developed by EPA for New Jersey's climate is available as an alternative compliance path for project enrollments after January 1, 2008, but requires higher levels of performance in some areas (such as lower duct leakage). New Jersey specific program requirements apply regardless of which method is used to determine upgrades.

Table 1.1 Typical Features of a New Jersey ENERGY STAR Home

Building Component/ Performance Element	Typical Minimum Specifications
Insulation	Complies with EPA Thermal Bypass Checklist
Basement/foundation walls	R-11 from footing to top of wall
Slab floor	R-11 under slab and around entire edge
Garage floors, overhangs	R-30 with full and permanent contact to subfloor
Walls, rim/band joists	R-19
Flat ceilings	R-38
Cathedral ceilings	R-30
Windows and skylights	U-factor of ≤ 0.35 and a SHGC of ≤ 0.39 (ENERGY STAR qualified); ≤ 18%of wall area
HVAC	Properly sized (ACCA *Manual J*), ENERGY STAR qualified, with programable thermostat(s)
Air Conditioning	14 SEER/12 EER, proper airflow and charge
Fossil fueled heating systems	Sealed combustion; 90 AFUE or higher for furnaces; 85 AFUE or higher for boilers
Heat Pumps	2.8 COP/13 EER or higher for ground source heat pumps; 8.5 HSPF/14 SEER or higher for air source heat pumps
Ductwork	Fully ducted supplies and returns, insulated and thoroughly sealed with mastic; located in conditioned space; program tested leakage ≤ 6% CFA (conditioned floor area).
Ventilation	ASHRAE standard 62.2 compliant, ENERGY STAR qualified and automatically controlled
Hot water heating	All pipes insulated
For all homes that are heated with a boiler	“Indirect-fired” storage tank system
For all other homes	Power-vented, sealed combustion stand-alone hot water heater with an Energy Factor (EF) of 0.62 or higher OR an on-demand water heater with an EF of 0.80 or higher.
Air Sealing (building envelope)	Air sealing and draft blocking to comply with EPA Thermal Bypass Checklist; program tested air leakage not more than 1 CFM per square foot (approx. 0.35 air changes per hour or less)
Lighting and Appliances	ENERGY STAR qualified

Understanding the Home Energy Rating System

Home Energy Rating System (HERS) ratings are used to compare the energy efficiency of a planned or completed home to a baseline energy-code compliant home. This comparison results in what is referred to as a rating “index,” which can be used as a simple measure of energy efficiency. An index of 100 indicates a home that just meets the 2006 IECC energy code (which serves as the basis of the current New Jersey energy subcode). Each point on the rating index indicates a 1% difference in energy consumption. **A lower index means less energy use.** The EPA uses this index as one of the parameters for certifying ENERGY STAR Homes. In New Jersey, the maximum allowable rating index for an ENERGY STAR Home is 85. In general, a home with an index of 85 points or less is at least 15% more efficient than a 2006 IECC code-compliant home.

This nationally recognized HERS system is based on tests, procedures, and software that have been standardized and approved by the National Home Mortgage Industry, the Residential Energy Services Network (RESNET), and the National Association of State Energy Officials (NASEO).

The ENERGY STAR certification standard is based on a combination of prescriptive and performance requirements. Blueprints, specifications and load calculations for each home are initially reviewed for compliance, and a preliminary energy rating is performed. If it is determined that the project will not meet program standards as proposed, a Program Technical Representative will work with you to establish one or more achievable upgrade packages. The upgrade package(s) will list all upgrades (such as insulation R-values, window thermal properties, air leakage specifications, lighting, appliances, and mechanical equipment efficiencies) projected to be the most cost effective upgrades necessary to bring all of the homes in your project into program compliance.

A pre-drywall inspection will be performed on each home in order to grade the quality of insulation installation, inspect air sealing and rough mechanical installation, and confirm compliance with the EPA Thermal Bypass Checklist. Upon completion of the home, final inspections and testing are performed to verify overall program compliance based on "as-built" conditions. Performance testing includes the use of diagnostic equipment to measure whole-house air leakage, duct leakage and system airflow.

10 Steps for Participation and Successful Completion

In order to receive full credit for program certification, participating homes or multifamily buildings must comply with all New Jersey ENERGY STAR Homes program requirements as outlined in this chapter. A list of your responsibilities is followed by an explanation of each step. If you need clarification, please contact your Program Account Manager or Technical Representative.

1. Submit proposed plans and specifications for initial review.
2. Receive and review your initial energy rating analysis and proposed upgrades.
3. Commit to program requirements and construction upgrades by signing the "Upgrade Package" and "Builder Acknowledgement" forms for the project.
4. Inform your subcontractors of their responsibilities.
5. Call the program scheduling department to schedule a pre-construction meeting with your Program Account Manager and Technical Representative, site personnel and subcontractors.
6. Schedule pre-drywall inspections.
7. Schedule final inspections.
8. Receive certification based on a final assessment of energy performance and program compliance.
9. Receive available incentives.
10. Promote and sell your New Jersey ENERGY STAR certified home(s)!

Program Participation in Detail

The following is a step-by-step guide to your participation in the New Jersey ENERGY STAR Homes program.

1. **Complete and submit project documents.** The following documents should be submitted as early as possible in the design phase:
    - A fully completed New Jersey ENERGY STAR Homes *Specification Submittal Form*
    - Architectural blueprints and site plans
    - Mechanical HVAC plans
    - *Manual J* cooling load calculations
    - Construction schedule, including the dates for groundbreaking and the projected build-out rate (if applicable)
2. **Review your initial energy rating analysis and upgrades.** Shortly after your submittal, you will receive a detailed report of your initial energy rating analysis and a proposed upgrade package with recommendations for achieving the ENERGY STAR level of performance and other program requirements.
3. **Commit to program requirements and construction upgrades by signing the enrollment forms for the project.** In some cases, there may be a number of potential upgrade combinations for you to choose from in order to reach the program standard. In other cases, options may be more limited. You will need to sign your

acknowledgement of program requirements and agree to incorporate a specific package of upgrades into your project.

- Sign your proposed upgrade package.
- Sign the *Builder Acknowledgement* form.
- Complete and submit the EPA ENERGY STAR *Partnership Agreement* (available online at www.energystar.gov).
- Return all documents, including your projected construction schedule.

4. **Inform your subcontractors of their responsibilities.** Ideally, you will have begun your participation early enough to write the program requirements and construction upgrades applicable to your project into your specifications and contracts with suppliers and trade subcontractors. Be sure to provide your contractors with the forms and information they will need to support your participation, including:
   - The EPA Thermal Bypass Checklist and Guide for insulation, air sealing, framing and other contractors working on the thermal boundary;
   - *Manual J* (or equivalent) sizing and quality installation verification requirements for HVAC contractors;
   - Mechanical ventilation and high efficiency lighting requirements for electrical suppliers and installers.
   - A copy of the *New Jersey ENERGY STAR Homes Field Guide*, which shows recommended construction practices.
5. **The pre-construction meeting** should occur at the building site, after framing and prior to rough HVAC mechanical installation in the first home of a project. To provide the best opportunity for program compliance, this meeting should include at least the builder, site supervisor, HVAC contractor, framing and insulation contractors. At this meeting, an Account Manager and Technical Representative will review the roles of your site personnel and contractors in meeting program requirements and the agreed upgrades for your project. The pre-construction meeting is required for the first home built in each project and for all custom built homes. Additional meetings will be conducted when requested by the builder, in the event of a change in personnel, or when deemed necessary due to non-compliance issues. **Allow approximately one hour for this meeting.**

⚠ **Please allow three business days** when calling to schedule any site meeting or inspection. To avoid delays in your construction schedule, please have a representative available on site at the time of inspection to correct any deficiencies as they are discovered. In the event that this is not practical, a re-inspection may be required to verify correction of failed items. **Be aware that re-inspections may impact your program costs or incentives.**

6. **The pre-drywall site visit** is used to inspect building components that are related to energy performance and the energy rating. This includes insulation, windows, HVAC systems, framing techniques, and general air sealing. Compliance with the Thermal Bypass Inspection Checklist will also be confirmed at this time. A home that does not comply with the checklist cannot be ENERGY STAR certified. A copy of the inspection report listing any items requiring correction will be provided.

⚠ **For additional information** on air leakage control and the Thermal Bypass Checklist (beyond what is provided in this guide), please review the Thermal Bypass Checklist Guide, available at www.energystar.gov. Click on “New Homes”, “For Residential Building Professionals” and then the new guidelines reminder.

7. **Final inspection and testing** to inspect and test the overall performance of the completed home with respect to program criteria includes:
   - **Visual inspection** of HVAC equipment, HVAC distribution systems, domestic water heating, insulation, lighting, appliances, and other energy rating-related components not installed or inspected at the time of the pre-drywall inspection.
   - **Air and duct leakage tests.** The air leakage test (blower door test) measures the air exchange between the inside and outside of the home’s air barrier. The duct leakage test measures the air leakage of the duct system to outside. An airflow test measures total system airflow for central air conditioning.

⚠ **Before scheduling a final inspection**, please ensure that:

- electric service has been connected and interior outlets are active.
- all door and window hardware has been installed.
- plumbing traps are filled or sealed.
- there is no other activity scheduled; the unit will be completely isolated for up to an hour.

NOTE: Revised load calculations are required if the installed system sizing has been modified since originally submitted.

8. **Certification:** The original energy rating(s) for your home(s) will be updated to include all of the information and performance data collected during the construction and inspection processes. Eligibility for program certification is based on:
   - passing all required inspections, including the EPA Thermal Bypass Checklist;

- meeting energy rating, performance, and prescriptive thresholds established by the EPA and the New Jersey ENERGY STAR Homes program;
- submission of program compliant verification of HVAC sizing;
- meeting all requirements for installation of specific equipment; such as program compliant lighting and mechanical ventilation;
- receipt of any payments assessed for additional re-inspections.

In the case of missing information, you will receive a letter specifying those items required for certification.

9. **Receive available incentives:** Once a home is certified, any available program incentives will be calculated and a check will be issued to the party identified on the *Builder Acknowledgement* form.

⚠ **Allow approximately 8-10 weeks** following your receipt of the Program Certificate for the check to arrive. Note that you may be required to provide a certificate of New Jersey State Tax Clearance prior to approval of incentive payments. Check with your NJ ENERGY STAR Homes Account Manager for more information.

10. **Promote and sell your New Jersey ENERGY STAR certified home(s).** Talk to your Program Account Manager about how the program can help you more effectively market your ENERGY STAR certified homes. Training for sales staff and creative support for advertising and promotions (e.g., the EPA "ENERGY STAR Homes Sales Toolkit") are available through the program at no cost!

Technical Requirements in Detail

In New Jersey, the national ENERGY STAR standard is supplemented by program-specific requirements. All requirements, both national and statewide, are summarized in this section.

ENERGY STAR Homes Standards

The EPA offers two compliance paths that can be used to achieve ENERGY STAR certification: performance-based, using the Home Energy Rating System (HERS, see below) and prescriptive, using a climate specific Builder Option Package (BOP). Both approaches require submission and review of plans and specifications as well as verification inspection and testing. Note that the BOP requires higher levels of performance in some areas (i.e., lower duct leakage). Speak with your New Jersey ENERGY STAR Homes Account Manager or Technical Representative if you are interested in this approach for new projects after January 1, 2008.

Performance-based qualification (HERS)

The primary feature of this compliance option is a requirement for a minimum level of energy efficiency (a maximum rating index of 85). The maximum HERS index is supplemented by the following list of mandatory requirements.

EPA ENERGY STAR Requirements

Thermal Boundary	Completed Thermal Bypass Inspection Checklist
Ductwork and air handler cabinet	Leakage ≤ 6 cfm to outside conditioned space / 100 sq. ft.
Central Air Conditioning	Properly sized
ENERGY STAR products	Include at least one ENERGY STAR qualified product category: • Heating or cooling equipment **OR** • Windows **OR** • Five or more ENERGY STAR qualified light fixtures, appliances, ceiling fans equipped with lighting fixtures, and/or ventilation fans
Whole house energy usage	HERS index: 85 or lower

This compliance method allows builders to “trade off” aspects of a home’s efficiency features to achieve a target without needing to meet every element of a rigid minimum standard, thereby adding flexibility to the design process. Accordingly, strengths in one part of a home’s design (e.g., high efficiency mechanical systems) may be used to offset relative weaknesses (e.g., average insulation levels) in another part of the design.

Thermal Bypass Checklist

The EPA has adopted a list of mandatory, energy efficient building practices that must be incorporated into the design and construction of all ENERGY STAR homes. This list, known as the *Thermal Bypass Checklist*, was developed to ensure the continuity and effective performance of a building’s thermal enclosure. It addresses a wide range of practices that includes—but is not limited to—properly enclosing insulation, protecting insulation from wind washing, filling in voids and sealing chases in the insulated attic plane, and identifying and sealing other bypasses that are commonly hidden in the building frame. All items on the checklist must be verified as having been completed before a house can be ENERGY STAR certified.

EPA Thermal Bypass Checklist Details as Illustrated in This Field Guide

Detail	Illustration	Comments
Air barrier/thermal barrier alignment	6.8	Checklist #1
Cantilevered floor	6.11	Checklist #3
Insulated floor above garage	6.12	Checklist #3
Dropped ceiling/soffit	6.13	Checklist #5
Attic knee wall	6.15	Checklist #2
Attic eaves; Attic knee wall; Atticaccess panel	6.16	Checklist #1 #2, #5
Attic eaves; Attic knee wall	6.17	Checklist #1, #2
Air barrier/thermal barrier alignment	6.18	Checklist #1
Piping penetration	12.4	Checklist #4
Chimney/flue chase	12.5	Checklist #4
Air barrier/thermal barrier alignment; Fireplace wall	12.6	Checklist #1, #2
Air barrier/thermal barrier alignment; Piping shaft penetration.	12.7	Checklist #1, #4
Shower/tub at exterior wall	12.8	Checklist #2
Recessed lighting	12.9	Checklist #5
Attic drop-down stair	12.10	Checklist #5
Staircase framing	Not shown	Checklist #2: Air barrier is fully aligned with insulated framing; any gaps are fully sealed with caulk or foam
Porch roof	Not shown	Checklist #2: Air barrier is installed at the intersection of porch roof and exterior wall
Whole-house fan penetration	Not shown	Checklist #5: An insulated fan cover is gasketed or sealed to the opening
Common walls between dwelling units	Not shown	Checklist #6: Air barrier installed to seal gap between common wall and structural framing

New Jersey-specific Technical Requirements

Insulation

Insulation R-values specified are nominal values for insulation only (not including drywall, sheathing, etc.). In assigning insulation R-values to your project(s), the lowest of the following values will be used:

- The manufacturer's listed value
- The value reported by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- The value reported by an accredited testing laboratory.

The quality of the insulation installation will also be inspected at the time of the pre-drywall site visit. R-values are adjusted from listed R-values, based on the quality of the installation. **The insulation installation quality will affect the energy rating index.**

The following is a list of requirements that apply generally to all insulated assemblies:

- Insulation must be installed in all exterior building areas and according to guidelines and specifications established by the insulation manufacturer and the Insulation Contractors Association of America (ICAA).
- Batt insulation must be fully lofted to the specified thickness and completely fill any cavity in which it is placed without any voids, gaps, air spaces, folds, or wrinkles.
- Insulation placement and condition must be consistent and uniform throughout all similar building components (e.g., all wall bays must be insulated to the specified level with no areas left uninsulated).
- Insulation must be protected from air movement and moisture, from both inside and outside the structure.
- Insulation must be installed around and under piping, wiring, etc. in a manner that minimizes reduction of R-value through compression.
- The flanges of faced insulation must be stapled to the building frame in a manner that minimizes compression of insulation material.
- Loose fill insulation must be installed to a uniform depth and completely fill any cavity in which it is blown to a sufficient density to ensure that no future settling or voids occur.
- A certificate verifying the product, bags, density, coverage area, and installed R-value must be provided for all loose fill insulation applications.

NOTE: Please provide program staff with a copy of the insulation certificate provided by your insulation contractor.

The following requirements are specific to **wall and rim/band insulation**:

- All walls (including attic walls) must be fully insulated and enclosed with an air barrier on all six sides.
- Wall insulation should be tight to all six sides of wall cavities, so as to eliminate convection within the cavity. Install top and/or bottom plates in locations where they are not present.

- Install insulation behind plumbing pipes and HVAC duct risers in exterior walls and garage partitions. Insulation should also be set behind and trimmed around electrical outlets, boxes, and wiring.
- All wall insulation shall be applied in a manner that protects the insulation from moisture.
- Insulated basement framed walls that are spaced off foundation walls must be blocked and air sealed at the top of the wall and around all openings (such as windows and doors).
- Install a minimum R-3 thermal break on the exterior side of all metal framed assemblies. Without a thermal break, a wall with metal studs will perform at an overall R-value significantly less than the product's rated value. Contact your Program Technical Representative for additional information.

The following requirements are specific to **ceiling insulation**:

- Insulation must cover the entire attic plane, including the top plates of all exterior walls.
- A channel that allows for the free passage of air between the insulation and the roof sheathing must be included in all ventilated attics (including ceiling-roof combinations such as cathedral ceilings).
- Unventilated roof systems must be insulated with either spray foam or rigid, board foam that is sealed at the seams. The foam must be installed in such a way that the roof structure is protected from moisture. Contact a Program Technical Representative for more information.
- Install all loose fill insulation in attics to a depth and density that will minimize future settling. Settled insulation thickness—and not initial installed depths—will be used to determine R-value. Attic eave baffles must be installed to prevent windwashing of this insulation.

See Chapter 12 to learn more about insulation code requirements, recommended practices, details, etc.

Windows and Skylights

U-factor and Solar Heat Gain Coefficient (SHGC) ratings for windows, skylights (and glazed doors) are for the entire unit, including glass, edge spacers, frame, etc. National Fenestration Rating Council (NFRC) certification is the primary resource for all window and skylight ratings. If NFRC ratings are not available, provide the manufacturer's calculations (preferably in electronic format using Windows™-based software). Where NFRC stickers are present, they should remain attached to the windows/skylights until at least the pre-drywall inspection. If they are removed prior to the pre-drywall inspection, written documentation of all U-factors and SHGC must be provided at the time of inspection.

See Chapter 7 to learn more about code requirements, recommended practices, details, etc. for windows.

Doors

An exterior grade, insulated and weatherstripped door must be installed at all exterior entrances, including basement bulkhead entrances and attic kneewalls. Doors to basements that are both unheated and uninsulated at the foundation walls must also be weatherstripped.

See Chapter 7 to learn more about code requirements, recommended practices, details, etc. for doors.

Heating Systems

The following is a list of requirements that apply to heating systems.

- To qualify for incentives, heating equipment must be ENERGY STAR qualified and have an efficiency rating that is at least as high as the minimums provided in Table 1.2. For new projects enrolling after January 1, 2008, all heating and cooling equipment must be ENERGY STAR qualified to be eligible for program certification. If no ENERGY STAR qualified equipment is available for a specific equipment configuration, the highest available alternative must be used (and documented for approval).

Table 1.2 Minimum Efficiency Standards for Heating System Incentives

Equipment	Minimum Efficiency
Gas Boiler	85 AFUE (Annual Fuel Utilization Efficiency)
Gas Furnace	90 AFUE (Annual Fuel Utilization Efficiency)
Air Source Heat Pump	8.5 HSPF (Heating Seasonal Performance Factor)
Ground Source Heat Pump	2.8 COP (Coefficient of Performance)

- Efficiency and capacity ratings are based on certified listings in the Air Conditioning and Refrigeration Institute (ARI) *Unitary Directory of Certified Products*, and/or the Gas Appliance Manufacturers Association's (GAMA) *Consumers' Directory of Certified Efficiency Ratings.*
- The components of air source heat pump system (i.e., the indoor and outdoor coils) must be matched and listed by ARI for efficiency and capacity ratings.
- Ground source heat pump systems must be designed and installed according to the manufacturer's instructions/specifications and the standards put forth by the International Ground Source Heat Pump Association (IGSHPA). When designing and installing an open loop system, it is particularly important to pay close attention to pumping power. Excessive pumping power will lead to reduced efficiency.

See Chapter 8 to learn more about code requirements, recommended practices, details, etc. for heating systems.

Cooling Systems

The following requirements apply to cooling systems.

- Central air conditioning equipment must be installed according to the manufacturer's instructions/specifications. The components of central air conditioning systems (i.e., indoor and outdoor coils) must be matched and listed by ARI for efficiency and capacity ratings. Airflow across the indoor coil must be verified by measurement to be within 10% of the manufacturer's specifications. The system must be "charged" with the proper amount of refrigerant.
- All cooling systems must be properly sized (see below for more detail relating to this requirement).
- To qualify for incentives, cooling equipment must be ENERGY STAR qualified. For new projects enrolling after January 1, 2008, all heating and cooling equipment must be ENERGY STAR qualified to be eligible for program certification. If no ENERGY STAR qualified equipment is available for a specific equipment configuration, the highest available alternative must be used (and documented for approval).
- Efficiency and capacity ratings are based on certified listings in the Air Conditioning and Refrigeration Institute (ARI) *Unitary Directory of Certified Products.*

Electric central air conditioning equipment must be documented to be no greater than 115% (up to 1/2 ton or 6000 Btu/hr over) of the calculated Air Conditioner Contractors of America (ACCA) *Residential Load Calculation Manual J, 7th Edition* (or equivalent) cooling load. Calculation parameters are provided below. Electric central cooling equipment that does not meet the sizing criteria will render the dwelling unit ineligible for program participation (and associated incentives) unless it is the smallest qualifying equipment available for the load.

- Equipment must be sized using 97.5% outdoor design temperatures. See Table 1.3 for the outdoor design dry bulb temperatures referenced by ACCA *Manual J* for New Jersey. Contractors should use the closest and most appropriate of these outdoor design temperatures (based on the location of the equipment installation) in their sizing calculations.

Table 1.3 Outdoor Design Temperatures for New Jersey (from ACCA *Manual J*)

Location	Outdoor Design Temperature
Atlantic City	89° F
Long Branch	90° F
Newark	91° F
N. Brunswick	89° F
Paterson	91° F
Phillipsbury	89° F
Trenton	88° F
Vineland	89° F

- The indoor design temperature must be no lower than 75° F; indoor relative humidity must be set at either 50% or 55%.
- Cooling loads are particularly sensitive to window type, area, and orientation. The specified window U-factor and Solar Heat Gain Coefficient (SHGC) must be used in the load calculations. Use dimensions of rough openings to calculate window areas.
- The infiltration rate must be set to "best."
- ACCA Appendix A-5 must be used for homes that have more than three (3) recessed lighting fixtures.

⚠ Load calculations should be submitted as early in your project schedule as possible (preferably at the time of enrollment) so that program staff can assist you in clarifying sizing requirements, if necessary. This includes copies of the computer program printout or calculation forms—including all assumptions and inputs used in the calculations.

See Chapter 8 to learn more about code requirements, recommended practices, details, etc. for cooling systems.

Mechanical Ventilation

A mechanical ventilation "system" brings fresh air into the home for the purpose of improving indoor air quality. Mechanical ventilation systems run either continuously or intermittently with automatic controls (e.g., a 24-hour timer). All homes are required to have automatically controlled mechanical ventilation that is ducted to the outside and capable of delivering fresh air in accordance with ASHRAE Standard 62.2-2004 (i.e., the minimum ventilation rate is determined by the following formula: CFM = (0.01 x CFA) + (7.5 x OCC), where CFA = Conditioned Floor Area and OCC = number of occupants = number of bedrooms + 1) . The following types of systems are acceptable:

- ENERGY STAR qualified exhaust fan systems, including ceiling, wall mounted, or remotely installed in-line fans;

- HVAC integrated systems, only if the air handler has a fan that is run by an electronically controlled or brushless DC motor ("ECM");
- HRV (Heat Recovery Ventilation) or ERV (Energy Recovery Ventilation) systems.

⚠ In order to remain eligible for program participation and all applicable incentives, documentation of actual ventilation components purchased and installed must be provided to program staff prior to certification.

See Chapter 9 to learn more about code requirements, recommended practices, details, etc. for mechanical ventilation systems.

Ductwork

The following requirments apply to air distribution systems:

- All air distribution systems must be fully ducted (i.e., use of panned joists or wall cavities for supply or return air is prohibited).
- All seams and joints on both supply and return duct systems must be adequately sealed with mastic compound meeting UL-181 specifications. This sealing requirement also applies to all supply and return duct boots, stackheads, and boxes where they meet drywall or the subfloor.
- **The use of any tape as a sealant is prohibited, unless it is used to seal an access to a component of the mechanical system.**

Controls

Programmable thermostats should be installed in all ENERGY STAR homes. An ENERGY STAR labeled thermostat will meet all of the following specifications:

- The capacity to automatically set-up or set-back the house temperature to control each heating and cooling zone.
- At least two set-up/set-back periods per day, and at least two different daily programs per week.
- Adaptive recovery to control heat pump systems with electric auxiliary heat. Adaptive recovery thermostats ramp up to the setpoint temperature in response to the outdoor temperature and, in so doing, minimize or eliminate use of supplemental electric resistance heaters.

Lighting & Appliances

Check current requirements at www.njenergystarhomes.com for installation of ENERGY STAR qualified light fixtures. Credit will be given only for fixtures installed in high-use locations (*excludes* closets, garages, unfinished basements, or other locations where lights are typically on for less than two hours per day). The efficiency of lights and appliances can impact the energy rating index; program participants are encouraged to use ENERGY STAR qualified light fixtures, compact fluorescent light bulbs (CFLs), and appliances wherever possible over and above program requirements.

⚠ Documentation of actual lighting and appliance components purchased and installed must be provided to program staff prior to certification. Manufacturer, make, and model of ENERGY STAR qualified lights and appliances are available through your Program Account Manager or Technical Representative, or by visiting the EPA ENERGY STAR website at www.energystar.gov.

Guidelines for Specific Construction Issues

Health and Safety Guidelines

To promote the general health and safety of the occupants of dwellings constructed to the New Jersey ENERGY STAR Homes program standards, the following guidelines are recommended for the construction of your dwelling units:

- All materials, systems, and appliances should be installed in accordance with manufacturer specifications and instructions.
- Residential dwellings that are enrolled in the New Jersey ENERGY STAR Homes program must meet or exceed all applicable New Jersey building codes.
- When considering code requirements, remember that homes built to program standards (including air infiltration reduction measures) will have an air infiltration rate “known to be less than 0.40 air changes per hour (ACH).” This low level of air infiltration will result in more stringent combustion air requirements.
- Install direct vent or power vented heating and water heating systems, or provide outside combustion air for any Category I or Category II vented systems (combustion appliances that operate with a non-positive vent static pressure) installed within the pressure boundary of the house. Direct vent appliances are connected and installed so that all air for combustion is derived from the outside atmosphere and all flue gases are discharged to the outside atmosphere. Power vented appliances operate with a positive vent static pressure and utilize a mechanical fan to remove combustion gasses from the appliance to the outside atmosphere.
- Select solid fuel fireplaces and stoves that meet the US EPA emissions standards, and install glass doors on all fireplaces.
- If the required mechanical ventilation system installed cannot also function as the local exhaust fan for an individual bathroom, a supplemental fan is highly recommended. Appropriately sized and vented kitchen fans or range hoods are also recommended.

- Carbon monoxide detectors should be installed in any dwelling unit that contains combustion equipment or is attached to a garage.
- Moisture problems must be mitigated. If moisture-related conditions (e.g. mold, mildew, standing water, etc.) are observed by a representative or agent of the program anywhere within the dwelling's systems or structure, you may be asked to provide evidence of successful mitigation prior to final certification and incentive payment by the program.

⚠ At their sole discretion, program staff reserve the right to withhold certification and incentives at any time based on unmitigated health, safety, or durability considerations. Program requirements do not preempt or supersede New Jersey building codes, and program staff do not determine whether applicable health, safety, and building codes have been met.

Complete Gut Rehabilitation/Restoration Guidelines

The following guidelines will help ensure that all gut rehab/restoration projects meet the New Jersey ENERGY STAR Homes program performance standards:

- Due to the possible impact on design/program participation, it is the program participant's responsibility to identify and address all building code, zoning, and/or historical preservation compliance issues as early in the construction process as possible.
- Complete all demolition/removal work through to the exterior shell of the structure so that all surfaces of all external building cavities are exposed and visible. An assessment of possible energy impacts of existing conditions and a determination of appropriate program compliance recommendations will be conducted at the pre-construction inspection, which is mandatory prior to any rehab/restoration construction work
- New doors and windows will almost always be required in order to meet performance standards.
- Install a solid core door leading to unheated space (such as a basement or garage), with appropriate weather-stripping devices in place.
- Masonry or concrete components that exhibit signs of excessive wear and/or deterioration may require the application of an approved sealer or continuous cementitious parge coat.

Air sealing and demonstrating compliance with the EPA Thermal Bypass Checklist can be particularly challenging when performing a gut rehabilitation or restoration. Pay particular attention to eliminating all air passageways to the exterior, attic, and basement, and between dwelling units. Recommendations include, but are not limited to:

- Where plank sheathing is used, consider the use of spray foam insulation.
- Cover planking with rigid or flexible sheet sheathing products such as plywood or plastic house wrap.
- Where balloon framing is present, install sealed draft stops between the basement and the first floor, the attic and the top floor and any intermediate floors.
- Install solid draft stops between top plates and the inside of brick exterior walls at all locations adjacent to attic spaces.
- Air seal and insulate all ceilings above unheated basements and all exposed ductwork in unheated space. Alternatively, the basement walls may be fully sealed and insulated.
- Seal all penetrations (HVAC, plumbing, electrical, etc.) to unheated space through both top and bottom plates.

Modular Construction Guidelines

Dwellings that consist either partially or entirely of factory-constructed components intended for assembly onto a permanent structural foundation are eligible for participation in the program. The following procedures apply:

- The initial specifications submittal and rating process are the same as for all construction types. However, in-plant verification of the Thermal Bypass Checklist is required. Contact information for the modular manufacturer must be provided at the time plans and specifications are submitted so program staff can: 1) establish the existence of an in-plant verifier; and 2) obtain a copy of the completed Thermal Bypass Checklist.
- In lieu of performing the initial inspection after insulation and prior to dry-wall, an inspection must be performed within one week (5 working days) after the setting of the structure (complete assembly on the permanent foundation). Although insulation and drywall are already in place, this inspection focuses on the air sealing issues and installation processes specific to this type of construction.
- For dwellings that have both factory-constructed and site-constructed components, an initial inspection must be completed after insulation and prior to drywall for the site-constructed sections.

As for all construction types, each unit must have been enrolled and inspected prior to occupancy in order to remain eligible for certification.

2

New Jersey Energy Subcode

This Guide Is Not the Code

The current residential energy code for New Jersey is a modified version of the 2006 International Energy Conservation Code (IECC), referred to as the New Jersey energy subcode. A New Jersey Edition of the IECC-2006, which incorporates all of the New Jersey amendments, is available from the International Code Council at www.iccsafe.org. Note that this Field Guide portrays these energy code requirements as completely and accurately as possible at the date of publication. However, building codes are subject to interpretation, as well as periodic changes. If you have any questions about the details of the code language, refer to the actual language in the current version of the code (see Appendix for ordering information). Wherever possible, references are made to the specific section number from the code so you can look it up. If questions of interpretation arise, contact the codes and standards division of the New Jersey Department of Community Affairs (see Appendix for contact information).

Applicability (IECC 101.4)

The 2006 IECC New Jersey Edition applies to all types of construction, both residential (Chapter 4) and commercial (Chapter 5, which references the 2004 ASHRAE Standard 90.1). The focus of this Field Guide is on low-rise (three stories high or less) residential new construction (detached one- and two-family dwellings and low rise multifamily buildings, including townhouses).

General Requirements

The following is a summary of the general requirements of the code (referred to in the code as mandatory provisions). You must follow all of the requirements that are applicable to your building project, regardless of the method that is chosen to demonstrate energy code compliance.

- **Air leakage** **(IECC 402.4)**—Leaks must be sealed between conditioned space and outdoors, and between conditioned space and unconditioned space. The code specifies locations that must be sealed, and gives examples of ways to seal them. Many examples of acceptable air sealing are found in Chapters 6 and 11, with code requirements highlighted in blue.
- **Moisture control** **(IECC 402.5)**—Unless ventilation is provided to allow moisture to escape, a vapor retarder with a perm rating of 1.0 or less (tested in accordance with Procedure A of ASTM E 96) is required on the winter warm side of insulated walls, floors and ceilings. (**Exception:** a vapor retarder is not required in locations where there are 5,499 Heating Degree Days (HDD) or fewer (see Table 2.1).
- **Mechanical systems** **(IECC Section 403)**—This section has requirements for controls, duct construction, duct insulation, pipe insulation, mechanical ventilation and equipment sizing. See Chapters 8 and 9 for specific requirements.

Compliance with these sections is **mandatory**, regardless of the code compliance path.

Compliance Analysis

Before you start building, you need to prepare a design that ensures you will comply with the code. In fact, you must do this before you can get a building permit. This is no different from any other part of the code, such as egress requirements, structural loads, etc. There are several methods that can be used to demonstrate energy code compliance; compliance can be demonstrated:

- prescriptively, by selecting a package of insulation R-values and glazing U-factors from tables that are included in the code;
- by performing manual U-factor calculations on a component-by-component basis, and showing that values are less than code-specified maximums;
- using RES*check* software;
- by participating in the New Jersey ENERGY STAR Homes program;
- using the simulated performance alternative (formerly referred to as “Systems Analysis”; see IECC Section 404).

Regardless of the method that is used, the list of specifications associated with demonstrating compliance should include the insulation R-values for all floors, walls, and ceilings and the U-factors for all windows, doors, and skylights. **Note that the notes in the illustrations related to code details**

do not mention R-values. That is because the R-values are determined by your compliance analysis. Most of the code-related notes apply to the general requirements (summarized on the previous page).

Prescriptive Compliance (IECC Section 402)

This method allows you to look up R-values and U-factors from tables. The prescriptive specifications from these tables provide minimum performance values for components of the thermal boundary, based on (1) the climate zone of the location where you are intending to build and (2) the window area of the house (expressed as a percentage of gross wall area). There are several different packages to choose from. These prescriptive packages can be downloaded from the internet by visiting the "Energy Codes" section at www.nj.gov/dca/codes (specifically "Bulletin 07-2").

The primary advantage of using the prescriptive compliance method is that it is comprised of a simple list of performance standards that does not require energy modeling or calculations (other than window-to-wall ratio) to determine whether a home is energy code-compliant. On the other hand, there is very little flexibility associated with this compliance method and in general, the level of stringency associated with the specifications is higher than what it might be using the other compliance methods. There are additional considerations for buildings that include steel-framed assemblies and/or mass walls. See IECC 402.2.3 and 402.2.4 for details.

Total UA Compliance (IECC 402.1.4)

The total UA for a house is the sum of the values that are produced when the U-factors (U) for all of the individual components of the thermal boundary are multiplied by the areas (A) of those components. If calculations can be used to demonstrate a level of energy efficiency that is at least as high as it would be if prescriptive specifications were used (i.e., if the calculated UA is less than or equal to what it would have been otherwise), then the building shall be deemed energy code-compliant. U-factors must be calculated on a component-by-component basis and compared to the maximum U-factors listed in IECC Table 402.1.3. Note that this table has been modified for New Jersey; the table that is included in the non-state-specific version of the 2006 IECC should be disregarded.

Compliance using RES*check* Software

The simplest way to perform UA tradeoffs—and to demonstrate compliance in general—is to use RES*check*, an easy-to-use software program that facilitates the compliance process. Using RES*check*:

- **Allows significant flexibility** for determining compliance specifications for most situations.

- **Allows the designer to trade off** better performance in one area, like higher R-values of insulation, to offset poorer performance in another, like higher U-factor windows. It also allows trading off higher efficiency heating equipment to offset a less efficient building shell.
- **Requires that you calculate square foot areas** for all insulated components of the building such as walls, floors, ceilings, windows, and doors.
- **Is the most forgiving** in the sense that it will be the easiest way to pass the compliance test for most houses.

The software is available for free at: www.energycodes.gov. Click on RES*check* under "Free Software Downloads." Instructions are also available with the software, and context-sensitive help menus are built in.

Some things to remember with RES*check*:

- **Always start by making sure the appropriate location and code have been selected.** The 2003 IECC (NOT the 2006 IECC) should be selected under "Code" in the menu bar at the top of the screen. The location (or municipality) that is selected should be based on the climate zone where you intend to build. See Table 2.1 (below) for the appropriate location.
- Use *gross* wall areas, including all windows and doors. RES*check* subtracts window and door area automatically.
- Remember to include band joist areas—except band joists of insulated floors—in the net wall area.
- Use window frame size or rough opening for window area, not the glass or sash size.
- Input the actual heating and cooling equipment efficiencies if you are using equipment that is rated above the code minimum.
- **The total UA shown on the compliance report ("Your UA") must be at least two percent less than the maximum UA for the home to be deemed compliant.**

Table 2.1 New Jersey Climate Zones

Heating Degree Days	Counties	RES*check* Municipality
4,500–4,999	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Salem	Audubon, NJ
5,000–5,499	Essex, Hudson, Mercer, Middlesex, Monmouth, Ocean, Union	Lakewood, NJ
5,500–5,999	Bergen, Hunterdon, Morris, Passaic, Somerset	Maplewood, NJ
6,000–6,499	Sussex, Warren	Hackettstown, NJ

ENERGY STAR Compliance

Compliance with the energy code can also be demonstrated by participating in the New Jersey ENERGY STAR Homes program. A copy of the *Builder Acknowledgement Form* should be submitted along with your permit application. Confirmation of a Final Inspection "pass" status and/or final certification may be required when applying for the Certificate of Occupancy. See Chapter 1 to learn more about participating in this program.

Performance-based Compliance (IECC Section 404)

This compliance method is based on a simulated energy performance analysis. Compliance is shown to be demonstrated when the projected, annual energy cost associated with the proposed home is less than or equal to the annual energy cost associated with a theoretical reference home (which is referred to in the code as the "standard reference design"). The parameters for the detailed calculations that must accompany this analysis are spelled out in IECC Tables 404.5.2(1) and 405.5.2(2). The approach is very similar to the one used to generate a Home Energy Rating System (HERS) index (described on page 13.)

The primary advantage of this method of demonstrating energy code compliance is that it allows builders to "trade off" different aspects of a home's efficiency features to achieve the required level of efficiency (energy cost) without meeting the rigid minimums that are the basis of the prescriptive compliance method. And unlike prescriptive compliance, the tradeoffs are not limited to UA equivalencies. The performance-based energy analysis takes into account a much wider range of efficiency features, including-but not limited to-insulation levels, window U-factors, orientation, mechanical efficiencies, air infiltration, and service water heating. Although theoretically you could use these tradeoffs to eliminate the need to insulate one or more building components or portions thereof, this approach is not recommended. It will result in an unbalanced investment, by requiring overcompensation somewhere else, and an increased potential for comfort or moisture problems due to cold surfaces.

Plan Review and Field Inspections

Building inspectors will be looking to see that the house meets the general requirements summarized earlier in this chapter, as well as the specifications that you submitted when you applied for the building permit. Insulation R-values and equipment efficiencies in the house must equal or exceed the specifications from the compliance analysis, and you must follow all general requirements, in order to pass code inspection. Window, door, and skylight U-factors must be equal to or less than the U-factors from the analysis. Note these issues:

- Insulation must be installed properly (see pages 131-134), and with R-value markings visible.
- The requirements for verifying window performance are on page 85. NFRC rating labels should remain attached to all windows until they are checked by a building code official.

Sunrooms

A sunroom is defined as "a one story structure attached to a dwelling with a glazing area in excess of 40 percent of the gross area of the structure's exterior walls and roof". If a sunroom addition is open to the existing structure, it must satisfy the same requirements that would apply to a newly built home or addition. If the sunroom is thermally isolated (i.e., it is separated from the conditioned space or the main building or structure by a sealed, insulated wall, door and/or window) and conditioned, then:

- The sunroom must have either a separate HVAC system, or be served by an HVAC zone that is separate from the rest of the building or structure.
- The minimum ceiling insulation R-value shall be R-19 in locations that have 5,499 Heating Degree Days (HDD) or less and R-24 in locations that have 5,500 HDD or more (see Table 2.1 for New Jersey climate zones). The minimum wall R-value shall be R-13.
- The maximum window U-factor shall be 0.50 and the maximum skylight U-factor shall be 0.75.
- Any new walls, doors, and/or windows separating the existing structure from the sunroom must meet the associated requirements for the main body of the house.

A thermally isolated sunroom that is not heated does not need to comply with the energy code.

3

House as a System

Moisture related failures, indoor air quality problems, combustion backdrafting, sooty "ghost" stains on walls and carpets, mold and mildew in homes—callbacks of these types have increased dramatically in recent years. They are often blamed on houses that are "over-insulated" or "too tight." Although these problems were unusual in the days when houses were leaky and uninsulated, they are not *caused* by these factors alone. In fact, it is rare to find a failure of this sort which is caused by any single factor. These problems are usually the result of the different components of the house interacting, as a system, in ways that were not foreseen by the builder or designer.

Over the last century, the introduction of new materials such as plywood sheathing and housewraps has changed the way houses are built. Houses are tighter, and there are many more pollutants found inside, generated by the occupants and by the building materials themselves. As energy costs have risen, insulation has become a necessity. The advent of central heating systems with automatic controls has contributed to increased consumer demand for comfort in their homes, and heating systems have become more efficient. In addition to advances in building construction, consumer lifestyle changes have altered homeowners' expectations. People want houses that are larger and more complex, with more features than ever before. All of these things have an effect on each other, and on the operation of the house system.

It is becoming widely recognized that many of the failures and warranty callbacks in new houses are a result of mis-applying new technologies or materials—not because they were installed "wrong," but because nobody predicted the effect that a change in one area might have on some other part of the the house. Often, the complexities of a building make it difficult to find the source of a problem, even after it occurs. Consider the following example (a true story):

Building Failure Case Study

A homeowner calls in a building science specialist to help with a moisture problem during the heating season. The house has condensation and mold in the attic and living space. The specialist arrives at the property, and an interview of the client shows that this is an ongoing problem; in fact, it has gotten worse. The customer had previously consulted with several contractors and the local utility company, and was informed that the solution to the moisture in his attic was to add ventilation. When he asked how much ventilation to add, he was told, “You can’t over-ventilate an attic.” He was also warned that soffit vents would do him no good if they were blocked by insulation. So he installed extra soffit ventilation and pulled the insulation back from the eaves to allow free air flow. Since the hip roof did not have much ridge area, the homeowner installed two turbine vents to satisfy the need for upper ventilation.

On inspecting the house, the specialist finds the following:

- The roof sheathing is damp and spotted with mold.
- The roof has continuous soffit vents and two turbine vents.
- The fiberglass batts in the attic have been pulled away from the eaves approximately 18".
- There is black mold growing on the second floor ceilings in rectangular patterns around the house perimeter.
- The relative humidity in the living space is measured to be higher than normal for winter conditions.
- The bathroom exhaust fans are vented outdoors, but have a very low air flow rate and are rarely used.
- A blower door test confirms that the building is fairly tight, but there is still communication between the attic and the living space, by means of top plates and an open plumbing chase.
- The clothes dryer in the basement has a vent to outside, but the hose is disconnected.
- There is a piece of plywood in the basement loosely covering a sump, which leads to a small stream running underneath the building.

It is clear to the specialist what has happened. First, the turbine vents drew air not only through the soffit vents as intended, but also drew more air than ever from the house into the attic. With the high levels of humidity in the living space, combined with the fact that leaks into the attic had never been sealed, the turbines were moving moisture into the attic even more quickly than before. Second, in his effort to open up the soffit vents, the homeowner removed the insulation. This created a cold surface all around the perimeter of his upstairs ceiling for moisture to condense, and mold to grow on. No one thought to look in the basement when diagnosing the problem, but this is where the source of the moisture was lurking all the time.

The specialist wrote up a repair punch list as follows:

- Cover the sump in the basement with a gasketed cover to discourage the water from evaporating into the house.
- Re-connect the dryer hose.
- Seal leaks into the attic, to minimize the path for moisture to reach the attic.
- Replace the turbine vents with standard roof vents.
- Re-insulate the perimeter of the attic.
- Install baffles to allow free air movement through soffit vents and to direct the air over, rather than through, the insulation.
- In at least one bathroom, install a continuous running, low-level exhaust fan vented to the outside, to ensure the proper ventilation rate.

When the building was inspected the following year, the moisture was gone and the occupants were healthier and more comfortable.

Why did this building fail? The answer lies in the the fact that nobody evaluated how one aspect of the building's construction might affect another part of the building. Additionally, nobody evaluated the effects of occupant behavior on the performance of the building. When the foundation was built, it was noted that the underground water might cause flooding problems, so the decision was made to include a sump. When the framing, exterior shell, and interior finish were installed, each contractor took enough care that the building ended up with a relatively air-tight shell. But the builder did not realize that by doing these two things successfully, they had created a highway for moisture to pass through the interior wall cavities directly from basement to attic. Bathroom fans were installed and properly vented outside, but nobody predicted that the occupants wouldn't use them.

Why was the moisture problem mis-diagnosed? This is primarily because the contractors making the assessment took too narrow a view when evaluating the house. If a problem occurs in the attic, it is easy to assume that you will find the answer by looking in the attic. However, the house system is complex enough that this is often not the case.

The House as a System

When one component of the building fails, or is even out of tune, it can set off a chain reaction with unexpected results. To successfully avoid these kinds of failures, it is necessary to take a systems approach to the design and construction of buildings. Every trade may do its job properly, but if nobody is paying attention to the issues of moisture sources and ventilation, a house can end up with serious mold and mildew problems. Every aspect of a home may meet the required codes, but there can still be carbon monoxide spillage into the living space. The construction supervisor may do a fine job of managing all the subcontractors, but if no one considers the interactions of the individual parts of the building, or thinks about how the building will perform when occupied, all this hard work may be inadequate.

It is easy to look at the house as a collection of components: foundation, frame, mechanical services, drywall, trim, fixtures and finishes. But there is more to a building than this. Figure 3.1 shows a schematic of the house system with some of its interactions.

The first step to understanding the house system is to realize that the building structure itself, and the mechanical systems in it, interact with each other and with the people in the building. People turn thermostats up and down, they move switches and valves, they build walls, cut holes, and leave windows and doors open or closed. Both the building and the mechanical systems also interact with the immediate environment around the house: how cold or hot is it, which direction is the sun shining from, how much wind or rain. These environmental factors change the building directly, causing parts of it to get hot or cold, or to get wet, and to dry out; and they also affect how comfortable people are inside, causing them to act in different ways relative to the building.

It is not necessary to make a study of every interaction that can happen in a building based on this concept. However, it is important for someone to take responsibility for the house as a whole system, and to think about common ways that the components in a house interact under everyday situations. It is imperative that house designers and general contractors learn the basics of the house as a system if they want to avoid these problems.

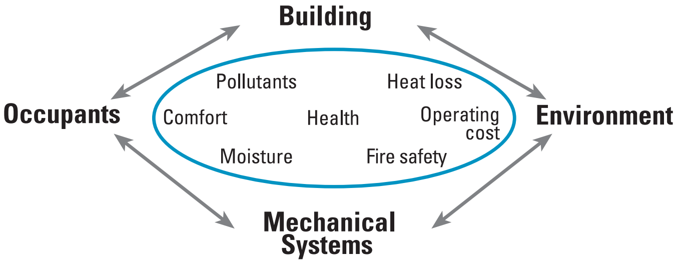
Fortunately, there has been much research in recent years and a growing body of field experience based on new construction, testing, weatherization and remediation work. Ice dams, indoor air quality problems, radon, nail pops in drywall, freezing pipes, combustion safety and backdrafting problems can all be reduced by understanding the basics of moisture and air movement. These effects can be understood on a level sufficient to avoid the most common problems, as long as someone is thinking past the individual parts and looking at the whole.

Going Further

This guide attempts to include details that are consistent with good building science as well as applicable codes. However, it is beyond the scope of this guide to address the subjects of moisture and air movement in much detail. Many of the sources listed in the Appendix contain excellent information on building science and house system interactions. The EEBA *Builder's Guide* has more detailed information on building failures, along with their causes and solutions.

FIGURE 3.1

The House as a System



4

Planning

This chapter gives designers, general contractors, and builders guidance on what energy-related issues are best resolved before breaking ground. Whether the house is designed by an architect with help from engineers, or by an owner-builder, good planning pays off with systems that work well together.

The Thermal Boundary

The thermal boundary is the collection of insulated and sealed floors, walls, and ceilings in the building that separate conditioned spaces from both unconditioned spaces and the outside (see Figures 4.1 and 4.2). A well-detailed boundary is one of the most critical aspects of a high performance home, affecting not only its energy efficiency, but also its durability and occupant comfort. Unfortunately, decisions relating to the placement and detailing of the thermal boundary are often made on the fly. Frequently (and regrettably) the concept of a thermal boundary is not even considered as part of the design and construction of a home; insulation is installed where the insulation subcontractor thinks it should be installed and there is little, if any, conscious effort devoted to air sealing.

A thermal boundary should be integrated with the design of all homes. Deliberate decisions about its placement and the materials that will be used to create the boundary are an important part of this process. There are two primary components to the thermal boundary: The first (insulation) resists conductive heat transfer. The second (air barrier) resists air flow. You should ensure that these two components are aligned with one another and installed continuously around the entire volume of conditioned space. In a set of drawings, one or more sections can be used to effectively convey this information.

Unfortunately, there is sometimes a disconnect between what is laid out in a set of plans and what is actually constructed in the field. For the thermal boundary, this disconnect can be remedied by complementing plans/specifications with the following guidelines:

- Make sure the general contractor and all subcontractors understand the design associated with the thermal boundary, and the importance of seeing the design through to completion.
- Facilitate implementation by having the necessary materials on site before they are required. Drywall and insulation, for example, may be required before a shower-tub assembly is installed (see Figure 11.8).
- Require all subcontractors to seal any penetrations they make through the thermal boundary. Provide them with the materials they may need, or alternatively:
- Assign someone (typically on the builder's crew) the responsibility of making sure that the integrity of the thermal boundary is maintained through every stage in construction.
- Perform a final air sealing check before insulation is installed.

Design Elements

The following is a rough outline of the construction process, paralleling the sequence of upcoming chapters. In each section, considerations that are unique to the planning phase are addressed. Some of the considerations relate to energy code compliance and some of them relate to ENERGY STAR compliance. Many relate to both.

Foundation

The treatment of a foundation wall depends on whether or not it encloses a conditioned space.

- If the foundation encloses a conditioned space, the foundation walls must be insulated. There is a right way (see Figures 5.4-5.6, 5.11) and a wrong way (see Figure 5.3) to insulate foundation walls; this portion of the home should be designed accordingly.
- If the foundation does not enclose a conditioned space, the insulation must run across the floor above the basement or crawlspace instead (see Figure 5.7).
- Basement wall insulation may be omitted from walls 50% or more below grade when high efficiency heating equipment is used throughout the home. See page 52 and IECC 101.5.3 (in the NJ-specific version of the IECC) for details.

There is a growing consensus among many in the energy efficient building industry that it is preferable to condition basements and crawlspaces. Planning for a conditioned basement or crawlspace offers the following advantages:

- It is easier to install continuous, uninterrupted air and insulation barriers along foundation walls than it is to install them as part of the floor assembly (which is obstructed by framing, pipes, wires, ducts, etc.) The foundation wall is often the better air barrier to begin with.

- It is easier to control the temperature, humidity, and comfort levels in a space that is enclosed by insulation and an air barrier.
- Mechanical and distribution systems are often installed in the basement or crawlspace, and they perform better in conditioned spaces.
- Many homeowners will eventually finish and use the basement space. If they install insulation poorly or are not informed about potential moisture issues, they are much more likely to create moisture and mold problems for themselves later on.

On the other hand, a conditioned basement or crawlspace may:

- Cost more to build. Even without factoring in slab insulation, the area of foundation walls is often greater than the area of the floor they enclose. Insulation that is exposed to the living space also needs to be protected from fire (by installing a code-approved barrier such as 1⁄2" gypsum board).
- Create a hidden pathway for insect entry (see page 55) and require protection of above-grade surfaces (if the insulation is installed on the exterior surface of the foundation, see Figures 5.6 and 5.10).
- Increase the need to focus on moisture control. It is especially important to build elements of moisture control into the design of a building that will include a conditioned basement (see pages 52, 54-55 and Figures 5.1-5.2).

Framing

In enclosed building cavities (e.g., walls and cathedral ceilings), the amount of insulation that can be added is limited by the framing depth. If the framing depth is not sufficient to accommodate the minimum amount of insulation required (by energy code or ENERGY STAR), the following options should be considered:

- Specify an insulation product that has a higher R-value per inch (see Table 4.13). High density fiberglass batts, for example, can be used to increase R-values where space is limited; they are also much easier to work with and install correctly. Some rigid board and spray foams can provide R-values as high as 6 per inch!
- Plan for a continuous layer of (rigid foam) insulation that is applied over the framing. Using continuous insulation is the best way to improve the effective R-value of an insulated assembly (see Figure 12.2). A 2x4 wall with 2" of rigid insulation, for example, will outperform a 2x6 wall with cavity insulation without affecting the depth of window and door openings.
- Use deeper framing. This is usually the least cost-effective option.

- Use a different compliance method and/or compensate for R-value limitation by improving performance in other areas (e.g. higher heating system efficiency, lower window U-factor, etc.)

Energy savings associated with framing can also be achieved by using details that (1) require less wood and leave more room for insulation (see Figures 6.9-6.10), and (2) include provisions for air sealing (see Figures 6.1, 6.2, 6.8 and 6.11-6.17).

Windows

Window type, quantity, orientation, and shading all play a significant role in determining the energy use of a home. Energy use can be minimized by orienting a home in such a way that most of the windows face south. South-facing windows capture heat from the winter sun but do not contribute as significantly (and undesirably) to heat gain in the summer when the sun is much higher in the sky. By contrast, east- and west-facing windows account for more heat gain in the summer than winter. It is preferable, therefore, to orient the long axis of a building east-west if possible. On the south side of the home, overhangs can be provided to allow for solar gain in the winter and to provide shade in the summer. On the east and west sides of the home, mature trees can provide shade. Regardless of orientation, high performance windows with low U-factors should be specified (see page 87 and Figure 7.1). In New Jersey, the need for heating and cooling can be reduced significantly by making smart choices with respect to window type, orientation, and shading.

Despite recent advances in window technologies, windows should still be viewed as weak spots in the thermal boundary (i.e., they allow for rapid transmission of heat from one side of the wall to the other). Performance-based compliance with energy code and ENERGY STAR standards is quite sensitive to the size and number of windows in a house. The more window area, the more difficult it will be to demonstrate compliance. This often results in having to push the efficiency of other building components to higher levels.

Mechanical Systems

Placement is one of the most important considerations with respect to designing a mechanical system. A designer usually has little control of the quality of mechanical installations, but they can influence their placement. Heating and cooling equipment, including the distribution system (ductwork or hot water pipes), should be located within the thermal boundary. Duct leaks that occur outside the thermal boundary can cause thermal, comfort, moisture, and backdrafting problems. Resist the temptation to use the wide open space of an unconditioned attic to “house” mechanical and distribution systems. Interior 2x6 walls, soffits, and floor trusses can all be used to facilitate the installation of mechanical systems within conditioned spaces. Consider planning for the space requirements for the mechanical systems and specifying them on the plans.

Heating and cooling systems tend to be substantially oversized in conventionally built houses. If the HVAC installer uses the same rules of thumb to size equipment for an efficient house, they will be even more oversized. Oversized equipment costs more to install and to operate. You can save money on a project by sizing the heating and cooling systems properly (both equipment and distribution systems). These savings can help pay for the upgrades to the building shell. Note that oversized air conditioning equipment will disqualify the home from participation in the NJ ENERGY STAR Homes program.

To promote efficiency and to eliminate the risk for backdrafting, sealed combustion heating systems and hot water heaters should be specified (see page 96). There are additional cost savings if a chimney can be eliminated as a result. Note that combustion flue gas venting options vary according to fuel type. (See Table 4.1 on page 44.)

A distribution system must also be determined during the planning phase. Again, there are numerous options and related considerations. (See Table 4.2 on page 45.)

Ventilation

An energy efficient home is an airtight home; an airtight home needs adequate, controlled ventilation. This line of thought is often expressed as "Build tight; ventilate right" (see pages 101-103). Ventilating "right" may lead you to adopt different strategies in different homes. Use the answers to the following questions to help you decide what will work best for the project you are working on:

- How big is the house? Large houses, especially those with high ceilings, have a greater volume of air to dilute pollutants. Small houses, especially those with several bedrooms, often require the most aggressive ventilation strategies.
- How many people will live in the house? More people will require more fresh air.
- What is the layout of the house? Relatively open, compact houses can be ventilated more effectively from a single point. Sprawling houses and two-story homes benefit more from distributed ventilation.
- How important is fresh air to the owners? Everyone needs fresh air, but some people value it more highly than others. If the owners need or expect very good indoor air quality, you should obviously plan for a system that will provide the desired result.

The installation of a background mechanical ventilation system is required when participating in the New Jersey ENERGY STAR Homes Program. Review the systems that are discussed in Chapter 9 and plan on incorporating one of them into your HVAC design.

Plumbing and Electrical

Pipes and wires that run through insulated assemblies create leakage pathways and insulation voids that compromise thermal performance. Just as with mechanical systems, plumbing and electrical components should be installed within conditioned space, and associated penetrations through the thermal boundary should be minimized and sealed. Consider planning for the space requirements of these building elements and specifying them on the plans.

Additional energy (and water) savings can be achieved by laying out the plumbing components in a sensible manner (e.g., installing a hot water tank in close proximity to the kitchen/bathrooms). See Chapter 10 for an overview of related recommendations.

Lighting and Appliances

Recessed lights in insulated ceilings must be rated for Insulation Contact (“IC” rated), and must be airtight as outlined in IECC 402.4.3. Units with a label that references ASTM standard E 283, MEC, IECC, or Washington State's energy code are acceptable. This requirement can also be satisfied by installing sealed, airtight boxes over recessed lights. For ENERGY STAR requirements, see table on page 110. For more information about energy efficient lighting, visit www.energystar.gov, click on “New Homes,” and go to *Advanced Lighting Package* on the right-hand sidebar.

Air Sealing

Air sealing is one of the most important aspects of energy efficient construction. Homes that are not consciously air sealed at key stages during construction rarely perform well. Adopt a proactive approach to air sealing. Important guidelines for adopting such an approach are outlined in the “Thermal Boundary” section of this chapter (see page 37).

In general, simple shapes are the easiest to seal. Many new homes are expansive and have designs that feature complex geometries. In these homes, pay extra attention to identifying and treating attic bypasses, framing transitions, and other potentially significant sources of air leakage (see Chapter 11). Also consider locating the thermal boundary where there is the greatest likelihood of achieving a continuously air sealed barrier (e.g., the roof instead of the ceiling; see Figures 6.15-6.17).

Insulation

Specify insulation products that are easy to install correctly, and that are appropriate for the unique characteristics of the assembly to be insulated (see Table 4.3). Rigid or spray foam, for example, are better choices for insulating foundation walls than fiberglass or cellulose (see Figures 5.3-5.6). Spray foams may be more appropriate for complex cathedral ceilings. Loose fill or blown-in insulation is more appropriate in flat attics. Some types of insulation, such as dense-packed or damp-spray cellulose, or spray foams, fill cavities completely, help to reduce air leakage, and add more R-value in the same sized framing cavity. Rigid foam applied to the exterior walls and/or ceilings not only adds R-value, but also reduces the thermal "bridge" of the framing, can form a good air barrier if the seams are sealed, and provides condensation resistance. Think about specifying some of these materials to improve the performance of the building.

Plan for Success

Good planning is important for good buildings, but good planning does not guarantee good buildings. Many building plans are drawn with exemplary construction details, and those details are ignored, botched, replaced, or omitted by "value engineering," before or during the construction process. Subcontractors often complete their jobs without consulting plans and without giving any consideration to how their work might affect other subcontractors. Similarly, general contractors who are not committed to the "house as a system" approach to building may not see the project through in a seamless, integrated fashion. No matter how it is defined, success will be unlikely in these cases.

Careful planning must be complemented by effective communication, teamwork, and testing. The designers on the front end of a project (architects, engineers) must work with the builder and subcontractors at the back end, and vice versa. A home energy rater or other energy consultant, acting as an independent third party, can also help to verify home performance (by performing visual inspections and testing) and can offer guidance from the design phase through to project completion.

Table 4.1 Heating fuel characteristics

Fuel Type	Venting Options	Other Considerations
Home Heating Oil	• Best vented through a chimney • Direct vent available, but requires careful design and installation • Combustion air kits available for some equipment	• Inexpensive fuel; high heat content • Low-output equipment not as common; hard to find right-sized equipment for low-energy homes • Fuel must be kept warm • Flue gases should not be allowed to condense in heat exchanger or vent • Equipment must be cleaned periodically
Liquid Propane	• Can be chimney or direct vented • Sealed combustion appliances common	• Usually the most expensive fuel; lower heat content per gallon than oil • Modulating burners can vary heat output • Higher efficiencies and reduced maintenance (most natural gas equipment is available in an LP version) • Suitable for small, tight, energy efficient buildings
Natural Gas	• Can be chimney or direct vented • Sealed combustion appliances common	• Wide range of equipment available; suitable for most homes. • Modulating burners can vary heat output
Wood/Biomass	• Best vented through a chimney • Direct vent available in electric pellet stoves • Combustion air kits available for some new stoves	• Cord wood less expensive than oil; pellets cost about the same as oil • Relatively low efficiency

Table 4.2 Distribution system options

Distribution Type	Considerations
Ducts (forced air)	• Usually the least expensive option, but the most prone to installation defects (poor sealing and/or insulation) which can dramatically reduce system efficiency • Often paired with a furnace and/or air conditioning system. Boiler can also be used as heat source by installing hydro-air handler • Long duct runs and/or poorly installed (undersized, poorly sealed, kinked, pinched, excessive turns, improperly balanced) ducts can seriously reduce heat delivery and occupant comfort levels • Ducts can be used to facilitate distribution of fresh air (by integrating a mechanical ventilation system) • Air handler can account for significant amount of electrical energy use; choose ECM motor to save electricity (see page 104)
Hot water baseboard	• Can only be paired with boiler or hot water heater • Must be sized according to the heat/cool loads, water temperature, and rated output. • Easier to divide distribution system into several zones
Hot water radiator	• Same consideration as above • Saves space compared to baseboards or ducts
Radiant floor	• Most expensive distribution system, but typically associated with highest comfort levels • Should be paired with condensing boiler for maximum efficiency • Radiant tubes can be embedded in concrete slabs (including thin, lightweight concrete slabs that can be applied to framed, wood floors) or can be secured to the floor from below. • Typically a poor match for a passive-solar heated slab floor; may not be a good investment in a very energy-efficient home
No distribution (space heater)	• Can adequately heat small, energy efficient homes that have a relatively open floor plan.

Table 4.3 Insulation Properties[1]

Form **Product(s)** — (R-value per inch)[2]	Method of Installation	Where Applicable	Advantages	Notes
Blankets: Batts or Rolls **Fiberglass** — (3.1-3.7, depending on density) **Rock Wool** — (3.3)	Fitted between studs, joists and rafters	All wall, floor, and ceiling cavities prior to hanging drywall	Inexpensive and readily available	• Only suited for standard stud and joist cavities that are relatively free from obstructions. • Prone to installation defects which can dramatically reduce effectiveness of insulation (see Figure 12.2). • High-density fiberglass batts (e.g., R-21 batts for 2x6 walls) provide a higher R-value per inch and are easier to install properly (see page 134). • Must be protected from "wind washing" (see page 134).
Loose-fill (blown-in) **Rock Wool** — (3.0) **Fiberglass** — (2.0 -2.5, depending on density) **Cellulose** — (3.5 - 3.7, depending on density)	Blown into place using specialized equipment (hopper, blower and hoses)	Enclosed building cavities and unfinished (open) flat attics	Fills gaps and voids typically found in irregularly shaped spaces and around obstructions. "Dense pack" cellulose can help to reduce, but not completely stop, air movement	• To avoid settling, insulation should be installed according to manufacturer's instructions. • R-value depends on density (number of bags per square foot), not thickness. • Dense pack cellulose has a slightly reduced R-value per inch. • Must be protected from "wind washing" (see page 134).

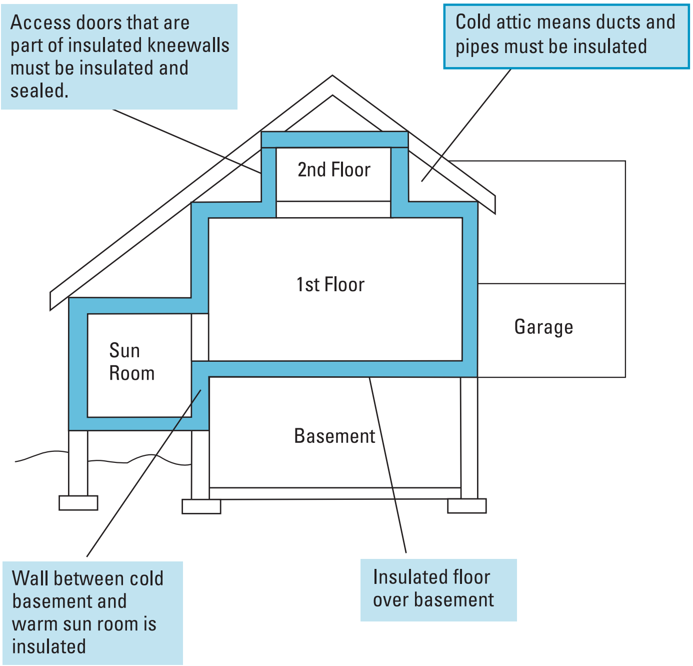
Form **Product(s)** — (R-value per inch)[2]	Method of Installation	Where Applicable	Advantages	Notes
Spray Applied **Cellulose** — "damp" - (3.5)	Same as above. A fine mist of water is applied simultaneously to make cellulose "stick"	Open wall cavities prior to drywall	Same as above	• Cost effective alternative to fiberglass batts. • Requires some drying time before interior wall sheathing is installed.
Spray Applied **Polyurethane Foam** — (3.4 - 6.0, depending on density)	Chemical components stored in separate containers; mixed in nozzle at end of hoses	All wall, floor, and ceiling cavities prior to hanging drywall	Provides excellent fit and air barrier	• Vapor permeance and price vary according to density. High density foam has a perm rating of less than 1 and is more expensive; low density foam has a perm rating of about 10-15 (at 5" thick) and needs an added vapor retarder. • Significant waste can be generated when excess foam is "shaved."
Rigid Insulation - Foam **Extruded polystyrene** (XPS) — (5.0) **Expanded polystyrene** (EPS or bead board) — (4.0) **Polyisocyanurate** — (6.0)	Cut to fit into building cavities or (preferably) over framing. Can also be applied directly to concrete (interior or exterior, see Figures 5.4 -5.10)	Slab floors, foundation walls, above grade walls, ceilings, and roofs	High R-value per inch. Significantly improves thermal performance when used as continuous, uninterrupted layer of insulation	• For fire safety, interior applications must be covered with 1/2-inch gypsum board or other building code-approved material • Exterior applications must be covered if exposed to sunlight.

1 Table adapted from Department of Energy, DOE/CE-0180/with Addendum 1, October 2002

2 Conservative estimates provided for use in absence of better documentation. In order to achieve listed R-values, insulation must be installed (1) according to manufacturer's instructions and (2) without any voids, gaps, or compression. Common installation practices vary by product and installation defects can significantly reduce the effective R-value.

FIGURE 4.1

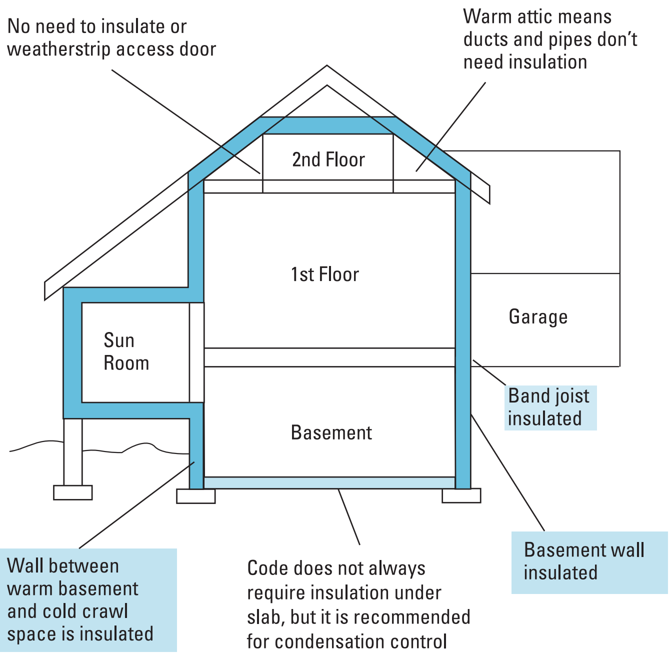
Typical cape with unconditioned basement



This is a schematic of a cape style house with an unconditioned basement and unheated kneewall areas.

FIGURE 4.2

Cape with conditioned basement and insulated rafters



This schematic shows the same cape style house with a heated basement and kneewall areas. Note that the two choices are independent of each other, it is possible to have heated kneewall attics with an unheated basement, or the reverse.

5

Foundation

Foundation Moisture

Aside from structural concerns, the most important consideration for foundation design is moisture. No client wants a wet basement. No client wants a damp basement. No client wants mold in their basement. If a dry basement is your objective, the first priority should be protecting it from bulk water by directing water down and away from the entire house at every possible point of entry (see Figure 5.1). Top-down foundation drainage should be complemented by the following (see Figure 5.2):

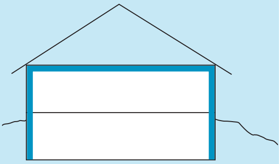
- A continuous capillary break that separates the basement slab and foundation walls from the ground.
- A continuous air and insulation barrier (to reduce the risk for condensation).

You can't go back to add these later (for a reasonable cost) so the time to do it is when you build the foundation. This applies to full foundations, to crawlspaces, and to slab-on-grade construction. Even with these precautions, the foundation walls may still be damp at times. You can't guarantee that mold won't grow. You can, however, minimize the potential for conditions that foster mold growth, and maximize the potential for walls to dry when they do get wet. To satisfy the requirement for a vapor retarder on the interior (warm in winter) side of insulated foundation walls, it is best to opt for products with perm ratings closer to 1 (e.g., polystyrene foam), and to avoid stronger vapor barriers (e.g., polyethylene sheeting or foil-faced products) which limit the potential for drying. The figures in this chapter show several possibilities for relatively forgiving, mold-resistant, insulated basement wall assemblies. If the proper drainage and capillary breaks are not present, and if care is not taken to avoid the pitfalls illustrated in Figure 5.3, it is better not to build a conditioned basement so that the foundation walls do not need insulating.

Energy Code Requirements

All basement spaces must be defined as "conditioned" or "unconditioned." See Figures 4.1, 4.2 and page 54.

Conditioned Basements

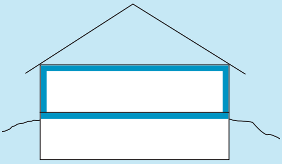


In a conditioned basement, you must:

- Insulate the foundation walls on the inside or the outside of the wall. The required R-value depends on the results of your compliance analysis.
- Insulation must extend from the top of the wall to the basement floor (IECC 402.2.6).
- Insulate the band joist of the floor framing above the basement.
- Seal air leaks in the foundation walls and slab floor, as well as the sill / band joist area.
- If the foundation is insulated with rigid foam on the exterior, the insulation must be protected with a rigid, opaque and weather-resistant barrier that extends at least 6" below grade (IECC 102.2.1).
- Basement wall insulation may be omitted when high efficiency heating equipment is used. See IECC 101.5.3 (the NJ-specific version of the IECC) for details.

Important note: When you are doing compliance analysis on a conditioned basement, you must look at each basement wall separately and determine, wall by wall, whether the wall is 50% or more above grade or more than 50% below grade. Walls that are 50% or more above grade, must be added in with above grade walls in your calculations, and insulated to the same R-value. Walls that are 50% or more above grade are considered above grade walls and must be treated as such; walls that are more than 50% below grade are treated as "basement walls."

Unconditioned Basements



In an unconditioned basement, you must:

- Seal air leaks in the floor system between the basement and the first floor, such as wiring and plumbing penetrations, and weatherstripping on the basement door. Include the basement door in your calculations.
- Insulate the floor above the basement. The required R-value depends on the results of your compliance analysis.
- Insulate the stairwell and the stairwell walls between the basement and conditioned first floor.

Slab-on-grade

Slab perimeter (edge) insulation must be installed where the slab is part of the conditioned space of the house and is at or within 12" of grade (see Figure 5.7). This includes a slab-on-grade house or addition, the walkout portion of a heated basement, or a breezeway that shares a slab with the garage.

The R-value to use depends on the results of your compliance analysis. If the slab edge insulation is on the exterior, the insulation must be protected with a rigid, opaque and weather-resistant barrier that extends at least 6" below grade (IECC 102.2.1).

Slab perimeter insulation must run all the way to the top of the slab. It may go down, or down and across, for a total of distance of either 24" or 48", depending on the climate zone of the location where you intend to build and the method that is used to determine compliance. See Figures 5.8-5.9 for examples.

Crawlspace

Historically, many building codes have required passive vents in exterior walls and minimal vapor barrier protection for crawlspace floors. While this strategy may have helped to reduce moisture loads at times, it also introduced moisture in the summer when outdoor air is more humid than the cool crawlspace. Building science has shown that ventilating crawlspaces often does more harm than good, and codes are starting to catch up with the more sensible approach of building a tight crawlspace with good drainage and vapor control. In fact, national model energy codes are beginning to include exceptions that allow for unvented crawlspaces that are either vented to the interior, conditioned, or provide air to the return side of a heat and/or air conditioning system (IRC R408.3 and IECC 402.2.8).

Ideally, a crawlspace should be constructed like a short basement, including:

- Adequate footing drainage
- Thorough, durable and continuous vapor barrier
- A continuous air and insulation barrier

If the crawlspace has a dirt floor, it must be covered with a continuous vapor barrier and all seams must be sealed with a good quality tape (e.g., 3M contractor's tape or Tyvek tape) or acoustical sealant.The vapor barrier must also be attached to the exterior walls, and all penetrations (including piers) must be sealed.

If a concrete slab is installed, rigid foam can be used in place of polyethylene.

The walls of an unventilated crawlspace must be insulated to a level that is determined by the results of your compliance analysis. As with any basement, it's important to keep inside air away from the foundation wall to prevent condensation (Figure 5.11).

If the crawlspace is unheated, the thermal boundary must run across the floor of the house. Treat the floor over a vented crawlspace as you would a floor over an unconditioned basement: air seal and insulate to the level indicated by the compliance analysis. Also consider enclosing the insulation with rigid insulation that is fastened to the underside of the floor joists.

NJ ENERGY STAR Homes

To meet the ENERGY STAR performance guidelines, you may need to put slightly more insulation in your basement walls (or the floor over the basement) than you would to meet the code. Other recommendations:

- Install at least 4" of uniform sized, washed stone underneath the slab floor. This acts as a capillary break to help prevent absorption of ground moisture. It also makes it easy to add a sub-slab ventilation system for radon mitigation, if radon is found after construction (see page 146).
- Insulate basement slabs, even in unheated basements. 1" of rigid polystyrene foam under the slab will keep it warmer in summer and reduce the chance of condensation which can wet the slab and lead to mold and mildew. This will also improve comfort and reduce moisture problems if the basement is finished off later.
- Do not install carpeting on below-grade slab floors unless the slab is insulated under its entire area, and the foundation is well drained. Moisture from condensation on an uninsulated slab, or drawn up by capillary action can lead to hidden mold and mildew problems in carpets.
- Always insulate under the entire surface of radiant heated slabs, even when the code does not require it. Most radiant equipment manufacturers specify insulation under the slab; if you are heating the slab, the insulation will reduce heat loss and improve comfort. Because of the high temperature of radiant heated slabs, a minimum of R-15 rigid insulation is suggested even though manufacturers may recommend less.
- Try to avoid crawlspaces. Where you do build over a crawlspace, be certain that the vapor retarder on the crawlspace floor is completely sealed at all seams and penetrations, and sealed to the wall.

Conditioned or Unconditioned?

The choice of whether to insulate the basement is yours, unless you have an intentional heat supply. There are several reasons for and against constructing a conditioned basement space:

- People often want to use basements. Even if they are not finished space, people often use basements for laundry, projects, storage or other uses. They really don't want the basement to be a very cold space in winter. If they do finish off the space later, it will be easier if the basement is already insulated.
- It's easier to air seal the foundation walls. Floors are usually far leakier than foundation walls, and are also harder to seal.
- There's no need to insulate HVAC ducts or pipes in a conditioned basement, which can save money.
- Warm basements are less likely to have condensation and related mold and mildew problems than cold basements.
- Insulating foundation walls has potential pitfalls. Exterior insulation may provide pathways for insects, must be protected, and tied in somehow with the wall above. Interior insulation cools foundation walls, and if drainage and insulation details are not built carefully there is substantial risk of condensation and mold growth.
- Insulating walls often costs more than insulating the floor over a basement.

Going Further

Other issues to think carefully about when planning foundation details include:

- **Concrete movement** and cracking can result in callbacks, air leaks and water entry in foundations. The EEBA *Builder's Guide* includes a discussion of concrete movement and control joints—which can reduce or eliminate these problems—as well as other foundation issues.
- **Moisture, drainage and capillary breaks**—Foundations are built in the ground. Depending on where you build, the ground is either sometimes wet or always wet. All foundations should be built with good drainage and moisture protection.
- **Insect entry**—Termites and carpenter ants can tunnel through rigid foam insulation. If the foam insulation is between the ground and the wood frame of the house, they can use it as a way to get to the wood without being seen. For this reason some model codes have prohibited the use of foam insulation above grade in termite-prone areas. While the Northeastern and mid-Atlantic states are not generally considered to be termite-prone, termite protection still warrants consideration.

  Termites don't eat foam board, but they will eat wood, causing structural damage. Carpenter ants don't eat either one, but they will nest in both and over long periods can cause structural damage.

There may be ways to effectively block insect entry from foam board to adjoining wood framing (or above grade foam sheathing); however, the details for such a system must be implemented very carefully. The energy code (and common sense) requires insulation in heated basements to the top of the foundation wall; after all, most heat loss occurs where the foundation wall is exposed above grade. You can't cut exterior foam board off at grade, so it may be better to insulate conditioned basements on the inside of foundation walls than to attempt an insect barrier between exterior foam and the wood framing.

- **Alternative foundation systems** such as insulated concrete forms (ICFs) or precast concrete walls can speed up the construction process (especially in the winter) and provide a pre-insulated, airtight assembly. They can be very cost-effective when compared to a poured concrete wall with a built-up insulated stud wall.

FIGURE 5.1

Top-down foundation drainage

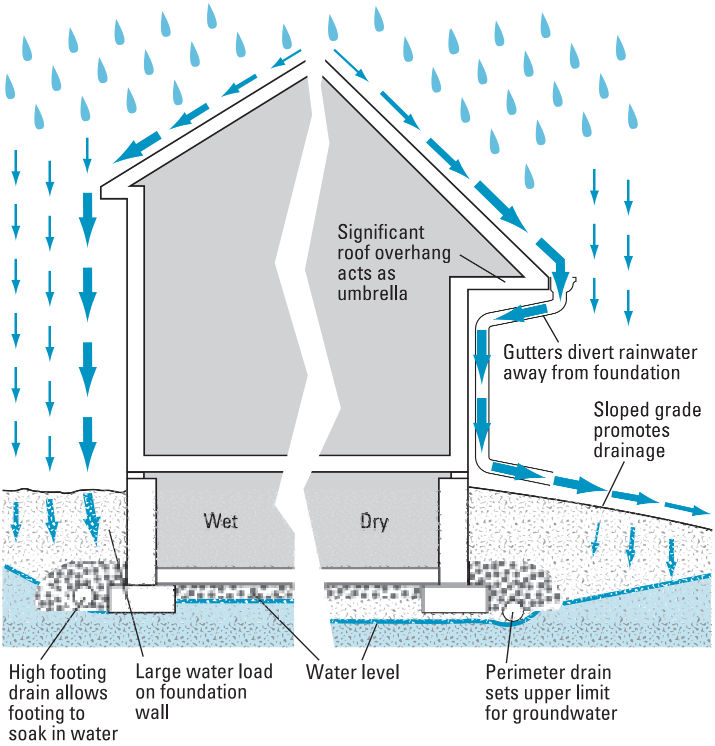
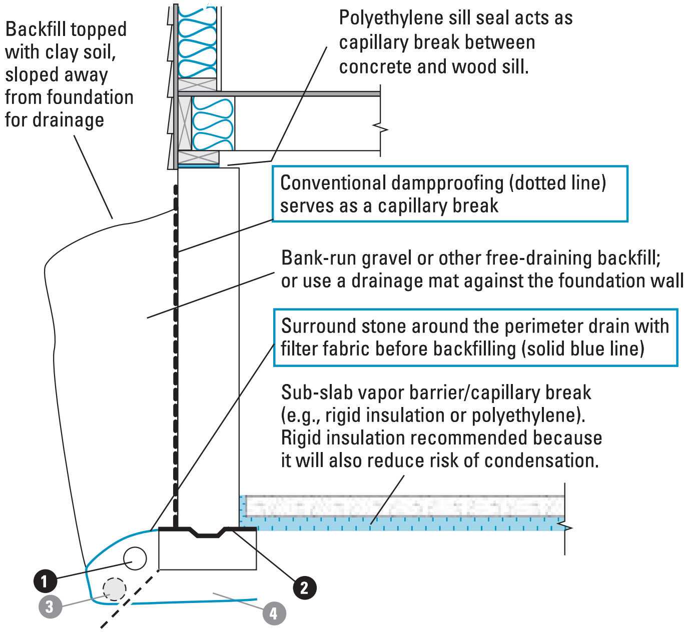


FIGURE 5.2

Foundation moisture control

All full and crawlspace foundations should incorporate these details.



① Perforated drain pipe at footing level, drains downhill to daylight or to sump pit inside basement

② Dampproofing or cement-based waterproofing applied to top of footing as capillary break between footing and wall (dark line)

Alternate Strategy—#3 and #4—more effective, where allowed by local codes. Note: the footing drain can only be installed below the footing level if the footing is completely supported by uniform sized washed stone, which is noncompressible. When in doubt about the bearing capacity of the underlying soil, consult a soils engineer.

③ Drain pipe installed below footing level (and beyond load bearing range of stone, as indicated by dotted line) to carry water away from footing

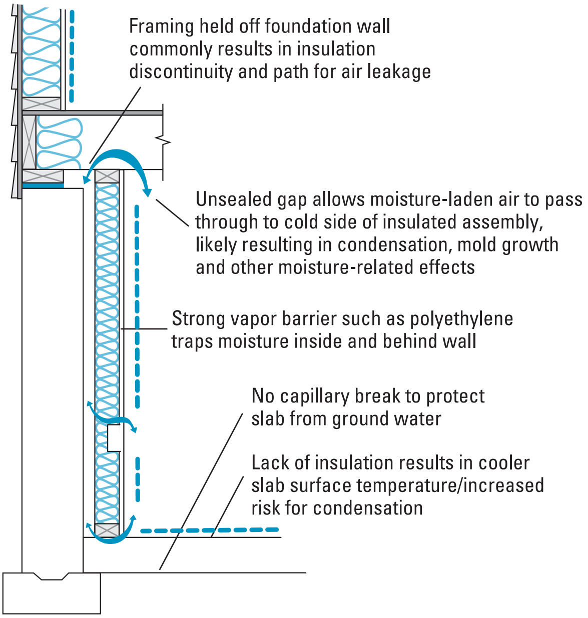
④ 4-6" *washed, uniform sized* stone (½" – 1½") under footing provides capillary break and drainage.

⚠ **CAUTION:** The stone surrounding the perimeter drain and under the slab and/or under footing must be uniform in size and washed (with no fine grains), to prevent settling or undermining.

TIP: One inch of rigid foam insulation under the slab will reduce the potential for condensation in the summer. Even if the foundation walls do not enclose conditioned space, condensation on the slab can contribute to moisture problems in the home.

FIGURE 5.3

Foundation insulation pitfalls


Framing held off foundation wall commonly results in insulation discontinuity and path for air leakage

Unsealed gap allows moisture-laden air to pass through to cold side of insulated assembly, likely resulting in condensation, mold growth and other moisture-related effects

Strong vapor barrier such as polyethylene traps moisture inside and behind wall

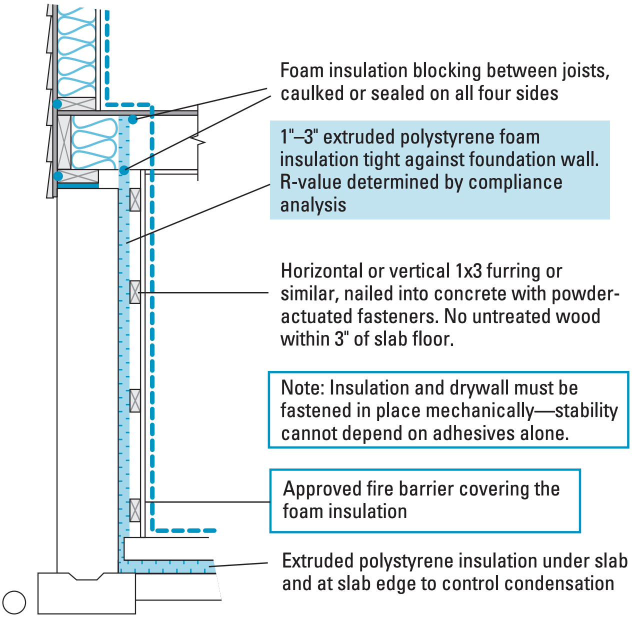
No capillary break to protect slab from ground water

Lack of insulation results in cooler slab surface temperature/increased risk for condensation

⚠ **CAUTION:** Even with careful detailing, a cavity-insulated frame wall is a poor choice for insulating foundation walls. All or most of the insulation should be continuous and sealed directly to the foundation (see Figures 5.4-5.6).

FIGURE 5.4

Conditioned basement with interior rigid foam



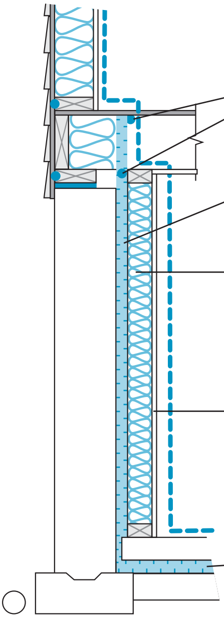
⚠ **CAUTION:** All vertical and horizontal joints in the insulation must be carefully sealed to prevent humid air from reaching the cool foundation wall, where it can condense.

TIP: Glass-faced gypsum board or cement "tile-backer" board is much less vulnerable to moisture than paper-faced drywall. It can be finished with veneer (skim-coat) plaster. Use vinyl or fiber-cement components for baseboard trim.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.5

Conditioned basement with interior stud wall



Foam insulation blocking between joists, caulked or sealed on all four sides

1"–2" extruded polystyrene foam insulation tight against foundation wall. R-value determined by compliance analysis

Insulated 2x4 (or 2x3) stud wall, wood or steel studs, pressure treated still plate

In locations that have 5,499 HDD or less (see Table 2.1), the IECC requires a vapor barrier on the warm-in-winter side of the insulation. To improve the foundation wall drying capacity, a vapor retarder with a perm rating closer to 1.0 (e.g. vapor barrier paint) should be used. Rigid insulation should comprise 40% or more of the total R-value to avoid condensation in winter.

Extruded polystyrene insulation under slab and at slab edge to control condensation

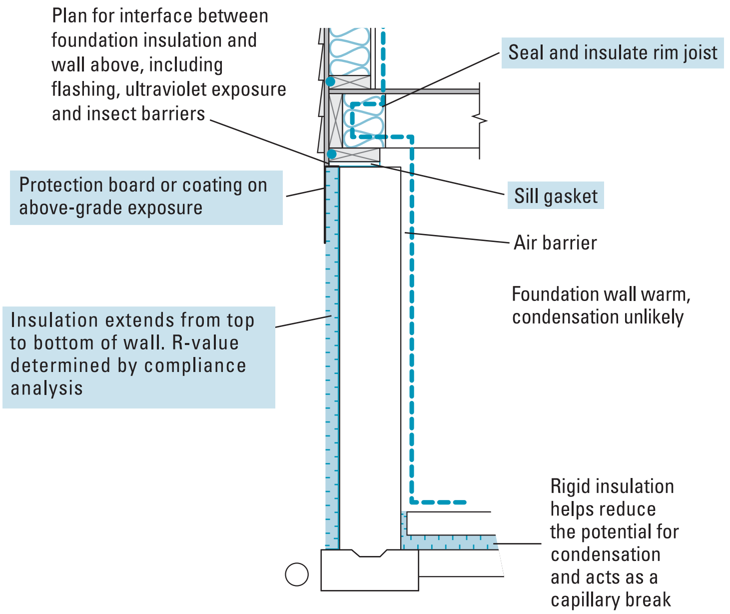
⚠ **CAUTION:** All vertical and horizontal joints in the rigid insulation must be carefully sealed to prevent humid air from reaching the cool foundation wall, where it can condense.

TIP: Glass-faced gypsum board or cement “tile-backer” board is much less vulnerable to moisture than paper-faced drywall. It can be finished with veneer (skim-coat) plaster. Use vinyl or fiber-cement components for baseboard trim.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.6

Basement with exterior rigid foam

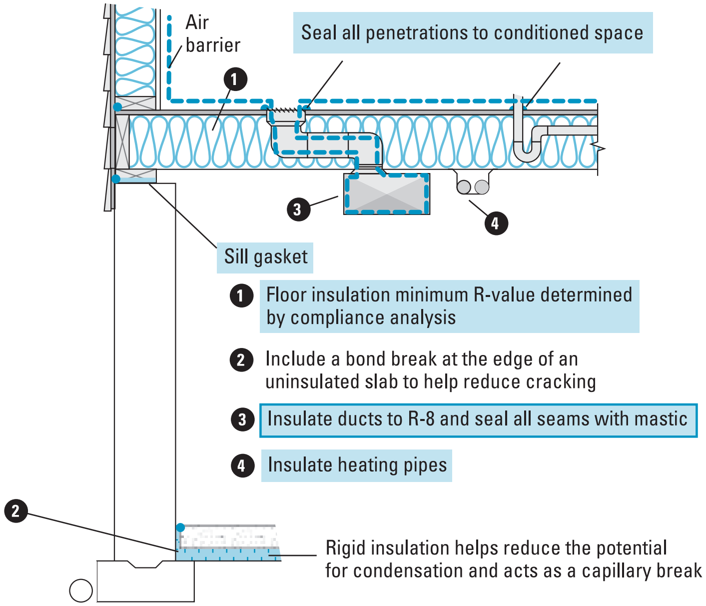


⚠ **CAUTION:** Exterior foam insulation may provide a pathway for termites and carpenter ants to reach framing. See page 55.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.7

Unconditioned basement



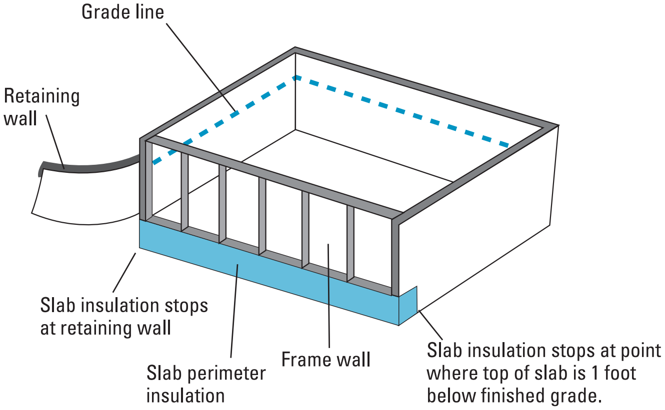
TIP: One inch of rigid foam insulation under the slab will reduce the potential for condensation in the summer. Even if the foundation walls do not enclose conditioned space, condensation on the slab can contribute to moisture problems in the home.

If conditioned space is adjacent to an unconditioned space (e.g., in a partially finished basement), then the wall between these two spaces must be insulated according to results of the compliance analysis.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

FIGURE 5.8

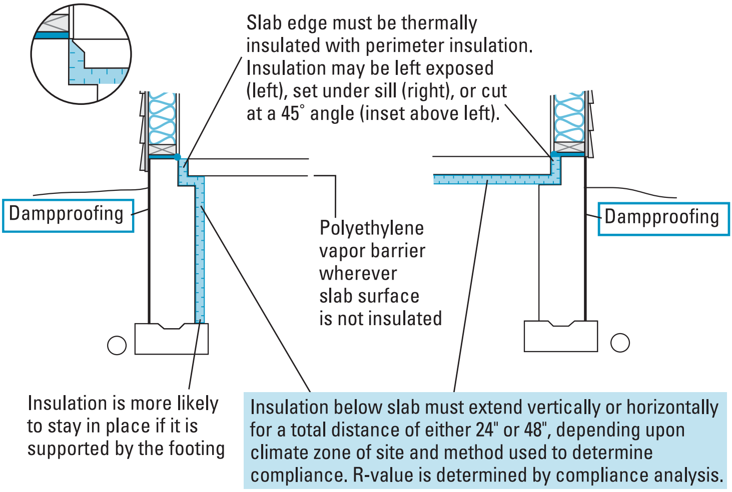
Slab edge insulation, walkout basement



This is a view of a basement with a frame wall on one side, showing the placement of slab perimeter insulation.

FIGURE 5.9

Slab on grade with interior insulation



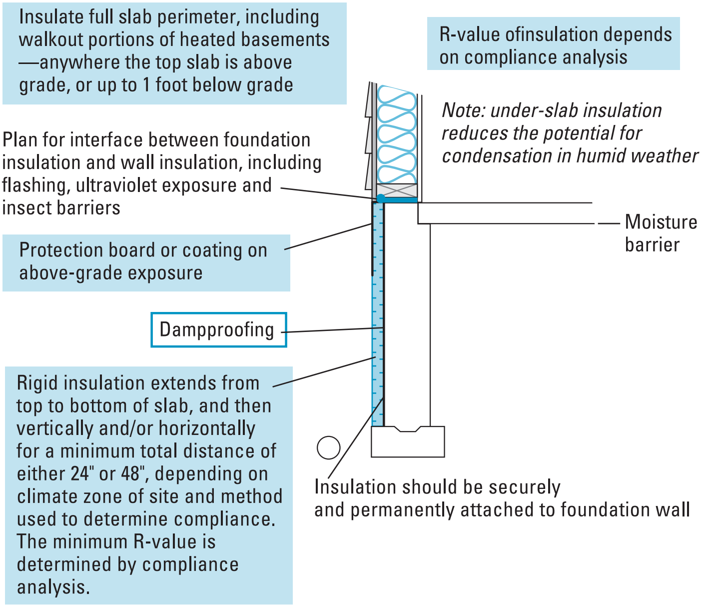
Slab edge must be thermally insulated with perimeter insulation. Insulation may be left exposed (left), set under sill (right), or cut at a 45° angle (inset above left).

Insulation below slab must extend vertically or horizontally for a total distance of either 24" or 48", depending upon climate zone of site and method used to determine compliance. R-value is determined by compliance analysis.

Most of the foundation moisture control strategies shown in Figure 5.2 apply to slab on grade construction as well. Details not shown for clarity.

FIGURE 5.10

Slab on grade with exterior insulation

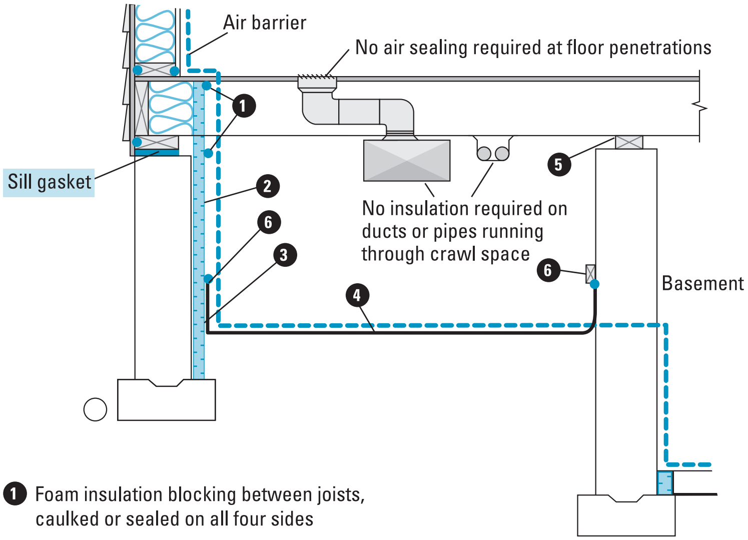


⚠ **CAUTION:** Exterior foam insulation may provide a pathway for termites and carpenter ants to reach framing. See page 55.

Most of the foundation moisture control strategies shown in Figure 5.2 apply to slab on grade construction as well. Details not shown for clarity.

FIGURE 5.11

Conditioned, unvented crawl space with interior insulation



❶ Foam insulation blocking between joists, caulked or sealed on all four sides

❷ Insulation must be in substantial contact with wall, with no gaps between pieces. It must extend to the top of the wall.

❸ Rigid insulation must extend from top of slab down to the finished grade level and then vertically and/or horizontally for another 24".

❹ A minimum 4-mil thick polyethylene vapor retarder is required by most codes. It is highly recommended to install 6-mil or laminated poly, lapped 12" and taped at all seams, and mechanically fastened and sealed to all walls, piers, columns, and service penetrations

❺ No air sealing or insulation needed next to conditioned spaces

❻ Extend vapor retarder 12" up walls and columns, and attach with nailer and adhesive

⚠ **CAUTION:** All vertical and horizontal joints in the insulation must be carefully sealed to prevent humid air from reaching the cool foundation wall, where it can condense.

Foundation drainage and capillary break details not shown for clarity—refer to Figure 5.2.

6

Framing

Energy Code Requirements

The following is a summary of the energy code requirements which might affect how a building is framed.

- **R-values of insulation**—The R-values determined from your compliance analysis can affect the dimensions of framing lumber you use. For example, an R-19 wall would often be built with 2x6 wall studs. However, there is almost always an alternative. For example, an R-19 wall can also be built with 2x4 studs, R-13 insulation and 1.5" of polystyrene foam board (R-6).
- **Air sealing details**—Most air sealing details can be carried out at any point up until the insulation and drywall are installed. However, many are much easier to implement during framing. Some of these critical details include band joist/sill areas, housewrap details (if housewrap is used as an air barrier), dropped soffit areas, draftstop blocking between wall and roof or wall and floor assemblies, etc. Detail drawings showing appropriate air sealing of these areas are shown in Figures 6.1, 6.2, 6.8, and 6.11-6.18.
- **Raised truss construction** or equivalent roof framing (IECC 402.2.1). This type of construction gives you some credit in the code compliance analysis, and also performs better. Examples of raised truss equivalents are shown in Figures 11.5-11.8.

NJ ENERGY STAR Homes

ENERGY STAR Qualification: Framing

Component	Compliance Highlights
Thermal Bypass Checklist	Many checklist items must be addressed at the framing stage (see Figures 6.8 and 6.11-6.18)

Other requirements may apply; see pages 15-22 for more details.

In addition to having to pay more attention to the air sealing details, you also may need slightly more insulation R-value in the walls or ceiling than you would just to meet the code. As noted previously, this can affect the dimensions of the lumber you use. However, there are some techniques you can use to help pay for these upgrades without compromising the structure of the building. Here are some suggestions:

- Use details that need less wood and leave more room for insulation at exterior wall corners, partition wall intersections, headers, and the like. See Figures 6.4-6.7. The EEBA *Builder's Guide* has a section on framing with detail drawings showing additional options.
- Housewraps have been marketed for years as air barriers, but their primary purpose and benefit is as a drainage layer behind the exterior cladding. No siding and flashing system is completely waterproof, so a dependable drainage plane under sidings is needed as a secondary line of defense. Appropriate counter-flashing details are critical, and a vented rain screen can provide the best performance for keeping water out of the building. Housewrap, properly installed and sealed with tape, can contribute slightly to the air tightness of a building, but does nothing to slow down air leakage in most large leaks, which are located in basements and attics.

  In addition, plastic housewraps may be incompatible with unprimed cedar and redwood, and with cement stucco materials; and perforated plastic housewraps have been shown to leak water much more rapidly than unperforated plastics or felt paper. Felt paper or building paper may be a good alternative as a drainage plane. The EEBA *Builder's Guide* has in-depth discussions about rain drainage planes and air flow retarder systems.
- Try to discuss HVAC layouts with mechanical subcontractors before framing. If you can adjust framing to allow space for ducts and pipes, layouts can be more efficient and less costly, and less damage will be done to the frame during installation. For example, if a long center wall in a two-story house is framed with 2x6 studs, duct risers can be easily installed for floor registers in the upper story. Be sure to align floor framing with wall studs. At the very least, be sure that adequate mechanical chases exist. This type of approach can save on duct installation costs. The EEBA *Builder's Guide* section on design has more ideas related to HVAC integration.
- Consider sealing air leaks in the exterior of the walls as well as the interior. Two air barriers are better than one air barrier. Exterior air barriers help keep cold out and help prevent wind-washing of the cavity insulation, and they are easy to install (see the EEBA *Builder's Guide* section on air barriers).

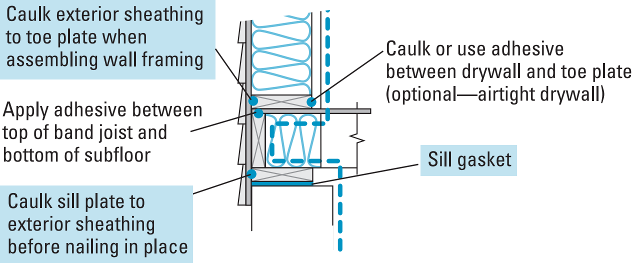
Going Further

Use advanced framing techniques that allow you to use less wood in the frame of the building, leaving more room for insulation and more room in the budget (see Figures 6.9-6.10). You can choose to use some of these techniques and not others; but you do have to think about how to apply these details. For example, don't use single top plates unless you "stack" roof, wall and floor framing. Don't use a single stud at the rough opening unless you hold the header up with hangers rated for the load. When they are applied properly, these techniques meet codes and work well. For more detail on advanced framing (sometimes called "Optimum Value Engineering") see *Cost Effective Home Building: A Design and Construction Handbook* by NAHB (contact information in Appendix).

Think about the ways in which framing affects the installation of an effective rain control system (roofing, siding, trim, flashing, etc.), and an effective water vapor control system (vapor retarders, roof ventilation, etc.). For example, roof framing has a direct impact on the effectiveness of various roof ventilation strategies. See the EEBA *Builder's Guide* for more on rain control, framing details for moisture control, insulation, sheathings and vapor diffusion retarders.

FIGURE 6.1

Sealing band joists during framing

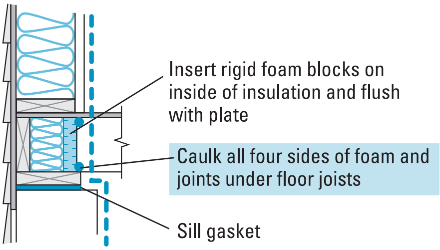


Remember to caulk or tape vertical seams between sheathing panels.

TIP: For better results, also use construction adhesive when setting the band joist on the sill.

FIGURE 6.2

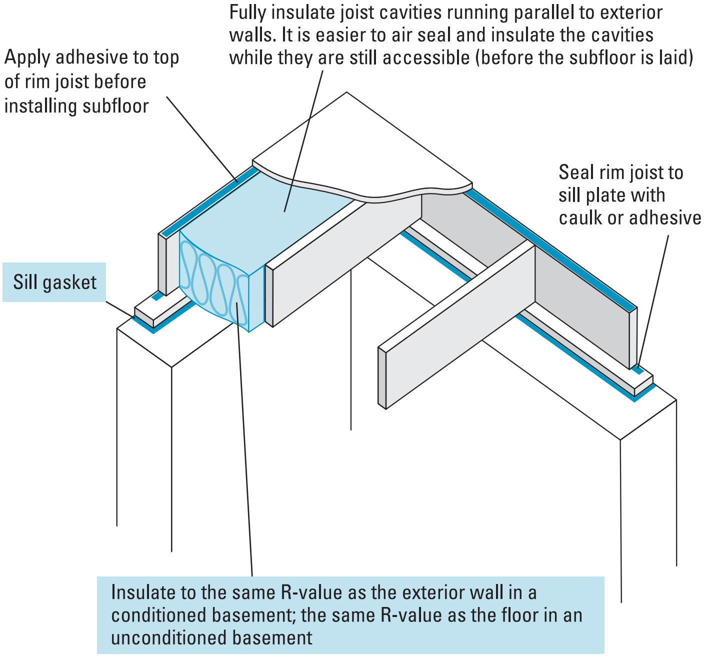
Sealing band joists after framing (alternate method)



Sealing the band joist is easiest to do during framing, but if it is missed at that time, this technique works well also.

FIGURE 6.3

Sealing and insulating band joists during framing

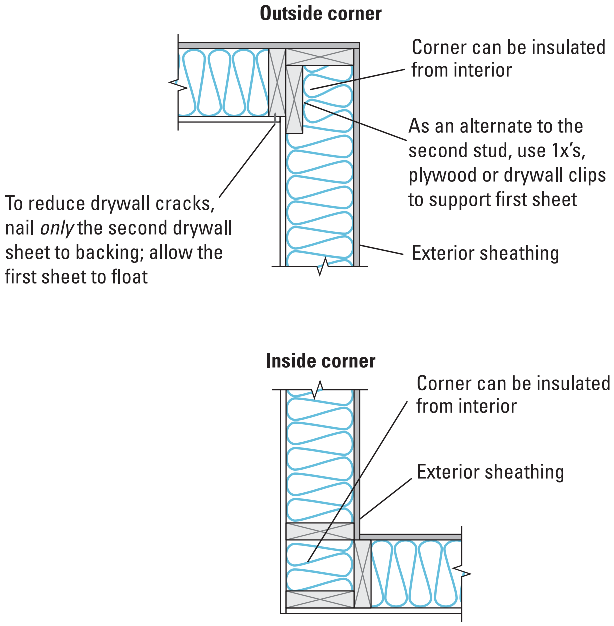


TIP: If you use a blown-in or sprayed insulation such as foam, blown-in cellulose or fiberglass, or a similar system, this area can usually be insulated with the rest of the house.

Insulating the band joist after the floor sheathing is installed can be very difficult, depending on the joist layout. Care must be taken to keep insulation dry when installed during framing.

FIGURE 6.4

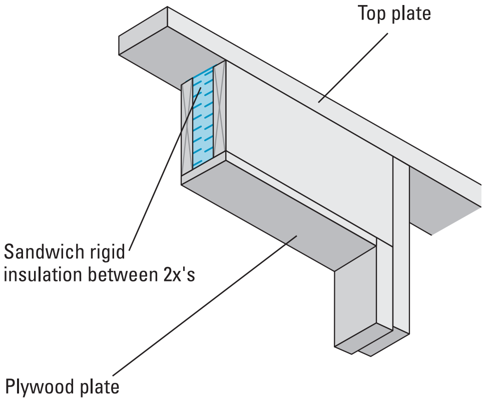
Insulated three-stud corners



Conventionally framed corners are difficult to insulate and use more wood than insulated three-stud corners. For more savings and reduced drywall cracking, use clips for drywall backing at outside corners instead of the third stud.

FIGURE 6.5

Insulated header in a 2x6 wall

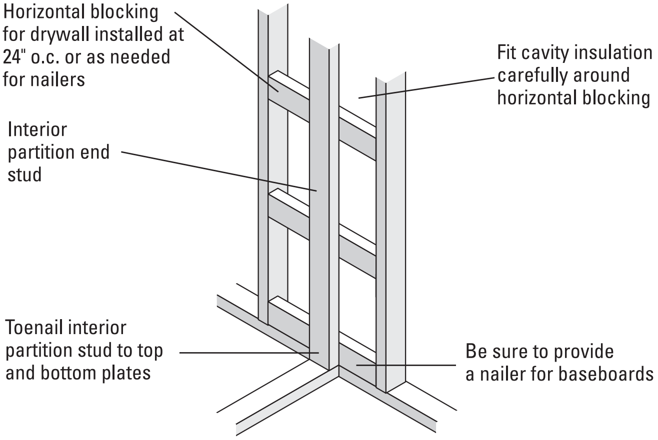


TIP: Use a few standard header sizes that will work in several locations. There is no need to size all headers equally.

As an alternative, insulated headers pre-manufactured from engineered wood I-beams and rigid foam may be used. Follow manufacturer's instructions regarding acceptable loading, span and support.

FIGURE 6.6

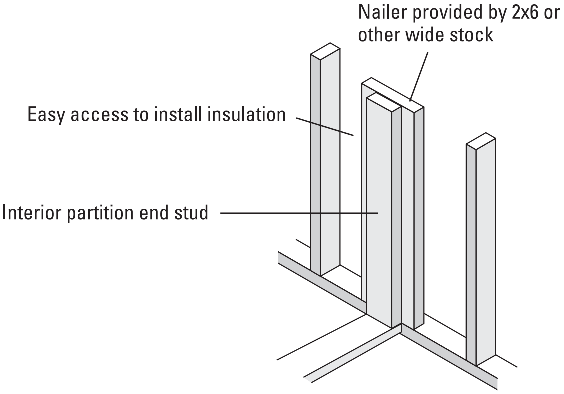
Ladder blocking for interior partition walls



Conventional box channels for partition walls are difficult to insulate. Ladder blocking (or vertical backing, Figure 6.7) use less wood, are easier to insulate, and are easier for electricians as well. See Figure 11.3 for air sealing details.

FIGURE 6.7

Drywall backing for interior partition walls



Vertical nailing stock can also be replaced by drywall clips to support drywall.

FIGURE 6.8

Cavity sealing example: chase on exterior wall

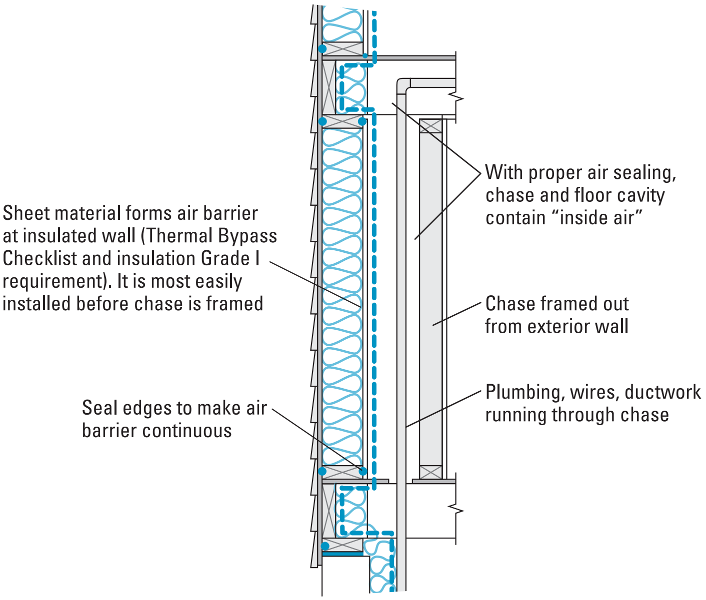
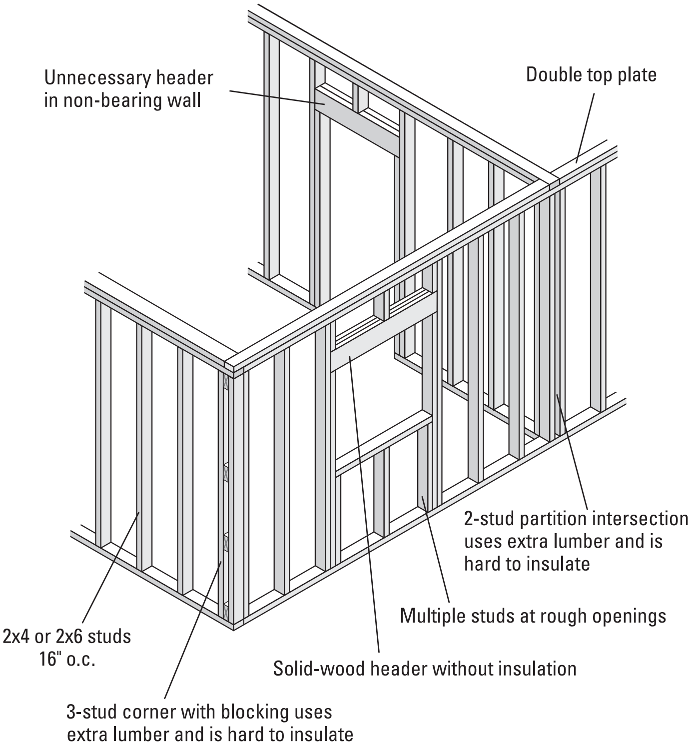


FIGURE 6.9

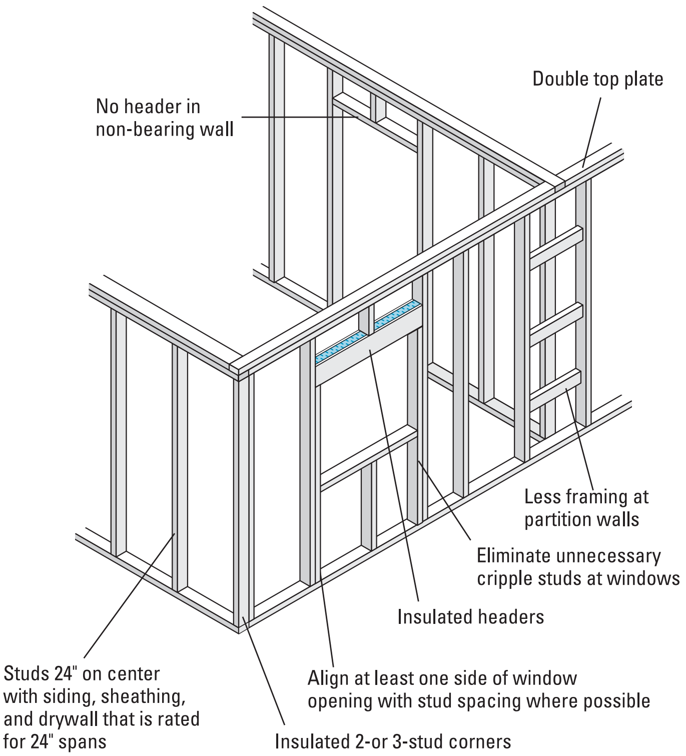
Conventional framing



Standard framing techniques use unnecessary wood and leave less room for insulation. Advanced framing techniques are tested and proven by the National Association of Home Builders, and meet structural codes. For more detail on advanced framing (sometimes called “Optimum Value Engineering”) see *Cost Effective Home Building: A Design and Construction Handbook* by NAHB (contact information in the Appendix).

FIGURE 6.10

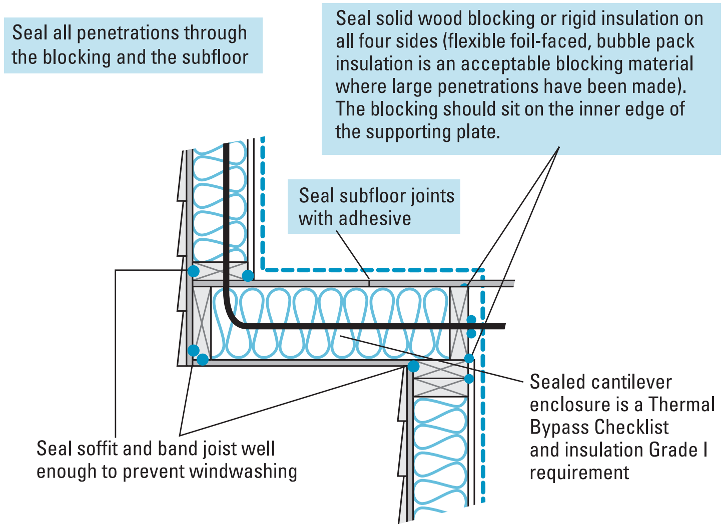
Advanced framing



Advanced framing uses up to 25% less wood, increases overall insulation R-values by 5 to 10%, and costs less to build. Most of these techniques can be used even when framing at 16" on center. The advanced framing techniques shown in this diagram are some of the simplest ones to incorporate into the structure of a building. Many other techniques are not shown. For more information about a wider variety of advanced framing opportunities, see the associated resources listed in "Framing/Alternatives" section of the Appendix.

FIGURE 6.11

Exterior cantilever floor with interior air sealing



Seal all penetrations through the blocking and the subfloor

Seal solid wood blocking or rigid insulation on all four sides (flexible foil-faced, bubble pack insulation is an acceptable blocking material where large penetrations have been made). The blocking should sit on the inner edge of the supporting plate.

Seal subfloor joints with adhesive

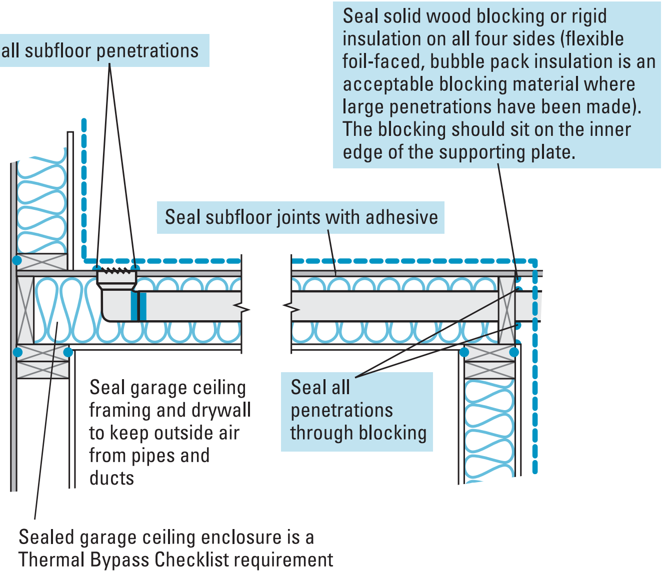
Sealed cantilever enclosure is a Thermal Bypass Checklist and insulation Grade I requirement

Seal soffit and band joist well enough to prevent windwashing

⚠ **CAUTION:** Blocking is often pushed out by subcontractors. Encourage subs to make slightly oversized holes in blocking which are easier to seal later, rather than removing the entire piece.

FIGURE 6.12

Tuck-under garage



Tuck-under garages and attached garages are especially important to seal and isolate from the rest of the house, not only because of heat loss but also for health and safety reasons. Air leakage paths from a garage into the house can bring car exhaust, fumes from stored gasoline or other dangerous chemicals, or fire from the garage into the house. The floor over a garage is also a common area for freezing pipes and poor heat distribution. Provide both an interior and exterior air barrier to thoroughly isolate the floor system and reduce these potential problems.

FIGURE 6.13

Dropped soffit on interior wall

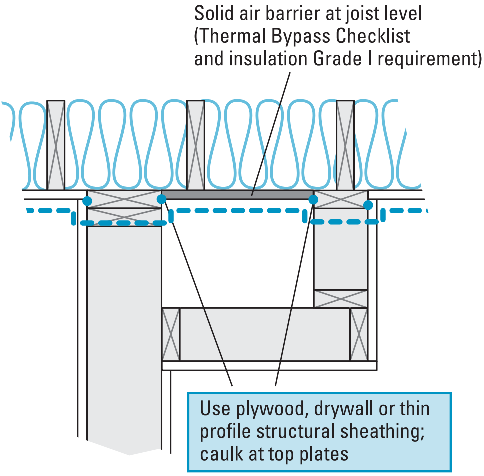
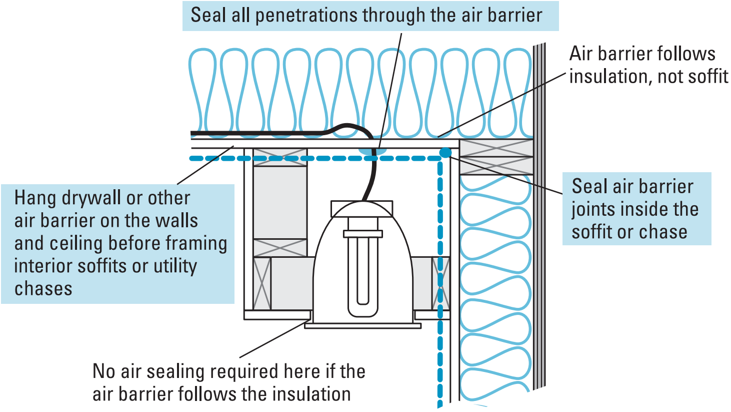


FIGURE 6.14

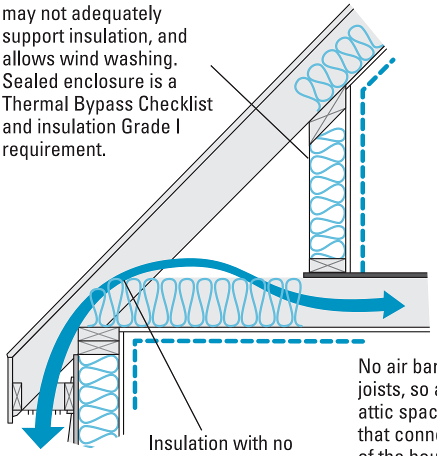
Interior soffit on exterior wall



Dropped soffits are commonly built with direct air paths from inside interior walls into attics. When recessed lights are installed, heat from the lights drives air leakage even faster. Installing air barriers before framing the soffit requires coordination of framing crews and materials.

FIGURE 6.15

Typical 1½-story knee wall



Unsheathed knee wall may not adequately support insulation, and allows wind washing. Sealed enclosure is a Thermal Bypass Checklist and insulation Grade I requirement.

Insulation with no baffle allows wind washing. Wind baffle is a Thermal Bypass Checklist and insulation Grade I requirement.

No air barrier between joists, so air moves between attic space and floor cavity that connects to other parts of the house. Air barrier is a Thermal Bypass Checklist requirement.

Typical knee wall details that are found in cape style homes, bonus rooms over garages, and the like are one of the largest and most common air leakage problems. This figure shows the air movement that allows outdoor air into all the joist bays, between floors. This problem can be eliminated by careful blocking of the floor framing under the knee wall, or by insulating the rafters and providing an air barrier, as shown in Figures 6.16-6.17.

FIGURE 6.16

$1^1/_2$-story knee wall outside the air barrier

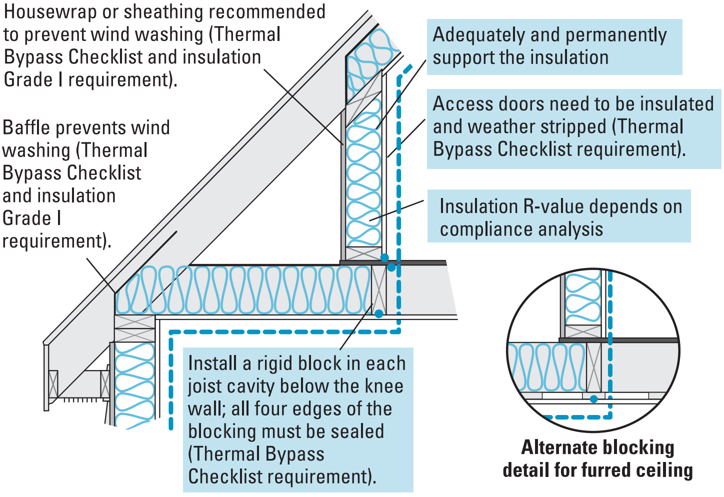


FIGURE 6.17

$1^1/_2$-story knee wall inside the air barrier

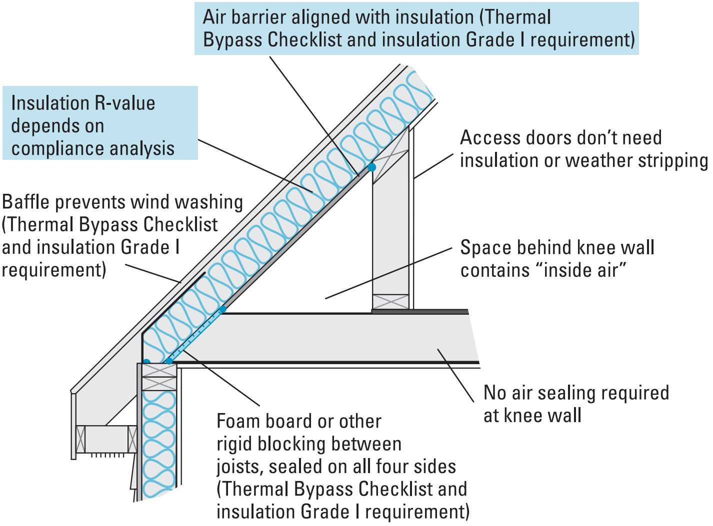
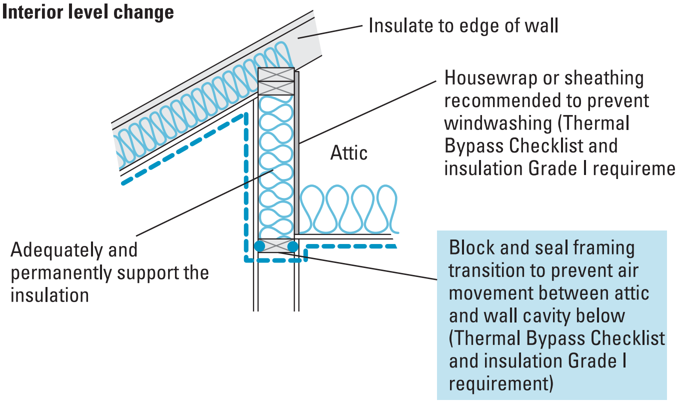
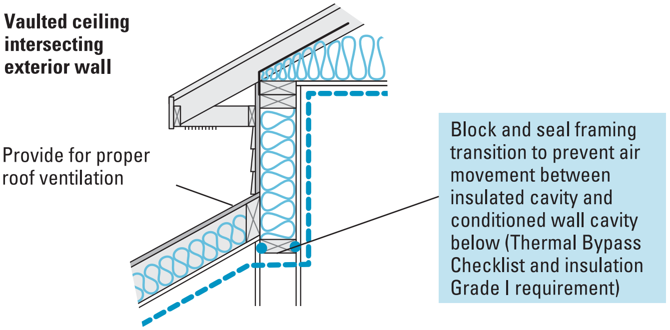


FIGURE 6.18

Sealing split levels


Interior level change


Vaulted ceiling intersecting exterior wall

The lack of draftstop blocking in typical split-level details is another large leak. Be especially careful around stairways framed near these areas in "Tri-level" homes.

7

Windows and Doors

Energy Code Requirements

The primary window requirement in the energy code is for the *U-factor* of installed windows (which includes skylights and glass doors). Note that the U-factor is 1/R, which means smaller U-factors have better thermal performance. This U-factor requirement will vary depending on the results of your compliance analysis. There are only two ways that the code lets you determine the U-factors for a given window:

- **NFRC rating (IECC 102.1.3)**—In order to take credit for a manufacturer's rated "U-factor," the product must be listed by the National Fenestration Rating Council (NFRC). The rating is based on simulations that are verified by a laboratory test, and its purpose is to provide a "level playing field" for all manufacturers to compare their products. The rating information should be available in product catalogs. Additionally, an NFRC sticker attached to every window unit displays the U-factor, along with other performance ratings that are less significant in the northern climate (see Figure 7.1). Be sure you don't remove the stickers until your building inspector has verified the installed product's U-factors!
- **Default tables**—For products that do not have an NFRC rating, you can use IECC Tables 102.1.3 (1 through 3). These tables contain default U-factors and Solar Heat Gain Coefficients (SHGC) for windows, glass doors, skylights and doors of various types. The main reason for these tables is to provide U-factors for the occasional non-rated side lite, transom window, decorative glazing unit, or door. You can use the default values for every window in a house, as long as the house passes the compliance analysis. However, the default U-factors are conservative, and don't allow credit for low-e coatings, gas fills, or any other feature that can't be verified in the field.
- **Remember** that when you calculate window (or skylight or door) area

for the purposes of code compliance, you must use the *whole* unit area (frame dimensions or rough opening). Don't use glass or sash sizes.

Prescriptive Compliance

If you are demonstrating compliance prescriptively, you will have a "Maximum" U-factor to use for all windows in the house. If you have windows (or skylights) with different U-factors, you can do an average U-factor calculation for the whole group.

NJ ENERGY STAR Homes

ENERGY STAR Qualification: Windows and doors

Component	Compliance Highlights
Windows	U-factor determined by HERS compliance analysis ENERGY STAR qualified windows can be used to satisfy the ENERGY STAR Products requirement (see page 14)
Doors	U-factor determined by HERS compliance analysis

Other requirements may apply; see page 17-18 for more details.

Windows

Although people commonly refer to double glazing as "insulating glass," it's important to realize that windows are not "insulated." Windows typically represent three to ten times greater heat loss (per square foot) than wall assemblies. The "best" commonly available, mainstream windows (double, low-e, argon, without special heat mirror films or other premium features) have an R-value of just over 3—that's more than triple the heat loss of the worst wall that most people would ever build today (R-11).

Glazings have improved steadily over recent years. Fifty years ago, the vast majority of windows were single glazed. Double glazing, until recently the norm in virtually all cold climates in the country, is rapidly being supplanted by double low-e. The upgrade cost for low-e coatings continues to drop, and for many products low-e is already standard. A low-e coating is a thin, invisible metallic film that is added to one of the two inside surfaces of glass. This coating has the effect of reducing the radiative coupling between the two panes of glass, markedly improving thermal performance. Gas fills such as argon or krypton are also common. These gas fills are denser than the gas—air—that is used in standard double windows. The higher density of the gas reduces conductive looping inside the window, improving the thermal performance even more. These two features are usually complemented by "warm-edge" spacers. These edge spacers are made of plastic or foam (instead of metal, which was used in the past). Consequently, less heat is conducted through the frames of the windows. Extra layers of glass (or more commonly, plastic films such as "heat mirror") with additional low-e coatings are available as well—usually at a premium price, but they are increasingly affordable. The best (highest performance) windows currently available combine all of these features and have frames that are made of foam-filled rigid fiberglass (see Figure 7.2). Foam-filled fiberglass frames conduct less heat than the typical wood or vinyl frames, and they are generally very durable and dimensionally stable.

The ENERGY STAR designation can be used as a baseline for window performance. While it is by no means a requirement to use ENERGY STAR windows in all New Jersey ENERGY STAR Homes, most builders do opt for them; the upgrade cost is fairly small for the benefits involved (efficiency, comfort, reduced condensation potential, etc.). To get a complete picture of the factors that affect the impact of window type on the energy performance of the building, you must also consider the following:

- **U-factors**—There are many different performance numbers associated with a given window type (see Figure 7.1). The only number that is used for energy code compliance is also one of the most important to you as a designer or builder; use the *whole-unit* U-factor (as determined by the National Fenestration Rating Council [NFRC]) to compare products. The lower the U-factor, the better it performs.
- **Solar Heat Gain Coefficient (SHGC)**—The SHGC is a measure of the amount of the sun's energy that is transmitted through a window. In New Jersey's mixed-humid climate, the SHGC is also an important factor in assessing the impact of window selection on home performance (despite the fact that it is not used in determining energy code compliance). Again, lower numbers indicate better performance.
- **Orientation**—South facing glass reduces heating loads and adds little to cooling loads. South facing glass is good. If you have south facing glass area (not including frame area) that's more than 7% of the floor area of the building, you should think about adding extra thermal mass to avoid overheating. East and west facing glass does not reduce heating loads in winter, but is the primary source of summer cooling loads. Limit east and west glass if you can; if you need large areas of glazing in these directions, consider using "southern" low-e products (which often cost the same if you order in advance) with low solar heat gain coefficients (SHGC).
- **Shading** is another way to reduce unwanted heat gain from east and west facing glass. Trees, overhangs, decks, or awnings can all be used to reduce the time that the sun shines in these windows. On the south side, properly designed shading can admit the sun in winter when it is low in the sky and block it out in summer when the sun is high.

Window installation is another factor that can affect not only the energy efficiency of a house, but also its durability. Regardless of the window type selected, care should always be taken to ensure that any water that gets behind the siding or through the window frame is drained and shed down, out and over the sheathing wrap or building paper. Use a properly lapped sill flashing that is integrated with the building drainage plane. An excellent resource for this and related flashing details is the EEBA *Water Management Guide* (see Appendix). Outdoor air should also be prevented from entering the house by sealing the window frame and/or casing to the rough opening in the framing (see Figures 7.2 and 7.4).

By carefully selecting windows, you can trade off upgrade costs immediately with dollars saved elsewhere. High performance glazings, when coupled with air sealing, can reduce peak heating and cooling loads, and allow substantial savings on mechanical equipment costs. For example, upgrading from double-pane to low-e glazings (or from low-e to heat mirror films), can reduce cooling loads by 1/2 to 1 ton in a typical house, saving enough on HVAC costs to pay for the window upgrade. Also, higher average surface temperatures and lack of drafts may allow HVAC contractors to put supply registers or baseboards near inside walls, saving significant installation costs.

Doors

Doors can generally be divided into two categories—those that are insulated and those that are not. Insulated doors typically have R-values between 2.5 and 7. Metal doors perform much better if they have *thermal breaks*—interruptions in the conductive metal components—built into the door and frame. Insulated fiberglass doors can achieve high R-values without special thermal breaks. Uninsulated doors (e.g. all wood doors) have R-values closer to 1. Most new doors that have any amount of glazing are also NFRC-rated (by U-factor), which makes it easier to compare one door to the next. Usually, aesthetics and price drive consumers to select one door over another, which is fine; doors take up a small enough area of the thermal boundary that the R-value has a small impact on the overall performance. Of course, all other things being equal, it's still a good idea to choose the most efficient one available.

FIGURE 7.1

NFRC Sticker

National Fenestration Rating Council
CERTIFIED

World's Best Window Co.

Millennium 2000+
Vinyl-Clad Wood Frame
Double Glazing • Argon Fill • Low E
Product Type: **Vertical Slider**

ENERGY PERFORMANCE RATINGS

U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
0.34	**0.25**

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance	Air Leakage (U.S./I-P)
0.41	**0.2**

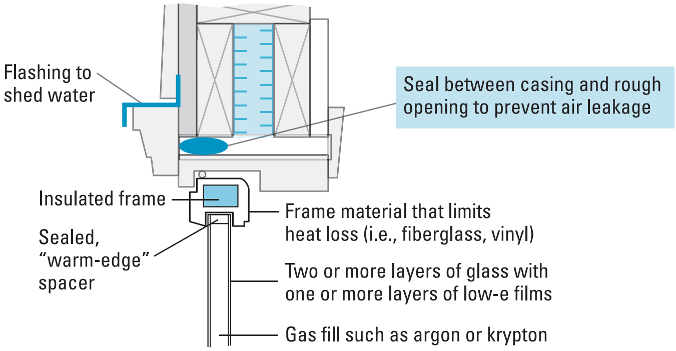
Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. Consult manufacturer's literature for other product performance information.
www.nfrc.org

TIP:

The National Fenestration Rating Council (NFRC) rating is the only way allowed by code to verify the manufacturer's rated thermal performance of windows, skylights and glass doors. A sticker similar to the one shown above is attached to each window. In addition to the performance ratings expressed above, condensation resistance (measured on a scale from 0 to 100; the higher the number the better) may also appear on the label. The ratings associated with condensation resistance and air leakage (measured in CFM/square foot) are optional; the manufacturer decides whether or not to include them. Performance ratings can also be found in the NFRC Certified Products Directory (see Appendix), or can be obtained directly from the manufacturer.

FIGURE 7.2

Features of a high performance window

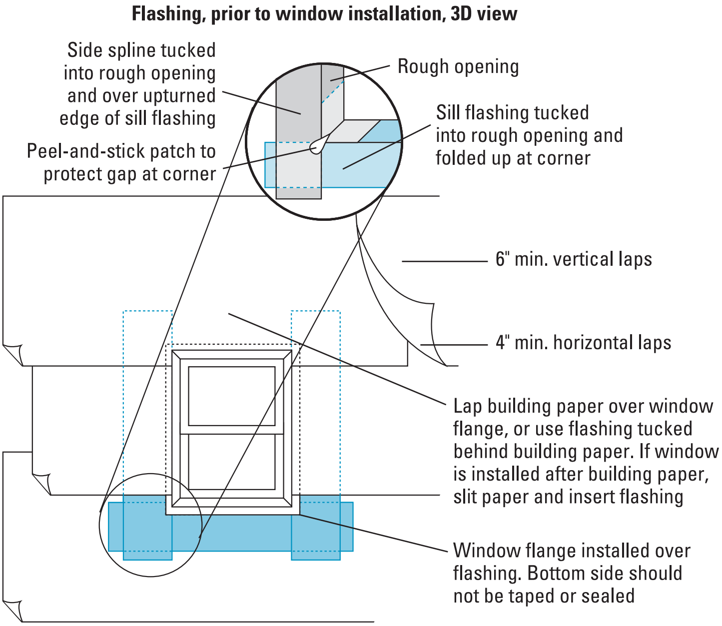


TIP: Most high performance windows are ENERGY STAR qualified. The parameters for ENERGY STAR qualified windows vary by climate. In New Jersey, ENERGY STAR qualified windows (and doors) must have a whole-unit U-factor of 0.40 or less and a SHGC of 0.55 or less.

NOTE: Window flashing should be integrated with building drainage plane; details not shown for clarity—refer to Figure 7.3.

FIGURE 7.3

Traditional style window flashing



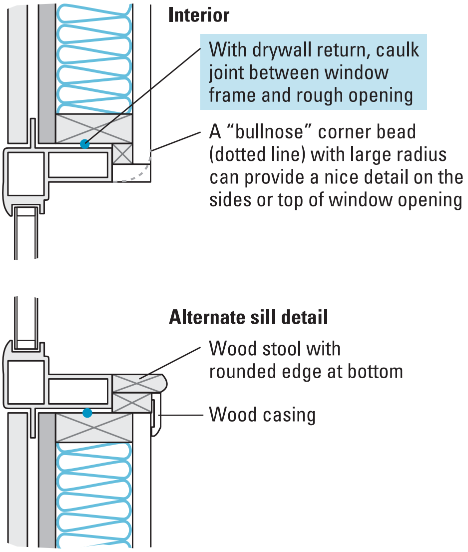
Note: Traditionally, the rough sill was prepared with felt or building paper; best practice today is to flash the rough sill with a more robust peel-and-stick membrane. A beveled or sloped sill or back dam to divert water to the exterior is also recommended.

⚠ **CAUTION:** It is difficult to convey the steps required to effectively flash a window opening in a single drawing. Furthermore, there are many combinations of window type and wall assemblies, so one procedure cannot be portrayed to work in every situation. Construction scheduling also affects the detailing: the process is different if you install the windows before, or after, the sheathing wrap.

There are many ways to do this right, but there are even more ways to do it wrong. This figure is only meant to convey an overall strategy. For step-by-step guidance and better specifics, please refer to the EEBA Water Management Guide (see Appendix for ordering information).

FIGURE 7.4

Window with drywall return



⚠ **CAUTION:** Do not use high-expansion foam. It may cause bowing of window and door frames and void the warranty.

NOTE: Window flashing should be integrated with building drainage plane; details not shown for clarity—refer to Figure 7.3.

8

Mechanical Systems

Energy Code Requirements

The energy requirements of the building code that apply to HVAC installations (IECC Section 403) are in addition to any plumbing, mechanical, and fuel gas codes that apply to these systems. Although it is generally the HVAC installer's responsibility to follow these requirements, the builder may also have to know what they are and to communicate them to the subs for a given project because they are in the building code. A summary of the HVAC requirements is provided below. Remember that these requirements generally apply to all residential buildings, but more complex mechanical systems typically found in multifamily residences may have to meet additional requirements.

- **Heat loss calculations and system sizing (IECC 403.6 and IRC M1401.3)**—Heating and cooling systems must be sized using load calculations that are based on Air Conditioning Contractors of America (ACCA) *Manual J* (see Appendix for ordering information) or another approved calculation method. In addition, note that Section M1601 of the IECC-2006 New Jersey Edition specifies that duct systems shall be fabricated in accordance with ACCA Manual D or another approved method.

  ACCA *Manual J* is required by the IRC One and Two Family Dwelling Code (see Section M1401.3). The design parameters used for these calculations are given in IECC Chapter 3.

- **HVAC system efficiencies**—The minimum efficiency requirements for HVAC systems follow federal minimum efficiency standards. See following table and the next bullet for more information.

Equipment	Rating	Minimum
Boilers (oil and gas)	Annual Fuel Utilization Efficiency	80
Furnaces (oil and gas)	Annual Fuel Utilization Efficiency	78
Heat Pumps (air source)	Heating Seasonal Performance Factor	7.7
Central Air Conditioning	Seasonal Energy Efficiency Ratio	13

- **Heating system trade-offs**—Many boilers and furnaces are more efficient than the code minimums. You can take credit in any of the compliance methods for systems with higher than minimum efficiency. Get the equipment efficiency ratings from your HVAC installer (or subcontractors you have worked with) *before* you do the compliance analysis. As a designer or builder you can specify high levels of efficiency, which makes it easier to meet the code. However, be careful to know in advance what your requirements are, and how much the upgrade costs.
- **HVAC controls**—The following is a summary of the control requirements that are included in IECC section 403:
    - Every heating and cooling system must be equipped with at least one thermostat (IECC 403.1).
    - Heat pumps that include auxiliary electric resistance heaters must have controls that lock out the auxiliary heaters above a preset outdoor temperature (IECC 403.1.1).
    - Circulation pumps that are part of a circulating hot water system must be equipped with shutoffs (IECC 403.4).
    - All mechanical ventilation systems must have controls to shut down when ventilation is not required. When the system is shut down, automatic or gravity-driven dampers at the points of intake and exhaust must be closed (IECC 403.5).
- **Duct and pipe insulation** (IECC 403.2 through 403.4) is required for all HVAC ductwork and pipes in unconditioned spaces. All ductwork must be insulated to a minimum of either R-6 (if the ductwork is located in floor trusses) or R-8 (for all other ductwork). All hydronic pipes that are either part of a circulating hot water system or carry water that is either less than 55°F or greater than 105°F must be insulated to a minimum of R-2.
- **Duct sealing** is required on all ductwork (IECC 403.2.2 and IRC M1601.3.1). All portions of stud bays or joist cavities used as ductwork must also be sealed. All connections and seams must be sealed with either mastic or fibrous tape embedded in mastic (see Figure 8.1). Only two types of tapes are permitted for use in duct sealing, and their applications are specific to the type of duct being installed. Respectively, tapes meeting UL 181A and 181B may only be used for rigid fiber ducts (A) and for flex ducts (B). Duct tape is not allowed for duct sealing.

- **Written materials** describing regular maintenance actions must be left with all HVAC and water heating equipment (IECC 102.3). A label with a reference to such material is also acceptable.

NJ ENERGY STAR Homes

NJ ENERGY STAR Homes Qualification: Mechanical systems

Component	Compliance Highlights
Heating	Minimum efficiency determined by HERS compliance analysis (at least ENERGY STAR qualified—see page 18)
Cooling	Minimum efficiency (where provided) determined by HERS compliance analysis (at least ENERGY STAR qualified—see pages 18-19) Cooling system must be right-sized.
Thermostat(s)	Programmable thermostat recommended
Ductwork	Maximum 6 CFM/100 square feet of allowable leakage conditioned floor area NJ ENERGY STAR Homes requires fully ducted supplies and returns, sealed with mastic compound.
Duct insulation, minimum R-value	Determined by HERS compliance analysis

Other requirements may apply; see pages 15-22 for more details.

General Recommendations

- **Bring ducts and pipes inside**—Ducts and pipes in unconditioned attics, garages, basements and crawlspaces lead to higher heat loss, discomfort, and ice dams. *Whenever* possible, bring the mechanicals inside the thermal boundary of the house. Builders and designers can help make sure that framers leave room to run the heating and cooling distribution system inside the thermal boundary.
- **Avoid ducts in outside walls**—If you must put a heating duct in an outside wall cavity, install *at least* R-14 rigid insulation between the duct and the exterior sheathing.
- **Use high efficiency equipment,** which will save the buyer money, and is one of the easiest ways to gain credit toward complying with ENERGY STAR standards or the energy code. Many utility companies have rebates or incentives available to help offset the higher purchase price of high efficiency heating or cooling systems. These incentives are usually linked to the ENERGY STAR performance standards listed below. Note that these performance standards are for HVAC systems only, and that the specification of these systems is only a requirement for the prescriptive compliance option.

Equipment	Rating	Minimum
Boilers (oil and gas)	Annual Fuel Utilization Efficiency	85
Furnaces (oil and gas)	Annual Fuel Utilization Efficiency	90
Heat Pumps (air source)	Heating Seasonal Performance Factor	8.2
Central Air Conditioning	Seasonal Energy Efficiency Ratio	14

The above are the most common system types. For more detailed information refer to the NJ ENERGY STAR Homes Builder Guidelines.

- **Use sealed combustion equipment** to avoid backdrafting and carbon monoxide in the home. Figure 8.2 shows one typical backdrafting scenario; any large exhaust fan can backdraft atmospheric vented combustion appliances. By installing sealed combustion boilers, furnaces, and/or water heaters you can avoid the expense of building a chimney; many of them can vent through the side wall (see Figure 8.3).
- **Use integrated systems**—Integrated heating/hot water systems can save energy and also save on installation costs. An integrated system (a boiler and an indirect fired water storage tank) is much more efficient than a stand-alone tank, uses only one burner to do both jobs, and needs only one venting system. If forced air is desired, a boiler can provide heat through a "hydro-air" fan coil. In a house with small heating loads, the fan coil can be supplied by a small, high efficiency, stainless steel water heater with a heat exchanger. This approach also saves space. Avoid using a "tankless coil" in the boiler (not the same as an instantaneous "tankless" water heater) for water heating; they have the lowest efficiency of all and are not permitted when using the prescriptive ENERGY STAR compliance option.
- **Sizing** for air conditioning systems (prescriptive ENERGY STAR compliance requirement) is especially important because the ability to dehumidify is an important part of their job. When an air conditioner is oversized, it is not as effective at removing water from the air. The air gets chilled enough, but ends up "cold and clammy." A properly sized air conditioning system not only saves money on installation, but actually provides a higher comfort level.
- **Consider setback thermostats** to give homeowners a convenient way to manage indoor temperatures. Although these thermostats will only provide a benefit if the occupants choose to use the setback feature, most people will use it. Setbacks can provide significant savings.

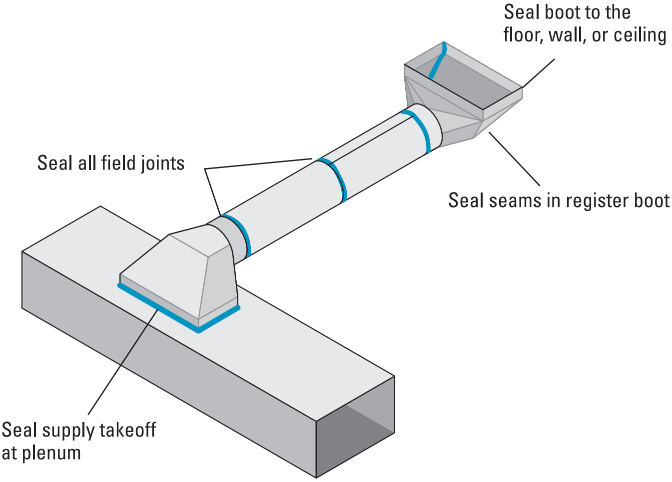
Going Further

There are a number of references listed in the Appendix specifically related to indoor air quality, ventilation, and HVAC systems.

FIGURE 8.1

Sealing duct runs within unconditioned spaces

Use mastic to seal all the locations shown here. Use fiberglass mesh as reinforcement for gaps larger than 1/8".



Leaky ductwork in unconditioned basements and attics is a major source of heating and cooling losses. Run ducts inside the thermal boundary wherever possible.

To apply mastic, use vinyl gloves and smear it in place by hand. Pay close attention to:

- folded corners on end caps, boots and takeoffs;
- plenum connections;
- filter racks;
- swivel elbows; and
- finger-jointed collars

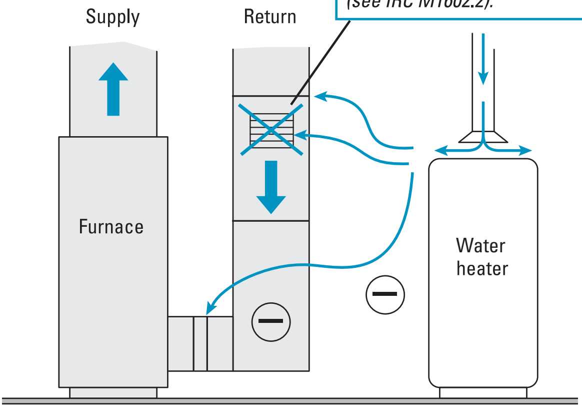
TIPS: Mastic is much faster to install and more reliable than the more common aluminum tapes.

FIGURE 8.2

Depressurization and backdrafting

This figure shows a typical scenario. Leaks in return ducts depressurize the basement. Depressurization can backdraft the water heater vent or the furnace burner. Backdrafted combustion products, which may include deadly carbon monoxide, are then circulated throughout the house.

Note: Return grilles are generally not allowed in mechanical rooms with atmospheric vented appliances (see IRC M1602.2).

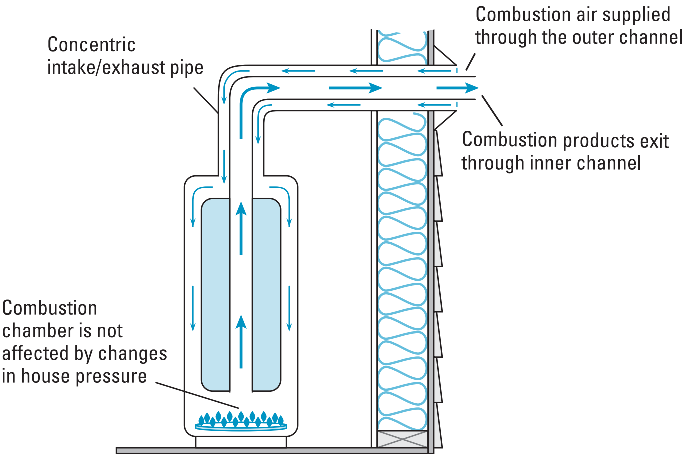


Depressurization that causes backdrafting can be created by any exhaust appliance. The large ones that are most likely to create depressurization include range vents, whole house fans, dryers, central vacuum, and fireplaces without outdoor air supply. Leaks in return ducts and/or the presence of return air registers in the vicinity of a combustion appliance can also cause backdrafting (as shown in the diagram above). **Mechanical code requirements for passive combustion air inlets or volume of air space do not guarantee against backdrafting,** yet they add to building heat loss.

The best way to avoid potential backdrafting issues is to install only sealed combustion or power vented equipment (furnaces, boilers and water heaters). Note that the higher efficiency water heaters typically used in ENERGY STAR qualified homes may be available with atmospheric venting, but that at a minimum a power vented option is recommended. A power vented upgrade may even be price neutral: Although equipment cost is typically higher, installation of a dedicated B-Vent is avoided with the less expensive installation of a PVC vent. **If atmospheric equipment is used in the NJ ENERGY STAR Homes program, a test should be performed to determine adequate draft under "worst case" depressurization conditions.**

FIGURE 8.3

Direct vent water heater

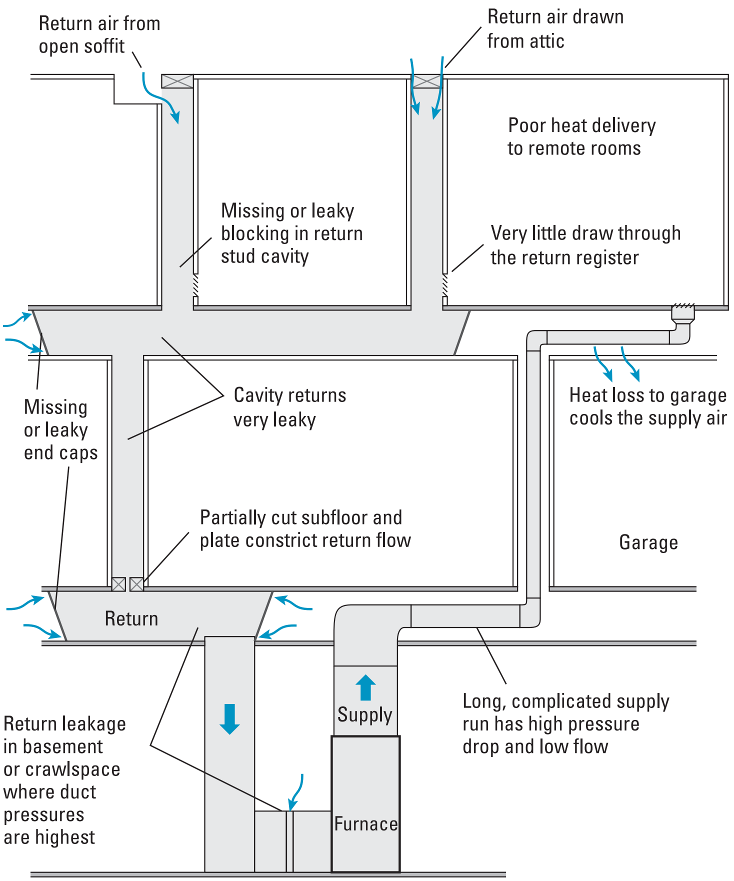


TIP: The placement of a direct vent appliance is limited by the allowable length of the intake/exhaust pipe. Plan carefully for locating these appliances.

The direct vent water heater is completely sealed from indoor air, so backdrafting into the living space cannot occur. Similar arrangements are available for furnaces, boilers, and gas or wood fireplaces and stoves.

FIGURE 8.4

Duct problems to avoid



9

Ventilation

The word "ventilation" can be interpreted in several ways. For example, it can be used to refer to the vents that provide air circulation in an attic or crawlspace. Vent systems for combustion appliances provide for removal of combustion gases. The focus of this chapter is on *mechanical* ventilation systems and how they can be used to reduce moisture inside our homes and improve indoor air quality. From this perspective, there are essentially two types of mechanical ventilation fans: local exhaust fans that are used to remove air from a specific location within a house (e.g., a kitchen range hood or a bath fan) and *background* mechanical ventilation systems that are used more generally to improve air quality in the house (also referred to as "whole-house mechanical ventilation" or "mechanical ventilation for indoor air quality"). Building codes focus on local ventilation; background ventilation is emphasized in this chapter.

Energy Code Requirements

The IECC does not include any requirement for background mechanical ventilation. The only requirements for mechanical ventilation are for local exhaust fans that are installed in kitchens and bathrooms (IRC Section M1507). Kitchen exhaust fans must be capable of exhausting air at a rate of at least 100 CFM (intermittently) or 25 CFM (continuously). Each bathroom must be equipped with a fan that is capable of exhausting air at a rate of at least 50 CFM (intermittently) or 20 CFM (continuously).

Where background mechanical ventilation is required by a program or jurisdiction, ASHRAE Standard 62.2 is usually cited (see page 103).

NJ ENERGY STAR Homes

ENERGY STAR Qualification: Ventilation

Component	Compliance Highlights
Whole-house	Mechanical ventilation with 24-hour automatic control is a New Jersey ENERGY STAR Homes program requirement ENERGY STAR ventilation fans can be used to satisfy ENERGY STAR lighting and appliance requirement (see page 14)

Other requirements may apply; see pages 15-22 for more details.

By contrast, all New Jersey ENERGY STAR Homes must include a mechanical ventilation system. Controlled mechanical ventilation provides the following benefits:

- **Healthier indoor air**—ASHRAE recommends that residential buildings be maintained at 30 to 60% relative humidity for optimum health. Why? Some biological contaminants thrive in low or high humidity, but most are minimized in this range. How do you control the humidity? In any climate and in any season, the first step is to control the air exchange rate. In the winter, dryness is caused by excess air leakage; when dry outdoor air is heated, the relative humidity drops. High humidity, on the other hand, is often caused by underventilation and poor source exhaust for moisture-producing activities such as cooking and bathing. Control the dryness by limiting air leakage, and control the moisture by ventilating the house. In the summer, the only way to control humidity is with mechanical dehumidification or properly sized air conditioning systems (see pages 143-144).

  A typical non-ENERGY STAR home has compromised air quality due to its materials and contents. Just as mechanical ventilation provides the ability to control humidity, it also allows occupants to dilute indoor pollutants like volatile organic compounds, fumes from solvents and cleaning agents, carbon monoxide, and other compounds people shouldn't be breathing.
- **More reliable and consistent supply of fresh air.** Leaving ventilation to random air leaks doesn't work. Even leaky buildings tend to be underventilated in the spring and fall, when there's little driving force for air movement. They are also overventilated in the winter when the driving forces are large, and when it costs more money to heat up the leaking air. Leaving ventilation to operable windows and doors doesn't work. Build the house tight enough to limit the air leakage, and then give the occupants control over background ventilation rates.
- **Reduced moisture**—As well as healthier indoor air, controlled ventilation helps to limit moisture problems in the building. Water is by far the

biggest threat to building durability. Exhausting water vapor as it is produced and keeping the indoor humidity reasonable is important in keeping the whole building free of moisture problems. Humid indoor air tends to find its way into building cavities and unconditioned spaces and to deposit water there. And once the building does get wet, high humidity will slow down the rate at which drying will occur. Kitchen range hoods should be exhausted to outdoors, especially if there is a gas range. Don't use dryer hose. Keep duct runs as short as possible. Of course, ventilation may not be adequate if moisture is getting into the house because of improper foundation drainage, roofing, or siding details.

- **Improved comfort**—Sealing air leaks in the building limits overventilation and drafts. Ventilation contributes to improved comfort in several ways. Controlling background ventilation rates reduces cooking odors, damp musty smells, "stale air," and elevated levels of carbon dioxide. By controlling indoor humidity, air sealing and ventilation work together to improve comfort.
- **Fewer callbacks**—A newly built house has a lot of moisture in it. Foundations, framing, drywall, plaster and paint all bring water into a new home. Depending on the weather and other conditions, there may be a lot of water. The most likely time to get a moisture-related callback is in the first winter of occupancy. When a new homeowner calls you to say "Our windows are sweating and there's mildew in the bathroom," what will you tell them? "Open a window?" How about, "Set your ventilation system to run more often (or at a higher speed)." Presto, the moisture problem is gone. Healthier, more comfortable people are less likely to complain and more likely to provide referrals.

How much ventilation?

ENERGY STAR guidelines reference ASHRAE Standard 62.2 as a means of specifying mechanical ventilation. This standard calls for a minimum of 7.5 CFM of fresh air per occupant plus one CFM for every 100 square feet of living space. For most moderately tight homes, the ventilation rates shown below will supplement natural air leakage to a level sufficient to promote good indoor air quality.

Background Ventilation Rates

Number of bedrooms	1	2	3	4	5
Ventilation CFM	30	45	60	75	90

To account for variances in occupant behavior and in home performance, the average flow rate should be adjustable with a variable speed control or a timer. It is also good practice to install a fan with excess capacity (typically 40-70 CFM) to provide flexibility in meeting varying ventilation needs.

Types of ventilation systems

- **Bath fan system**—The easiest type of ventilation system to install is a simple exhaust fan system. Choose one bath fan to upgrade with a quiet fan (less than 1.5 sone, preferably). People won't use a fan that sounds like an airplane. Choose a model that is rated for continuous operation (typically 30,000 to 50,000 hours). This is to make sure it doesn't break after a year or two. The fan must be ducted to outdoors. This type of system is inexpensive; makeup air comes in through small leaks that exist even in a very tight building. It is not as effective at providing fresh air to upstairs rooms as a fully ducted supply air system, such as an energy recovery system (see below).
- **Central exhaust**—This is a middle-of-the road type of system. You can run ducts from the bathrooms and kitchen to a central exhaust fan, which has a 24-hour timer or variable speed control. Be careful to size the ducts for adequate airflow, to balance the system properly, and to get adequate airflow from each bathroom for moisture removal. Most exhaust fans are not rated for range hood duty, so don't place the kitchen exhaust register right over the stove! This system also gets its makeup air through leaks in the building shell. Although central exhaust fans are often installed in the attic, putting the fan in the basement and exhausting out the band joist eliminates the need to insulate the ducts and places the fan in a location that stays warm, isn't dusty, and is much easier to get to for service. It also eliminates a void in the attic insulation.
- **Return makeup air**—These systems pull fresh air into the home through the return duct of a forced-air distribution system (see Figure 9.1). They are better than exhaust type systems at distributing fresh air into all the rooms in a house. In order for this approach to be effective and economical, a few issues need to be covered. The fan needs some sort of control that will run it even if there is no need for heating and cooling, or the house won't be ventilated during those times. When the heating or cooling needs are greatest, the fan will be running a lot, and the house will be overventilated unless the rate is controlled. In this case, the rate should be controlled by installing a mechanical damper on the duct that connects the system to the exterior. The position of the damper, in turn, is set by the control that provides periodic calls for ventilation air. Also, using a forced air system for ventilation means that the fan will run more, so electrical cost becomes a concern because typical furnace or air conditioner fans use a lot more power than typical ventilation fans. The operating cost can be reduced by using an electronically commutated motor (ECM), which is required by the NJ ENERGY STAR Homes program if using this method to provide fresh air ventilation.

- **Energy recovery ventilation (ERV)** systems simultaneously pull exhaust air from the bathrooms and kitchen, and deliver fresh air to the living area and bedrooms, or to the return plenum of a whole-house air handler (see Figure 9.2). The two air streams run through an exchange core where heat and humidity are transferred from one stream to the other. Be aware that even a large ERV may not adequately remove moisture from bathrooms if the exhaust ducts are run to many locations; it may be better to use a smaller ERV unit and to install separate bath fans for fast removal of steam. **Heat recovery ventilators (HRVs)** do not transfer moisture between the two air streams and are more appropriate in homes without air conditioning.

Ducts and Controls

All exhaust fans must be ducted all the way outdoors (not into attics or other spaces). Any ducts running through unconditioned spaces must be insulated to minimize condensation. The commonly-used vinyl flex duct is not recommended. Much better air flow can be obtained with smooth-walled rigid ducts of aluminum or steel. PVC duct pipe also works well. Minimize sharp turns. Use mechanical fastenings (screws, clamps) rather than tape. Seal the ducts airtight. Noise can be minimized by using flexible mountings for fans and by attaching the ducting to the fans with short lengths of flex duct.

Controls are important. Fans on switches don't run for a long enough time. One step better is a wind-up timer that will run the fan for a specific number of minutes and then shut off automatically. Some fan/light combinations have a "delayed off" function for the fan. The best strategy is to provide some minimum ventilation automatically even if no one ever turns anything on. You can have the fan run all the time or put it on an automatic timer. Simple 24-hour pin type timers work well, or you can install more sophisticated controls that offer more options. Dehumidistats, which turn on and off based on humidity the way a thermostat does based on temperature, may seem to be a good option, but the setting needs to be changed according to the season. Most occupants won't do that consistently.

New homes tend to have a lot of moisture stored in the building materials, and they also typically have chemical compounds in the air from carpets, paint, cabinetry, etc. It may be a good idea to ventilate the building at a somewhat increased rate for some time, including the first winter, when many houses experience their greatest levels of window condensation.

FIGURE 9.1

Return duct fresh air

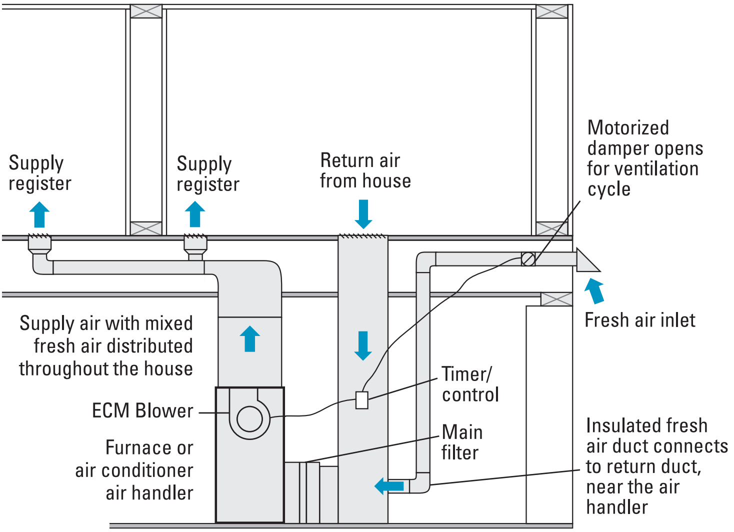
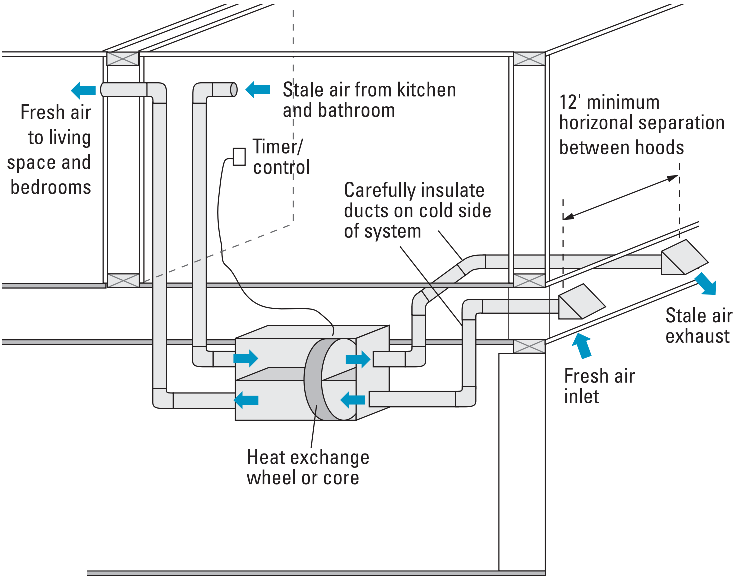


FIGURE 9.2

Energy (or heat) recovery ventilation



10

Plumbing and Electrical

Energy Code Requirements

Sealing penetrations

All penetrations through the thermal boundary of the building must be sealed (see Chapter 11). This can be done by individual subcontractors, but is more likely to be done by the builder. Electricians and plumbers can help by cutting slightly oversized holes to allow room for spray foam (see Figure 11.4), and by minimizing unnecessary penetrations.

Recessed lights

Recessed lights in insulated ceilings must be rated for Insulation Contact ("IC" rated), and must be airtight. See page 42 for further details.

Tub/shower units on exterior walls

Be sure these have an adequate air barrier in place before installing the unit. This includes insulation and a vapor retarder as well. See Figure 11.8.

NJ ENERGY STAR Homes

ENERGY STAR Qualification: Plumbing and Electrical

Component	Compliance Highlights
Water heater, minimum efficiency	Determined by HERS compliance analysis
Lighting and Appliances	Check for the latest New Jersey specific requirements. Five or more ENERGY STAR qualified light fixtures, appliances, ceiling fans equipped with lighting fixtures and/or ventilation fans may be used to satisfy EPA's ENERGY STAR products requirement (see page 14)

Other requirements may apply; see pages 15-22 for more details.

Plumbing and electrical penetrations are major sources of air leakage in buildings. In addition, pipes and wires in exterior walls can make it difficult to install insulation properly. Keep plumbing out of exterior walls whenever possible (especially if the walls are being insulated with fiberglass batts). Try to run electrical wires low across walls, so it is easier to split batts on either side. If the walls are insulated with a blown- or sprayed-in insulation, there is less concern about interference. It's still a good idea to run plumbing in interior walls, or stay as close as possible to the interior in a 2x6 or larger wall, to avoid problems with freezing pipes.

Going Further

Water Conservation

Energy savings associated with service water heating can be achieved by opting for high efficiency mechanical systems (see Chapter 8) and also by reducing the amount of hot water that is actually consumed. Here are some ways to save water and the energy used to heat it.

- **Look for the Environmental Protection Agency (EPA) WaterSense label** to find efficient products (see www.epa.gov/watersense). WaterSense^{SM}, a voluntary partnership program, seeks to promote water efficiency and enhance the market for water-efficient products and services. Fundamentally, the goal of WaterSense is to decrease indoor and outdoor non-agricultural water use through high efficiency products and simple practices. The program helps customers identify water-efficient products in the marketplace, while ensuring product performance and encouraging innovation in manufacturing.
- **Low flow fixtures**—Showerheads with a 2.0 gallon/minute (GPM) capacity conserve water but still have enough flow for a comfortable shower. Kitchen faucet aerators should be rated at 1.5 GPM, bathrooms at 1.0 GPM.
- **Water saving appliances**—Front-load washing machines use an average of 10 gallons per wash *less* water than similarly sized top-load washing machines. Such machines save electricity, detergent, and the energy used to heat wash water. They spin the clothes more thoroughly dry than conventional machines, saving even more.
- **House design**—Plan for centralized plumbing by locating the kitchen, bathrooms, the laundry room and the water heater in a common vertical space. By grouping and stacking in this manner, hot water can be readily delivered to the locations where it is required, resulting in less water use and a reduction in heat loss through the hot water pipes.
- **Distribution**—If long runs from the water heater to the plumbing fixtures cannot be avoided, consider installing a parallel pipe (or home-

run) system to reduce pipe losses as a result of the direct connection between the hot water source and the fixture (see Figure 10.1).

Hot Water Circulation

In large houses, recirculating hot water pipe loops are sometimes used to keep hot water close to every fixture. As an alternative, a *demand* recirculation system can be used to reduce "standby" losses. These systems rapidly replace water in the pipe with hot water before the tap is opened. Although there is a slight delay in the delivery of hot water to the fixture, the energy savings compared to the continuously circulating loop is significant.

Heat Recovery

Most of the hot water used in a home goes down the drain with plenty of heat still left in it. A drain water heat recovery device (see Figure 10.2) can capture some of that heat and send it back to the water heater using no electricity and with no moving parts. These systems work best when there is a prolonged usage of hot water (i.e., when the hot water is draining at the same time that the water tank is filling). A drain water heat recovery system is typically installed in the drain line below the most commonly used shower, or on the main drain just before it exits the house. Cold water bound for the water heater is preheated as it circulates around the drain line, picking up heat from the drain water.

FIGURE 10.1

Home run plumbing

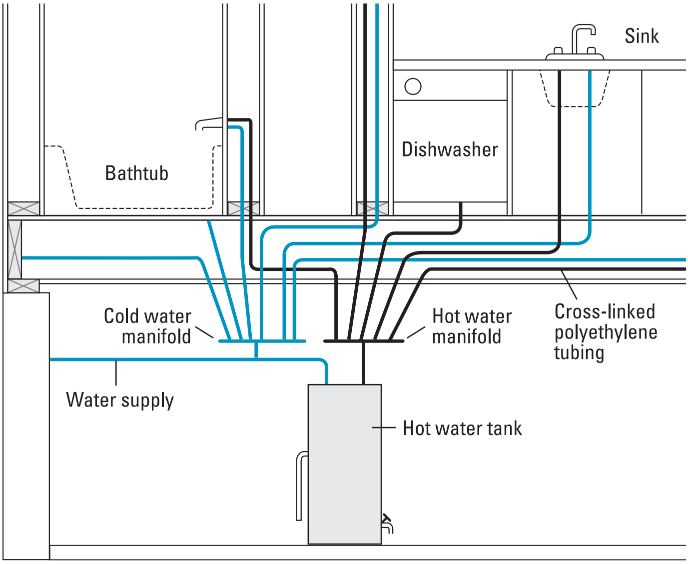
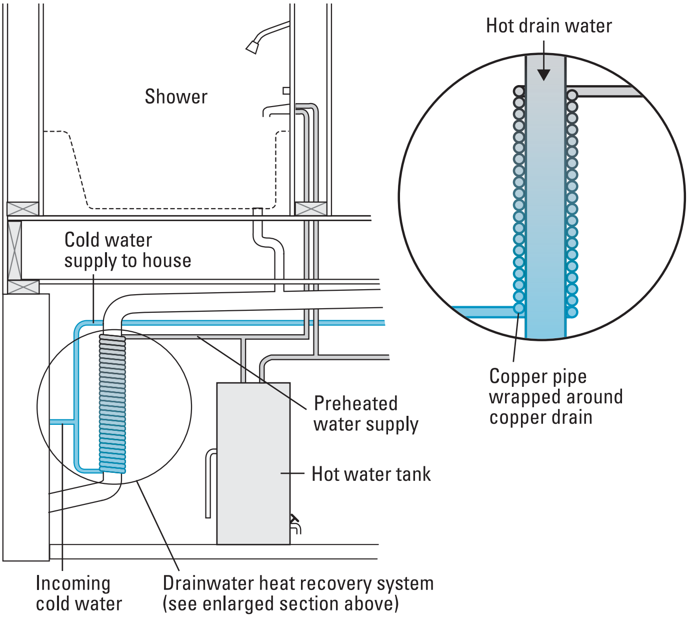


FIGURE 10.2

Drainwater heat recovery system



Piping arrangement shown for illustrative purposes only. Please consult manufacturer's recommendations and local codes for details of piping requirements.

11

Air Sealing

Energy Code Requirements

The code has a list of areas that must be sealed (IECC 402.4), and gives examples of sealants to use. The leaks to be sealed include leaks between conditioned and unconditioned space, and leaks between conditioned space and outdoors. Note that fiberglass batts do not stop air and cannot be used as a sealant.

It is interesting to note the extent to which code requirements for air sealing and fireblocking overlap: “Fireblocking shall be provided to cut off all concealed draft openings (both vertical and horizontal)…” (IRC Section R602.8). Fire is much the same physically as heat loss, except it’s much faster and more destructive. Specific fireblocking requirements parallel the requirements for air sealing that are outlined in the IECC, calling for draft stops that address the following:

- Hidden leaks in walls that intersect with attics and/or basements, including the openings around and associated with chimneys, ducts, vents, furred ceiling spaces, and the like (chaseways and cavities).
- Leaks that result from a change in ceiling height (e.g. soffits, drop ceilings).
- Leakage pathways associated with stair stringers.

In general, wherever draftstopping makes sense from an energy perspective, it is probably also required by fire code. Fire code however, may call for draft stops in places that do not align with the thermal boundary (such as between two heated floors). With respect to energy efficiency, these stops are less of a concern.

Fireblocking and air sealing requirements not only overlap, but are also complementary. With fireblocking, the emphasis is placed on selecting an appropriate material to serve as a draft stop (acceptable materials include 2" of lumber, 3/4" nominal plywood or particle board, 1/2" drywall or 1/4" cement board). Energy code complements this requirement by calling for the perimeters of these stops (or baffles) to be sealed to the surrounding surfaces. Both steps are required to achieve a complete and effective air barrier.

It is important to note that there is also one way in which these two sections of the code are *not* complementary. In addition to the items listed above, mineral and glass fiber materials are also allowed for use as fire stops. Fibrous materials however, are ineffective at stopping air. Consequently, they should not be used where air sealing is required.

The IECC goes on to require sealed draft stops anywhere there are openings between conditioned and unconditioned space. The following is a list of some of the most important locations:

- **Between wall and roof or ceiling; wall and floor; between wall panels.** These are often some of the largest leaks in a house. They typically occur in places where cavities between studs or joists connect a conditioned space to an attic or basement area. “Draftstop” blocking is the simplest way to deal with these leaks. Typical examples are shown in Figures 6.11-6.18.
- **Penetrations** of utility services through walls, floors, ceiling/roofs, wall plates. Plumbing, electrical, duct and chimney chases are examples of these leaks. See Figures 5.7, 6.8, 6.11-6.12, 6.14, and 11.1-11.7.
- **Door and window frames**—Rough openings should be sealed to frames with low expansion foam, caulking, or backer rod and caulk. Be careful, even with low expansion foam; if you fill large spaces it can still push out the jambs. To control this, don’t worry about filling the entire space; just bridge the gap between the rough opening and the jamb. See Figures 7.2 and 7.4.
- **At foundation/sill**—The numerous framing members between the top of a foundation wall and the toe plate of the wall above allow significant leakage. The weight of a house is not enough to force these pieces together. Foam “sill seal” between the foundation and sill is commonly used. In addition, seal the band joist area according to Figure 6.1 or 6.2. Note: vertical “steps” in the foundation height (where the grade changes) need special attention to avoid air leakage. Sill sealer will not generally stop air leakage in these locations.
- **Around/behind tubs and showers**—These leaks cause heat loss, and are common causes of comfort complaints and freezing pipes. Bathrooms over garages are especially prone to such problems. See Figures 11.7-11.8.
- **At attic and crawlspace panels**—Attic scuttles, pull-down stairs, access doors through knee walls into unheated attic spaces, and

access from a conditioned basement space into a crawlspace all need weather-stripping as well as insulation. See Figure 11.10.

- **At recessed lights**—The requirements for recessed lights are given on page 109, and Figure 11.9.

Durable caulking, gaskets, tapes and/or housewraps should be used to seal these areas. The code also says to "allow for differential expansion and contraction of the construction materials," for example where wood, metal, concrete and/or plastic join each other. If you use housewrap for an air barrier, it should be installed according to manufacturer's instructions. These instructions generally call for careful detailing and taping of all seams, including—but not limited to—the edges around window and door openings, at the sill area, and where exterior walls meet roof lines. Also note that housewrap generally does not address many of the most significant leakage pathways in a house (which are typically found in attics and basements). See page 144 for more information about bulk water control.

NJ ENERGY STAR Homes

ENERGY STAR Qualification: Air Sealing

Component	Compliance Highlights
Maximum allowable air leakage rate	Determined by HERS compliance analysis
Thermal Bypass Checklist	Most checklist items are air sealing requirements. Continuous air barrier must align with insulation. See figures 11.4–11.11.

Other requirements may apply; see pages 15-22 for more details.

Air sealing is an important part of energy efficient construction, but does not neatly fit into any one category of subcontractor. Some air sealing is done most easily by framers as they put the pieces together. Some can be done by drywall crews. Some insulation contractors specialize in air sealing. But it is the builder who is ultimately responsible to see that adequate air sealing is done by the right people at the right times. If planned thoughtfully and done at the right stages of construction, most air sealing can be done with very little added expense. If you pay attention to the air sealing requirements of the energy code, you will already be well on the way to building a New Jersey ENERGY STAR Home.

The concept of air sealing is to provide a continuous air barrier all the way around the house. It does not mean hermetically sealing the building—there will always be leaks and cracks where air can get in and out. It does mean thinking about what material is going to stop indoor air from mixing with outdoor air (see Table 11.1, page 121). Note that in all drawings, the dotted line (in color) represents the primary air barrier.

Here are some hints to help with air sealing:

- **Get the biggest leaks first.** This may seem obvious but it's not. There's little point in caulking the small cracks or sealing electrical boxes if you have a plumbing chase or floor system that leaves a hole of ten, or twenty, or forty square feet, straight into an attic. A simple rule of thumb is: first seal up the ones you can crawl through; then seal up the ones a cat can crawl through; then go after the details.
- **Get the least expensive ones next.** Think about ways that you can build air sealing into tasks you are doing anyway, with materials that are on hand. Some examples: specify drywall adhesive or acoustical sealant on top plates and end studs of partition walls. Specify construction adhesive on all layers of floor framing instead of just the subfloor. Use leftover scraps of rigid insulation to block off chases or floor cavities. Then, before drywall is hung, have one person go around with a foam gun and seal up all the small wiring and plumbing penetrations in top plates or end studs, as well as the window and door frames. If you do whatever you can in two or three hours, it will make a big difference in most houses.
- **Once the drywall is up, all the leaks become invisible.** They don't go away—they just disappear so you can't see them. Walk through the house before the drywall crew shows up, imagine that only the ceiling sheetrock has been applied and ask yourself, "Can I stick my hand past the sheetrock, through the insulation and into an attic space from here?" Then imagine the sheetrock has been applied only to the walls and ask yourself a similar question: "Can I stick my hand through the insulation to the outside or to an unconditioned space (e.g., a garage) from here?" If the answer to either question is "Yes," then draft stops or blocking should be added before the drywall is hung. It will never happen later. (Of course if you are using "airtight drywall approach" then the drywall itself may be a substantial component of your air barrier. See Airtight Drywall Approach section (below) and Figures 11.1-11.3 for more information.)
- **Insulating and air sealing are separate issues.** Though some insulation materials resist the flow of air more than others, the choice of insulation material alone does not ensure air tightness. Proper detailing is important. Many air leaks occur in locations other than where the insulation is typically installed (for example, under a bottom wall plate, or around a window). No insulation will adequately seal large chases. Even when using a material like spray foam, care should always be taken to identify and address remaining leakage pathways.

- **Interior wood finishes should be backed by a separate, continuous air barrier.** Wood planking, tongue and groove wood products, etc. allow significant quantities of air to pass through their assemblies. These assemblies should never be left open to insulated building cavities that are part of the thermal boundary. Back these finishes with a continuous air barrier, such as drywall or rigid insulation that is sealed at the seams.

Other techniques

Much of the focus on building very tight buildings has historically concentrated on interior air barriers, particularly sealing and detailing of polyethylene vapor retarders as the primary air barrier. This should not be done in any house that has air conditioning. Use a material that's already there, such as the drywall or exterior sheathing, as the primary air barrier. The use of "airtight drywall," for example, can significantly enhance the air tightness of a home at little extra cost.

Airtight drywall approach

If you use adhesive or acoustical sealant to attach drywall to top plates and end studs of partition walls, where they meet insulated walls and ceilings, this helps keep the air in the wall from getting "out." Add adhesive around window and door rough openings and caulk around electrical boxes to complete a reasonable air barrier. At a minimum, specify adhesive on all top plates of walls that intersect insulated ceilings. If your drywall crew doesn't want to do that, you can squeeze a thick bead of acoustical sealant in these areas, and you have an instant gasket. See Figures 11.1-11.3 for more about "airtight drywall approach."

What if I build the house too tight?

There is no way to build a house "too tight." Tight is good. You *can* build an underventilated house (see pages 101-103), but not if you put in a ventilation system. Tight houses save the customer money and reduce callbacks, *but you must* install ventilation. Mechanical ventilation is strongly recommended for all new homes because it's the only way to ensure an adequate level of air exchange, regardless of how tight the house is. And the ventilation air will cost *less to heat than a leaky house*, every time.

Going Further

In addition to energy savings, you get other important advantages by building a tighter house. Tight construction can help reduce:

- **Ice dams**—Most discussion of ice dam prevention concentrates on passive ventilation of the roof sheathing, such as continuous soffit and ridge vents. Ice dams are caused by heat in the attic melting snow from the bottom. Although ventilation does dilute heat that gets into the attic, reducing the *flow* of heat is more important. Sealing up air leaks into the attic is the most important factor in reducing ice dams, followed by keeping HVAC out of the attic, and proper insulation.

- **Moisture in building frame**—Most of the focus on preventing water vapor from getting to cold surfaces (wall sheathing, attic structures, etc.) has traditionally centered on vapor retarders. Vapor retarders are important; but it has been shown that, in the average home, over 100 times more water vapor is carried into these spaces by leaking warm, moist air, than by diffusion. Seal up the air leaks (and install mechanical ventilation) to reduce moisture that causes structural damage and health risks. See the EEBA *Builder's Guide* for more on the relationship between vapor diffusion retarders and air flow retarders, and the mechanisms of vapor diffusion.
- **Freezing pipe problems**—Most pipe freeze-ups are a result of moving cold air, not just cold temperatures. Of course it is important to keep pipes on the warm side of insulated assemblies. However, it is also critical to define a good air barrier and keep the pipes on the "inside." Many pipe freezes occur in areas such as garage ceilings, kneewall floors, and other places where the air barrier is typically not well defined. See Figures 6.12 and 6.15.
- **Insects and rodents**—Of course air sealing alone won't keep vermin outside the building, but it will greatly reduce their access to the living space. Be careful about exterior rigid insulation on foundations, which can provide invisible insect access into the house (see page 55).
- **Fire spread**—In general, efforts devoted to air sealing a house will also improve fire safety. See page 115 for more information.

A wide variety of materials can be used to air seal a building. Material compatibility, the size and location of the leak, ultraviolet and/or high heat exposure, etc. should all be considered when selecting the products to be used. Important material-specific considerations are outlined in the following table.

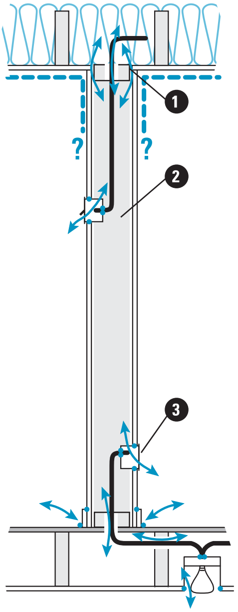
Table 11.1 Air Sealing Materials

Material (Products)	**Notes**
Gaskets (backer rod, sill seal, EPDM gaskets, Trelleborg, Willseal 600)	• Gaskets are commonly used around windows and doors and between the foundation and mud sill, but can also work well in most other areas where a seal is required • More tolerant of differential movement of building assemblies than foam or caulk • Pre-formed EPDM gaskets are expensive, but can be very effective for sealing sill plates, drywall-to-plate connections, and other areas
Low Expansion Foam (Pur Fil, Great Stuff)	• Ideal for sealing gaps that are between 1/4" and 1/2" (e.g., around windows and doors, wiring holes, drywall cutouts, etc.) • Not rated for use in high temperature locations • Difficult to clean up; not for use on finish materials • Cans that are equipped with a reusable gun are the easiest to use and the best value • Protect from UV exposure
High Expansion Foam (Zero Draft, Froth Pak)	• Ideal for sealing locations with multiple leakage pathways, such as a band joist, top plates in an attic (after the drywall has been installed), a chase that is obstructed by ducts, pipes and/or wires, and other hard-to-reach areas • Do not use around windows and doors • Protect from UV exposure
Acoustical Sealant (Quiet Seal, Tremco)	• Durable caulk that stays flexible and accommodates differential movement of building assemblies • Can be used to seal drywall to framing ("air tight drywall approach") • Only sealant that permanently adheres to polyethylene • For indoor use only
100% Silicone Caulk, Urethane Caulk	• Durable caulk for indoor or outdoor use • Use to seal gaps that are up to 3/8" (see manufacturer's instructions) • Not paintable • Caulking should never be used on the building exterior as a barrier to rainwater entry; it's not dependable for that application
Siliconized Acrylic Caulk	• Use to seal gaps that are up to 3/16" • Less flexible and durable than 100% silicone, but paintable • Use only where painting is required
Fire-rated Sealants (fire-rated caulking, furnace cement, high heat mortar)	• Non-combustible • Use to seal gaps around chimney/fluepipes • Wide variety of products, available in tubes or tubs
Rigid and Semi-Rigid Blocking (cardboard, foil-faced bubble pack or foam board insulation, wood, sheetrock, etc.)	• Blocking is needed to seal bypasses/chases that are too big to seal using any of the materials listed above • Perimeter of blocking should sealed to surrounding materials with foam or caulk • Metal flashing, sheet metal and/or foil-faced rigid fiberglass can be used to seal large leaks around chimneys or fluepipes • Wood, sheetrock, cement board or sheet metal must be used to seal bypasses/chases that are part of a fire-rated assembly (between dwelling units or between a dwelling unit and an attached structure that is categorized as a different type of occupancy)

FIGURE 11.1

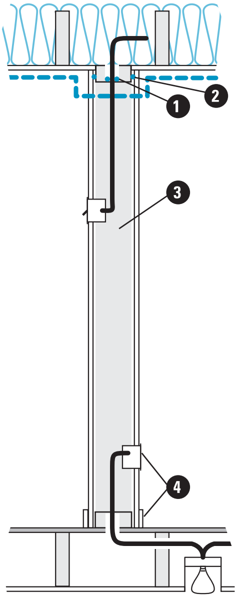
Strategic sealing: interior partition wall intersection with attic

Poorly defined air barrier



A lot of material and effort may be needed with no guarantee that leakage will be stopped.

Well-defined air barrier



Sealing the top plate, before the drywall is hung, requires little effort and completes the air barrier at the insulated ceiling.

❶ Air barrier is broken at attic/wall intersection. Top plate shrinks away from drywall when wood dries

❷ Wall cavity serves as duct linking unconditioned attic to rest of house

❸ Many potential air leakage paths. Sealing one may simply shift leakage to another.

❶ Seal top plate penetrations

❷ Seal drywall to framing–"airtight drywall approach"

❸ "Inside air"

❹ No need to seal drywall penetrations in interior wall

FIGURE 11.2

Sealing intersections at the ceiling

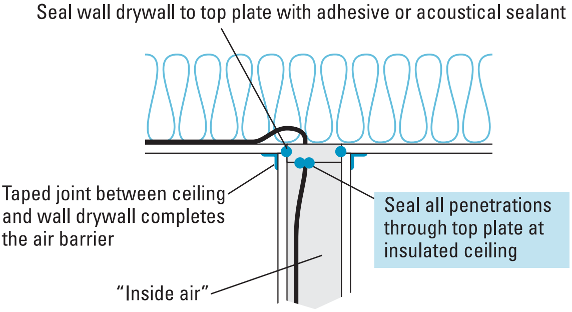
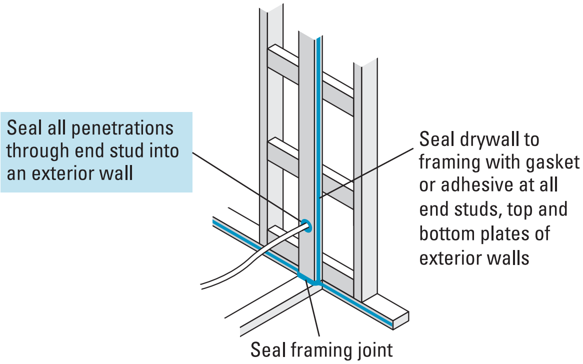


FIGURE 11.3

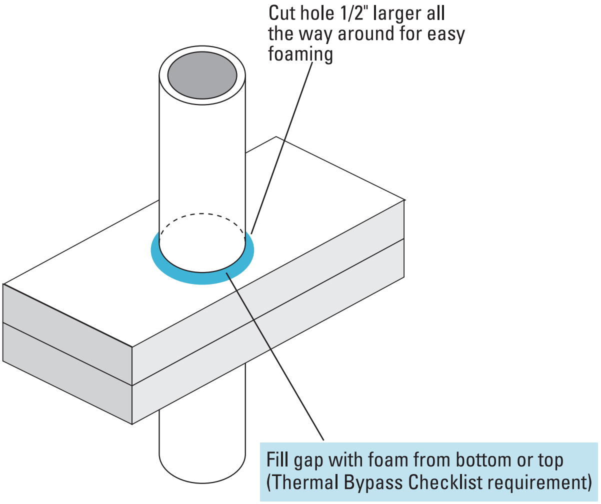
Sealing intersections at exterior walls



The sealing techniques shown in Figures 11.1 to 11.3 are the fundamental components of the "airtight drywall approach" (which includes airtight or sealed electrical boxes, and carefully sealed band joists as well). Even if you are not using a complete "airtight drywall" system, specifying adhesives at top plates and end studs will significantly reduce air leakage. Be especially careful at the intersections where multiple partition walls meet each other at insulated ceilings.

FIGURE 11.4

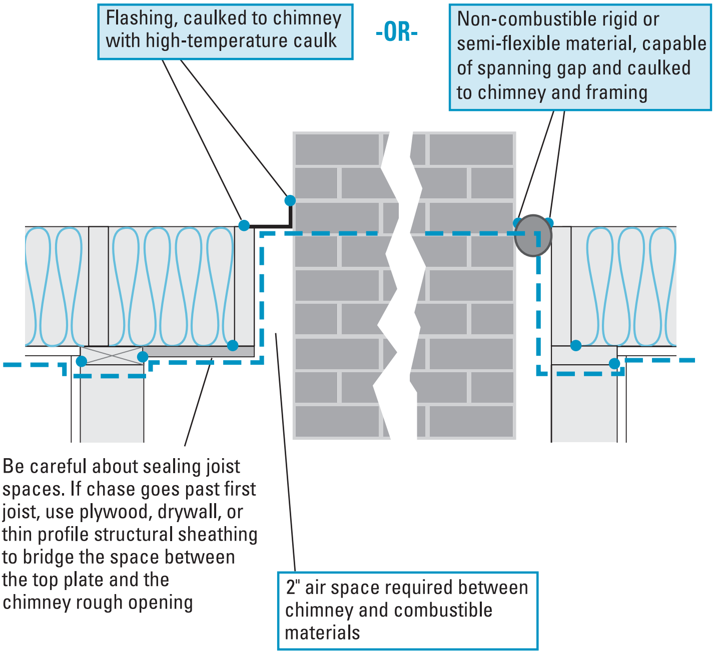
Sealing plumbing vent pipes



Plumbing vent pipes can be sealed with foam from above or below. Long, straight pipe runs may be sealed using a rubber boot or roof boot to address the movement of pipes relative to the framing. This requires coordination with the plumber, to install it as the pipe goes in.

FIGURE 11.5

Chimney Chases

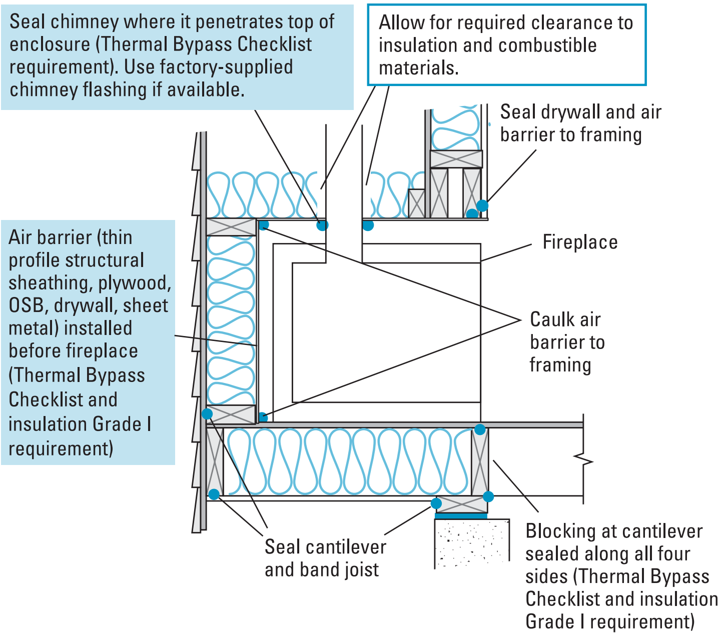


Chimney/flue shaft seal is a Thermal Bypass requirement. Duct chases can be just as large a leak, but ducts can be sealed directly to framing with spray foam.

Unsealed chimney chases are often one of the largest leaks in a house. Be careful to keep combustible materials at least 2" from the chimney, and use high-temperature silicone caulking or firestop caulk. Many prefabricated chimneys have draft blocking and/or insulation guard kits available to fit them; follow the manufacturer’s instructions.

FIGURE 11.6

Air sealing fireplace enclosures



Seal chimney where it penetrates top of enclosure (Thermal Bypass Checklist requirement). Use factory-supplied chimney flashing if available.

Allow for required clearance to insulation and combustible materials.

Seal drywall and air barrier to framing

Air barrier (thin profile structural sheathing, plywood, OSB, drywall, sheet metal) installed before fireplace (Thermal Bypass Checklist and insulation Grade I requirement)

Blocking at cantilever sealed along all four sides (Thermal Bypass Checklist and insulation Grade I requirement)

TIP: In some instances with complex framing, such as a home entertainment center recessed above the fireplace cavity, it may be simpler to use the exterior sheathing as the air barrier. However, it is still necessary to seal the top of the chase as shown in Figure 11.5.

Be sure to install the air barriers and do the sealing before the fireplace is set in place.

FIGURE 11.7

Boxed-in tub in insulated floor

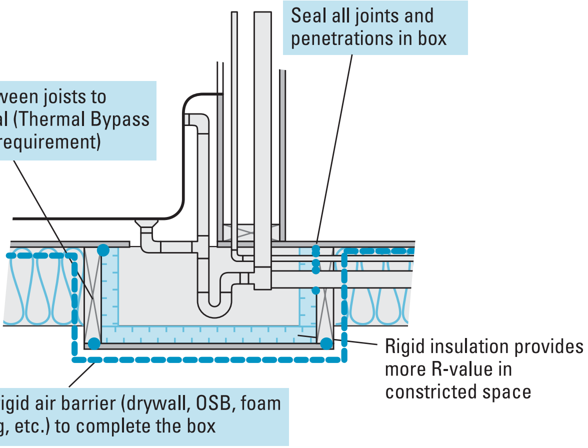
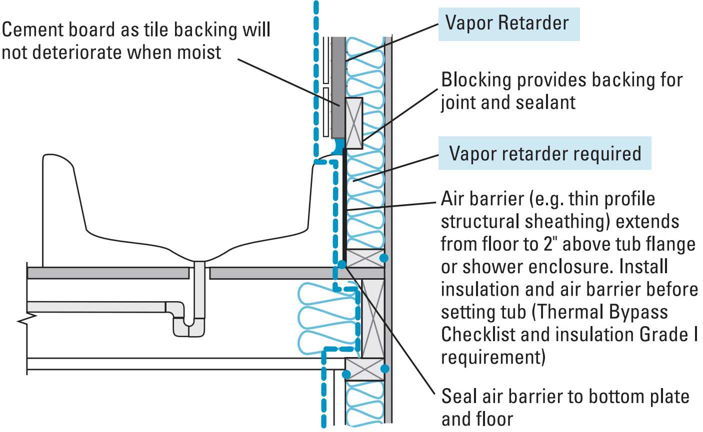


FIGURE 11.8

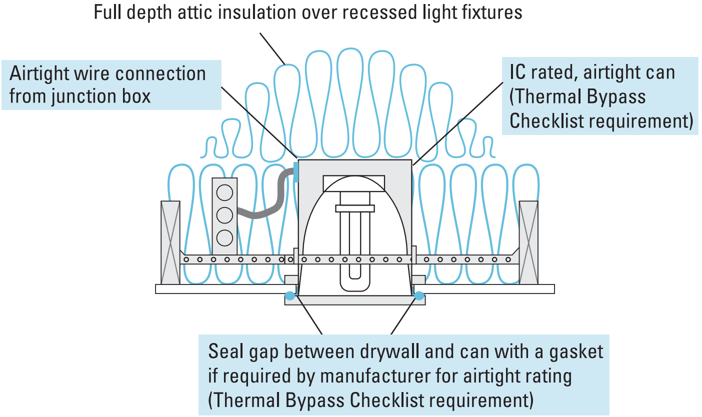
Sealing tub and shower enclosure



⚠ **CAUTION:** Do not use standard or moisture resistant drywall as a tile backing material in this application. They deteriorate when they get wet.

FIGURE 11.9

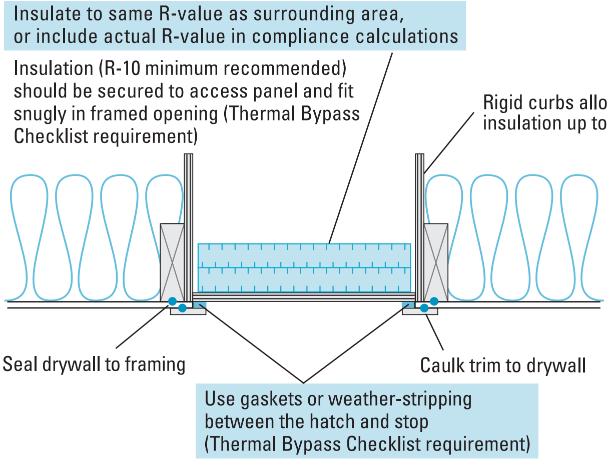
Recessed lights



⚠ **CAUTION:** Recessed lights must be specifically designed for air tightness and for contact with insulation. Do not attempt to seal or insulate recessed lights that are not designed for this purpose.

FIGURE 11.10

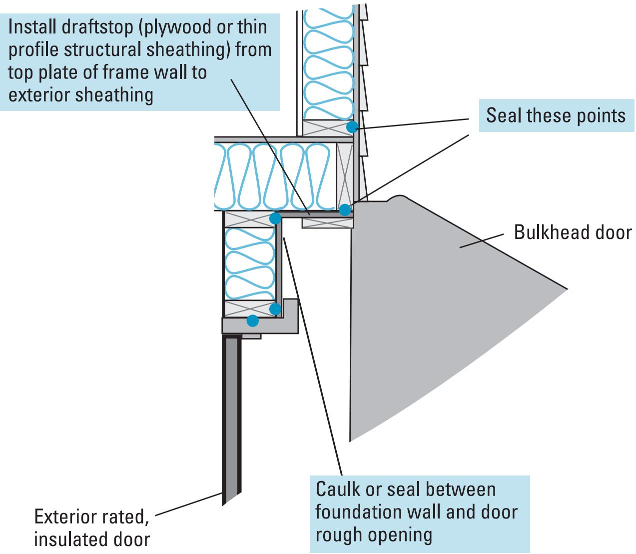
Attic hatch



TIP: If the attic is accessed from an unheated space, like a garage, hatch air sealing and insulation are not required.

FIGURE 11.11

Bulkhead door detail



⚠ **CAUTION:** This area may contribute to air leakage even in an uninsulated basement.

12

Insulation

Energy Code Requirements

Insulation R-values

The R-values of insulation in any part of the thermal boundary are defined by your compliance analysis. Whether it is a prescriptive table, a RES*check* printout or any other approach, the minimum R-value for each component is specified and documented with the building permit application (IECC Section 104). If, during construction, you want to substitute a lower than specified R-value for a particular component (wall, ceiling, etc.), you must redo the compliance analysis to make sure the change does not result in non-compliance, and re-submit the paperwork with the new specifications. You may have to substitute higher R-values somewhere else in the building to compensate, or choose a different method of determining compliance.

Proper installation

All R-values are based on proper installation. For fiberglass batts, this means:

- **Full loft**—Insulation should be fluffed to its full thickness, not compressed, and not rounded or scalloped at the edges.
- **Fill the cavity**—Insulation should be in snug contact with all wall studs, plates, sheathing and drywall. In ceilings and floors, it should be in contact with the drywall or subfloor, and extend all the way to the joists on both sides without gaps (see Figure 12.2).
- **Cut around obstacles**—Insulation should be split around wires and small pipes, cut out around electrical boxes, larger pipes and other obstacles, and split over cross bridging in floors. Never stuff insulation in to get it to "fit" (see Figure 12.1).

Refer to industry standards such as *Fiber Glass Building Insulation: Recommendations for Installation in Residential and other Light-Frame*

Construction (North American Insulation Manufacturers Association), or *Standard Practice for Installing Cellulose Building Insulation* and *Standard Practice for the Installation of Sprayed Cellulosic Wall Cavity Insulation* (Cellulose Insulation Manufacturers Association). These resources are listed in the Appendix.

Documentation of R-values (IECC 102.1.1 and 102.1.2)

Many common insulation products have R-value markings right on them. Faced and unfaced fiberglass batts, and rigid foam insulation must be installed so the markings are visible to the building inspector. If you are using blown- or sprayed-in insulation such as cellulose, spray foam, or blown fiberglass, the installer should provide a certificate showing installed thickness, settled thickness, the square feet of coverage, the number of bags (or amount of material) used, and the net installed R-value. For blown-in attic insulation, "tell-tale" inch markers are also acceptable, provided they show installed thickness and settled thickness (a minimum of one marker per 300 square feet of attic is required.)

Credit for "raised truss" construction (IECC 402.2.1)

Insulation in flat or cathedral ceilings is assumed to be compressed over the exterior walls, as is typical (Figure 12.4). If you can install the insulation in such a way as to get the *full R-value* of insulation all the way to the outside of the exterior wall, then you can take credit for "raised truss" in your compliance analysis. In the prescriptive method a raised truss or its equivalent allows you to substitute R-30 insulation when R-38 is specified, or R-38 for R-49. For the other methods, it gives you some credit toward your point score. This does not mean you have to use a raised heel truss to get this credit; examples of alternative methods are shown in Figures 12.5-12.7, 12.9. Depending on the roof geometry and the care of installation, you may not even need to modify the framing. For example, a high-pitched roof truss with a large overhang may not need any special treatment to achieve the full R-value at the eaves.

Access Openings

Attic hatches, scuttles, pulldown stairs, etc. must be insulated to the same R-value as the surrounding area, or the actual R-value must be accounted for in your calculations.

Steel Framing

Steel is an excellent conductor of heat. Consequently, the effective performance of insulation in steel framed building assemblies is reduced dramatically. Cold interior surfaces near the steel studs bring an increased potential for condensation and mold growth. Code accounts for the thermal "bridging" that results from the use of steel framing by making insulation requirements more stringent. The easiest way to meet these requirements is to add a layer of continuous, rigid insulation that covers all the framing and acts as a thermal "break" (see IECC Table 402.2.4 for insulated steel and wood wall equivalencies).

NJ ENERGY STAR Homes

ENERGY STAR Qualification: Insulation

Component	Compliance Highlights
Insulation R-values	Determined by HERS compliance analysis
Thermal Bypass Checklist	Insulation must be installed in full contact with continuous air barrier

Other requirements may apply; see pages 15-22 for more details.

Proper application of insulation materials is critical to the success of any ENERGY STAR home. In response to this fact, the national Home Energy Rating System (HERS) industry has developed guidelines for assessing insulation installation quality. These guidelines (summarized below) are an integral part of not only the HERS industry, but also the New Jersey ENERGY STAR Homes Program; the installation grade must be factored into the HERS analysis that is used to determine performance-based compliance. A Grade I installation is required when using the prescriptive compliance option.

- **Grade I**—Near perfect installation quality (full height, full width, full depth, no voids, no gaps, cut to fit neatly around any intrusions, etc.). Grade I is also used to describe insulation that is generally installed according to manufacturer's instructions and/or industry standards. There are other location-specific requirements for Grade I for walls, ceilings and floors.
- **Grade II**—Average installation quality with a minimum of voids and compression. Insulation may have occasional defects such as gaps around wiring, electrical outlets, plumbing and other intrusions. There are other location-specific requirements for Grade II for walls, ceilings and floors.
- **Grade III**—Poor installation quality, which may include gaps, voids, compression, rounded edges or "shoulders," incomplete fill, etc.

Here are some additional guidelines:

- **Faced batt insulation** may be installed by stapling the flanges to either the sides or face of the framing that runs along the edges of the batt (see Figure 12.3). When side stapling, be sure to staple the tabs neatly (no buckling), and to compress the batt only at the edge of each cavity and only to the depth of the tab itself. Face stapling is generally considered to be preferable to side stapling from an energy perspective, but the performance difference is likely to be small. Face stapling is often disliked by drywall installers. To lessen the potential impact, be sure to set staples firmly into the studs, avoid pulling fiberglass fibers over the face of the studs, and mark the stud locations on the floor.

- **High density fiberglass batts** such as R-15, R-21, R-30C and R-38C get a higher R-value in the same cavity. They also tend to be stiffer, and fluff up so it is easier to get a good fit without compression. Although not an ENERGY STAR requirement, it is a good idea to use high density batts if you are using fiberglass, and you can get credit for the added R-value in the code analysis as well.
- **Beware** of manufacturer claims representing R-values of particular products. "Equivalent" R-value may not be a legitimate descriptive term. This caution applies especially to alternative insulation materials, such as "radiant"/reflective products, or to systems (such as structural insulated panels, insulating concrete forms, or special concrete products) that claim to have an "equivalent" R-value due to some added quality, such as air tightness or thermal mass, that should not be included in the actual R-value.
- **Air barriers and eave baffles to prevent wind washing.** No matter how well you install insulation, cold air washing through it will not only severely compromise its effectiveness, but also increase condensation potential by cooling the vapor retarder. Eave baffles made of cardboard or foam board are essential (see Figures 12.5, 12.6 and 12.8); if the baffle extends above the top of the insulation, no vent chute or "propavent" is required. Also vulnerable are exposed insulated walls, such as attic knee walls (Figures 6.15, 6.16 and 6.18). Cover the exposed fiberglass on the attic side with a vapor permeable air barrier such as housewrap, polystyrene foam, drywall, or similar material. Floor insulation over piers, cantilevers and the like should also be sealed to prevent outside air from circulating into the insulation (Figures 6.11 and 6.12). Flat or sloped attic insulation need not be covered, but baffles should be provided near eaves (see Figures 6.16, 6.17, and 12.5, 12.8, and 12.9).
- **Cavity fill types that improve air tightness**—Some insulation materials can help. See page 43.
- **Avoid strapped ceilings**—1x3 furring strips running perpendicular to the joists provide a cavity for free air circulation, which often compromises the insulation performance, especially near eaves and in cathedral ceilings. Once nailed in place, they also make it very difficult to install insulation properly. This is another area where money can be saved while thermal performance is improved.

- **Higher R-values in sloped ceilings** can be achieved with smaller framing by adding sister joists with plywood gussets (see Figure 12.9) or by adding a continuous layer of rigid insulation on the underside of the roof rafters.

FIGURE 12.1

Insulating around plumbing, wiring, and other obstacles

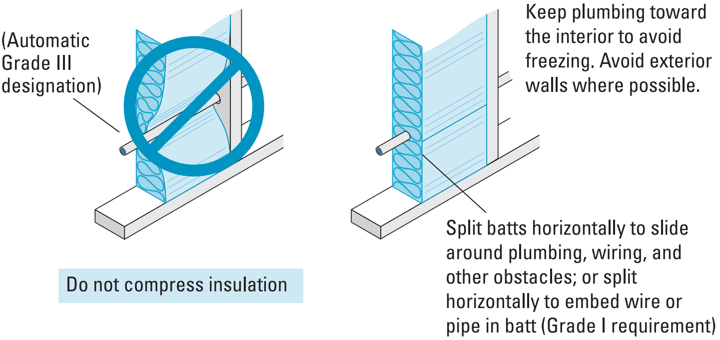
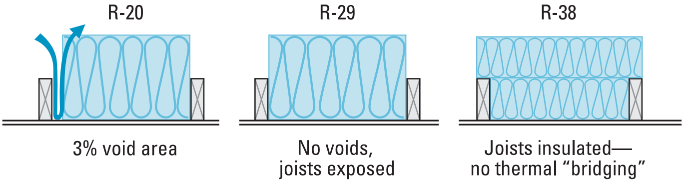


FIGURE 12.2

Effective R-value of insulation

This schematic shows the effect of insulation installation quality and technique on effective (or installed) R-values. Note that the same depth of insulation (12", nominally R-38) is used in all three cases.



⚠ **CAUTION:** Most of initial R-value is lost as void area increases. For example, increasing the void area above from 3% to just 6% would result in an effective R-value of only 15.

FIGURE 12.3

Face-stapling versus inset stapling kraft-faced batts

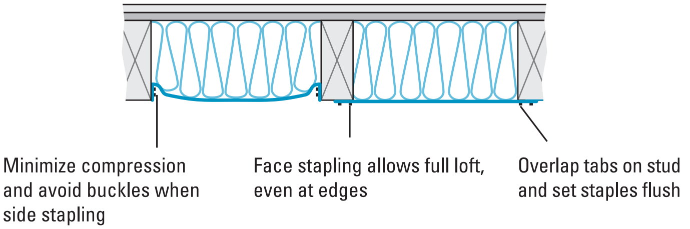


FIGURE 12.4

Conventional truss

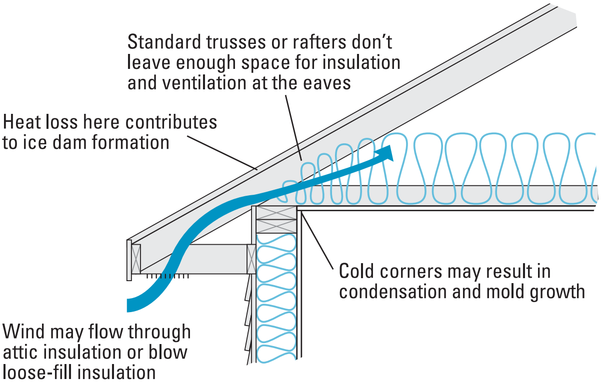
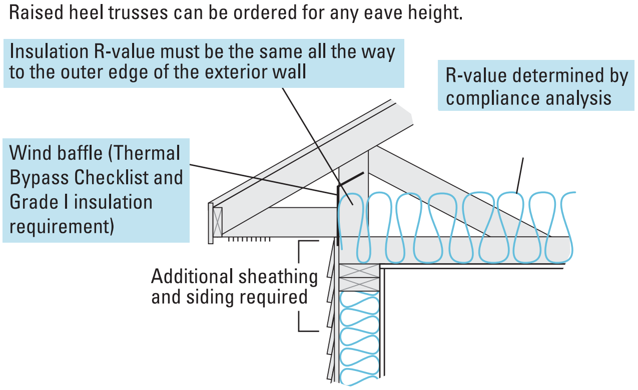


FIGURE 12.5

Raised heel truss

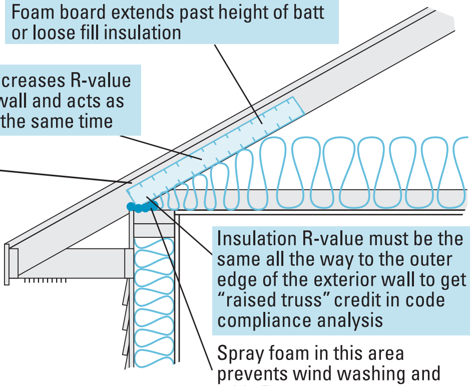


Credit is given in the code compliance analysis for better performance. See Figures 12.6 and 12.7 for other options.

⚠ **CAUTION:** Trusses must be sized carefully so that the truss heel lines up with the edge of the wall below.

FIGURE 12.6

Conventional truss or rafter with insulated eaves



Foam board extends past height of batt or loose fill insulation

Foam board increases R-value over exterior wall and acts as wind baffle at the same time

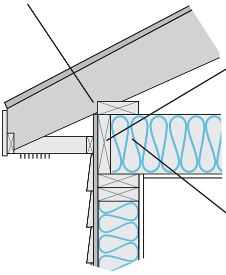
1" ventilation air space (no need for separate "propa" vent chutes) (IRC R806.3)

Insulation R-value must be the same all the way to the outer edge of the exterior wall to get "raised truss" credit in code compliance analysis

Spray foam in this area prevents wind washing and adds R-value at corner

FIGURE 12.7

Conventional rafter with raised plate



Rafter-joist connection must be engineered to transfer spreading loads from rafter to joist

No need for baffle at eaves, band joist prevents wind washing

Full R-value to edge of wall allows "raised truss" credit

FIGURE 12.8

Vented cathedral ceiling

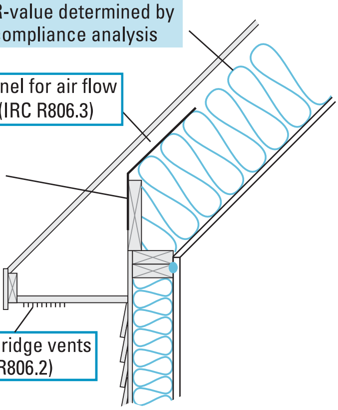
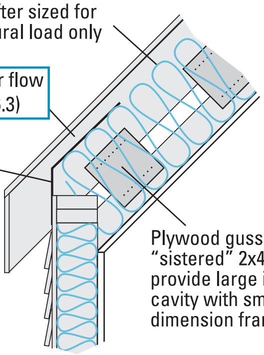


FIGURE 12.9

Cathedral ceiling with built-up rafters



13

Health and Safety

There is increasing concern among the public about indoor air quality, moisture, and mold. There is a lot of confusion and misunderstanding; the media often portrays moisture and mold problems as a result of "tight" construction and energy-efficient design. In reality, most of the mold and moisture problems in buildings result from poor exterior water management, followed by thermal and air barrier defects. We are now using more and more building materials that are subject to damage and decay from moisture, and provide better nutrient sources to mold than we did even 10-15 years ago. In fact, the recent emphasis in codes and building practice on using highly vapor permeable exterior sheathings and highly impermeable interior vapor barriers has led to some dramatic building failures resulting from inward-driven moisture in air-conditioned buildings in the North.

Besides the obvious issues of liability and insurance, any builder or designer who wishes to set him- or herself apart can learn the basics about healthy construction, indoor air quality, and especially mold and water management. While you must be careful not to promise a "mold free" environment, you can certainly create an edge for yourself as a designer or builder of homes with "reduced risk" for mold and other air quality concerns. In fact, these concerns may attract a lot more attention among buyers than energy efficiency! In truth, if you design and build a building to be mold resistant, comfortable, and healthy it will be an energy-efficient building as well.

Overview

There are many issues relating to health and safety in residential buildings. Structural integrity and loading of beams, seismic, wind and snow loads, fire protection and egress, basic sanitation, and electrical safety are all covered in building codes and associated mechanical, fire, plumbing and electrical codes. The majority of requirements in most codes are related to life safety issues: prevent the building from falling on people, help get them out quickly in case of a fire, prevent electrocution and fire hazards from wiring, and provide for clean, reliable potable water and waste removal. These are the immediate, obvious health and safety issues which codes quite properly govern to ensure a basic level of security for homebuyers, and a level playing field for builders. Codes that address other health related concerns such as fresh air ventilation standards are often not clearly understood. And there are some less obvious, but perhaps equally important issues that arise in residential building construction. The purpose of this section is to provide a brief overview of the health and safety aspects of the "house system." This summary is only a brief introduction to "healthy construction" concepts; more resources are provided in the Appendix.

Are cars safer than homes?

Not really, but you can think about these health and safety issues in the context of shopping for an automobile. Whether you buy a luxury model, a compact economy car, a gas-guzzling sport-utility, or a race car, you expect a certain level of safety. Even though these cars may perform very differently and fill different needs, they all have seat belts, headlights, and air bags. Similarly, even though houses are designed differently to meet many different needs, they should all have a basic set of protections for health and safety beyond those that are found in building codes. Air sealing and water vapor control is just as critical as a seat belt in a car. A mechanical ventilation system is as essential as an airbag. Sealed combustion equipment and a carbon monoxide detector can be compared to headlights and taillights, and a good exterior water management system is the equivalent of windshield wipers. You wouldn't buy a car without these safety features, and every home should have health and safety as a priority as well.

Priorities

People are becoming more and more aware of the health hazards associated with indoor mold exposure, dust mites, volatile organic compounds, and other airborne contaminants. The incidence of asthma has nearly doubled in the last 20 years, and scientists believe that changes in the indoor environment are the primary cause. Researchers have found that indoor air quality is more polluted—sometimes as much as 100 times more—than outdoor air, and this pollution contributes to allergies, nausea, sinusitis, fatigue, and even extreme chemical sensitivities. In addition, some building scientists suspect that many cases of low-level carbon monoxide poisoning go undiagnosed. Because some people have special health conditions or environmental sensitivities it is difficult to choose a standard that can be applied universally. However, a basic approach to creating a safe, healthy home can be summarized by five principles, all of which involve control of the indoor environment: control of air flows, water vapor flows, energy flows, particulate flows, and pollution sources and flows. The following paragraphs outline the basic approaches to accomplish this level of control:

- **Air flows**—unintended air flows can be unhealthy for many reasons. These air flows can result from the stack effect (uncontrolled infiltration), duct leaks in basements and attics, unbalanced supply and return duct flows, exhaust fans, or combustion appliance makeup air, all of which create air pressures. Low pressures in basements can increase concentrations of radon, sub-soil pesticide treatments, or other soil gases in the home, as well as increased energy loads. High pressures can result in warm, moisture laden air being pushed into exterior walls or into attics and roof systems, where water vapor can condense and cause mold, mildew and decay. Air flows caused by induced pressures or by the stack effect can conduct deadly car exhaust or fumes from stored chemicals from a garage right into the house, or can backdraft combustion appliances. For all these reasons, it is important to reduce or eliminate unintended air flows from homes. The most important methods to control air flows are as follows:
  - Create a very tight building enclosure by sealing air leaks
  - Design ducts properly for balanced air flows
  - Seal ducts tightly
  - Install only sealed combustion appliances, including fireplaces that have tight-fitting glass doors and a ducted outdoor air intake
  - Design and install makeup air for large exhaust appliances if necessary
- **Moisture flows**—Either too much or too little moisture can be unhealthy. High humidity can lead to increased concentrations of biological contaminants such as mold and mold spores, dust mites, mildew, bacteria and viruses. Low humidity can result in increased incidence of respiratory infections, rhinitis (chronic runny nose), and discomfort. It is generally recommended to keep indoor moisture levels between 30 and 60 percent relative humidity (some experts say 35 to 50 percent, which is very close—also see page 101). To do this reliably year-round you must:
  - Build a very tight house to reduce the air exchange that dries air in the heating season and brings in humid air in the summer. This includes tightly sealing any ducts that may be outside the thermal boundary.
  - Provide controlled ventilation air to reduce moisture loads in winter.

  - Provide spot ventilation for bathrooms and kitchens, and any other special sources of moisture loading (pool, hot tub, fish tanks, etc.).
  - Provide dehumidification or air conditioning in the summer. Note that oversized air conditioning will not provide the level of dehumidification needed to keep humidity levels under control; it is actually better to have a slightly undersized air conditioning system for optimum health throughout the summer. With a slightly undersized air conditioner, the indoor air temperature may drift up by a degree or two for a few hours during the hottest days of the year. Indoor air quality, by contrast, will be improved for the vast majority of the humid cooling season.
- **Bulk water** leaking into a home (or from plumbing) can also be a source of high humidity or wet building materials, resulting in many of the same biological contaminants. The following steps are also critical to controlling moisture in buildings:
  - Foundation water management systems, such as capillary breaks, footing drainage, rainwater drainage and grading.
  - Exterior water management systems such as flashing, siding and roofing details, and a properly installed secondary drainage plane (building paper or housewrap) behind siding. Even better is a vented rain screen, with an air space between the siding and the drainage plane. Be especially careful of flashing details where roofs and decks meet vertical walls. (See EEBA's *Builder* and *Water Management Guides*.)
- **Energy flows**—Limiting energy use in a building is related to health, although less directly than the other approaches in this list. In addition to the increased energy loads that result from large air flows through the building enclosure, cold, poorly insulated surfaces may lead to condensation, mold and mildew. It is also possible that when people living in a home are more comfortable, they will tend to be healthier.
  - Select windows that have, at a minimum, low-e glazing and argon gas fills. Higher performance glazings, heat mirror films, "warm-edge" spacers, and insulated frames will all raise surface temperatures and reduce the chance of condensation and fungal growth on the glass and sash.
  - Higher levels of insulation, and framing details that avoid thermal "bridging" of framing from inside to outside surfaces, will also reduce condensation problems and increase comfort.
  - Insulate basement walls and slab floors to prevent condensation in the summer, even if they are not in the finished living space.

  - Duct insulation and vapor jackets on the exterior of insulated ductwork is critical. Anywhere heating, air conditioning, or exhaust air ducts travel through unconditioned spaces, they should be well insulated, and the vapor jacket on the outside of the insulation should be uninterrupted. Ducts that carry cold air in winter, located in conditioned space or unconditioned basements, should also be insulated carefully with an exterior vapor jacket installed. (Examples include ventilation supply ducts, or the outdoor exhaust duct from a heat recovery ventilator.)
- **Particulate flows**—Most homes have no real provisions for filtering the indoor air. Filters that are provided with furnaces, central air conditioners or heat pumps are only designed to protect the equipment from damage. Better air filters can reduce many of the particles that can cause health problems. High Efficiency Particulate Attenuation (HEPA) filters are the best grade of filter, which may be indicated for people with existing respiratory ailments. It's a good idea to design a whole-house ventilation system or air distribution system with the capability of adding a HEPA filter later, if needed. Avoid electrostatic filters, ionizers, and any air treatment devices that produce ozone. Also note that any filter must be carefully designed into the air handling system, to account for any pressure resistance created by the filter.
  - One advantage of balanced, supply and exhaust ventilation (such as an Energy Recovery Ventilator) is that the fresh air supply can be filtered, unlike exhaust-only systems.
  - Whole house air circulation with filtration can be provided by the air handler fan of a furnace or air conditioner. Use a low speed setting on the blower with constant or intermittent circulation. Controls are available that keep track of blower run time to ensure minimum ventilation rates.
- **Contaminant sources and flows**—This category is last on the list, because it has the least to do with energy; however, reduction of contaminant sources is perhaps the most important priority. Sources are many: volatile organic compounds (VOCs) are found in paints, paint strippers, solvents, wood preservatives, and carpeting, as well as stored fuels and automotive products; formaldehydes are found in manufactured wood products such as interior grade plywood, medium density fiberboard (MDF), carpets, and furniture; stored household chemicals such as cleaning products, aerosol sprays, and moth repellents are often toxic; and pesticide and herbicide treatments may be present immediately around or stored in the home. Radon gas can be drawn into the house from below the ground, if it is present. Some of these products are not under the control of the builder or designer

of the home, but many of them are. Reduction, separation and dilution are the main strategies to reduce contaminant exposures.

- Source reduction is the most effective way to reduce exposure. If you reduce the source, you need less separation and dilution. Use of low VOC paints, glues and finishes, hard surface flooring (wood or tile) instead of carpeting, wood cabinets or sealed MDF, and non-toxic wood preservative treatments all have the potential to improve the health of the occupants.

  Most of these options are within the scope of the builder to influence.
- Separation from the living space of those contaminants that can not be eliminated is the next best strategy to reduce exposure. One aspect of this that is often overlooked is the elimination of unwanted air flows; be sure to keep air that has a high likelihood of contamination away from the people in the house. These areas especially include garages, combustion appliances, and the earth around the foundation. These air flows are under direct control of the builder, although builders rarely pay attention to them.
- Dilution is the last strategy, and by no means least important. Fresh air ventilation is important to help ensure that contaminants that are present (or may be introduced after the house is finished) can be reduced to safe levels. At a minimum every home should have a simple exhaust only ventilation system; balanced supply and exhaust systems with or without heat recovery allow filtration and control the source of the supply air.
- Radon pre-mitigation is a form of controlling contaminant flows. Every basement or on-grade slab should have at least 4" of uniform, washed stone underneath, 1/2" to 1-1/2" diameter, with no fine particles. Put it under the insulation if you are insulating the slab. Radon levels should be tested after occupancy by an EPA-certified lab. If high levels are found the stone will allow for effective sub-slab depressurization with a fan to be added later. At a minimum, install a short stub of 4" PVC pipe vertically through the slab, left 4-6" above and capped off. The bottom end should be in the stone layer. Even better, run the pipe right up through the roof, and if a fan needs to be added later it can be easily installed in the attic with a minimum of disruption.

Resources

Codes

New Jersey Department of Community Affairs
Division of Codes and Standards
PO Box 800
Trenton, NJ 08625-0800
(609) 984-7609
www.nj.gov/dca/codes

The *International Energy Conservation Code (IECC)* and the *International Residential Code (IRC) for One- and Two-Family Dwellings* are all available from:
International Code Council, Inc.
5203 Leesburg Pike, Suite 600
Falls Church, VA 22041-3401
(866) 427-4422
www.iccsafe.org

The RES*check* software and users guide, the prescriptive worksheets, instructions and support materials are available as free downloads from:
www.energycodes.gov/rescheck

Model Energy Code (1995)
International Code Council
Falls Church, VA
(708) 799-2300

ASHRAE/IES 90.1-1989, Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings
American Society of Heating, Refrigeration and Air Conditioning Engineers
Atlanta, GA
(404) 636-8400
www.ashrae.org

ENERGY STAR Homes and Products

National ENERGY STAR Program
US Environmental Protection Agency
ENERGY STAR Hotline
(888) STAR-YES
www.energystar.gov

New Jersey ENERGY STAR Homes Program
(866) NJ-SMART
(866) 657-6278
www.njenergystarhomes.com
www.njcleanenergy.com

General Building Science

Builder's Guide-Cold Climate (2004)
Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

Building Science for Building Enclosures (2005) by John Straube and Eric Burnett
Building Science Press, Inc.
Westford, MA
www.buildingsciencepress.com

Water in Buildings: An Architects Guide to Moisture and Mold (2005) by William B. Rose
John Wiley & Sons, Inc.
Hoboken, NJ
(201)748-6011
www.wiley.com

Foundations and Basements

Building Concrete Homes with Insulating Concrete Forms (1996), an instructive video

Insulating Concrete Forms Construction Manual (1996)

The Portland Cement Association's Guide to Concrete Homebuilding Systems (1995)
Portland Cement Association
Skokie, IL
(847) 966-6200
www.cement.org
www.concretehomes.com

Design Guide for Frost-Protected Shallow Foundations (1996)
NAHB Research Center
Upper Marlboro, MD
(800) 638-8556
www.nahbrc.org

Framing/Alternatives

Cost Effective Home Building: A Design Construction Handbook (1994)
NAHB Bookstore
Washington, DC
(800) 223-2665
www.builderbooks.com

Building with Structural Insulated Panels (2002) by Michael Morley
The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com

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Williston, VT
(802) 879-3335
www.jlconline.com

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Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com

Passive Solar, Windows

Guidelines for Home Building and accompanying BuilderGuide (1990) a passive solar design software
Sustainable Industries Building Council
Washington, DC
(202) 628-7400
www.sbicouncil.org

Certified Products Directory (updated annually)
National Fenestration Rating Council
Silver Spring, MD
(301) 589-1776
www.nfrc.org

Residential Windows: A Guide to New Technologies and Energy Performance (2nd ed.-2000) by John Carmody, Stephen Selkowitz, and Lisa Heschong
W.W. Norton & Co., Inc.
New York, NY
(800) 223-4830

RESFEN 3.1 (1999), an energy use calculation software
Lawrence Berkeley National Laboratory
Berkeley, CA
(510) 486-4000
windows.lbl.gov/software/resfen/

Mechanical Systems and Ductwork

ASHRAE Fundamentals 2005
American Society of Heating, Refrigeration and Air Conditioning Engineers
Atlanta, GA
(404) 636-8400
www.ashrae.org

Consumer's Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment (updated twice annually)
Gas Appliance Manufacturers Association, Inc.
Arlington, VA
(703) 525-7060
www.gamanet.org

Directory of Certified Unitary Equipment Standards (updated twice annually)
Air Conditioning and Refrigeration Institute
Arlington, VA
(703) 524-8800
www.ari.org

Duct Leakage Diagnostics and Repair (1995), an instructive video
The Energy Conservatory
Minneapolis, MN
(612) 827-1117
www.energyconservatory.com

HRAI Residential Mechanical Ventilation Manual
Heating, Refrigeration and Air Conditioning Institute of Canada
5045 Orbitor Drive, Building 11, Suite 300
Mississauga, Ontario, Canada L4W 4Y4
800-267-2231 or (905) 602-4700
www.hrai.ca/site/skilltech/hraicatalogue

Residential Duct Systems: Manual D (1995)

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Air Conditioning Contractors of America
Arlington, VA
(703) 575-4477
www.acca.org

Your Home Cooling Energy Guide (1992) by John Krigger
Saturn Resource Management
Helena, MT
(800) 735-0577
www.srmi.biz

Air Sealing, Moisture Control, Indoor Air Quality, and Ventilation

Healthy House Building, A Design and Construction Guide (2nd ed.-1997) by John Bower

Moisture Control Handbook: Principles and Practices for Residential and Small Commercial Buildings (1993) by Joseph Lstiburek and John Carmody

Understanding Ventilation: How to Design, Select and Install Residential Ventilation Systems (1995) by John Bower

Water Management Guide (2004) by Joseph Lstiburek

Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

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Environmental Protection Agency
Washington, DC
www.epa.gov/iaq
www.epa.gov/radon/construc.html

Residential Mechanical Ventilation (1997)
Heating, Refrigerating and Air Conditioning Institute of Canada
Mississauga, Ontario, Canada
(800) 267-2231
www.hrai.ca

Insulation

Cellulose Insulation Manufacturer's Association
Dayton, OH
(937) 222-2462
1-888-881-CIMA
www.cellulose.org

North American Insulation Manufacturer's Association
Alexandria, VA
(703) 684-0084
www.naima.org

Energy Efficiency—General

Insulate and Weatherize (2002) by Bruce Harley
Build Like a Pro series
The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com

Residential Energy (3rd ed.-2000) by John Krigger
Saturn Resource Management
Helena, MT
(800) 735-0577
www.srmi.biz

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Canadian Home Builder's Association Builders Manual
Canadian Home Builder's Association
Ottawa, Ontario
(613) 230-3060
www.chba.ca

Green Building Guidelines (3rd ed.-2003)
Sustainable Building Industries Council
Washington, DC
(202) 628-7400
www.sbicouncil.org

Environmental Resource Guide on CD-ROM
Iris Communications, Inc.
Eugene, OR
(541) 767-0355
(800) 346-0104
www.oikos.com

Publications—Periodicals and Catalogs

Energy Design Update
Aspen Publishers, Inc.
New York, NY
(800) 638-8437
www.aspenpublishers.com

EEBA Excellence: Newsletter of the Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

Environmental Building News
Brattleboro, VT
(802) 257-7300
(800) 861-0954
www.buildinggreen.com

Fine Home Building
The Taunton Press
Newtown, CT
(203) 426-8171
(800) 477-8727
www.taunton.com/finehomebuilding

Home Energy Magazine
Berkeley, CA
(510) 524-5405
www.homeenergy.org

Journal of Light Construction
Williston, VT
(800) 375-5981
www.jlconline.com

Product Distributors

The Energy Conservatory
Minneapolis, MN
(612) 827-1117
www.energyconservatory.com

Energy Federation, Inc.
Westboro, MA
(800) 876-0660
www.efi.org

Positive Energy Conservation Products
Boulder, CO
(303) 444-4340
(800) 488-4340
www.positive-energy.com

Shelter Supply, Inc.
Lakeville, MN
(952) 898-4500
(800) 762-8399
www.sheltersupply.com

Tamarack Technologies
Precision Ventilation Products
West Wareham, MA
(800) 222-5932
www.tamtech.com

Organizations

Affordable Comfort Inc.
Waynesburg, PA
(724) 627-5200
www.affordablecomfort.org

Energy and Environmental Building Association
Bloomington, MN
(952) 881-1098
www.eeba.org

Florida Solar Energy Center
A Research Institute of the
University of Central Florida
Cocoa, FL
(321) 638-1000
www.fsec.ucf.edu

Insulation Contractors Association of America (ICAA)
(703) 739-0356
www.insulate.org

National Association of Home Builders
Research Center
Upper Marlboro, MD
(800) 638-8556
www.nahbrc.org

Residential Energy Services Network
Oceanside, CA
(760) 806-3448
www.resnet.us

Rocky Mountain Institute
Snowmass, CO
(970) 927-3851
www.rmi.org

Sustainable Buildings Industry Council
Washington, DC
(202) 628-7400
www.sbicouncil.org