An energy efficient building envelope contains both a thermal barrier and an air barrier. The key to an effective thermal barrier is proper installation of quality insulation products. A house should have a continuous layer of insulation around the entire building envelope. Studies show that improper installation can cut performance by 20% or more. While some types of insulation reduce air leakage, most do not, so always follow the guidelines in Chapter 4 to limit the air leakage potential as much as possible.
INSULATION MATERIALS

It can be confusing to try to characterize insulation because many materials come in a variety of forms. The insulation industry continues to develop new products to meet the increasing demand for specialized products.

FIBER INSULATION

- Fiberglass products come in batt, roll and loose-fill form, as well as a high-density board material. Many manufacturers use recycled glass in the production process. Fiberglass is used for insulating virtually every building component, from foundation walls to attics to ductwork.
- Cellulose insulation, made from recycled newsprint, comes primarily in loose-fill form. Loose-fill cellulose is used for insulating attics and can be used for walls and floors when installed with a binder or netting. Because of its high density, cellulose has the advantage of helping stop air leaks in addition to providing insulation value.
- Rock and mineral wool insulation is mainly available as a loose-fill product. It is fireproof and many manufacturers use recycled materials in the production process.

FOAMS

- Extruded polystyrene (XPS), a foam product, is a homogenous polystyrene produced primarily by three manufactures with characteristic colors of blue, pink, and green.
- Polyisocyanurate and polyurethane are insulating foams with some of the highest available R-values per inch. They are not designed for use below-grade, unlike the polystyrene foam insulation products.
- Open-cell polyurethane foam is used primarily to seal air leaks and provide an insulating layer.
- Polycyrene foam, used primarily to seal air leaks and provide an insulating layer, is made with carbon dioxide rather than more polluting gases, such as pentane or hydro-chlorofluorocarbons (HCFC), used in other foams.

INSULATION AND THE ENVIRONMENT

There has been considerable study and debate about potential negative environmental and health impacts of insulation products. These concerns range from detrimental health effects for the individual installer to depletion of the earth’s ozone layer.

Concerns exist when the individual installer breathes in fiberglass and mineral wool fibers; as yet, there is no accepted universal proof that either is a carcinogen. Using cellulose raises flammability issues. However, fire retardant chemicals are added to cellulose; this, along with its greater density, provides the same or greater fire safety when compared to other insulation products. For years, foam products contained CFCs, which are the blowing agents, which helped create the lightweight foams. CFCs are quite detrimental to the earth’s ozone layer. Blowing agents now used are pentane, HCFCs or carbon dioxide.

Expanded polystyrene uses pentane. Pentane has no impact on the ozone layer, but has been implicated in increasing smog formation. The insulation materials of extruded polystyrene, polyisocyanurate and polyurethane use primarily HCFCs. These are 90% less harmful to the ozone layer than CFCs.
companies are moving to non-HCFC blowing agents. Finally, open-cell polyurethane uses carbon dioxide as a blowing agent. The carbon dioxide does not affect the ozone layer unlike other blowing agents.

For additional information about these and other insulation materials, see Table 5-1. An R-value is a measure of the thermal resistance of a material. Higher R-values indicate better resistance to heat flow through material.

<table>
<thead>
<tr>
<th>Type of Insulation</th>
<th>Installation Method(s)</th>
<th>R-value per inch</th>
<th>Indoor Air Quality Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fiber Insulation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellulose</td>
<td>Loose-fill, wet-spray, dense pack, stabilized</td>
<td>3.0 – 3.7</td>
<td>Fibers and chemicals can be irritants, should be isolated from interior space</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>Batts, loose-fill, stabilized, rigid board</td>
<td>2.2 – 4.0</td>
<td>Fibers and chemicals can be irritants, should be isolated from interior space</td>
</tr>
<tr>
<td>Mineral Wool</td>
<td>Loos-fill, batts</td>
<td>2.8 – 3.7</td>
<td>See fiberglass</td>
</tr>
<tr>
<td><strong>Foam Insulation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open-cell Expanded Polystyrene (beadboard)</td>
<td>Rigid boards</td>
<td>3.6 – 4.2</td>
<td>Concern only for those with chemical sensitivities</td>
</tr>
<tr>
<td>Closed-cell Extruded Polystyrene</td>
<td>Rigid boards</td>
<td>5</td>
<td>Concern only for those with chemical sensitivities</td>
</tr>
<tr>
<td>Closed-cell Polyisocyanurate</td>
<td>Foil-faced rigid boards</td>
<td>5.6 – 7.7</td>
<td>Concern only for those with chemical sensitivities</td>
</tr>
<tr>
<td>Closed-cell Phenolic Foam</td>
<td>Foil-faced rigid board</td>
<td>8</td>
<td>Concern only for those with chemical sensitivities</td>
</tr>
<tr>
<td>Open-cell Polyisocyanene</td>
<td>Sprayed-in</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Open-cell Soy-based Foam</td>
<td>Sprayed-in</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Closed-cell Polyurethane</td>
<td>Sprayed-in</td>
<td>5.6 – 6.8</td>
<td>Concern only for those with chemical sensitivities</td>
</tr>
<tr>
<td>Open-cell Polyurethane</td>
<td>Sprayed-in</td>
<td>4.3</td>
<td>Unknown, appears to be very safe</td>
</tr>
</tbody>
</table>

**INSULATION STRATEGIES**

Commonly used fiberglass and cellulose products are the most economical, while foam products should be used more judiciously. However, the wide variety of spray-foam products now on the market warrants serious consideration in many homes. In attics, loose-fill products are less expensive than batts or blankets. Blown cellulose and rock wool are denser than fiberglass, which helps them stop air leaks.
Critical guidelines for installing any insulating material are:

- Seal all air leaks between conditioned and unconditioned areas;
- Obtain complete coverage of the insulation;
- Minimize air leakage through the material;
- Avoid compressing insulation to less than its rated thickness;
- Avoid lofting (installing too much air) in loose-fill products; and
- Avoid thermal bridging.

**FIBER INSULATION STRATEGIES**

Fiber insulation requires care during installation to prevent compression. When installed, fiber insulation must have an air barrier on all six sides to meet the requirements of the ENERGY STAR® Thermal By-pass Checklist. The only exceptions are the horizontal surfaces in attics and when touching the floor in a crawl space. Common problems with fiber insulation installations are:

- Not cutting batts around wiring and plumbing in walls;
- Not installing an air barrier on the attic side of a knee wall; and
- Not creating an air barrier on all six sides of the floor insulation below a room over a garage.

**FOAM INSULATION STRATEGIES**

Foam products are primarily economical when applied in thin layers as part of a structural system. Foam products are a good choice to help seal air leaks.

Examples of appropriate locations to apply foam insulation products include:

- Foundation wall or slab insulation;
- Exterior sheathing over wall framing;
- Forms in which concrete can be poured;
- As part of a structural insulated panel for walls and roofs; and
- As part of complex framing in which fiber insulation would be difficult to install.

**FOUNDATION INSULATION**

Insulating the foundation of a residence is more difficult than insulating most other areas of a residence because of the environment surrounding the insulation. If the insulation is below grade, then it must resist the pressure of the soil, provide drainage if needed, and be termite resistant. If the insulation is external to the foundation and above grade, then some method of providing protection from mechanical damage (weed eaters, etc.), must be provided. In the case of brick siding, the builder must use some method of insulating the stem wall.

While insulating the interior of a foundation eliminates some of these difficulties, it presents its own unique problems. These problems include:

- Preventing air from reaching the concrete foundation wall, causing condensation;
- Ensuring that the insulation meets fire codes; and
- Determining how it can be finished.

Carefully consider the options provided in the following sections to ensure that a complete solution is possible in each specific residence. Table 5-2 provides some information on the economics of insulating basement walls to the prescriptive level in the 2006 IRC.
Table 5-2  Economics of Foundation Insulation Systems

<table>
<thead>
<tr>
<th>Type of Treatment</th>
<th>Energy Savings * ($/yr)</th>
<th>Break-even Investment‡ ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry Wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R – 4 continuous vs. R–0</td>
<td>208</td>
<td>1,377</td>
</tr>
<tr>
<td>R – 10 continuous vs. R–4</td>
<td>71</td>
<td>819</td>
</tr>
</tbody>
</table>

*For 1,000 sq ft of wall in Lexington, KY; energy savings are compared to an R – 4 concrete block wall.
‡ See Chapter 2 for information on break-even investment.

SLAB-ON-GRADE INSULATION

In many homes, the bottom-heated floor is a concrete slab-on-grade, meaning that a slab, situated near ground level, serves as the floor itself. Uninsulated slabs lose considerable heat in winter through their perimeter.

TERMITE PROBLEMS IN SLAB INSULATION

While slab insulation reduces energy bills, care must be taken because termites can burrow undetected through slab insulation to gain access to the wood framing above. The industry is working on solutions to the termite problem, but in the meantime, check with pest control companies to ensure termite contracts are valid for insulated perimeter slabs.

PREVENTING TERMITE PROBLEMS

Preventing termite problems is a key goal of any building, especially where a visual inspection of the foundation is not possible. Some important preventive measures are:

- Create good drainage—slope soil away from the home and install foundation drains.
- Remove organic matter—remove all wood from around the foundation before backfilling.
- Direct moisture away from the home—use well maintained gutters and downspouts that connect to a drainage system.
- Provide continuous termite shields—protect wooden sill plate and other framing members. The sill plate should be made of termite resistant lumber.
- Treat soil—make certain to hire a reputable termite company that will provide a full guarantee against pests. Install termite traps or other monitoring methods so that the occupants can see if pests are around the building.

SLAB INSULATION DETAILING

Detailing perimeter slab insulation should be planned carefully to prevent both aesthetic and moisture problems, see Figure 5-1 and Figure 5-2. The goals of detailing work are to blend foundation exterior finish with framed wall finish, prevent moisture problems, and create at least 2 feet of continuous perimeter insulation. Once again, make certain your termite contract covers homes with slab insulation.
Figure 5 – 1  Exterior Insulation of Termite Retardants

Figure 5 – 2  Slab Insulation Placement Options
FOUNDATION WALL INSULATION

Builders use concrete block or poured concrete to build foundation walls and other masonry walls. Insulating foundation walls is more difficult than insulating framed walls; there is no convenient cavity into which insulation can fit.

EXTERIOR RIGID FIBERGLASS OR FOAM INSULATION

Rigid insulation is more expensive than mineral wool or cellulose; however, its rigidity is a major advantage (Figure 5-3). Rigid insulation can be placed directly over a foundation wall prior to backfilling and yields excellent insulating value. In addition, the exterior insulation will help protect waterproofing and will allow the block or concrete wall to provide thermal mass in winter and summer.
INTERIOR FOAM WALL INSULATION

Foam insulation can be installed on the interior of foundation walls, but it must be covered with a material that resists damage and meets local fire code requirements, as in Figure 5-4. Half-inch drywall will typically comply, but furring strips will need to be installed as nailing surfaces. Furring strips are usually installed between sheets of foam insulation; however, to avoid the direct, uninsulated thermal bridge between the concrete wall and the furring strips, a continuous layer of foam should be installed underneath or on top (preferred placement) of the nailing strips.

Figure 5-4  Interior Basement Wall Insulation  (R - 10 to R - 14)
INTERIOR FRAMED WALL

In some cases, designers will specify a framed wall on the interior of a masonry wall, Figure 5-5. The wall should include provisions for both continuous insulation and careful air sealing. If a continuous insulation layer is not provided between the wall and the block, air sealing is critical. If warm moist air leaks into that area it will condense on the wall and create conditions that promote mold growth.

Figure 5–5  Interior Framed Wall Insulation (R – 13 Cavity)
INSULATED CONCRETE FOUNDATION (ICF) SYSTEMS

Foam insulation systems, which serve as formwork for concrete foundation walls, can help the builder save on materials and can cut heat flow. Once stacked, reinforced with rebar, and braced, they can be filled with concrete.

Key considerations are:

- **Bracing requirements**: bracing the foam blocks before construction may outweigh any labor savings from the system. However, some products require little bracing.
- **Stepped foundations**: make sure of the recommendations for stepping foundations. Some systems have 12-inch high blocks or foam sections, while others are 16-inch high.
- **Reinforcing**: follow the manufacturer’s recommendations for placement of rebar and other reinforcing materials.
- **Concrete fill**: make sure that the concrete ordered to fill the foam foundation system has sufficient slump to meet the manufacturer’s requirements. These systems have been subject to blow-outs when the installer did not fully comply with the manufacturer’s specifications. A blow-out is when the foam or its support structure breaks and concrete pours out of the form.
- **Waterproofing**: many standard waterproofing treatments, which use organic compounds, will degrade the foam insulation that make up the insulated forms. Follow the manufacturer’s guidelines regarding safe and effective waterproofing products and techniques.
- **Termites**: these systems may require approval by code inspection officials. Also, be sure to consult with a reputable termite contractor.

INSULATING CRAWL SPACE WALLS

For years, building professionals have assumed that the optimal practice for insulating floors over unheated areas was to insulate underneath the floor. However, studies have found that insulating the walls, in well-sealed crawl spaces can be an effective alternative to underfloor insulation. Because the crawl space remains cool in summer, the home can conduct heat to the crawl space if there is no insulation under the floor. Homes with sealed and insulated crawl space walls must also have a completely sealed ground cover system, typically using polyethylene, see Figures 5-6 and 5-7.
SEALED CRAWL SPACE VENTILATION REQUIREMENTS

- The International Residential Code specifies that the crawl space requires one of the following for crawl spaces without foundation vents:
  - Ventilation fan that either exhausts or supplies 1 cfm of air per 50 square feet of crawl space floor, or
  - Supply air from the heating and cooling system equal to 1 cfm of air per 30 square feet of crawl space floor.
- Furnaces or water heaters that are located in these areas and require outside air for combustion should have a direct inlet duct from the outside.

SEALED CRAWL SPACE WALL INSULATION REQUIREMENTS

- Cover the earth floor with 6-10 mil polyethylene (recommended in all homes). Seal all seams in the plastic with caulk or mastic (typically used for duct sealing). Lap the plastic up the foundation wall until above outside grade and seal it against the wall. Do not install foundation vents.
- Leave a 1 or 2 inch gap at the top of the insulation to serve as a termite inspection strip.
- Insulate the band joist area, in addition to the foundation wall.
- Seal carefully between the crawl space or basement and the house interior.
- Builders should review plans for the insulation with local building officials to ensure code compliance.

Advantages of crawl space wall insulation:

- Less insulation required (around 800 square feet for a 2,000 square foot crawl space with 4-foot walls instead of 2,000 square feet of R-19 under the floor);
- Pipe insulation is not required (spaces should stay warmer in winter);
- Much lower humidity levels during warm weather; and
- Reduction in cooling load and cooling bills with only a slight increase in heating bills compared to crawl spaces with near perfect underfloor insulation.

Disadvantages of crawl space wall insulation:

- The insulation may be damaged by rodents and other pests;
- If the crawl space is leaky to the outside, the home will lose considerably more heat than standard homes with underfloor insulation; and
- If the site has improper drainage, the crawl space will be wet; therefore, proper site drainage is essential for a dry crawl space.

INSULATING UNDER FLOORS

Most floors in conventional homes are constructed with 2x10 or 2x12 wood joists, wood I-beams, or trusses over unconditioned crawl spaces or basements. Generally, insulation is installed underneath the subfloor between the framing members. To meet the 2006 IRC prescriptive guidelines for Climate Zone 4, homes need R-19 floor insulation.

Most builders use insulation batts for insulating framed floors. The batts should be installed flush against the subfloor to eliminate any gaps that may serve as a passageway for cold air between the insulation and floor.
Most insulation contractors use special rigid wire supports to hold the insulation in place. For the insulation to stay in place over several decades, installers must carefully install the wire supports 16 inches apart (Figure 5-8).

The framed floor area above a garage represents a special case for insulation to meet the thermal bypass requirements for ENERGY STAR® Certification. Insulation in this location must fully fill the space between the floor and the sheet rock ceiling of the garage. In addition, some method of blocking must be provided at the ends, if the insulation does not extend the entire width of the garage.

**INSULATING WALLS**

To solve some of the energy and moisture problems in standard wall construction, builders should follow the key components for energy efficient construction discussed in Chapter 1. Some of these features involve preplanning, especially the first time that these energy efficient improvements are used. In addition to standard framing lumber and fasteners, the following materials will also be required during construction:

- Foam sheathing for insulating headers;
- 1x4 or metal T-bracing for corner bracing;
- R-13 batts for insulating behind shower/tub enclosures and other hidden areas during framing;
- Rigid material for sealing behind shower/tub enclosures and other areas that cannot be reached after construction; and
- Caulking or foam sealant for sealing areas that may be more difficult to see later.

Enclosed cavities are more prone to cause condensation, particularly when sheathing materials, with low R-values, are used. Ensure that a continuous air barrier system is installed. The presence of wiring, plumbing, ductwork, and framing members lessens the potential R-value and provides pathways for air leakage. Locate mechanical systems in interior walls. Avoid horizontal wiring runs through exterior walls and use an air sealing insulation system.

The interest in providing more energy efficient homes has created several new methods of insulating standard 2x4 walls. While the insulation cavity is limited to 3.5 inches thick, new methods can increase the R-value of the insulation or ensure that the placement is correct, no gaps or missed areas, or both. It is likely that new methods will continue to develop as long as 2x4 wall construction is common.

**BATT INSULATION**

While batt insulation in walls has been the standard for wall insulation, it has one primary drawback, the quality of the installation. Properly installed and protected by an air barrier on all six sides, batt insulation can perform as desired. Proper installation includes cutting the batts so that they can be installed around any materials in the wall cavity, such as electrical wiring or plumbing and avoiding side stapling.

Side stapling can compress the insulation and create an air space between the insulation and the interior finish, which allows cold air to circulate within the wall cavity (Figure 5-9). The combined effect of the compressed insulation and air circulation can substantially reduce the effective insulating value of an R-13 batt. Side stapling also results in the Home Energy Rater having to reduce the quality of the insulation, which results in a lower HERS score.
The insulation flange is designed to be stapled to the face of the studs at 12 inch intervals. Face stapling the batt ensures that the insulation will completely fill the stud cavity and minimize air circulation. The facing typically has too many tears and seams to function as an adequate air barrier; however, it does serve as a vapor retarder.

An alternative to side stapling insulation batts with flanges is to use unfaced batts. They are slightly larger than the standard 16 or 24 inch stud spacing and rely on a friction-fit for support. Since unfaced batts are not stapled, they can often be installed in less time. In addition, it is easier to cut unfaced batts to fit around wiring, plumbing, and other obstructions in the walls.

**BLOWN LOOSE-FILL INSULATION**

Loose-fill cellulose, fiberglass, and rock wool insulation can also be used to insulate walls. These products are installed with insulation blowing machines and held in place with a glue binder or netting. Blown insulation provides good coverage in the stud cavities; however, it is important to allow excess moisture in the binder to evaporate before enclosing the wall cavities with a vapor barrier or interior finish.

Loose-fill materials with high densities, such as cellulose installed at 3 to 4 pounds per cubic foot, are not only excellent insulators, but also seal air leaks and reduce sound transmission. Some people get the cellulose almost as much for its sound deadening as for its insulation properties. Fiberglass is less dense than cellulose and does not provide as much resistance to air circulation. Therefore, builders must consider the additional benefits of air sealing when evaluating the economics of blown cellulose.

Neither unfaced insulation batts nor loose-fill products provide a vapor retarder. The 2006 IRC no longer requires vapor retarders in Climate Zone 4.

**BLOWN FOAM INSULATION**

Some insulation contractors are now blowing polyurethane or polyisocyanene insulation into walls of new homes. This technique seals air leaks effectively and with closed-cell foams provides high R-values in relatively thin spaces. The builder should examine carefully the economics of foam insulation before deciding on its use.

**METAL FRAMING**

Builders and designers are well aware of the increasing cost and decreasing quality of framing lumber. Consequently, interest in alternative framing materials, such as metal framing, has grown. While metal framing offers advantages over wood, such as consistency of dimensions, lack of warping, and resistance to moisture and insect problems, it has distinct disadvantages from an energy perspective.

Metal framing serves as an excellent conductor of heat (Table 5-3). Homes framed with metal studs and plates usually have metal ceiling joists and rafters as well. Thus, the entire structure serves as a highly conductive thermal grid. Insulation placed between metal studs and joists is much less effective due to the extreme thermal bridging that occurs across the framing members.
Researchers have delved into numerous ways to provide for a thermal break in walls with steel framing. The most effective solution has been to increase the insulating value of the sheathing. However, the home still suffers considerable conduction losses into the attic if the ceiling joists and rafters are steel-framed. The best solution to heat gain through steel framing in attics is to install a thermal break, such as a sill sealer material, between wall framing and ceiling joists. Then place a layer of foam sheathing underneath the ceiling joists before installing drywall.

**STRUCTURAL INSULATED PANELS**

Another approach to wall construction is the use of structural insulated panels (SIP), see Figure 5-10. They consist of 4- or 6-inch thick foam panels onto which sheets of structural plywood or oriented strand board (OSB) have been glued. These structured insulated panels reduce labor costs, and because of the reduced framing in the wall, have higher R-values and less air leakage than standard walls.
SIPs are 4 feet wide and generally 8 to 12 feet long. There are many manufacturers, each with a unique method of attaching panels. Each manufacturer has worked out procedures for installing windows, doors, wiring, and plumbing. In addition to their use as wall framing, SIPs can also form the structural roof of a building.

While homes built with SIPs may be more expensive than those with standard framed and insulated walls, research studies have shown SIP-built homes have higher average insulating values and fewer air leaks. Thus, SIPs can provide substantial energy savings to balance the added costs.

**WALL SHEATHINGS**

Many of Kentucky's builders use ½-inch wood sheathing (R-0.6) to cover the exterior walls of a building before installing the siding. Instead, use expanded polystyrene (R-2), extruded polystyrene (R-2.5 to 3), polyisocyanurate or polyurethane (R-3.4 to 3.6) foam insulated sheathing. (All R-values are per ½ inch.)

The recommended thickness of the sheathing is based on the desired R-value and the jamb design for windows and doors, usually ½ inch. Be certain that the sheathing completely covers the top plate and band joist at the floor. Most manufacturers offer sheathing products in 9- or 10-foot lengths to allow...
complete coverage of the wall. Once it is installed, patch all holes, which also helps to ensure protection against condensation.

Advantages of foam sheathing over wood or fiberboard include:

- Saves energy;
- Easier to cut and install;
- Protects against condensation; and
- Less expensive than plywood or OSB.

Disadvantage of foam sheathing over wood or blackboard:

- Requires the use of let-in bracing to provide structural support, Figure 5-11.
2X6 WALL CONSTRUCTION

There has been considerable interest in Kentucky in the use of 2x6s for construction. In most code jurisdictions, 2x6s can be spaced on 24 inch centers, rather than the 16 inch centers required for 2x4s. The advantages of using wider wall framing are:

- More space provides room for R-19 or R-21 wall insulation;
- Thermal bridging across the studs is less of a penalty due to the higher R-value of 2x6s and wider stud spacing;
- Less framing reduces labor costs; and
- There is more space for insulating around piping, wiring, and ductwork.

Disadvantages of 2x6 framing include:

- Wider spacing may cause the interior finish or exterior siding to bow slightly between studs;
- Window and door jambs must be wider and can add $12 to $15 per opening; and
- Walls with substantial window and door area may require almost as much framing as 2x4 walls and leave relatively little area for actual insulation.

The economics of 2x6 wall insulation are affected by the number of windows in the wall, since each window opening adds extra studs and may require the purchase of a jamb extender. Table 5-5 shows a comparison of 2x4 versus 2x6 framing. Walls built with 2x6s, having few windows, provide a positive economic payback. However, in walls in which windows make up over 10% of the total area, the economics become more questionable.

<table>
<thead>
<tr>
<th>Description of Wall</th>
<th>Average R-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wall Only</td>
</tr>
<tr>
<td>No window</td>
<td></td>
</tr>
<tr>
<td>2x4</td>
<td>13.04</td>
</tr>
<tr>
<td>2x6</td>
<td>19.00</td>
</tr>
<tr>
<td>2 windows</td>
<td></td>
</tr>
<tr>
<td>2x4</td>
<td>12.59</td>
</tr>
<tr>
<td>2x6</td>
<td>18.38</td>
</tr>
<tr>
<td>4 windows</td>
<td></td>
</tr>
<tr>
<td>2x4</td>
<td>12.10</td>
</tr>
<tr>
<td>2x6</td>
<td>17.69</td>
</tr>
</tbody>
</table>

*400 sq ft with R – 13, 2x4 construction versus R – 19, 2x6 construction.
**All windows are U – 0.40, 15 sq ft.
Selecting the combination of framing material, framing method, insulation level and sheathing to create the most energy efficient walls’ system, that is economically feasible, is complicated by the number of options available. Table 5-6 lists 15 different combinations and shows the energy savings and break-even investment for each compared to standard 2x4 wall construction. Techniques, such as advanced framing, may not result in large energy savings but, because they use fewer materials, may actually result in no additional cost of construction.

<table>
<thead>
<tr>
<th>Type of Treatment</th>
<th>Energy Savings *($/yr)</th>
<th>Break-even Investment ‡ ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2x4 Wall</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R – 13 batts, standard framing</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>R – 13 batts, standard framing; R – 3 sheathing</td>
<td>57.00</td>
<td>641.71</td>
</tr>
<tr>
<td>R – 13 batts, advanced framing</td>
<td>10.00</td>
<td>112.58</td>
</tr>
<tr>
<td>R – 13 batts, advanced framing; R – 3 sheathing</td>
<td>62.00</td>
<td>698.00</td>
</tr>
<tr>
<td>R – 15 batts, standard framing</td>
<td>18.00</td>
<td>202.64</td>
</tr>
<tr>
<td>R – 15 batts, standard framing; R – 3 sheathing</td>
<td>69.00</td>
<td>776.80</td>
</tr>
<tr>
<td>R – 15 batts, advanced framing</td>
<td>29.00</td>
<td>326.48</td>
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<tr>
<td>R – 15 batts, advanced framing; R – 3 sheathing</td>
<td>75.00</td>
<td>844.35</td>
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<tr>
<td><strong>2x6 Wall</strong></td>
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<td></td>
</tr>
<tr>
<td>R – 19 batts, standard framing</td>
<td>77.00</td>
<td>866.87</td>
</tr>
<tr>
<td>R – 19 batts, standard framing; R – 3 sheathing</td>
<td>105.00</td>
<td>1,182.09</td>
</tr>
<tr>
<td>R – 19 batts, advanced framing</td>
<td>84.00</td>
<td>945.67</td>
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<tr>
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<td>109.00</td>
<td>1,227.12</td>
</tr>
<tr>
<td>R – 21 batts, standard framing</td>
<td>86.00</td>
<td>968.19</td>
</tr>
<tr>
<td>R – 21 batts, standard framing; R – 3 sheathing</td>
<td>112.00</td>
<td>1,260.90</td>
</tr>
<tr>
<td>R – 21 batts, advanced framing</td>
<td>84.00</td>
<td>945.67</td>
</tr>
<tr>
<td>R – 21 batts, advanced framing; R – 3 sheathing</td>
<td>117.00</td>
<td>1,317.19</td>
</tr>
</tbody>
</table>

*For a 2,000 sq ft home with 1,774 sq ft of net wall area located in Lexington, KY.
‡See Chapter 2 for information on break-even investment.

**CEILINGS AND ROOFS**

Attics over flat ceilings are usually the easiest part of a home’s exterior envelope to insulate. They are accessible and have ample room for insulation. However, many homes use cathedral ceilings that provide little space for insulation. It is important to insulate both types of ceilings properly. In addition, builders are beginning to insulate the roof deck to create a conditioned attic space. One benefit is to bring an HVAC system, installed in an attic, into a conditioned space to reduce duct loss.
ATTIC VENTILATION

In winter, properly designed roof vents expel moisture that could otherwise accumulate and deteriorate insulation or other building materials. In summer, ventilation reduces roof and ceiling temperatures, thus saving on cooling costs and lengthening the roof’s life.

IS VENTILATION NECESSARY?

At present, building science experts are researching attic ventilation. For years, researchers have believed that the cooling benefits of ventilating a well-insulated attic are negligible. However, some experts are now questioning whether ventilation is even effective at moisture removal. While the 2006 IRC allows for an insulated roof deck, it does not allow for a sealed attic. Builders should follow local code requirements until alternatives to attic ventilation have been widely accepted and the IRC has accepted their use.

INSULATED ROOF DECKS

The 2006 IRC uses the term “unvented conditioned attic assemblies” to refer to what is commonly called an insulated roof deck. The 2006 IRC provides for insulated roof deck under specified conditions. These conditions do not apply if a 1 inch air space is provided between the insulation and the roof sheathing. This situation does not meet the definition of an insulated roof deck because it allows the attic to be vented, even though the insulation is close to the roof. The conditions for Climate Zone 4 include:

1. No interior vapor retarders are installed on the ceiling side (attic floor) of the unvented attic assembly.
2. An air-impermeable insulation is applied in direct contact to the underside/interior of the structural roof deck.
3. Sufficient insulation is installed to maintain the monthly average temperature of the condensing surface above 45°F (7°C). The condensing surface is defined as either the structural roof deck or the interior surface of an air-impermeable insulation applied in direct contact with the underside/interior of the structural roof deck.

In addition to meeting these requirements, the fire code requirements must also be met; this may limit the use of some insulating materials for this application.

In general, to insulate the roof deck, some type of spray-on insulation or combination of insulations is used. When insulating the roof deck, the attic gables must also be insulated to complete the conditioned envelope and must provide an air barrier to meet the thermal bypass requirements for walls. An insulated roof deck allows the HVAC duct system to be brought into the conditioned space as well as allowing the attic to be used for storage, etc.

It is possible to use rigid foam insulation above the roof deck sheathing to raise the condensing surface temperature above the requirement in the code; however, in most of Climate Zone 4, that would require an insulation level of an R-10. Typical rigid foams would require a 2 inch layer to be applied and then protected with another layer of sheathing to attach the roof covering material.
VENT SELECTION

If ventilating the roof, locate vents high along the roof ridge and low along the eave or soffit (see Figure 5-12). Vents should provide air movement across the entire roof area. There are wide varieties of products available including ridge, gable, soffit, mushroom, and turbine vents.

The combination of continuous ridge vents along the peak of the roof and continuous soffit vents at the eave provides the most effective ventilation. Ridge vents come in a variety of colors to match any roof. Some brands are made of corrugated plastic that can be covered by cap shingles to hide the vent.
GUIDELINES FOR ATTIC/ROOF VENTILATION

The amount of attic ventilation needed is determined by the size of the attic floor and the amount of moisture entering the attic. General guidelines are:

- Provide 1 square foot of attic vent for each 150 square feet of attic floor area.
- The total vent area should be divided equally between high and low vents; thus, if 5 total square feet of vent are needed, locate 2.5 square feet at the ridge and another 2.5 square feet at the soffit.
- Attic vent areas should be the net free area, or about 70% of the total vent area.

POWERED ATTIC VENTILATOR PROBLEMS

Electrically powered roof ventilators can consume more electricity to operate than they save on air conditioning costs; they are not recommended for most designs, see Figure 5-13. Power vents can create negative pressures in the home that may have detrimental effects, such as:

- Drawing air from the crawl space into the home;
- Removing conditioned air from the home through ceiling leaks and bypasses;
- Pulling pollutants, such as radon and sewer gases, into the home; and
- Backdrafting fireplaces and fuel-burning appliances.
ATTIC FLOOR INSULATION TECHNIQUES

Loose-fill and batt insulation can both be installed on an attic floor. Guidelines for ensuring a quality loose-fill attic insulation installation are:

- Seal attic air leaks, as prescribed by fire and energy codes.
- Follow manufacturers’ clearance requirements for heat-producing equipment found in an attic, such as flues or exhaust fans. Local building codes may mandate other blocking requirements. Use metal flashing, plastic or cardboard baffles, or pieces of batt insulation for blocking. Table 5-10 summarizes attic blocking requirements.
- Use cardboard baffles, insulation batts, or other baffle materials to preserve ventilation from soffit vents at eave of roof.
- Insulate the attic hatch or attic stair with batts or foam insulation attached to the attic hatch or placed under the steps of the pull-down stairs. For added protection, use the foam boxes sold for insulating over a pull-down attic stairway.
- Avoid fluffing the insulation (blowing with too much air) by using the proper air-to-insulation mixture in the blowing machine. A few insulation contractors have “fluffed” (added extra air to) loose-fill insulation to give the impression of a high R-value. The insulation may be the proper depth, but if too few bags are installed, the R-values will be less than claimed.
- Obtain complete coverage of the blown insulation at similar insulation depths. Staple attic rulers throughout the attic to ensure uniform depth of insulation.

<table>
<thead>
<tr>
<th>Object</th>
<th>Recommended Action*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recessed light</td>
<td>Use airtight, insulated cover (IC) models</td>
</tr>
<tr>
<td>Doorbell transformer</td>
<td>Install on rafters or other roof framing to avoid insulation</td>
</tr>
<tr>
<td>Masonry chimney</td>
<td>As specified by local fire codes, typically 2 inch clearance</td>
</tr>
<tr>
<td>Metal chimney</td>
<td>Follow manufacturer’s recommendations, typically 2 inch clearance</td>
</tr>
<tr>
<td>Flues from fuel-burning equipment</td>
<td>Follow manufacturer’s recommendations</td>
</tr>
<tr>
<td>Kitchen/bath exhaust</td>
<td>Duct to the outside</td>
</tr>
<tr>
<td>Heat/light/ventilation</td>
<td>Follow manufacturer’s recommendations, typically 3 inch clearance</td>
</tr>
<tr>
<td>Uncovered electric boxes</td>
<td>Cover the box with rated metal plate; caulk around box, if necessary, and insulate</td>
</tr>
<tr>
<td>Whole house fan</td>
<td>Install blocking up to the fan housing; leave 3 inch clearance around fan motor</td>
</tr>
<tr>
<td>Attic access door</td>
<td>Block around the door if blowing in loose-fill insulation; weatherstrip and insulate door or hatch</td>
</tr>
</tbody>
</table>

*These are general guidelines. Follow specific manufacturer’s recommendations.
Guidelines for ensuring a quality batt, attic insulation installation:

- Seal attic air leaks, as prescribed by fire and energy codes.
- Block around heat-producing devices. Insulate the attic hatch or attic stair. When installing the batts, make certain they completely fill the joist cavities, Figure 5-14. Shake batts to ensure proper loft. If the joist spacing is uneven, patch gaps in the insulation with scrap pieces. Try not to compress the insulation with wiring, plumbing or ductwork. In general, obtain complete coverage of full-thickness, non-compressed insulation.
- If two layers of batts are used, install top layer perpendicular to joists.

INCREASING THE ROOF HEIGHT AT THE EAVE

One problem area in many standard roof designs is at the eave. There is often insufficient space for full insulation without blocking air flow from the soffit vents. If the insulation is compressed, its R-value will decline. Figure 5-15 shows several solutions to this problem. If using a truss roof, purchase raised heel trusses that form horizontal over-hangs. They should provide clearance for both ventilation and insulation. In stick-built roofs, where rafters and ceiling joists are cut and installed on the construction site, an additional top plate, which lays across the top of the ceiling joists at the eave, will prevent compression of the attic insulation. The rafters sitting on this raised top plate allow for both insulation and ventilation.
The raised top plate design also minimizes wind washing of the attic insulation. Wind washing occurs where air entering the soffit vents flows through the attic insulation. When installing a raised top plate, most framing crews also place a band joist over the open joist cavities of the roof framing. The band joists help prevent wind washing, which can reduce attic insulation R-values on extremely cold days and can add moisture to the insulation.

Raised top plates also elevate the overhang of the home, which may enhance the building's attractiveness. The aesthetic advantage is especially useful in one-story homes with standard 8-foot ceilings.
**PROBLEMS WITH RECESSED LIGHTS**

Standard recessed fixtures require a clearance of several inches between the sides of the lamp’s housing and the attic insulation. In addition, insulation cannot be placed over the fixture. Even worse, recessed lights create air leaks between the attic and the home. IC-rated fixtures have a heat sensor switch, which allows the fixture to be covered with insulation. However, these units also leak air.

Airtight, IC-rated fixtures are now required by the 2006 IRC. Alternatives to recessed lights include surface-mounted ceiling fixtures and track lighting, which typically contribute less air leakage to the home.

**CATHEDRAL CEILING INSULATION TECHNIQUES**

Cathedral ceilings are a special case because of the limited space for insulation and ventilation within the depth of the rafter. Fitting in a 10-inch batt (R-30) and still providing ventilation is impossible with a 2x6 or 2x8 rafter.

The 2006 IRC allows R-30 cathedral ceiling insulation for Climatic Zone 4.

**BUILDING R-30 CATHEDRAL CEILINGS**

Cathedral ceilings, built with 2x12 rafters, can be insulated with standard R-30 batts and still have plenty of space for ventilation. Some builders use a vent baffle between the insulation and roof decking to ensure that the ventilation channel is maintained.

If 2x12s are not required structurally, most builders find it cheaper to construct cathedral ceilings with 2x10 rafters and high-density R-30 batts, which are 8¼ inches thick. Some contractors wish to avoid the higher cost of 2x10 lumber and use 2x8 rafters.

If framing with 2x6 and 2x8 rafters, insufficient space is available for standard R-30 insulation. Higher insulating values can be obtained by installing rigid foam insulation under the rafters. However, foam is expensive and using thicker rafters with batt or loose-fill insulation may be substantially less costly. A fire-rated material must cover the rigid foam insulation when used on the interior of the building. Five-eighths inch drywall should meet the requirement; check with local fire codes or building inspectors for confirmation.

**SCISSOR TRUSSES**

Scissor trusses are another cathedral ceiling efficiency framing option. Scissor trusses have a greater roof pitch than ceiling pitch, thus creating more space than standard framing provides between the roof and the ceiling. Make certain scissor trusses provide adequate room for both R-30 insulation and ventilation, especially at their ends, which form the eave section of the roof.
CEILINGS WITH EXPOSED RAFTERS

A cathedral ceiling with exposed rafters or roof decking is difficult and expensive to insulate well. Often, foam insulation panels are used over the attic deck as shown in Figure 5-16. However, to achieve R-30, 4 to 7 inches of foam insulation, costing $1 to $3 per square foot, are needed.

In homes where exposed rafters are desired, it may be more economical to build a standard, energy efficient cathedral ceiling and then add exposed decorative beams underneath. Note that homes having tongue-and-groove ceilings can experience substantially more air leakage than solid, drywall ceilings. Install a continuous air barrier, sealed to the walls, above the tongue-and-groove roof deck.
RADIANT HEAT BARRIERS

Radiant heat barriers (RHB) are reflective materials that can reduce summer heat gain in attics and walls (Figure 5-17). While not generally a substitute for insulation, they can be used in concert with minimum levels of insulation to lower air conditioning costs during warm and hot weather.

Radiant heat barriers have a controversial history in the Southeastern United States because manufacturers oversold their benefits during the late 1980s and early 1990s. In particular, some sales representatives made excessive claims about the performance of the product and priced it too high to provide a reasonable payback.