responsiblenergy

new home planner

Congratulations on your decision to build a new home

Madison Gas and Electric's (MGE) *New Home Planner* book contains valuable information on resource-efficient construction products and practices. When you have questions, talk to our Home Energy Line energy experts at (608) 252-7117. Or visit us online at mge.com.

As your community energy company, we're committed to helping you make informed decisions that will increase the energy efficiency of your new home today while protecting the environment for tomorrow.

welcome!

MGE invites you to make the most of this *New Home Planner*. Count on it as a guide for making energy-efficient, environment-friendly building decisions that benefit generations to come.

So, please, come on in! We begin with an overview of how to use the planner. Learn about key concepts such as ‘energy-efficient home,’ ‘resource-efficient home,’ ‘green building,’ and the ‘house-as-a-system.’ It hammers home the advantages of building with energy- and resource-efficiency in mind.

Then move through key planning areas including design considerations, structure, mechanicals, appliances, lighting, and insulation/equipment recommendations. You’ll also find a handy glossary of terms.

The valuable information on resource-efficient construction products and practices gives you a lot to build on. And for those questions not answered by the planner, we invite you to talk with our Home Energy Line energy experts at 608-252-7117 or visit us online at www.mge.com.

As your community energy company, we’re committed to helping you make informed energy decisions today while protecting our environment for tomorrow. Again, welcome to the MGE *New Home Planner* and congratulations on your decision to build a wonderful new (and efficient) home!

Energy- and resource-efficiency at home and everywhere throughout our community. It’s our responsibility.

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The illustrations accompanying this text have been provided by the Canadian Home Builders' Association (CHBA) from their publication entitled *Canadian Home Builders' Association Builder's Manual*. If you are interested in purchasing a copy of the manual, they accept a check, Visa or MasterCard. The cost is $65 plus $20 shipping payable to:

Builders' Manual Sales
Canadian Home Builders' Association
150 Laurier Avenue West, Suite 500
Ottawa, Ontario K1P 5J4
CANADA
Phone: 613-230-3060

Order form: http://www.buildermanual.com/

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your new home

your new home

After careful thought and consideration, you have decided to build a new home. Now you are faced with hundreds of decisions: Purchasing a building site. Securing a mortgage. Determining the size and style of the house. Selecting the features that best meet your family's lifestyle.

Energy efficiency and indoor air quality play a role as well. How much insulation is enough? Which furnace and air conditioner saves energy? What steps ensure the air you breathe is fresh? How are moisture problems prevented?

That's why we wrote the *New Home Planner* – to help you make informed decisions about energy- and resource-efficient construction products and practices for your new home.

The *New Home Planner*: Who it's for, how to use it

The *New Home Planner* can help anyone planning to build an energy- and resource-efficient home in a northern climate similar to Madison, Wis. It is an overview of the many decisions made as you plan a new home.

Builders, architects, and the construction trades can gain insight into the reasons we feel the "house-as-a-system" concept is the most prudent new home construction strategy.

This book is based on our experiences with area builders. It is arranged in the same order as the actual design and construction process – from site selection and house placement to choosing appliances and lighting. If you would like more information, please call our Home Energy Line at 252-7117.

What is an energy-efficient home?

There are as many definitions of an energy-efficient home as there are builders to build them. Advanced homes, high-performance homes, zero energy homes, passive solar homes, and Passive Homes are just a few of the names used to describe an energy-efficient home. In this book, energy-efficient construction refers to a home that is certified by a third-party inspection program to reduce energy use 18% to 90% compared to a code-built home. Savings will vary depending on the program used. See the chapter on New Construction Programs.

What is a resource-efficient home?

A resource-efficient home uses fewer resources to minimize its impact on the environment – now and throughout the life of the home. This means the home is designed to reduce energy use and to use fewer and/or sustainable resources to do it. Local sources are sought for materials and products whenever possible to reduce transportation cost. Jobsite waste is minimized due to the planning process, and the small amount of waste is recycled. Ultimately, the home has a smaller environmental footprint.

What is green building?

"Green" building is an umbrella term that means designing and building a home with reduced environmental impacts over the life of the home. It places a high priority on health, the environment, and resource conservation. These priorities expand the classic building design concerns – economy, utility, and durability.

A green home incorporates some or all of the following features:

- Size based on the owners' needs.
- Minimal effect on the surrounding environment.
- Efficient use of materials, energy, and water.
- Durable materials that require only low-impact maintenance.
- Safe, healthy, and comfortable.

The details of any green design depend on the needs and priorities of the homeowner, the building site, the local climate, regional resource issues and, of course, the budget.

What makes a building green?

Designing a home to be energy and resource efficient is the first step. Considering renewable energy sources for the home is another.

There are three options for using renewable sources of electricity. They include purchasing renewable electricity from the local utility (MGE offers wind and solar power through Green Power Tomorrow), purchasing renewable energy certificates, and installing on-site renewable generation, such as solar photovoltaic or wind systems.

Green design addresses some important issues:

- Reduce human exposure to noxious materials.
- Conserve nonrenewable energy and scarce materials.
- Minimize life-cycle ecological impact of energy and materials used.
- Emphasize the use of renewable energy and materials that are sustainably harvested.
- Protect and restore local air, water, soil, flora, and fauna.

Advantages of an energy- and resource-efficient green home

Homes built using the methods described in this book share these characteristics:

- Cost-effective insulation levels.
- Sealed building envelope.
- Balanced ventilation system.
- Safe combustion of fuels.
- Efficient use of resources.

These houses feature:

- **Safe interior environment.** Backdrafting of potentially dangerous flue gasses into the living space is virtually eliminated. Sealed or power-vented combustion equipment must be installed or the combustion air for mechanical equipment must be from outside the house.
- **Healthy indoor environment.** Air quality controlled by a mechanical ventilation system that exhausts stale air and replaces it with fresh outdoor air. The fresh air is mixed with indoor air, conditioned, and distributed throughout the house.
- **Durable construction.** Construction details reduce the moisture problems that cause deterioration of your home's structure and interior finishes.
- **Greater comfort.** The building envelope is tight to reduce air leaks. This eliminates drafts and keeps out dust, insects, and most outside noise.
- **Energy efficiency.** Optimum insulation levels and equipment efficiencies save energy.
- **Energy savings that qualify for Energy-Efficient Mortgages.** Lenders may allow up to a 2% increase in the debt-to-income ratio because of the savings from greater energy efficiency. Monthly utility bills are less, leaving more money for mortgage payments. Federal programs are in place that allow lenders to sell their energy-efficient mortgages to Fannie Mae and Freddie Mac.

First cost vs. life-cycle cost

Life-cycle cost analysis reviews the total cost of a home over its life – initial purchase, energy use, maintenance, and replacement.

While building a green home without spending more is certainly possible, sometimes it makes sense to spend more up-front for savings down the road. For example, energy improvements to the building envelope (insulation, glazings, passive-solar design) can often be paid for through reduced cost of mechanical equipment.

But even if the savings don't pay for the entire extra up-front costs within a relatively short period of time, it still makes sense to include those measures because life-cycle costs will be lower.

The same argument holds true for a more expensive siding or decking material that will last 50 years instead of 20 years. Most recycled material products don't need to be painted or resurfaced, which reduces the life-cycle maintenance cost.

The "house-as-a-system" concept

To ensure the construction of healthy, energy-efficient homes, the house should be thought of as a system (see Figure A-1). It contains many components – walls, roof, windows, insulation, plumbing, electrical, heating, cooling, ventilation – that interact. Each of these subsystems can not only affect the performance of the house in general, but they can also affect the occupants and other systems within the house. How they interact determines the home's performance (e.g., cost, energy consumption, humidity level, durability, structural integrity), and a home's performance impacts the occupant's satisfaction (e.g., health, safety, comfort). A systems approach involves understanding the impact of changes on whole house performance and should maximize comfort and health and minimize energy waste and moisture damage.

Historically, designers and builders thought of these components individually. Today, we recognize they interact with each other to form a complete system. If a change is made to one part of the system, it is very likely that something may need to be done to compensate for that change.

This concept is best illustrated by an example. Rising energy prices have spurred great interest in energy-efficient construction. Builders are adding more insulation, and homes are becoming tighter due to

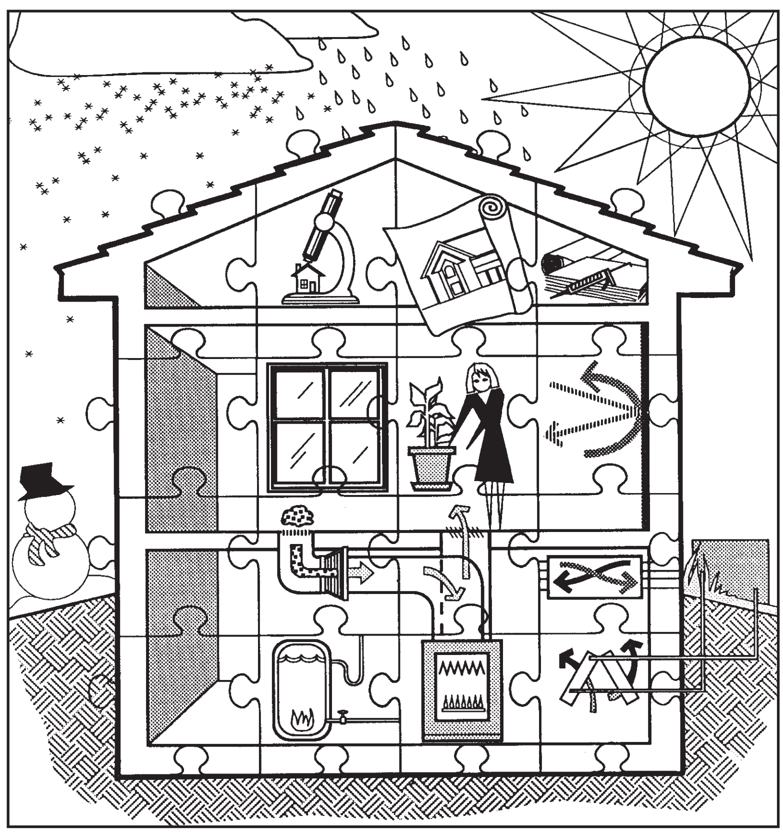

Fig. A-1: The house as a system

additional air-sealing measures. So, a change was made to the air tightness in the system and if the house is not viewed as a system, an indoor air quality or moisture problem could be created. Sealing up the home is good for saving energy but it can create unintended consequences. The solution is to add some type of mechanical ventilation system to bring in fresh air when needed.

Understanding the house-as-a-system concept will help the homeowner and builder make educated decisions about the best combination of systems for your home.

What is a Zero Energy Home (ZEH)?

Strictly speaking, a ZEH should be called a Net Zero Energy Home (NZEH). In the United States, a NZEH generally refers to a home where, on an annual basis, the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the home. The home still uses energy but it is offset, hence the term "Net." Solar photovoltaic panels or wind turbines usually provide the renewable energy.

In other words, the NZEH uses electricity from the electric utility grid. However, unlike most homes, the NZEH puts electrical energy back into the grid. Ideally, the amount of electricity put back into the grid equals the amount used from the grid. This means that during any particular month, the home may have used either more or less grid electricity than it put back into the grid. The goal is that by the end of a year, the electricity taken from the utility grid is offset by the solar electricity put back into the grid.

It is essential the home be built with more than average insulation levels and air tightness and passive solar design to minimize the energy needed. The Passive House, described in this publication, is an excellent model to use for building a NZEH. Since it uses so little energy, only a small renewable energy system would be needed.

MGE and energy efficiency

MGE is committed to energy efficiency in new home construction. We made this commitment to energy efficiency for three simple reasons.

First, it's the right thing to do – ethically and environmentally. Efficient energy use is a responsibility to future generations and for the welfare of our planet today.

Second, it's good customer service. An energy-efficient new home lowers your energy costs and increases your disposable income. That strengthens the economic base of our service territory.

Third, it's good business practice. We can serve more customers with our current electric-generating capacity and natural gas supplies. Large capital and operating costs are avoided so we can keep your energy costs low.

MGE and renewable energy

MGE is committed to "greening" our electricity grid by investing in renewable energy sources. To avoid the steep upfront cost of a personal system but still use green energy, many customers participate in MGE's Green Power Tomorrow to reduce their carbon footprint.

Some MGE customers are interested in owning their own renewable energy systems. Before investing in expensive renewable energy systems, customers are encouraged to improve their energy efficiency and reduce their energy use so less electricity needs to be generated.

When customers install their own systems, many choose to sell the power they produce to MGE. In this way, they become part of the community grid that helps provide electricity to all MGE customers. Others use the energy themselves but still rely on MGE to supply the power they need beyond the generating capacity of their own system and when the sun's not shining or the wind is not blowing. MGE works hard to maintain a reliable electric system and the ability to supply electricity precisely when our customers need it. This back-up power role requires the same equipment and service as is needed for supplying 100% of a customers' electricity.

Other sources of information

The following organizations (in alphabetical order) can provide you with more information on resource- and energy-efficient home construction practices and products.

Building America Program - U.S. Department of Energy

Web site: http://www1.eere.energy.gov/buildings/building_america/

Building America forms research partnerships with all facets of the residential building industry to improve the quality and energy efficiency of homes. The goal is to develop cost-effective solutions that dramatically reduce the average energy use of housing while improving comfort and quality.

Building Science Corporation

30 Forest St
Somerville, MA 02143

Phone: 978-589-5100 x5296

Fax: 978-589-5103

Web site: www.buildingscience.com

A Boston-based architecture and building science consulting firm internationally recognized for expertise in moisture dynamics, indoor air quality, and forensic (building failure) investigations. Their focus is preventing and resolving problems related to building design, construction, and operation. They promote energy efficiency and environmental responsibility within the constraints of marketable and affordable building technology. Their Web site has a variety of excellent publications on building science issues as well as information on the Building America Program.

Energy Efficiency and Renewable Energy Network

Web site: http://www.eere.energy.gov/

A U.S. Department of Energy online Internet resource to a variety of information on efficiency and links to other similar Internet home pages.

Energy and Environmental Building Alliance

6520 Edenvale Blvd., Suite 112
Eden Prairie, MN 55346

Phone: (952) 881-1098

Fax: (952) 881-3048

Web site: www.eeba.org

A good resource for builders and others interested in energy-efficient construction practices and technologies for residential and light-commercial buildings. Check out the "Houses That Work" section.

Iris Communications, Inc.

Post Office Box 5920
Eugene, OR 97405-0911

Phone: 541-484-9353

Fax: 541-484-1645

Web site: www.oikos.com

E-mail: iris@oikos.com

A Web site dedicated to sustainable and energy-efficient construction. Includes online databases, newsletters, and other references. See the Library section for excellent building science information.

Madison Area Builders Association

5936 Seminole Centre Court
Madison, WI 53711

Phone: 608-288-1133

Fax: 608-288-1136

E-mail: builders@maba.org

Web site: www.maba.org

Visit their "Consumer Resources" section to find information on building a new home. There's also a search engine to find builder and associate members of the organization.

Passive House Institute US (PHIUS)

Web site: http://www.passivehouse.us/passiveHouse/PHIUSHome.html

Email: info@passivehouse.us

Mailing address:
PHIUS
110 S. Race St., Suite 202
Urbana, Illinois 61801

Phone: (217)-344-1294

The Passive House Institute US (PHIUS) is a consulting and research firm working to further the implementation of Passive House standards and techniques nationwide. The Passive House concept represents today's highest energy standard with the promise of slashing the heating energy consumption of buildings by an amazing 90%. PHIUS is authorized by the Passivhaus Institut of Germany as the official certifier of the Passive House standard in the United States.

Focus on Energy New Homes Program

Phone: 1-800-762-7077

Web site: http://www.focusonenergy.com/Residential/New-Home/

The Focus on Energy New Homes program builds on the national ENERGY STAR® program by adding building standards that are more specific to Wisconsin's extreme weather while emphasizing comfort, combustion safety, and durability.

The Focus on Energy New Homes program utilizes trained, certified consultants who work closely with your builder.
To certify a Focus on Energy home, the consultant coordinates up to three site visits with the builder during the construction and completes performance tests to ensure the home works as designed – comfortable, safe, durable, and energy efficient.

Wisconsin Environmental Initiative - Green Built Home Program

16 N. Carroll Street, Suite 840
Madison, WI 53703-2726

Phone: 608-280-0360

Fax: 608-280-0361

Web site: http://wi-ei.org/greenbuilt/

E-mail: info@wi-ei.org

WEI administers the Green Built Home Program. This program was started in 1999 as a partnership with the Madison Area Builders Association. The program promotes and certifies resource-efficient homes in Wisconsin, Minnesota, and Illinois. It was created to lessen the environmental impacts of residential construction, educate home buyers about green built products and processes, increase the demand for green and energy-efficient building practices, and recognize builders who take proactive measures to protect the environment.

responsiblenergy

design considerations

MGE

design considerations

The big picture

Your home design decisions affect the performance of components that may seem unrelated. Consider these factors early in the design process to improve performance and lower costs. You also will ensure the home's subsystems are working together, not against each other.

Basic whole-home design guidelines

The whole-home design process begins when the occupants' needs are assessed and a project budget is established. Whole-home design considers the energy-related impacts and interactions of all building components including the building site; the envelope (walls, windows, doors, and roof); heating, ventilation, and air-conditioning (HVAC); and interior features like lighting, controls, and appliances. These design characteristics can be incorporated in setting whole home energy design goals. In addition, incorporating sustainable (green) principles in the design process ensures an environmentally sensitive home with a low impact on the environment. Decisions about integrating the home into the surroundings, landscaping for optimal water runoff, jobsite recycling, use of recycled-content products, sustainably harvested lumber, nontoxic paints and finishes, and water-saving fixtures should be made at this stage.

The following basic guidelines will help you build a home that uses substantially less energy, produces lower greenhouse gas emissions, and uses fewer resources without compromising comfort or increasing the cost substantially.

- Choose a building site that allows you to orient the long sides of the home to take advantage of passive solar.
- Consider incorporating active solar in the design of the home.
- Incorporate "green" design principles during the planning stages.
- Strive to design a less complicated, smaller home. In general, the larger and more complicated the design, the more energy used by the home and the larger its environmental footprint.
- Optimize the layout and floor plan to take advantage of natural ventilation, efficient use of space, practical traffic flow and proper progression from "public" to "private" areas.
- Add as much insulation on all six sides as your budget will allow. More insulation assures lower costs for equipment to condition the space and lower utility bills.
- Make it as air tight as you possibly can. A home cannot be built "too tight" as long as a ventilation system with the proper controls is installed.
- Install a heat-recovery or energy-recovery whole house ventilation system that operates automatically. It's the best solution to provide good indoor air quality.
- Incorporate a three-pronged approach to ensure good indoor air quality (see Indoor Air Quality below).
- Add high-performance windows and place them wisely – windows are the weak spot in the thermal shell so plan accordingly.
- Purchase energy-efficient heating, cooling, and water-heating equipment.
- Purchase ENERGY STAR® appliances and efficient lighting.

These bullet points are discussed, in order, below.

Building site

Site selection is the first step in the building process. If you don't have a building site, list the criteria that are important such as southern orientation, densely wooded, large or small, rural or urban. Lot costs, property taxes, the size of your new home, and availability of municipal services, zoning and deed restrictions, and plans for future development in the area are also important site-selection issues.

If you have a building site, these characteristics affect the design:

- Size of the site (obtain a plot plan from local authorities).
- Slopes, valleys, and drainage.
- Soil conditions (obtain a soil test: the softer the soil, the larger the foundation).
- Trees (location, types, sizes, and ages).
- The sun's path across the site during the year (see Figure B-1).
- Shading potential.
- Zoning (what building types are allowed).
- Building codes (building setbacks, area allowances, fire codes).
- Local covenants (some developments have very specific building restrictions).
- Access to water, sewer, gas, electricity.

Consider how your home can be positioned on the site to take advantage of the sun's heat and light. Remember that natural surroundings such as hills and trees provide shelter from winter winds. A basic understanding of these issues can have a significant effect on the energy performance of a building.

Passive solar design

Passive solar design is used throughout the world and produces homes with low energy costs, reduced maintenance, and superior comfort. As a design approach, passive solar design can take many forms. It can be integrated to greater or lesser degrees in every building. It balances four primary elements: orientation, windows, overhangs/shading, and thermal mass to optimize use of the sun's energy. For the best performance, these elements should be included in the right amount and in the right places.

Any home design can be adapted to benefit from passive solar. Many of the key components add little or no cost because they require only simple design modifications using conventional building materials. Relocating the building's footprint to a more favorable solar orientation costs nothing and equates to a 20% to 30% reduction in yearly heating costs. Ordinary windows and patio doors can act as solar collectors. Proper room orientation and appropriate shading help reduce overheating and glare. And, open floor plans and generous natural lighting are desirable features in any home, regardless of energy efficiency issues.

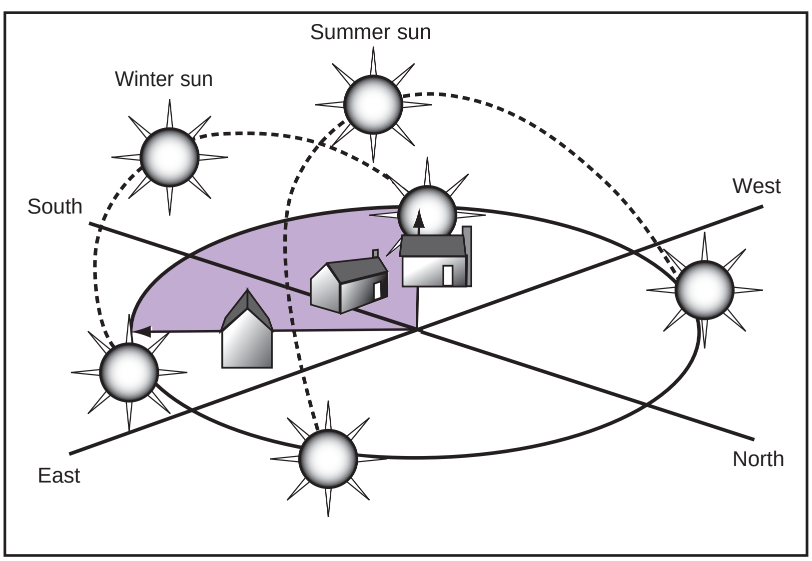

Fig. B-1: Summer vs. winter sun angle

It is not necessary to add a greenhouse-style enclosure with curved glass roofs to benefit from passive solar. The key is to start with well-established solar design guidelines and then apply them with flexibility to complement the building's architectural style. A good passive solar design allows for the addition of active solar hot-water systems and photovoltaic electric arrays, either now or in the future.

Passive solar hints:

- Orient your home so the long side is within 10° of true south to maximize winter sun and summer shade.
- Install south-facing glass to collect solar heat during the winter when the sun is low in the sky. The amount of glass on this side of the home should be between 7% to 12% of the home's finished square footage.
- Reduce the number and size of windows on east-, west-, and north-facing walls to the following percentages. Consider transom or clerestory windows to allow adequate daylight and airflow.
  - East- and north-facing glass should equal about 4% of the total square footage.
  - West-facing glass should be about 2% of the total square footage.
- Use landscaping to protect your home from wind and sun. Evergreen trees planted on the north side of your home provide an effective wind buffer because they do not lose their needles in winter. On the south side, shade trees protect your home from the heat of the sun in the summer and allow the sun to warm your home in the winter when the leaves have fallen (see Figure B-2).
- Use overhangs to reduce overheating in the summer when the sun is high overhead (see Figure B-3).

  Overhangs should fully shade south-facing windows during the summer months and allow full sun on windows during the wintertime. It is fairly simple to achieve full shade on June 21, the summer solstice, when the sun is high. Shading in August becomes more difficult because increasing the overhang depth also will shade the window in April when more solar gain may be desirable for heating. This is where a slight easterly rotation of the house can help.

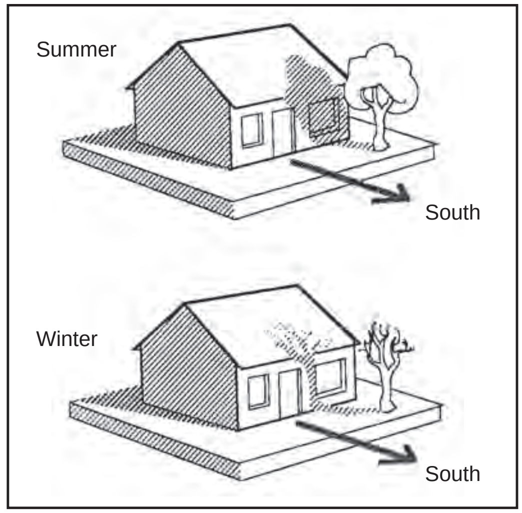

Fig. B-2: Deciduous trees for summer shading

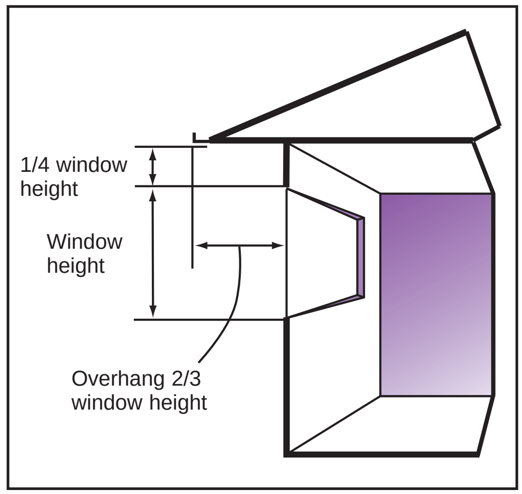

Fig. B-3: Overhang length for a south-facing window

West and east windows require much longer overhangs, and these windows are best shaded by other methods such as porches or trees. During the late summer and early fall months, it may be necessary to close blinds or curtains and pay more attention to passive cooling strategies, like opening windows when the temperature drops below the inside house temperature and closing up the house in the morning before the day begins to warm. Likewise, in late spring there may be a few cool days where more heat is desired than is entering the partially shaded south windows. Conserving the heat that does enter by using insulated curtains on the windows can be highly effective.

There are Web-based tools that provide visual feedback about the performance of an overhang on a horizontal window. Search the Internet for "overhang design tool" to find these tools.

- Consider external shading devices such as louvers, screens, awnings, or lattices that will allow winter sun in and block the summer sun. Internal shading such as shades, blinds, and window quilts will help but are not as effective because the solar radiation enters the building before it is blocked.
- Prevent overheating in the winter by using thermal mass inside the home. Thermal mass absorbs heat during the day and releases it at night, helping to minimize temperature swings. A standard wood-frame home can be built with enough drywall, floor coverings, wood, etc., to provide thermal mass for a south-facing glazed area up to about 7% of the total floor area. In general, if south-facing glass is less than 7%, no additional thermal mass is needed. If south glass exceeds 7% of the floor area, install materials with high thermal mass inside the house, such as concrete or masonry.

Active solar

Active solar systems typically involve roof- or ground-mounted panels and related equipment. Your home's position on the lot is very important for active solar systems. Make sure the surfaces you want to use for the systems take full advantage of available sunlight.

There are two basic types of active solar systems for residential use:

- **Thermal** uses either hot air or a liquid (antifreeze or water) that is heated in the solar energy collectors, transferred to the interior space or to a storage system, then distributed according to the design of the system.
- **Photovoltaic (PV)** solar panels convert sunlight directly to direct current (DC) electricity. An inverter is needed to convert the DC to alternating current (AC) for use in your home.

Thermal solar domestic hot water systems. Most thermal solar systems are used for domestic hot water. Flat plate collectors are usually rack-mounted on your roof or designed to blend into the roof line for a more aesthetically pleasing look. A typical system uses two 4x8 collector panels, an 80-gallon water storage tank, a heat exchanger, and a pump to move the heat transfer liquid through the system. The collectors should face directly south to receive full sun from 9 a.m. to 3 p.m. throughout the year and be positioned at an angle of 43° to 45° relative to the horizon. Water-heating savings of 50% to 70% per year can be expected.

PV systems. PV cells change the sun's rays directly into DC electricity. An inverter then converts the DC current to AC current for use in the home. PV systems reduce the amount of air pollution and greenhouse gases that result from the use of fossil fuels used to generate the electricity for your home.

These systems have several advantages:

- Contain no moving parts.
- Require little maintenance.
- Produce electricity without polluting the environment.

There are two basic types of PV cells/panels: crystalline and amorphous (thin film).

Crystalline panels, usually rack-mounted on your roof, are the most efficient for converting sunlight into electricity, with efficiencies ranging from 12% to 20%. They are usually the best choice for a home solar system but also are the most expensive.

Amorphous photovoltaics, or thin film silicon panels, cost less to produce but also are less efficient. The efficiency of thin film panels ranges between 6% and 10%. They take twice as much space to make the same amount of electricity as crystalline panels.

Building Integrated Photovoltaics (BIPV) Solar Panels. A twist on thin film solar panels are BIPV's. BIPVs can replace more traditional building elements.

Choose from cells in the form of roof shingles, standing-seam metal roofing, tiled roofing shingles, and exterior insulation systems for a more aesthetically pleasing look. BIPV panels are more expensive and less efficient than traditional solar panels. Many consumers consider them to be the best-looking option on the market.

For best results, orient the panels due south with an angle to the horizon of 43° to 45°. There is a small reduction in efficiency with a 10° to 40° angle. Residential PV systems usually have a capacity of 2 to 7 kilowatts, which requires about 270 to 1,000 square feet of roof space.

Consider the payback period when you design your system. To reduce the size and cost of your system, specify high-efficiency lighting such as compact fluorescent bulbs and fixtures throughout the home. Consider daylighting options such as solar tubes that bring natural light into the home and reduce your electricity needs.

A PV system can reduce electric bills by as much as 30% to 50% depending on the amount of sun it receives, its size, efficiency and, of course, homeowner use. Currently, Wisconsin allows "net metering." If your PV system is connected to the local utility grid, you may sell power back to the utility if you produce more electricity than you need. MGE electric customers can also opt to sell all the electricity produced from their PV system to MGE through the Clean Power Partners program.

PV system costs have declined at a rate of about 9% annually for the last 15 years. But the electricity they produce is still more costly than electricity from conventional power plants. Consult with the Focus on Energy renewable representatives (1-800-762-7077) to get an idea of lifecycle-equivalent kilowatt-hour cost.

PV solar systems are most cost-effective when they displace more expensive heating fuels, such as electricity, propane, and oil heat. Federal tax credits and state incentives also improve cost effectiveness as they can combine to reduce the initial system cost by more than 40%. Currently, Wisconsin's Focus on Energy program offers incentives for both types of systems, and the federal government offers a 30% tax credit for solar energy systems until 2016.

If you plan to incorporate an active solar system into your design, make sure you have a solar survey and consult with an architect, solar engineer, or solar contractor. Before installing a solar energy system, investigate local building codes, zoning ordinances, and subdivision covenants, as well as any special regulations pertaining to the site. Contact your local jurisdiction's zoning and building enforcement divisions and any appropriate homeowner's, subdivision, neighborhood, and/or community association(s) to check on local compliance issues.

Green design

Green design (also called sustainable design, environmental design, environmentally sustainable design, environmentally-conscious design, etc.) is the philosophy of designing the built environment to comply with the principles of economic, social, and ecological sustainability. The goal of green design is to build homes that reduce the use of nonrenewable resources and use other resources more efficiently to minimize the home's environmental impact. Green design is one reaction to the global environmental crisis and is considered a means of protecting the environment and its natural resources.

Here are some green design principles to consider:

- Design for durability and longevity. Longer-lasting and better-functioning products are replaced less frequently, reducing the impacts of producing replacements.
- Use products with recyclable materials and recycled content.

- Design to use only local and regional resources.
- Look for the least toxic materials and manufacturing processes.
- Design for reuse and recycling. Look ahead to when materials may need to be replaced. Can the material be recycled or reused?

The role of shape and size

The typical American home size has jumped from 983 square feet in 1950 to over 2,300 square feet in 2006 – over a 130% increase. Since 2006, average housing size has decreased about 9% to about 2,100 square feet. In 1950, single-family homes were built with an average of 290 square feet of living space per person; in 2006 that number increased to about 900 square feet per person. Since 1940, the average number of people living in an American home has dropped from 3.7 to 2.6. In 2004, 43% of new homes had 9-foot ceilings, up from less than 15% in the 1980s. Up until 2006, the trend has been smaller families living in larger homes.

Many variables affect energy use – family size and lifestyle, thermostat settings, equipment efficiencies, etc. In general:

- Smaller and simpler designed homes cost less to heat and cool.
- The ratio of floor area to wall area affects energy use. Ranch-type homes with long, rambling floor plans usually have a much greater percentage of wall area in relationship to floor area. The greater the ratio of wall area to floor area, the greater the potential for heat loss and the more it will cost to heat and cool.
- Volume of living area (cubic feet of heated space) affects energy use. Homes designed with cathedral or vaulted ceilings require more energy for heating and cooling.

Home size is typically measured in square feet of living area. The relationship between energy use and square footage can be deceiving. Two homes with the same living area and equal amounts of insulation can have drastically different energy use. Assuming the thermostat is set the same, a traditional two-story home with standard 8' high ceilings will require less energy to heat and cool than the same home with cathedral ceilings. Similarly, a ranch-style home will require more energy to heat and cool than a similar size 2-story home. A useful rule of thumb to remember is: The more elaborate or unconventional the home design, the more attention to energy efficiency is needed.

Layout and floor planning

A functional floor plan has these features:

- Efficient use of space in each room (use scale drawings of furniture early in the planning stage to assess the layout).
- Minimal number of circulation paths which reduce useful space.
- Proper progression from areas which are "public" to those which are "private."
- Appropriate use of passive solar gains and daylighting.

Beyond purely functional requirements, consider aesthetic and comfort factors. The layout should exploit the best views. If possible, locate the living and family room on the south side to get the most benefit from passive solar gains and daylighting (see Figure B-4).

Where possible, orient your home so that windows can take advantage of natural ventilation from prevailing winds. A position that takes advantage of prevailing southwesterly winds can reduce cooling costs. The effectiveness of natural ventilation schemes depends on the layout of partition walls and on the location of windows and doors (see Figure B-5). An attached garage on the north end of the home protects heated space from direct winter winds.

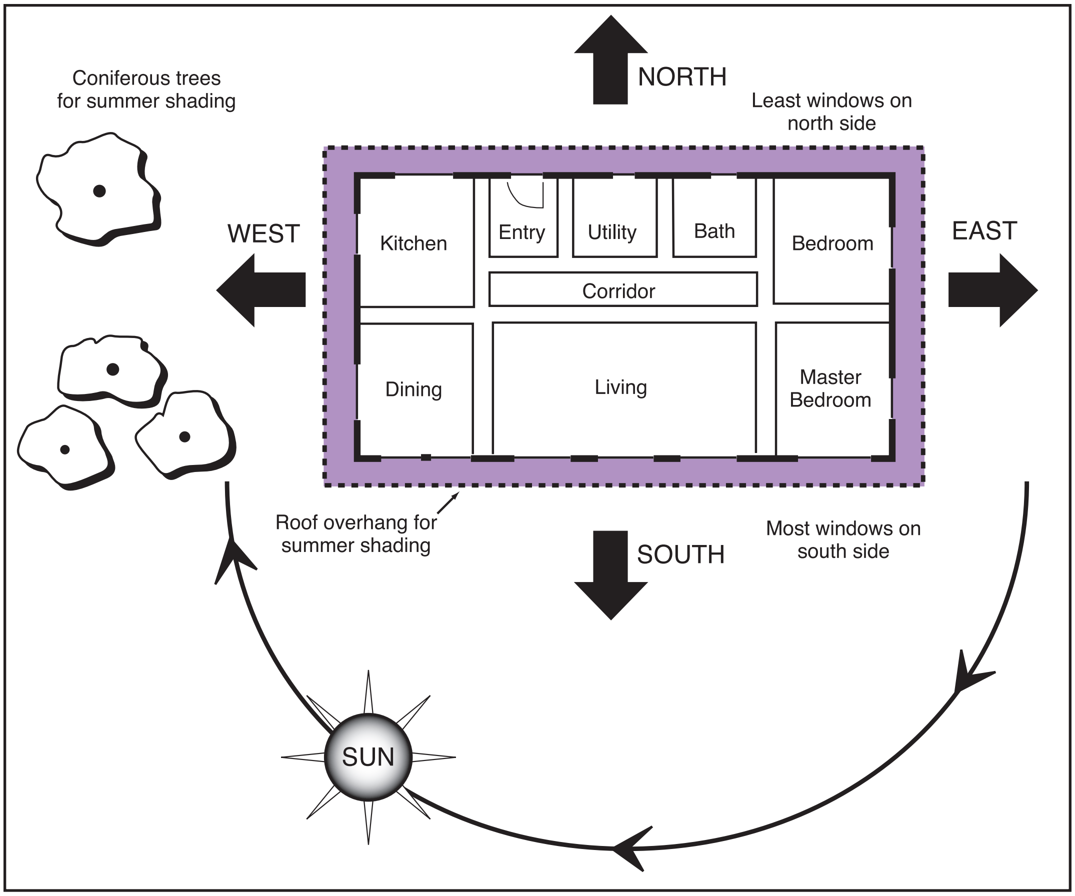

Fig. B-4: Typical house zone plan with solar light and shading considerations

A large expanse of windows has a negative effect on energy efficiency, especially if they face north. Decide what can be done now to maximize energy efficiency without sacrificing the view. If north-facing windows cannot be avoided:

- Offset the energy penalty with high-performance windows.
- Increase insulation levels in other areas.
- Install more non-openable windows.

Consider how many windows are needed to take advantage of the view. Decide whether a door is needed on the north side of the home. If so, should it be solid or glass? If glass, specify high-performance glass and choose swinging rather than sliding glass doors.

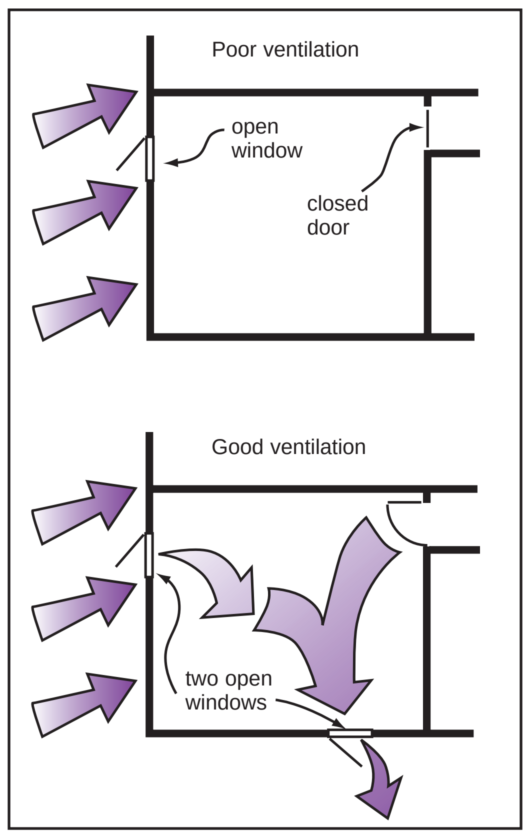

Fig. B-5: Natural ventilation

Insulation planning

Planning is particularly important for insulation. Insulation types, levels, and placement of insulation should be included with the home plan. Open spaces created by cathedral and vaulted ceilings are very popular in new homes. The way some cathedral and vaulted ceilings are constructed limits the amount of insulation that can be installed. Local building codes require a 1" minimum air space between the underside of the roof sheathing and the insulation, which further restricts space. Questions to pose during the design stage are:

- What type of insulation should I use given the confined space? (In a limited space, a closed-cell spray foam insulation is usually the best choice).
- How much insulation value can be achieved given the space restriction?
- Which insulation will provide the best air tightness? (Foam or dense pack fiberglass/cellulose are the best choices.)

For more information on types and placement of insulation, see the Insulation section in the Structure chapter.

Airtight envelope

"Build tight, ventilate right" should be the underlying concept for today's new high-performance homes. A home can be built too tight **only** if there is no whole house ventilation system designed into the home. A tight home:

- Reduces drafts and moisture penetration into walls and ceilings.
- Enhances the performance of a heat-recovery ventilator.
- Adds to the home's structural integrity.

Studies show that building an airtight envelope can more reliably create a more energy-efficient home than simply adding more insulation. Homes should have a continuous air barrier system, a combination of materials linked and sealed together, that surrounds all conditioned space. In a cold climate, having both an interior and exterior air barrier is recommended.

Air leakage through the building envelope can lead to drafts, unnecessary heat loss in winter or heat gain in summer, condensation and moisture damage in hidden cavities, rain penetration, poor indoor temperature and humidity control, and increased energy use. The only way to ensure that a home is air tight is to have a blower door test performed.

If recessed lighting is planned for the home, make certain to specify an airtight fixture or build a sealed box within the cavity around a standard fixture. Sealing recessed lights in this way helps prevent escape of heat and moisture into the attic and eliminates possible structural damage due to moisture condensation. It is best, however, to avoid recessed lighting in favor of track lighting or other surface-mounted lighting.

The importance of an airtight envelope cannot be stressed enough.

Whole house ventilation

Whole house ventilation systems provide controlled, uniform ventilation throughout a home. These systems use one or more fans and duct systems to exhaust stale air and/or supply fresh air to the house. In an airtight home, natural ventilation won't provide the necessary air changes for good indoor air quality, so some type of whole house ventilation system is a necessity.

Indoor air quality

A three-pronged approach should be followed to ensure a healthy living environment.

1. Don't install products and building materials that will off-gas and pollute the air. Formaldehyde and other volatile organic compounds (VOCs) are given off by some building mate-

rials. Select nontoxic or low-emitting building materials and finishes. It is easier to incorporate a high level of indoor air quality during the design stage than it is when the home is almost completed.

2. Filter the air to reduce particulate matter and/or various gases. A forced-air heating and cooling system provides an easy way to filter house air. If a hydronic system is used, your whole house filtration options are limited.
3. Ventilate to replace stale air with fresh outside air.

Read more about ventilation and filtration in the Mechanicals chapter.

Windows

Make sure that your home is correctly oriented on the lot to take advantage of sunlight for light and heat, then consider window placement. The window area determines how much solar heat enters the space. South-facing glass should be at least 5% to 7% and usually no greater than 12% of the conditioned square footage of the home. Heat from the sun entering south-facing windows and doors with glass can provide between 20% and 30% of the heat required to keep a home warm in winter.

For northern climates, double- or triple-pane, argon-gas-filled window assemblies with warm edges (thermal spacers that reduce heat conduction through the frame) are advised. Look for whole-window U-factors that range from .15 (super efficient) windows to .35. Read more about types and placement of windows in the Windows/Skylights section of the Structure chapter.

Lighting planning

Good home design allows for high levels of natural lighting (daylighting) in areas that are normally occupied during the daytime. Kitchens, breakfast areas, and living rooms should be oriented to receive as much daylight as possible. White or light-colored interior finishes enhance the effects of daylighting.

In addition to traditional windows, clerestories, skylights, light tubes, and atrium spaces represent other ways to bring daylight into a building. Much of the art of daylighting lies in the use of simple architectural details such as wide window sills, louvers, walls, and other methods of bouncing light deep into a building. Use daylighting wherever practical.

High-efficiency lighting such as compact fluorescent bulbs and fixtures, which save 75% compared to standard incandescent bulbs, should be employed throughout the home. Read more about energy-efficient lighting in the Lighting chapter.

Saving energy is in the details

You can improve energy efficiency by thoroughly planning during each phase of the design process. Keep in mind that every part of your home – from how it sits on the lot, to the number and placement of windows and doors, to the types and amounts of insulation, and to the heating and ventilation systems – is part of a system. Each part has an effect on your home's efficiency and durability. Attention to these details will ensure your home is as energy efficient and healthy as possible.

If you have questions on building site selection or home orientation and how it affects energy efficiency, call us at 252-7117.

responsiblenergy

new construction programs

new construction programs

Home construction programs

Several construction programs are available in Wisconsin to help homeowners navigate the building process and achieve the home of their dreams. All are voluntary and provide third-party verification certificates. With these programs, you get the added benefit of knowing you're helping preserve Wisconsin's environment. Less energy used means fewer environmental effects on our air, water, and land.

Focus On Energy New Homes Program (NHP)

This voluntary program provides third-party site visits to help ensure your home will be safe, healthy, durable, comfortable, and energy efficient.

The NHP is part of Wisconsin's Focus on Energy Program, started in 1999, which also includes energy efficiency and renewable programs for homeowners, businesses and farms. In 2010, the program changed its name from the Wisconsin Energy Star® Homes program to the New Homes Program. As of 2010, more than 350 builders have partnered with this program to certify more than 13,000 homes across the state.

The program has established a network of builders, trades, and consultants who can build high-performance homes that typically save 18% or more energy than homes built to State building codes. A consultant, trained through the NHP, gets involved in the design stage, provides on-site assistance during construction, and does at least two on-site inspections and the final performance testing.

The program requires certain criteria be met concerning air tightness, insulation, ventilation, and combustion safety. It also provides education and technical assistance to builders on methods to meet and exceed code requirements. The result is a home that is not only energy efficient, but comfortable, durable, and safe.

To certify your home to NHP standards, if you haven't chosen a builder yet, refer to the list of New Home Builder Partners on their Web site. If you have already selected a builder who is not on the list, you can join the program by committing your home to be built to these standards.

For more information call 1-800-762-7077 or go to the Web site at http://www.focusonenergy.com/Residential/New-Home/.

Green Built Home (GBH) Program

GBH is a national award-winning local-green-building initiative that reviews and certifies new homes and remodeling projects that meet both sustainable building and energy standards. The program, implemented in 1999, was formed by a partnership between the Wisconsin Environmental Initiative and the Madison Area Builders Association. GBH is also available as a co-branded home certification with the National Association of Home Builders' National Green Building Standard.

GBH is currently one of more than 40 green building programs nationwide and was the first program east of the Mississippi. Between 1999 and 2010 it has certified over 4,900 homes in Wisconsin, Minnesota, and Illinois.

Homebuyers and homebuilders work together to select features from the GBH checklist. Each checklist feature has a point value and the home must earn at least 60 points to be certified. In addition, the checklist outlines basic requirements that each home must meet, including WESH certification, ENERGY STAR appliances, recycling, indoor air quality, and erosion control standards. GBH-certified third-party verifiers will then review completed checklists, plans, and other submittals; conduct site visits; and document that all basic requirements and green built specifications are met for every home entered into the program.

For more information: http://wi-ei.org/greenbuilt/

LEED for Homes (LEED-H)

LEED-H is part of the Leadership in Energy and Environmental Design (LEED®) certification and was launched officially by the U.S. Green Building Council in 2008. It applies to single-family and low- to mid-rise multifamily buildings, production homes, manufactured and modular housing, and existing homes.

The LEED-H process certifies home projects, not builders or products, although certain products can help projects earn certification. The program measures a builder's approach to such issues as innovation and design, locations and linkages, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and awareness and education.

LEED-H has four certification levels:

- Certified (45-59),
- Silver (60-74),
- Gold (75-89), and
- Platinum (90-136).

The builder is required to hire a LEED-H provider who manages a team of Green Raters and work under contract with the USGBC. The provider conducts field inspections and performance testing with a minimum of two site visits. The provider or Green Rater verifies all points earned.

For more information: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=147

NAHB National Green Building Standard

In 2007 the National Association of Home Builders (NAHB) and the International Code Council (ICC) partnered to establish a much-needed and nationally recognizable standard definition of what is meant by "Green Building." A consensus committee was formed to develop this standard in compliance with the requirements of the American National Standards Institute (ANSI). The resulting ANSI-approved ICC-700-2008 National Green Building Standard defines green building for single and multifamily homes, residential remodeling projects, and site development projects while still allowing for the flexibility required for regionally appropriate best green practices. The standard is the first green rating system for new homes to be approved by ANSI.

There are four green certification levels available in the standard: Bronze, Silver, Gold, and Emerald. A builder, remodeler or developer must incorporate a minimum number of features in the following areas: energy, water, and resource efficiency; lot and site development; indoor environmental quality; and homeowner education. The more points accrued the higher the score and level.

An online scoring tool is available at www.nahbgreen.org, where builders and remodelers can also find NAHB Research Center-accredited verifiers to inspect their green projects.

Passive House Program (Passivhaus)

The term passive house (Passivhaus in German) refers to a rigorous, voluntary standard for energy efficiency in buildings. It results in ultra-low energy buildings that require very little energy for space heating or cooling. A certified Passivhaus home will save 85% to 90% more energy than a home built to current Wisconsin building code.

The Passivhaus standard originated in Germany in 1996. In 2007 the Passive House Institute US (PHIUS) was formed in Urbana, Ill., to make the program available to American homes. As of this writing (2010), one has not been built in Wisconsin although there are dozens in the United States and over 15,000 in Europe.

A Passive House is a very well-insulated, virtually airtight building that is primarily heated by passive solar gain and by internal gains from people, electrical equipment, etc. Energy losses are minimized. Any remaining heat demand is provided by an extremely small source. The heat required in these homes is so small it can be supplied by a small air-source split-system heat pump that can provide cooling as well.

A Passive House is a comprehensive system. High-performance triple-glazed windows, super-insulation, an airtight building shell, limitation of thermal bridging, and balanced energy recovery ventilation are integral parts of the home. Avoidance of heat gain through shading and window orientation also helps to limit cooling load. An energy recovery ventilator provides a constant, balanced fresh air supply. The result is an impressive system that not only saves over 80% of space-heating costs and carbon emissions but also provides extremely good indoor air quality.

The standard is not confined only to residential properties; several office buildings, schools, kindergartens, and a supermarket also have been constructed to the standard. Passive design is not the attachment or supplement of architectural design but an integrated design process with the architectural design. Although it is mostly applied to new buildings, it also has been used for retrofits and rehabs.

For more information: http://www.passivehouse.us/

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consumer energy incentives

consumer energy incentives

Federal tax credits

The American Recovery and Reinvestment Act of 2009 extended many consumer tax incentives originally introduced in the Energy Policy Act of 2005 (EPACT) and amended in the Emergency Economic Stabilization Act of 2008 (P.L. 110-343).

A tax credit is generally more valuable than an equivalent tax deduction because a tax credit reduces tax dollar-for-dollar while a deduction only removes a percentage of the tax that is owed. Consumers can itemize purchases on their federal income tax form, which will lower the total amount of tax they owe the government.

Consumers who install solar energy systems including solar water heating and solar electric systems, small wind systems, geothermal heat pumps, and residential fuel cell and microturbine systems can receive a 30% tax credit for systems placed in service before Dec. 31, 2016. Existing homes and new construction qualify. Principal residences qualify; second homes and rentals units do not.

To see an updated summary of the federal tax credits available to consumers, go to http://www.energystar.gov/ and click on “Tax Credits for Energy Efficiency.”

State of Wisconsin incentives

In addition to federal tax incentives, homeowners and builders may be eligible for Cash-Back Rewards for Focus on Energy homes constructed in a participating electric and natural gas utility territory.

Focus on Energy makes program changes at the beginning of each year, so incentives may change. For the most up-to-date information either call 800-762-7077 or visit the Focus on Energy Web site at http://www.focusonenergy.com/Residential/New-Home/.

Database of State Incentives for Renewables and Efficiency (DSIRE)

For a comprehensive listing of information on federal, state, local, and utility incentives, go to http://www.dsireusa.org/.

responsiblenergy

structure

MGE®

structure

Insulation

Insulation is used to increase comfort and lower energy use. Consider cost, estimated length of payback, and limitations based on construction techniques to decide which insulation to use.

When making the cost-versus-payback decision on insulation, remember that:

- Payback is based on present energy costs. When energy costs increase, payback time is reduced.
- Adding more insulation to a completed home may be unrealistic or difficult and expensive.
- Comfort is enhanced as insulation levels increase. Comfort cannot be measured in payback calculations.

Learning how insulation works, how its effectiveness is measured, and what types are available will help you understand recommendations we make in this book.

How insulation works

Insulation creates a thermal barrier between the living space and the exterior of your home. It contains a network of air pockets that slow heat flow. Heat flow isn't stopped – it's just slowed down.

Measuring the effectiveness of insulation

Throughout this book you will find various references to the "R-value" of insulation. "R" refers to thermal resistance or the ability of a material to resist heat flow. There are many different types of insulation products for use in new construction. They have different purposes and properties but all have R-values. R-values are usually stated as R per inch and are additive. The greater the thickness, the higher the R-value, the more effective the insulation. Keep in mind, however, the 'diminishing returns' aspect of insulation. For each successive doubling of the insulation, the R-value is doubled but there isn't a doubling of the savings. Refer to the "Recommendations" section for what levels to use in our Wisconsin climate.

Types of insulation

Each type of insulation is sold under various brand names, sometimes with minor variations in composition. We'll discuss those most commonly used in new home construction in the Madison area.

Standard fiberglass batts

A common insulating material is fiberglass, which is available in batts or rolls. Rolls are normally 16 to 64 feet long and come in widths of 15 and 23 inches, allowing them to fit standard house framing. Batts are similar to rolls except they are precut to specific lengths for ease of handling. Both are available with a vapor retarder (faced) or without a vapor retarder (unfaced). Both are available in a range of thicknesses from 2 to 12 inches. Standard-density fiberglass batts have a nominal R-value that ranges from 3.2 to 3.8 per inch of thickness (see Figure E-1). A standard-density 5.5-inch thick fiberglass batt would have an R-value of approximately 19.

Proper installation, however, is critical to achieve the effective insulation value. Incorrect batt installation can reduce effective R-value (insulation value) by up to 28%. So an incorrectly installed 5½-inch batt rated at R-19 would achieve an effective insulation value of only R-13.7. Air movement through the batts within the cavity reduces the effective insulation value even more.

Medium-density fiberglass batts

The amount of fiberglass in these batts is greater than in standard batts. Because the number of air pockets is increased within the material, heat loss is slowed to a greater degree resulting in a higher R-value. A 5.5-inch thick batt has an R-value of about 21.

Spray-in-place insulation applications (open cavities)

The primary advantage of spray-in-place insulation applications is that there is little room for installer error. Wall and ceiling cavities, including areas around outlet boxes and closely spaced framing, can be completely filled. Completely filled cavities reduce heat loss and air infiltration.

Spray-in-place systems commonly available in the Madison area include:

- **Fiberglass/cellulose insulation with netting** (known as BIBS or blown-in blanket system). This system uses a fine plastic netting installed across the framing studs to hold the insulation in the stud cavity. A hose with a hard end is then punched through the netting to deliver either dry fiberglass or cellulose to open wall cavities. The insulation is packed into all nooks and crannies of the stud cavity and infiltration is virtually eliminated. The R-value of fiberglass in a 5.5-inch thick wall cavity is about 21.
- **Damp spray cellulose** is similar to the above system except no netting is used. The installer uses a flexible hose to spray the cellulose mixed with a water-based glue that bonds and holds the insulation in the open cavity. The excess is shaved off with a special roller and is reused. Freshly applied cellulose should contain between 30% to 40% moisture by weight and have a density of about 3 pounds per cubic foot. The cellulose should be allowed to dry to below 20% moisture content before the wall is closed up. Drying time can vary, depending on the weather, but is usually about 24 to 48 hours. This method of insulation has excellent air-sealing properties. Cellulose is actually recycled newspaper treated with a fire retardant. The R-value of cellulose is approximately 3.7 per inch of thickness when it is installed in this manner (see Figure E-1).
- **Closed-cell polyurethane spray foam** has an aged R-value of between 5.5 and 6 per inch and has a density of about 2 lbs/cu ft. It is moisture resistant and has low-water vapor permeability. This foam contains no formaldehyde, does not shrink over time, adds strength to a wall, and will virtually eliminate air infiltration where installed. It is sprayed via a flexible hose into an open cavity where it forms an airtight bond to the sheathing and framing members. Some building codes do not recognize polyurethane foam as a vapor retarder and require the installation of polyethylene sheeting or like material. It is very effective in areas that are difficult to insulate such as vaulted ceilings and sill boxes.
- **Open-cell polyurethane spray foam** has an aged R-value of about 3.5 per inch in densities ranging from 0.4 to 1.2 lbs/cu ft. It has similar air-sealing properties as closed-cell polyurethane but is not as rigid or as moisture resistant but it is less expensive.

Insulation Material	R-value per inch
Blanket/Batt fiberglass:	
Standard density	3.2
Medium density	3.8
Mineral wool	3.5
Loose fills:	
Fiberglass	2.5-3.0
Mineral wool	3.3
Cellulose	3.7
Rigid Board:	
Expanded polystyrene (beadboard)	3.8-4.4
Extruded polystyrene	5.0
Fiberglass drainage	4.0
Polyisocyanurate	6.0
Structural insulated sheathing	6.0
Spray-in-place:	
Damp spray cellulose	3.7
Fiberglass	3.8
Polyurethane (closed-cell foam)	6.0
Polyurethane (open-cell foam)	3.5
Polyicynene (foam)	3.5

Fig. E-1: R-value of insulation materials

- **Polyicynene spray foam** is an open-celled material. It is similar to polyurethane in its air-sealing properties but it has about half the R-value and is about 75% less dense. Icynene is water-vapor permeable and therefore Wisconsin Code requires application of a vapor retarder in above-grade wall applications. The densities of open-cell foams are around 1/2 to 3/4 lbs/cu ft.

Both types of foam are commonly used in building applications. Since foams are more expensive than batts or cellulose, consumers sometimes choose to have the installer first spray a foam layer into the cavity and then fill the rest with batts. If this method is chosen, at least 2 inches of polyurethane or 3.5 inches of polyicyene should be sprayed first to reduce the possibility of moisture condensation within the cavity during the cold months. In a standard 2x6 wall, it is recommended that at least 1 inch of extruded polystyrene be installed on the exterior to reduce thermal bridging of the studs.

Attic ceilings can be foamed in the same way and then covered with blown-in cellulose or fiberglass. Attics are typically the source of the greatest air leakage in a house and this method ensures a very tight attic.

The choice of where to install the different foam products depends on the conditions of each installation. For example, you would not install open-cell foam where it could absorb water because this would ruin its insulating ability. Closed-cell foam would be a good choice where the greatest R-value per inch is needed such as 2x4 walls or cathedral ceilings.

Is spray polyurethane foam (SPF) considered to be "green"? The discussion of whether SPF is green or not gets complicated pretty fast.

Virtually all SPF systems on the market today contain some degree of renewable sucrose or soy-based content so they can be considered green to some degree.

SPF is produced from the reaction of two components referred to in the industry as the A side and B side. Each side makes up 50% of the product. Much like epoxy glue, the two sides are mixed together as they come out of the nozzle, which causes a chemical reaction and creates the "spray foam." While the A side is a petroleum-based isocyanate, the ingredients that make up the B side will vary from product to product consisting of a blowing agent, fire retardants, surfactants, catalysts, and polyols. Most polyols are manufactured from sucrose-based agricultural or oil-based materials or recycled post-consumer and post-industrial PET (polyethylene terephthalate).

So in reality, all SPF products are at least 50% petroleum based. The other half is made up of varying percentages of petroleum and bio-based products. The percentage of the total product usually contains no more that 15% soy or bio-based material, but manufacturers are reluctant to divulge their product content.

So the question is: What does the percentage of bio-based ingredients need to be in a product before it is considered green? The answer will probably vary for each person asked. However, the U.S. Department of Agriculture has proposed the criteria that if a material is at least 7% renewable content, the claim of being "bio-based" is valid.

The decision to use spray foams centers on the following issues. All spray foam insulation, including soy based, is green in the sense that they can help reduce your energy bills compared to standard fiberglass insulation. The content of the spray foam is more subjective, so its use will be a personal decision dictated by each person's conscience. Spray foam is more expensive but it's the best way to ensure a tight, energy-efficient home.

Loose-fill insulation products

Loose-fill is the term used by insulation contractors when referring to insulation packaged in bags. Loose-fill insulation is typically mixed in a large motor-driven hopper and delivered through a hose into open attics. Fiberglass, mineral wool, and cellulose are most commonly used for insulating open attics in the Madison area. Loose-fill fiberglass and mineral wool have R-values that range from 2.5 to 3.7 per inch of thickness. R-values are determined by the type and the installed density of the product. Bag count, or the number of bags used, is important in determining R-value. Stated on each bag is the number of bags needed per 1,000 square feet to achieve a certain R-value. Loose-fill insulation products will settle over time so the only sure way to determine the correct R-value is the bag count.

Rigid board insulation products

There are several types of rigid board insulation commonly used in the Madison area. They are:

- Extruded polystyrene (XPS),
- Molded expanded polystyrene (EPS),
- Foil-faced polyisocyanurate, and
- Structural insulated sheathing.

All are sold in 4x8 or 9 foot sheets and are available in various thicknesses. XPS has an approximate R-value of 5 per inch of thickness. Depending on density, EPS foams have R-values that range from 3.8 to 4.4 per inch when dry. Foil-faced polyisocyanurate has an advertised R-value of 7 per inch of thickness although the aged R-value is closer to 6. Structural insulated sheathing has a thermal resistance of R-3 for half-inch thickness (see Figure E-1).

Structural insulated sheathing panels are a relatively new product on the market. The product is a marriage of two proven sheathing materials – foam sheathing (polyisocyanurate) and structural laminated fibrous board. It is more rigid and impact resistant than traditional foam sheathing and can be used as a weather- and air infiltration-resistant barrier as well as structural wall bracing. Additionally, one manufacturer's product contains 80% postconsumer recycled material.

Applications for rigid board insulation

Rigid board insulations are primarily used as siding underlayment or exterior foundation insulation and can be used as interior foundation insulation. Because of differences in the board properties, there are some limitations in their applications.

Foil-faced polyisocyanurate and lower density EPS should not be used in exterior below-grade applications because they can wick moisture, which degrades the insulation value. In cold climates, freezing temperatures may damage the insulation. Because foil is a perfect vapor barrier, foil-faced polyisocyanurate should not be used as an exterior above-grade wall sheathing unless it is installed to meet the requirements of a "water-managed wall system" (see Glossary).

XPS foam can be used in all exterior below-grade applications. Higher densities of EPS can be used below grade but are not as resistant to moisture as XPS. For this reason, EPS, in ground contact, should only be installed in well-drained situations in more moderate climates.

In addition to increasing the overall R-value of the wall assembly, rigid board insulation:

- Reduces air infiltration (if properly taped).
- Keeps the outermost portion of the insulated wall cavities warmer, which helps reduce the possibility of condensation.
- Increases the R-value of framing members, which can account for about 25% of the total wall.
- Acts as a shield to prevent wind-driven rain from entering wall cavities and can be used as a rain barrier if properly taped.

Radiant barriers

Radiant barriers are materials that are installed in buildings to reduce summer heat gain and winter heat loss and have the potential to reduce heating and cooling energy use. They usually consist of a thin sheet or coating of a highly reflective material (like foil or aluminum) applied to one or both sides of a number of substrate materials. A radiant barrier reduces the amount of heat radiated across an airspace that is adjacent to the radiant barrier. The reflective surface must face an open airspace and must remain relatively dust-free for it to be most effective. Unlike the more common types of insulation (i.e., fiberglass, cellulose, etc., that trap pockets of air which reduces heat conduction), radiant barriers only reduce radiant-heat transfer. A radiant barrier alone is not an effective way to control heat gain in an attic. It must be used with adequate insulation and ventilation. They are predominately beneficial for buildings in cooling-related climates and tend to offer little, if any, heating energy savings in northern heating-dominated climates.

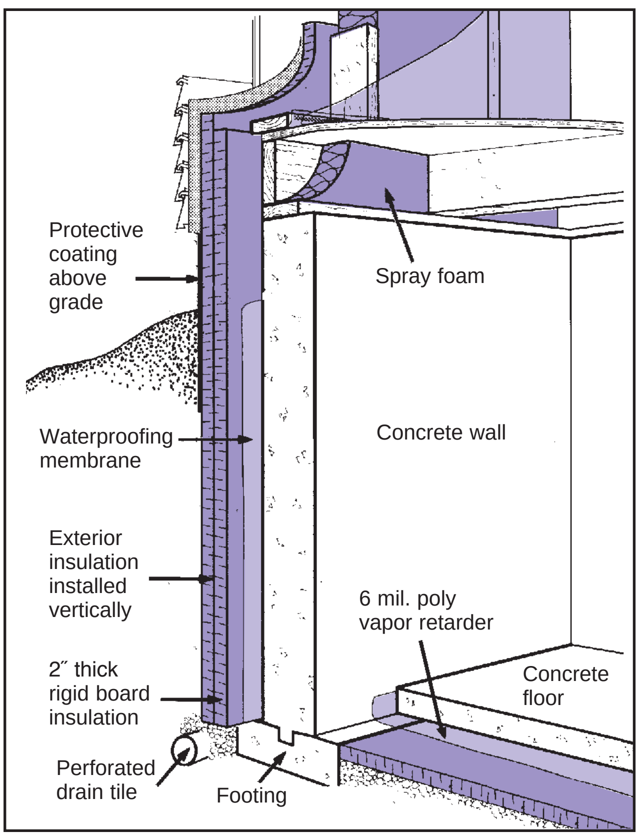


Fig. E-2: Exterior insulated concrete foundation

Basements

In the Madison area, basements are typically considered to be heated or semi-heated, even if the area is not intentionally heated. Heat loss from ducts and/or pipes usually keeps the basement temperature within 10 degrees of the floor above. An increasing number of new homes have been designed with living space in the basement. To make your basement comfortable, safe, durable, and energy efficient, consider the options in this section.

Concrete floors

If you plan to incorporate living area in the basement, we recommend installing a minimum of 1-inch thick R-5 XPS insulation directly under the concrete basement floor. XPS satisfies the Wisconsin Uniform Dwelling Code requirement of a 1.0 perm-rated material under the basement floor. The seams could be taped to keep the foam together while the concrete is being poured, or a 6 mil vapor retarder can be installed over the styrofoam. A low-slump concrete should be used to reduce curing time (see Figure E-2).

If the basement floor will be carpeted, the insulation below the concrete floor will keep the concrete floor warmer, thereby greatly reducing the possibility of condensation and mold problems.

Walk-out basement

If your new home will have a basement wall or walls that are completely exposed (a walk-out basement), these walls should be insulated to the same R-value as the above-ground walls. Basements with ground-level access to the outside will probably be used as living space either now or in the future, so it makes sense to specify an equal amount of insulation when your house is constructed. Also, the edge of the concrete slab, per Wisconsin building code, should be insulated with at least 2 inches of R-5 extruded polystyrene to reduce cold from penetrating into the interior.

Traditional poured concrete walls

We recommend insulating basement walls on the outside. Exterior insulation:

- Protects the waterproof coating from damage during backfilling.
- Serves as a capillary break to keep moisture out.
- Protects the foundation from the effects of the freeze-thaw cycle in cold climates.
- Reduces the potential for condensation on surfaces in the basement.
- Conserves room area, relative to installing insulation on the interior.

The typical basement wall in the Madison area is a poured concrete wall which is formed using removable wood forms.

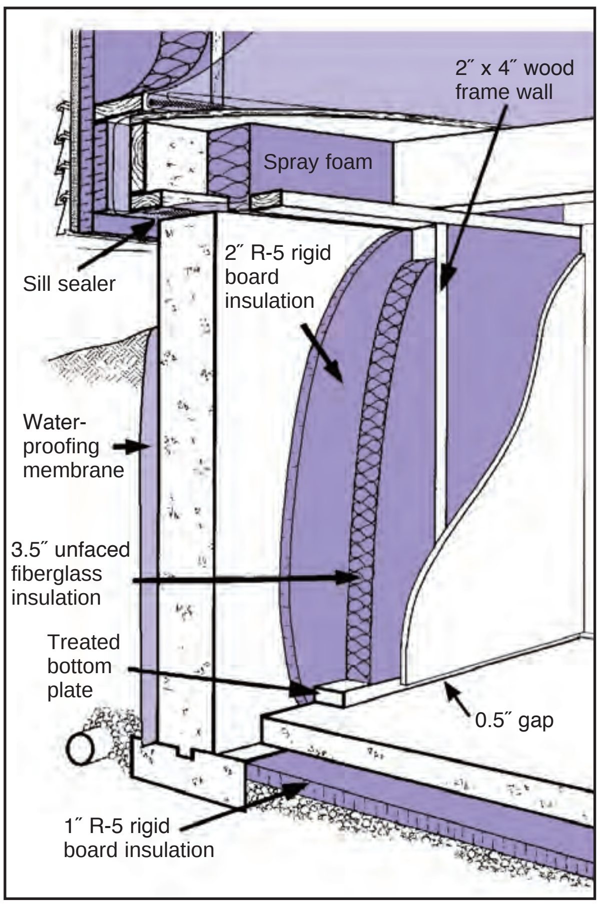


Fig. E-3: Interior insulated concrete foundation

After the forms are removed, we recommend the wall be waterproofed (not just damp-proofed) on the exterior. Then, at least 1 or 2 inches XPS insulation should be installed over the waterproofing. It should be fastened with metal fasteners and installed all the way to the footings. It is not advisable to try to save money by only insulating 4 feet down from the top of the foundation. Experience has shown that as the backfill settles, it can pull down the foam to expose the above-grade concrete.

Before backfilling, a protective coating or covering is applied to the planned above-grade insulation. Many different coatings or coverings can be used to protect against damage from lawn mowers, weed trimmers, and degrading effects of ultraviolet light.

Another exterior foundation treatment used in the Madison area is a fibrous board material that is installed over a sprayed-on waterproofing membrane. Water flows down through the fiberboard to the drain tile by means of vertically striated fibers within the board. The board has an R-value of 4.1 per inch when dry and virtually nothing when it is wet. While the system is excellent for drainage, it does not provide constant thermal protection for the concrete wall.

Once the exterior is insulated, interior walls can be finished by constructing a treated 2x2 or 2x4 wood frame wall with a treated bottom plate and installing drywall or some other covering down to within a half-inch of the basement floor. It is acceptable to leave the frame wall uninsulated as long as the exterior is waterproofed and insulated to at least R-5.

If below-grade concrete walls are to be insulated on the interior without first insulating the exterior, one of these two methods can be used:

- **Method 1** - 2 inches of XPS should first be attached to the concrete wall (see Figure E-3). The styrofoam can be attached using styrofoam-compatible adhesive and/or wood furring strips nailed through the XPS with power-driven nails or screws. The seams should be taped using a styrofoam compatible tape. One half-inch drywall or another 15-minute fire-stop material is required to cover the styrofoam. One company makes an XPS board that has precut, slotted edges that accommodate wood furring strips that are used to attach the drywall. If a frame wall is desired, it can be constructed using a treated bottom plate after the styrofoam is installed. Leave at least a half-inch gap between the floor and the drywall. The stud cavities can be left uninsulated or any type of unfaced fibrous insulation can be installed. In this situation, it is acceptable to install fibrous insulation below grade as long as there is 2 inches of styrofoam between it and the concrete wall. Also, it is critically important to insulate and seal the top of the foundation wall. This can be done using rigid board styrofoam and sealing the seams with caulk or spray foam insulation.

- **Method 2** - Build a 2x4 frame wall with a treated bottom plate, leaving a 1 inch space between the concrete and the studs. Closed-cell spray polyurethane insulation is then sprayed into the stud cavities against the concrete wall. An R-value of 27 can be achieved using this method. The intent is to keep wood, paper, or any material that mold uses as a food source away from the concrete wall. It is very important that no vapor retarder polyethylene sheet material be installed on or within the wall. Below-grade basement wall assemblies with an interior vapor retarder will have difficulty drying if they become wet.

Below-grade finished areas should be designed to dry to the interior.

"A basement wall will remain dry only if it is built to handle all the different ways in which water can move into and through basement walls. Since walls will at times get wet in spite of good design and construction, basement walls must also be able to dry. Drying typically means towards the interior. Rarely are foundation assemblies able to dry towards the exterior except above grade." – Nathan Yost, M.D., Joseph Lstiburek, Ph.D., P.E.

Fiberglass batts or insulating materials that are not moisture resistant should not be used in below-grade interior wall assemblies unless the wall is first insulated with closed-cell polyurethane or a minimum R-5 XPS insulation. Wisconsin State Code requires a 15-minute fire-stop material be installed to cover the foam insulation on the interior surface. Half-inch drywall meets this requirement.

Many basements in newly constructed homes are being insulated only on the interior with materials that are not moisture resistant. The possibility for moisture/mold problems increases in direct proportion to the relative humidity levels in the basement. Keeping the basement humidity levels at or below 50% year-round greatly reduces the possibilities for problems. Of course, good drainage away from the foundation walls is essential (see Landscaping section).

Insulated concrete forms (ICF)

ICFs are lightweight styrofoam forms that create a cavity into which the concrete is poured and then stay in place to produce a highly insulated structural concrete wall with excellent sound-proofing characteristics. ICF walls provide R-values between 17 and 35 and may be used for either above- or below-grade walls. Rebar is generally installed onsite to reinforce the concrete.

The forms are typically made from pure foam-plastic insulation but may also be made from a composite of cement and foam insulation or a composite of cement and processed wood. Most ICF manufacturers use either EPS with an average R-value of 3.8 per inch or XPS with an average R-value of 5 per inch.

ICFs generally provide higher R-values than typical concrete or block foundation wall construction. Concrete and block foundations can be insulated after construction to reach R-values equivalent to ICFs, but perhaps not as affordably or easily.

Although all ICFs are identical in principle, the various brands differ widely in the details of their shapes, cavities, and component parts. Products are further differentiated by how forms attach to each other and how finishes are attached to the wall. Some forms require metal or plastic ties that are inserted through the foam to build the form on site. Others have ties premolded in the form. Most ICFs knit together with interlocking tongue-and-groove joints and stack like toy building blocks.

ICFs come in three basic form-types: blocks, panels, and planks (see Figure E-4):

- **Block systems** resemble conventional concrete masonry units. A typical block unit is 8 to 16 inches tall and 16 inches to 4 feet long. Block ICFs generally arrive at the site with ties in place, either as a metal or plastic piece, or as part of the molded block.
- **Panel systems** resemble traditional plywood forms and are the largest ICF systems available in sizes 1 to 4 feet tall and 8 to 12 feet long. Panel systems allow a large section of wall area to be erected in one step but may require more cutting in the field. The panels have flat sides and are connected to one another with metal or plastic ties.
- **Plank systems** consist of long, narrow planks of foam held together at a constant distance apart by metal or plastic ties. Planks may have notched, cut, or drilled edges that the ties fit into. Plank-shaped forms range in height from 8 to 12 inches and are either 4 or 8 feet long. They differ from block systems in that they can be shipped flat, either because the ties can bend or because the ties are inserted as the wall is constructed.

The resulting shape of the concrete will be one of several shapes: flat, waffle- or screen-grid, or post-and-beam.

As with conventional basement foundations, ICFs must be waterproofed or damp-proofed below grade to prevent water penetration between the form joints. Whether you damp-proof or waterproof depends on the amount of water in the soil at the site. A nonpetroleum-based material should be used to avoid foam deterioration. Like other foams, ICFs must also be protected above grade from ultraviolet rays and incidental damage.

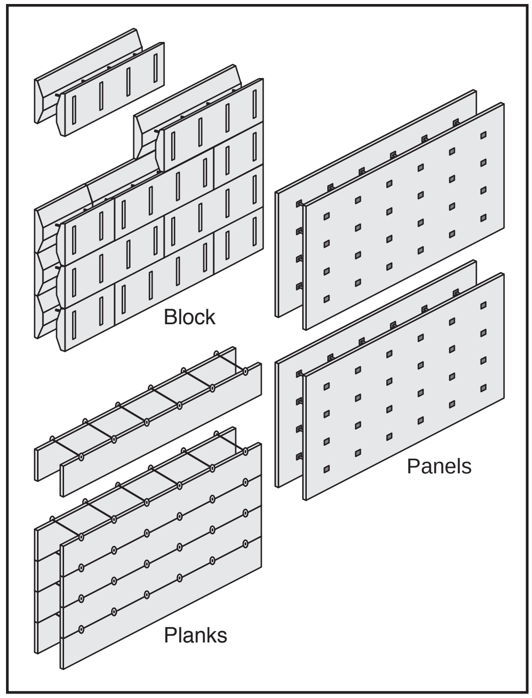


Fig. E-4: ICF walls in 3 basic form-types: block, panels, and planks

Whatever the differences among ICF brands, all major ICF systems are engineer-designed, code-accepted, and field-proven. ICFs have been used in commercial and residential construction in the United States since 1978. Many manufacturers belong to the Insulating Concrete Form Association, an industry trade group.

Precast, pre-insulated foundation wall panels

Another type of foundation wall is custom built in a controlled factory environment. The panels are trucked to the job site on a flatbed semitrailer. There, cranes lower the custom walls onto a bed of clean, crushed stone, where they are permanently fixed into place. A triple bead of special sealant is used to form a tight permanent seal against moisture.

A trained crew from the factory can install a typical basement in five hours on a properly prepared site which is about one-sixth of the time needed for a formed concrete wall.

Precast concrete foundation and wall panels can take many forms. Some consist of steel-reinforced concrete ribs that run vertically and horizontally in the panels. Others are solid precast concrete panels.

The panels consist of a high-strength, low-water concrete mix that requires no additional damp- or waterproofing. They are cast from 5,000 psi concrete instead of the 2,500 to 3,000 psi mix that is typical on most onsite pours. They are reinforced with steel rebar and polypropylene fibers for added strength and insulated with either 1 to 2½ inches of XPS. The walls feature built-in accesses for wiring and small plumbing, treated wood nailers for easy drywall installation, and custom openings for windows and doors.

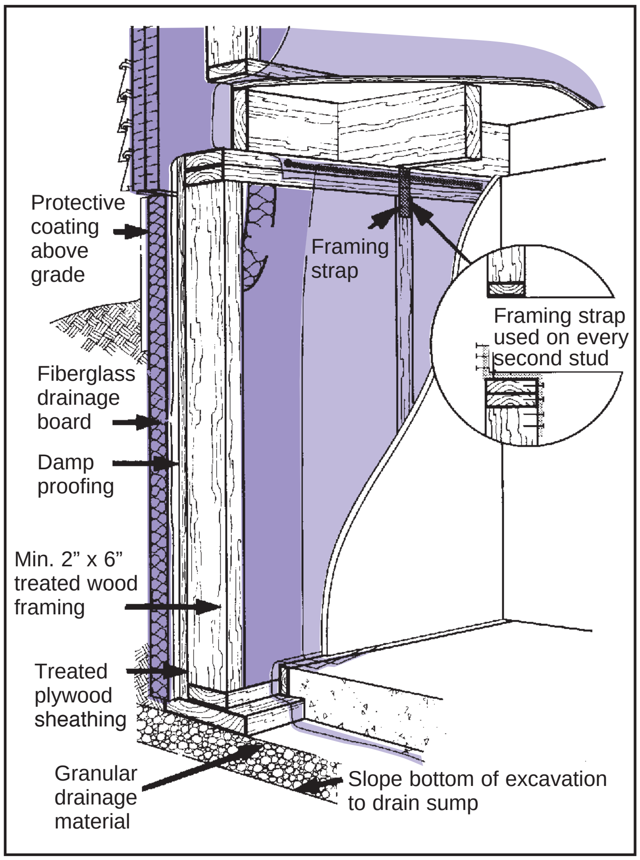


Fig. E-5: Preserved wood foundation

Some manufacturers cast the concrete against foam insulation that provides the form during manufacture and added R-value in the wall. Panels range in size from 2 to 12 feet in width by 8 to 12 feet in height and are typically installed with a crane on top of 4 to 6 inches of compacted stone. The stone facilitates sub-slab drainage and adequately carries and transfers the load from the foundation wall. Panel connections consist of bolts and sealant. The foundation can be backfilled as soon as it is braced per manufacturer's specifications.

One panel manufacturer features solid concrete studs at 2 feet on-center, a built-in concrete footer, and a 1¾-inch exterior concrete face. The stud cavities provide space for R-21 batt insulation. Coupled with the XPS, an insulating value of R-26 to R-33 can be achieved.

Use of precast panels should be submitted for approval by the building official at time of building permit application.

Preserved wood foundations (PWF)

Although installing wood foundations is not very common in the Madison area, they can offer advantages for the builder and the homeowner. Wood foundations have an advantage in very cold weather because wood does not freeze as concrete will. This means no delays in scheduling foundation starts if you want to begin construction during winter months. From a homeowner's point of view, the benefits are comfort, dryness, finishability, and energy efficiency.

Site-built wood foundation construction typically consists of treated 2x6 or 2x8 framing in conjunction with half-inch thick treated plywood sheathing (see Figure E-5). With wood foundations, more attention must be paid to stress due to backfilling pressure and to the diversion of groundwater than with poured concrete basements. For these reasons, most experts encourage novice builders to work with a company that sells factory-fabricated foundation panels.

Preserved wood foundations are approved by all major building codes in the United States and have been available for a number of years. They now account for about 5% of the market and are gaining in popularity.

Some of the first wood foundations were installed in the 1980s in Iowa. These same foundations are performing as efficiently today as the day they were installed. Research and case studies have shown that preserved wood foundations, if installed correctly, offer distinct advantages when compared to concrete foundations. No one knows the life expectancy of a wood foundation, but at least one company guarantees their foundation system for 75 years.

For additional information on preserved wood foundations, download the free publication *PWF Design & Construction Guide* from the Southern Pine Council at www.southernpine.com/pwf.shtml.

Foundation drainage

No one wants water in their basement. Water that seeps in through walls or pushes up through the floor after a hard rain or melting snow can cause expensive damage and is very aggravating.

The best time to specify drainage procedures is during the planning stage. Water drainage should be discussed with your builder. The slope of your lot, the height of the water table, and the soil composition should all be considered.

Installing perforated drain tile is recommended, even if it does not seem warranted. Some contractors install drain tile as a matter of course; some do not. Installing drain tile before the basement foundation is backfilled is easily accomplished and inexpensive (see Figure E-2). Consider installing drain tile on the inside as well as the outside of the footings and connecting them in three or four places. All drain tile should be surrounded with at least 4 to 6 inches of clean gravel before backfilling is done.

Keeping the basement dry is accomplished by proper grading of the site (1 inch per foot on dirt surfaces and a 1/4-inch inch per foot on hard surfaces such as concrete or asphalt), installing perforated drain tile, and waterproofing the basement walls.

Installing a sump pump in the floor prevents water from accumulating in the basement. Sump pumps are often installed in homes built in low-lying areas and also will reduce water damage if a water pipe breaks or if the sewer backs up.

Radon-resistant construction

Radon is a naturally occurring radioactive, odorless gas that comes from the soil. It is estimated that about 20% of existing Wisconsin homes have radon levels in excess of Environmental Protection Agency (EPA) limits (4 picocuries/liter of air) for at least part of the year.

Radon enters basements by pressure-driven flow through cracks and openings in basement floors and walls. Basement air tends to be at slightly lower pressure than soil air, due mainly to the stack effect (warm indoor air rising in cold seasons). As the warm buoyant air rises, it pulls replacement air into the house at the lower levels (see Figure E-37). Because there is no way of testing for the presence of radon gas until after your home is constructed, it's a good idea to plan for a radon-resistant home.

Radon-resistant home construction involves (1) avoiding openings to soil, sealing sumps, and basement cracks and (2) controlling air pressure under the basement slab.

The most commonly installed system used in homes that have a basement or slab-on-grade is referred to as sub-slab passive stack (see Figure E-6). This system draws the radon gas from beneath the basement floor and naturally pulls it outside.

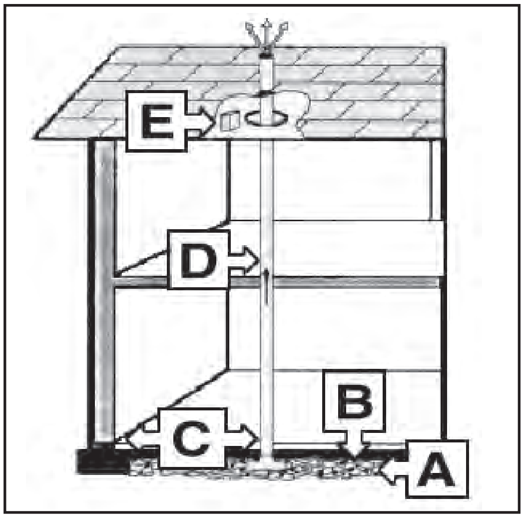


Fig. E-6: Passive stack

Before the basement slab is poured, a 6 mil or greater plastic sheeting, or 1-inch extruded polystyrene foam with taped seams (B) should be placed over 3 to 5 inches of clean or washed stone (A). The washed stone forms a network of air pockets beneath the finished floor that allows free movement of radon gas as it enters through the soil.

Then, a four-inch diameter PVC stack (D) is placed vertically from under the slab, up through an interior-heated partition of the house and through the roof. When outdoor air is cold, warmer air in the stack rises and creates a slight depressurization under the slab if the sub-slab region is well sealed (C) from the basement. It's a good idea at this point to rough-in wiring from the basement to the attic and add a junction box in the attic (E) in case a fan is needed later on.

Passive stacks in properly built and sealed new construction typically reduce the radon in indoor air by 50% compared to the radon measured with the stacks capped.

Radon levels in a home can be elevated despite these precautions, though it is significantly less likely. In such cases, installing a fan in the stack, in space originally provided in the attic (E), ensures adequate control of the radon at low additional cost.

The extra cost to build passive radon resistance into new construction, where gravel and a vapor barrier are standard (as in most of Wisconsin), is just for the PVC stack, the extra wiring, and the materials and time to seal up cracks and the sump.

Radon levels can change from season to season and even from day to day. Charcoal canister kits that test radon levels in your home over a three-to-seven-day period are available. If, after testing, the results indicate levels that exceed EPA limits, retest with a more sophisticated kit for a longer period of time (up to a year) to determine average annual radon levels. The testing should be done in the lowest living space level in the house.

Discuss a plan for radon control with your contractor. Specifying radon control measures now could make a dramatic difference on the saleability or resale value of your home.

More information and specifications for radon-resistant construction can be obtained from the EPA's radon Web site and from the Radiation Protection Section of the State of Wisconsin's Division of Public Health (608) 267-4795.

Ring joists/sill boxes

Ring joists and sill boxes are described as the area around the perimeter of the basement ceiling where the floor joists rest on top of the foundation walls (see Figure E-7).

Two different types of building materials, concrete and wood, which expand and contract at different rates in reaction to changes in temperature, meet at this

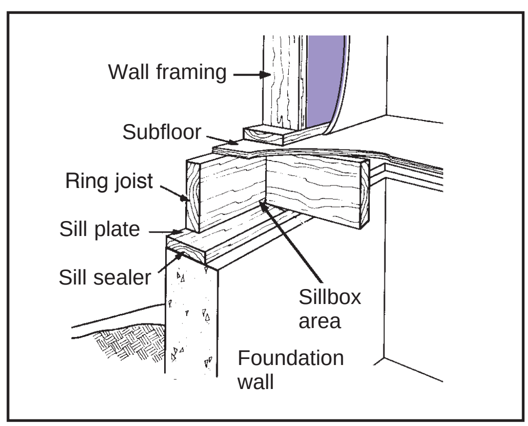


Fig. E-7: Floor framing

point. Even the best concrete-forming job can leave gaps between the sill plate and the top of the foundation wall. Some type of sill sealer typically is used between the sill plate and concrete, but extra care should be taken here to prevent heat loss and air infiltration.

Sill boxes are one of the most important areas in your home to insulate and seal properly. Preplanning measures for insulating and sealing this area will provide an airtight floor-to-foundation assembly.

These measures should be specified before construction begins, because the floor is assembled and fastened to the foundation walls soon after the foundation wall forms are removed. R-19-faced fiberglass batts cut to fit each sill box is standard practice in the Madison area and will satisfy minimum building codes. However, if sealing measures are not included when the floor is constructed, a fiberglass batt alone will not be adequate in stopping air infiltration.

Installing spray foam insulation to the sill box will effectively eliminate air infiltration and heat loss at the ring joist and is highly recommended.

Also, specify sealing around all utility penetrations through the sill box after construction has been completed.

Floors over unheated spaces

Floors over unheated spaces, cantilevered floors (see Figure E-8), or bay or bow windows that also project out past the

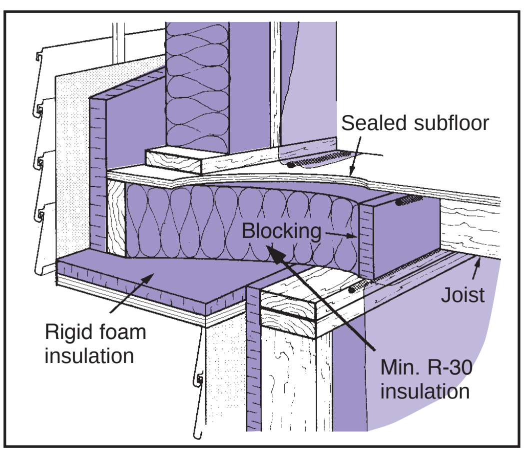


Fig. E-8: Cantilevered floor insulation

walls of the house should be insulated to at least R-30 or as much as space will permit.

Floors over unheated spaces are especially susceptible to air infiltration and should be sealed with the same care that an outside wall or ceiling receives. Floors over garages often have heating ducts or waterlines that run through the joist spaces. Flexible insulated ducts should be specified for heat runs, and waterlines should be rerouted to eliminate the possibility of freezing.

Additionally, floors over garages should be completely filled with insulation. Spray-in-place insulation is ideal for these floors especially when floor trusses are used. Fiberglass batting is typically installed from the garage side in the Madison area. This is acceptable only if the batting completely fills each joist space and the cavities are well sealed. Remember to specify sealing all penetrations through the subfloor before the finished floor is installed.

Many customers have questions about the use of vapor retarders on floors over garages. Any material with a permeance rating not exceeding 1.0 qualifies as a vapor retarder. Most of the sheathing materials used for subflooring meet this requirement.

Slabs (concrete poured on grade)

Building a house on a concrete slab is not a common practice in the Madison area. Often a part of the house such as a family room behind the garage or a heated sun space is built on a slab. If this is specified, the concrete slab should be insulated on its underside with a minimum of 2-inch thick XPS board insulation. The frost walls should also be insulated, on the outside, to a depth of 4 feet with a minimum of 2-inch thick rigid board. This should include areas where the slab meets the basement or garage walls of the house. Floating slabs are designed to move slightly with changes in temperature. Their perimeter should be insulated

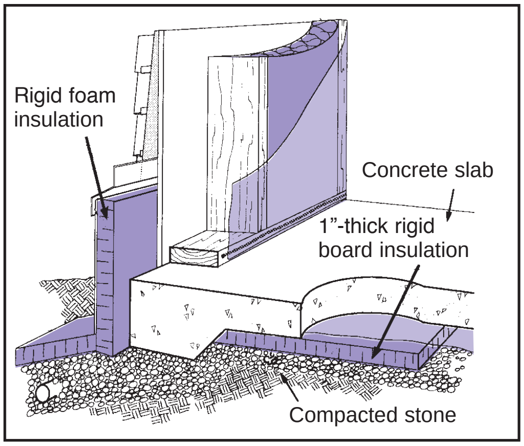


Fig. E-9: Floating slab on grade

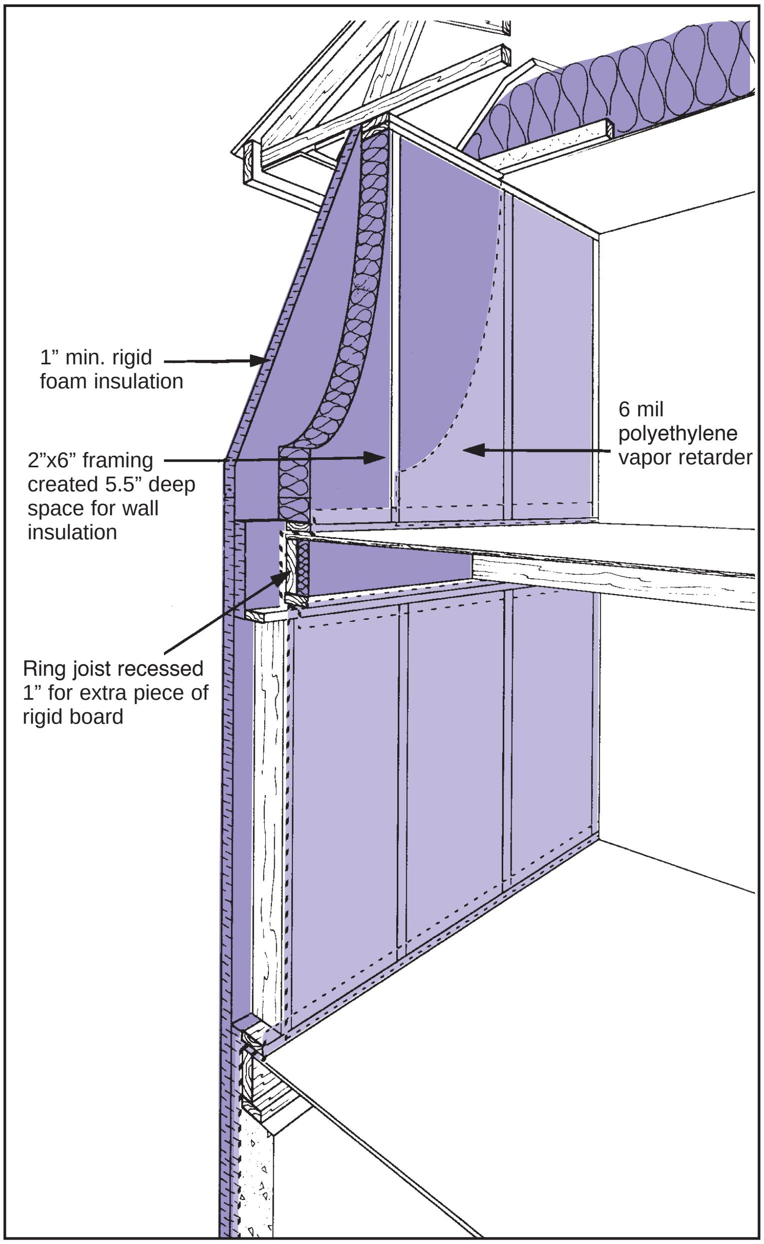


Fig. E-10: 2"x6" stud wall with rigid board insulation

with one piece of rigid board installed vertically and one piece installed at an angle (see Figure E-9).

Above-grade walls

Standard wall construction

For well over a hundred years, the standard wall framing for houses consisted of wood 2x4 studs (vertical framing) spaced on 16 inch centers. When insulation first came into general use in the late 1940s, the common method of insulating was to install 1- to 2-inch-thick mineral wool batts between these framing members. Fiberglass batting eventually replaced mineral wool, and for many years after, a 2½-inch thick batt was used as standard insulation in conjunction with 2x4 framing.

During the energy crisis in the mid-1970s, various framing and insulating combinations were used. Currently, the most common practice in the Madison area is the use of 2x6 studs spaced 16 inches on center. This creates a 5.5-inch deep space for insulation between the studs which is normally insulated with 6-inch R-19 batt insulation. (The maximum R-value from an R-19, 6-inch batt in a 5.5-inch space is about R-18.) Oriented strand board (OSB) is then used as exterior sheathing. The overall R-value for this method is R-15.7 (always compare above-grade wall assemblies using the weighted or overall R-value).

A better sheathing alternative is to substitute 1-inch extruded polystyrene rigid board insulation for the OSB (see Figure E-10). This method increases the overall R-value to R-20.8 and reduces the possibility of condensation occurring within the wall. Because the styrofoam is not as strong as the OSB, the corners will have to be cross-braced by half-inch plywood or OSB installed to the corners to add racking strength to the wall.

Keep in mind that overall R-values include the framing as well as the insulation. The wood framing members have a much lower R-value, so the overall insulation effectiveness of the wall is reduced. This is called the “framing factor.” In a typical wall assembly, wood framing makes up about 25% of the total surface area. Rigid board insulation helps reduce heat loss through otherwise unprotected studs.

Drainage plane

To keep moisture and mold problems to a minimum, it is imperative to design above-grade wall structures to dry if they get wet. All above-grade wood-frame wall assemblies require a drainage plane coupled with a drainage space, unless the house is in a region where it rains less than 20 inches per year. Madison averages about 30 inches of rainfall per year.

A drainage plane consists of a water-repellent material, overlapped to drain downward, and extending continuously over the whole building exterior. The drainage plane, coupled with an airspace, flashing connected to the drainage plane, and weep holes creates a system that provides drying capability to the wall. Joe Lstiburek, prominent building scientist and moisture expert, refers to this system as a “water-managed wall system.” He says “If you’re missing any one, or you do any of them wrong, you can expect trouble.”

For the drainage plane to be effective it must be continuous. Every single door and window flashing as well as roof-wall intersections and all service penetrations must tie into the drainage plane and shed water to the outside of it, not behind it. One reverse lap or unflashed penetration has the potential to ruin the whole wall.

There are many choices of drainage plane material and much discussion over which is best. The most common drainage planes on houses are the various building papers – asphalt-saturated felt, plastic house wraps, and coated papers.

Traditionally, drainage planes consisted of tar paper-installed shingle-fashion behind exterior claddings coupled with a flashing at the base of the wall to direct rainwater that penetrated the cladding systems to the exterior. It was important that some form of airspace or drainage space was also provided between the cladding system and the drainage plane to allow drainage.

With wood siding, the drainage space is typically intermittent and depends largely on the profile of the siding. Ideally, wood siding should be installed over furring strips, creating a drained (and vented) airspace between the drainage plane and the wood siding. With vinyl and aluminum siding, the drainage space is more pronounced and furring is not necessary.

With stucco claddings, the drainage space was traditionally provided by using two layers of asphalt-impregnated felt paper. The water absorbed by the felt papers from the base coat of stucco caused the papers to swell and expand. When the assembly dried, the papers would shrink, wrinkle, and de-bond from the back of the stucco providing a convoluted, but reasonably effective, drainage space. This drainage space was typically around 1/8-inch wide.

When constructing stone veneers, a 3/8-inch airspace coupled with a drainage plane is common. This is often done using a thick plastic Brillo®-pad material covered with a filter cloth which is installed over a #30 felt. Water-managed exterior insulation and finish systems (EIFS) grooved foam has grooves 3/8-inch wide and plastic mesh spacers which provide an airspace of 3/8 inch or more. The grooves or spacers are installed over a drainage plane.

With brick veneer, a minimum 3/8-inch airspace coupled with a drainage plane is required to control rainwater. Both are necessary. Also, when brick gets wet and then is exposed to the sun, water vapor is pushed inwards toward the insulated wall cavity. One drainage plane solution is to install a #30 felt onto the sheathing and a vapor permeable water resistant house wrap. These, coupled with the airspace provide an excellent water-managed wall.

When using foam sheathings with brick veneer, a drainage plane and drainage spaces are both still required. The foam sheathing can be installed in such a manner as to act as a drainage plane on its own or a drainage plane can be installed under the foam sheathing to provide this function. It is not recommended that building papers be installed over foam sheathing. They should always be installed under the foam because it is not possible to staple building papers into foam and have the building paper be wind resistant.

Foam sheathing can act as an effective drainage plane if vertical joints are shiplapped or tongue-and-grooved and if horizontal joints are flashed. The addition of building paper is unnecessary in such a case.

Other framing and insulating alternatives

There are other wall-framing and insulating methods that improve energy efficiency and comfort.

Single 2x4 stud walls

Some builders are returning to building homes with 2x4 exterior walls instead of 2x6. The use of 2x4 can save money on related framing and finishing costs. Window jamb extenders are no longer needed and 2x4s are less expensive than 2x6s. Other benefits are increased square footage of living space and reduced wood use.

Use of a 2x4 wall does not mean energy efficiency has to be compromised. In fact, the R-value can be about 20% higher compared to a 2x6 wall with OSB sheathing. For example, a 3.5-inch high-density fiberglass batt used in conjunction with 1.5-inch extruded polystyrene exterior sheathing would yield an overall R-value of 19.4 (see Figure E-11a). Compare that to what is currently standard practice in Madison, a 2x6 wall with R-19 batt and OSB sheathing, at R-15.7 (see Figure E-11b). Spray-in-place insulation such as foam, cellulose, or fiberglass would be excellent energy-efficient choices for cavity insulation in 2x4 framed walls.

Staggered stud walls

In this framing method, the top and bottom wall plates are 2x6 or 2x8, but the studs used are 2x4. These studs are staggered on 16-inch centers. Staggered means that half of the studs are fastened at the outside edge of the wall plate and half are fastened at the inside edge.

Since the studs are not connecting the inside of the wall to the outside of the wall, heat loss directly through the studs is eliminated. If sprayed-in-place insulation is installed with this framing method, rigid board insulation may not be necessary. There are many variations employed by builders using this

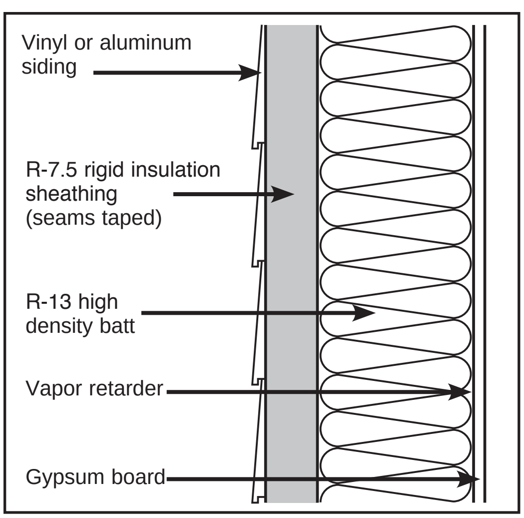


Fig. E-11a: 2″x4″ wall, 16″ O.C., R-19.4 overall

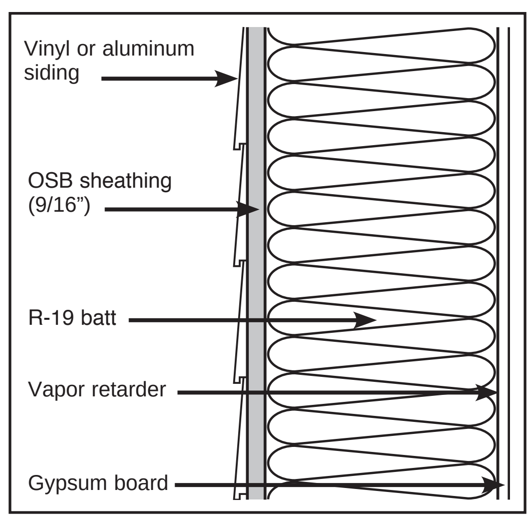


Fig. E-11b: 2″x6″ wall, 16″ O.C., R-15.7 overall method. It offers additional benefits such as reduced noise levels and enhanced comfort. Disadvantages include added labor to assemble the wall and possible increases in material costs.

Double 2x4 stud walls

In this method, two separate 2x4 walls are constructed next to each other, usually with added space between, with the studs offset in much the same way as with the staggered stud wall. Direct heat loss through the studs is eliminated, and more insulation can be installed since there are two separate walls. This method of framing also offers noise-level reduction and enhanced comfort. Double 2x4 wall construction is sometimes referred to as "super insulation," meaning that a very high R-value can be achieved depending on the thickness and density of the insulation materials used. Disadvantages in using this type of wall assembly include an increase in material cost, additional labor to assemble the walls, and reduced square footage of living area (see Figure E-12).

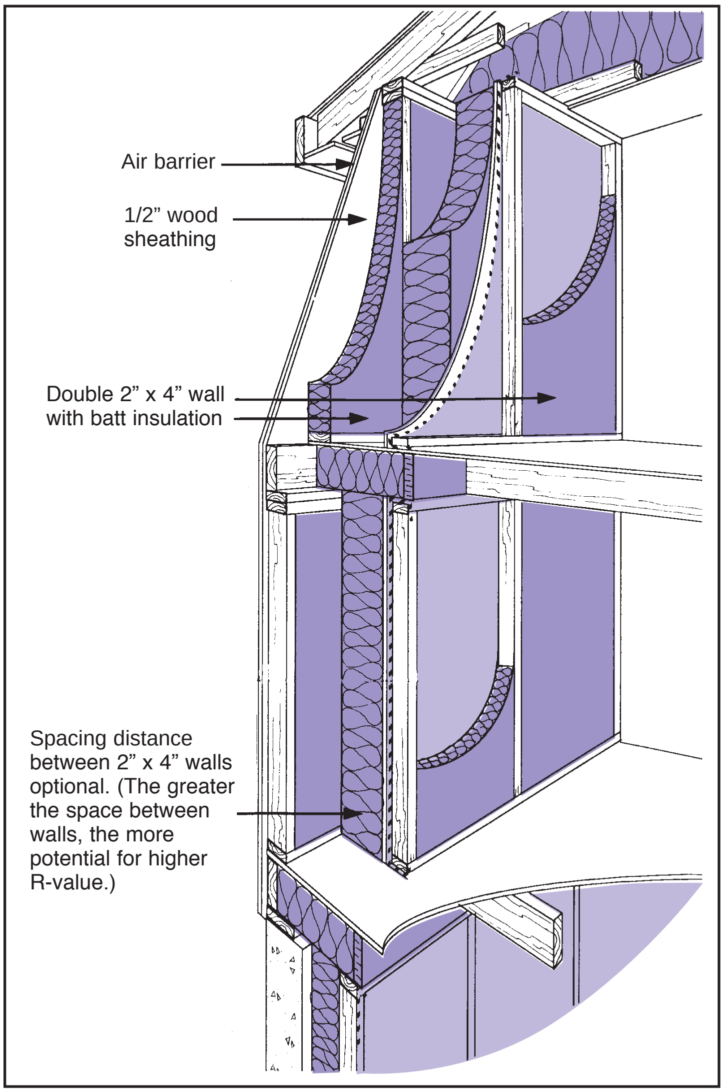


Fig. E-12: Double 2″x4″ insulated walls

Structural insulated panels (SIPS)

Also referred to as foam core panels or stress skin panels, these panels are made from a thick layer of foam (polystyrene or polyurethane) sandwiched between two structural layers of Oriented Strand Board (OSB) or plywood (see Figure E-13). Some manufacturers present alternative panels with fiber-cement siding, waterproofing materials, drywall (interior skin), etc. Some panels provide horizontal and vertical 1½-inch diameter electrical chases parallel to the floor. Special chases also can be installed into SIP panels (i.e., for home theatres, special appliances, and/or tool needs). Wiring is simply pulled through the chases during the construction process.

The panels can be used in floors, walls, and roofs for residential and light com-

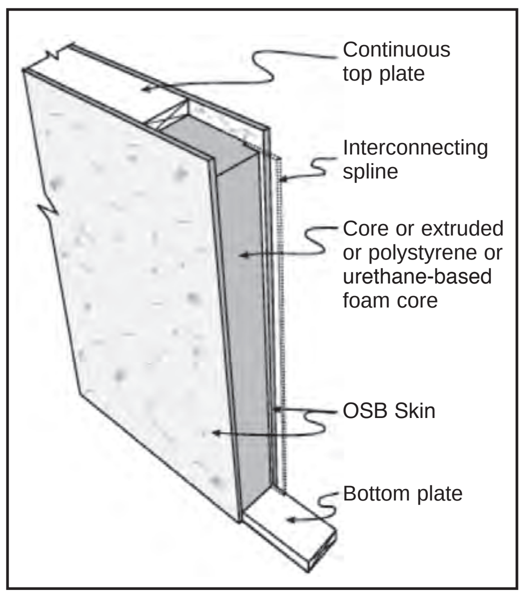


Fig. E-13: Structural insulated panel

mercial buildings. These factory-made panels are available in various lengths and thicknesses and are usually custom designed and cut for each home.

Insulated panel advantages are:

- Significantly reduced labor associated with building the house shell.
- Reduced material costs associated with framing and insulation.
- High R-values.
- Easily achieved airtight assembly (see Figure E-14).

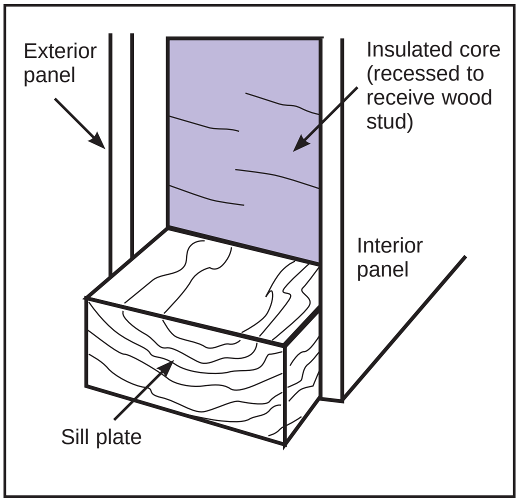


Fig. E-14: Stress skin panel joinery

Disadvantages may include less design freedom and difficulty in making design changes after construction begins.

On-site constructed SIPS panels

A newer-patented product, from a company in Idaho, is a lightweight SIPS-like panel comprised of high-density polyurethane foam with integrated wood or PVC studs that is sandwiched between two foil-faced radiant vapor barrier skins. They can be used for walls, floors, and roofs and are available in sizes of 4 feet wide and up to 10 feet long. Dimensional stability, rigidity, racking, creep, and overall strength are provided by the foamed in-place studs placed either 16 inches or 24 inches on center depending on thickness. A staggered stud wall, to reduce thermal bridging, is also available in the 2x6 and 2x8 panels.

The panels are laid on the floor deck and attached together with screws or nails utilizing the “ship lap” joint on their edges. Top and bottom plates of standard dimensional 2x4, 2x6, or 2x8 lumber are attached on-site. Window and door openings can be cut from the panels using a skill saw and framed using dimensional lumber. For wiring and plumbing, a channel is routed in the polyurethane between the studs and an “L” drill is used to bore through the studs. The channel is then spray-foamed closed. Next, they are stood up, braced, and are faced with an OSB exterior and a gypsum board interior.

The manufacturer claims an R-value of 26 for the 2x4 wall panel, R-42 for the 2x6 panel, and R-52 for the 2x8, although the aged R-value of the insulation is about 20% less than that.

These panels have an advantage over standard SIPS because of their light weight. In most cases, they can be moved around on the job site and assembled without using a crane, thereby saving money and time.

Steel stud framing

Steel framing offers freedom from the fluctuating cost of lumber. Its main drawback, high thermal conductivity (steel is more than 400 times more conductive than wood), can make steel a less desirable option. When used in an exterior wall, steel studs form a “thermal bridge” that can reduce the in-cavity R-value by anywhere from 20% to 50%. Thermal losses through wood studs reduce the R-value by less than 10%. Another problem has been the tendency of “ghost marks” to form on walls built with steel studs.

A “thermal break” inserted between the steel and the exterior can help to reduce this problem. Rigid board insulation is installed as exterior sheathing. Thermal losses can also be reduced by using a combination of wood and steel. Wood trusses and sill plates can be used to reduce heat loss up through the attic and down through the concrete.

Contrary to noted problems, a study conducted by researchers at Oak Ridge National Laboratory concluded that, if designed properly, it is possible to construct metal stud walls that perform as well as wood-framed walls.

I-joist walls

I-joists are an engineered framing component with top and bottom chords separated by an OSB web (see Figure E-15). Normally they are used for floors and ceilings but recently have been used for wall framing. They are installed vertically in place of the wall studs. They are available in widths from 9 to 16 inches.

On the positive side, the heat requirement for the home is greatly reduced as a result of the high levels of insulation. For example, a 12-inch I-joist filled with dense pack cellulose has an R-value of over 44. They also reduce cold bridging and provide less shrinkage and expansion movement than using solid timber joists.

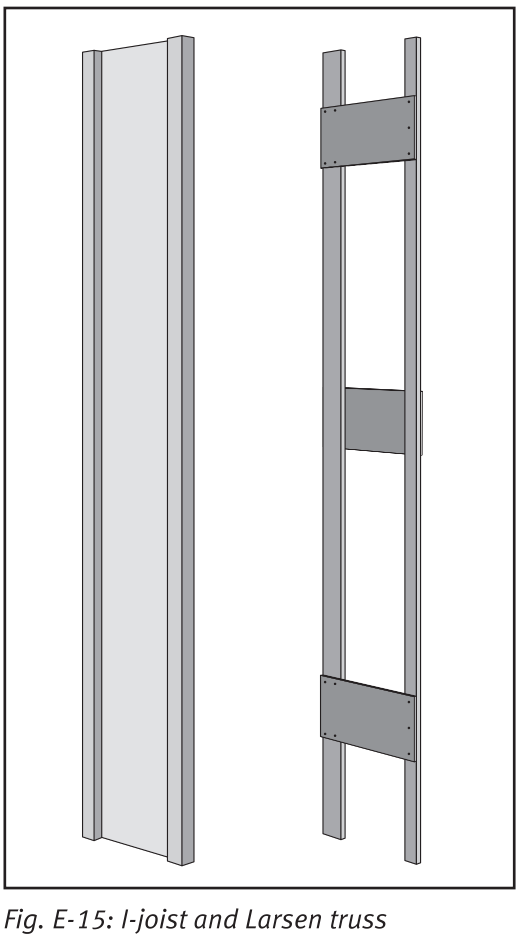


Fig. E-15: I-joist and Larsen truss

On the negative side, the on-site constructed walls need a crane to position them, which can add to cost. Also, before using I-joists for walls, contact the manufacturer to ensure they can be used for that purpose.

Some of the more high-performing homes have used I-joists for wall framing, most notably the Passive Homes in Urbana, Ill.

Larsen truss wall system

A Larsen truss is a site-built ladder-like parallel chord truss used to add large amounts of insulation to the wall (see Figure E-15). They can be built as an exterior insulation cavity, independent of the structural frame wall, or can be consolidated into the structural framing. Much like the I-joist walls used in the Passive House, a Larsen truss wall can be insulated to R-40 or more depending on the truss thickness. The major difference between the two is the I-joist wall is easier to insulate because of the OSB webbing between the 2 parallel chords.

Advanced framing techniques

Advanced house framing, sometimes called Optimum Value Engineering (OVE), refers to a variety of techniques designed to reduce the amount of lumber used and waste generated in the construction of a conventionally wood-framed house. OVE uses engineering principles to reduce the amount of lumber while still meeting model building code structural performance requirements. Advanced framing actually replaces lumber with insulation material, which maximizes the R-value and improves energy efficiency. Additional construction cost savings result from reduced waste disposal, which results in less waste going into the landfill.

While the system can be applied as a whole package, many of its components can be used independently, depending upon the specific needs of the project. Framers unfamiliar with the techniques may need training, and the initial use of these techniques may temporarily slow down framing operations. In general more planning is needed when using these techniques.

The following list covers each of the innovations that form part of the OVE system:

- **24-inch on-center framing**

  Wall and floor framing spacing can often be widened to 24 inches on center (roof framing spacing is already typically 24 inches). This strategy can be combined with modular layout and single top plate for added economy, but also can be used independently.

- **Modular layout**

  Building to a 24-inch module and using 24 inches on center wall and floor framing can maximize framing material cost savings. Few homes can be entirely confined to a rigid module because crucial dimensions such as the width of a tub or corridor are not modular. The most important dimensions to keep on the module are overall dimensions to the outside of framing. To maximize savings, window sizes and placement should be coordinated with the module.

- **Single top plate - exterior and bearing walls**

  This technique must be used with modular layout and is typically used with 24-inch on-center framing. By stacking the wall, second floor, and roof framing, it is possible to use a single top plate because the plate does take any vertical loads. Steel plates or straps are used to maintain continuity of the plate in the absence of a second, overlapping plate.

- **Single top plate** - interior nonbearing partitions.

  Any nonbearing partition can be built with a single top plate.

- **Right-sized headers**

  Instead of sizing all headers in bearing walls to accommodate the worst case load and span, size each header for its particular load and span.

- **Insulated headers**

  A typical header, over a door or window, is usually constructed on-site from 2 studs with an air space between them. In a 2x6 wall, for example, 2½ inches of rigid board insulation can be sandwiched between the 2 studs to form an insulated header that reduces heat loss and gain.

- **2-stud or 3-stud exterior corners (California corners)**

  When using 2x6 stud construction, the preferred method for constructing an exterior corner is the 2-stud method (see Figure E-16). A 2-stud corner eliminates the need for a third non-structural stud that is used only to fasten the drywall to. Instead, drywall clips, or stops (see Figure E-19), are used to fasten the drywall. This method

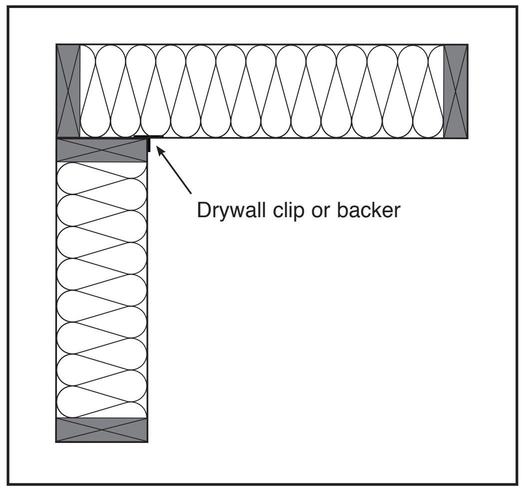


Fig. E-16: 2-stud exterior corner

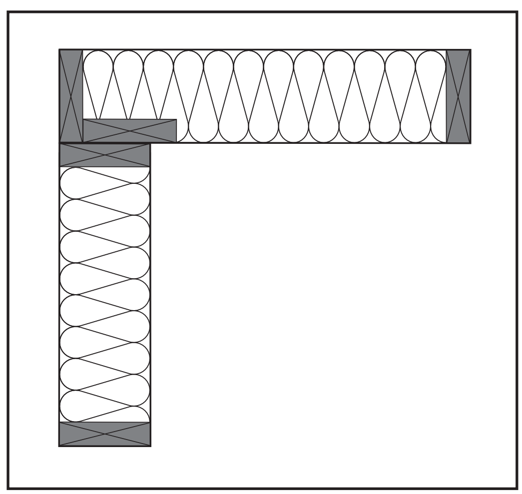


Fig. E-17: 3-stud exterior corner

saves material and provides space for the maximum amount of insulation. If structural requirements allow, drywall clips can be used in 2x4 stud construction as well.

If drywall clips aren't used, a third stud needs to be added to provide a surface to attach the drywall (see Figure E-17). Compared to the 2-stud corner, this method reduces the insulation in the corner by about 20%. Both of these corner details for a 2x6 stud wall provide better insulation than the standard way of corner framing (see Figure E-18).

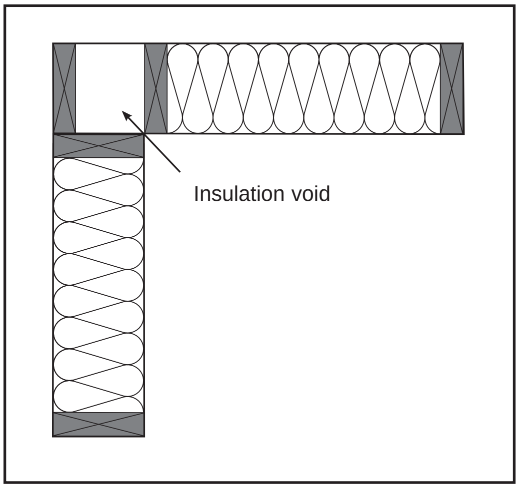


Fig. E-18: Standard exterior corner

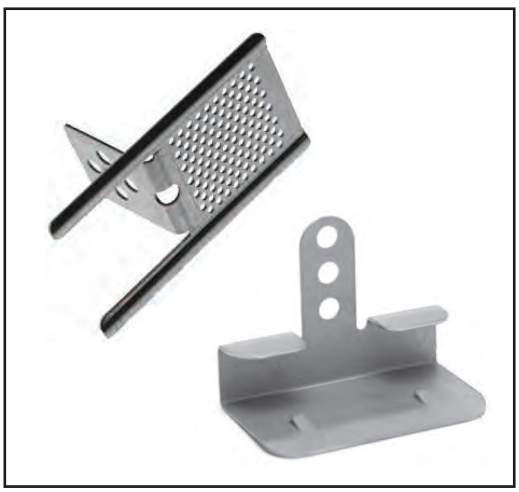


Fig. E-19: Drywall clips

The standard way of framing also uses three studs, but this configuration does not allow insulation to be easily installed after the framing is done, leaving a cold spot, which increases heat loss and the likelihood for condensation occurring during cold weather.

- **Drywall clips (also called drywall stops)**

  Small pieces of hardware (see Figure E-19) that function as backing to fasten drywall. The clips eliminate the need for an additional stud.

- **Partition connections to exterior walls (t-walls)**

  In standard construction, studs are added at each side of a partition, which serve only to provide a surface for attaching drywall. In addition to wasting wood, this type of connection creates an area that is difficult to insulate (see Figure E-20).

  OVE construction uses a 1x6, 2x6, or 2x8 stud (turned 90º) to attach the inside walls to exterior walls and as a drywall nailer (see Figure E-21). Not only does this method allow for more insulation in the space, but framing is faster because there's no need to measure for inside wall placement. Alternatives include installing "ladder blocks" or using drywall clips instead of installing the blocking stud (see Figure E-22). This method allows the maximum amount of insulation to be installed.

This has been a brief overview of above-grade wall framing and insulation options. One way to approach wall construction and insulation options is to simply ask each prospective bidder to price two or three different wall systems. This will tell you a lot about their experience, their willingness to work with you, and differences in cost between options. And remember, benefits like comfort and quiet cannot be measured in a payback calculation.

If you have any questions about wall framing and insulating options, ask your contractor or call us at 252-7117.

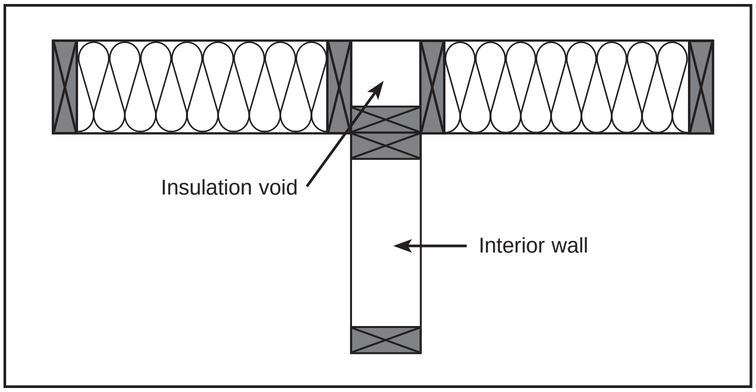


Fig. E-20: Standard construction

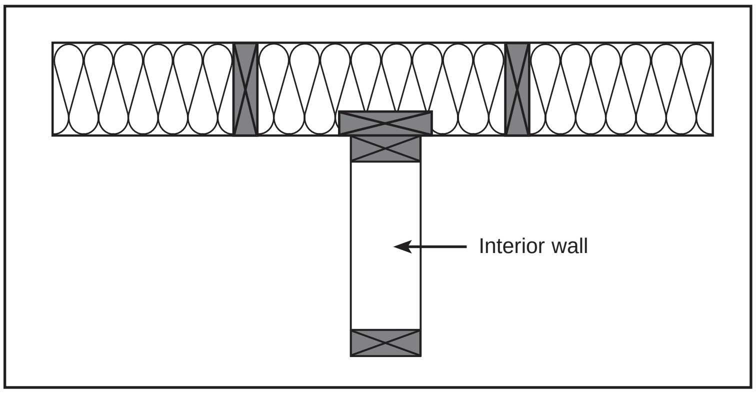


Fig. E-21: OVE construction - alternative #1

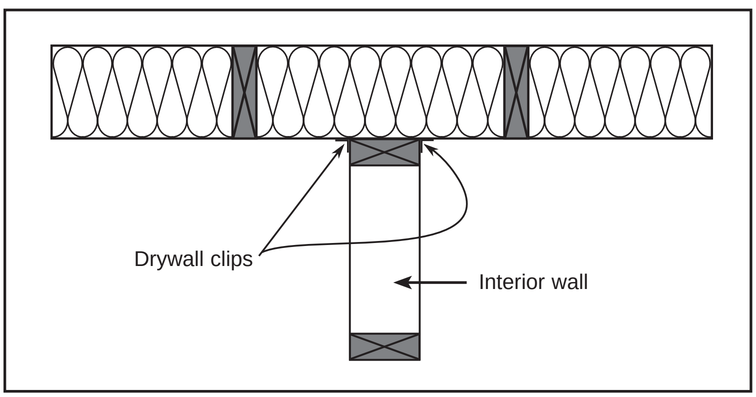


Fig. E-22: OVE construction - alternative #2

Ceilings/attics

Open attics

Insulation subcontractors install on average an R-value of 40 to open attics in the Madison area. We recommend installing R-44 to R-50. For very high-performance homes, R-60 is specified.

Energy trusses

Energy trusses, also known as raised heel trusses or stepped trusses are "built up" where they rest on the outside wall. This allows the same amount of insulation to be placed around the perimeter of the attic as is placed in the center of the attic. Since most attic insulation is at least 10 inches, a 10-inch energy truss is justified (see Figures E-23 and E-24).

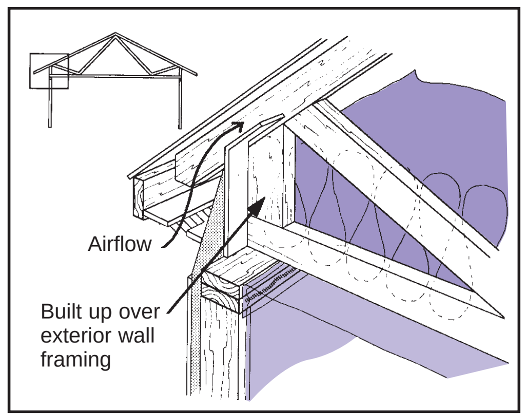


Fig. E-23: Raised heel conventional truss

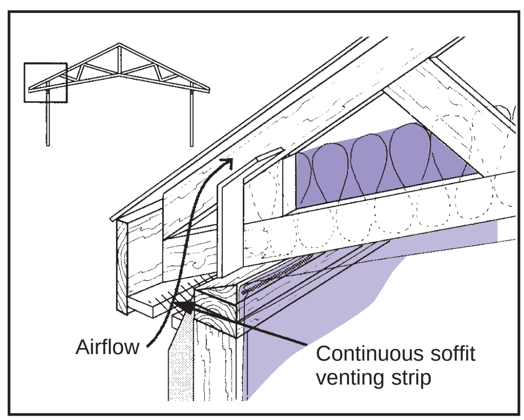


Fig. E-24: Raised heel scissor truss

Attic venting

Attic venting allows moisture in the attic to escape. Fifty percent of attic venting should be installed in the soffit area and 50% along the ridge or at the highest point of the roof. City and state building codes require a minimum of one square foot of free vent area for every 300 square feet of attic floor area.

We recommend installing continuous soffit and ridge venting to maximize airflow through the attic. Heated moist air in the winter rises into attic spaces around penetrations in ceilings. A balanced low-to-high airflow (characterized by continuous soffit and ridge venting) carries moisture-laden air to the outdoors. Ideally, attic spaces should be within 6° to 10° of the outside temperature at all times. Continuous venting also keeps the attic cooler in summer which helps lower the cost of air-conditioning (see Figure E-24).

Attic access

Area building codes require that attics must be accessible for maintenance purposes. Unfortunately, accesses are typically located in an upstairs closet or hallway and generally are not adequately insulated or sealed with weather stripping.

Whenever possible, specify attic access within an unheated part of the house (over the ceiling of an attached garage is a good example). When the access must be located in a heated area, make sure the access is insulated and weather stripped around the perimeter of the access cover. Rigid board insulation cut to fit and secured to the top side of the attic hatch works better than attaching a piece of fiberglass. Rigid board secured properly will not fall off if the hatch is opened. And it adds a bit more weight which provides a better seal against the weather stripping (see Figure E-25).

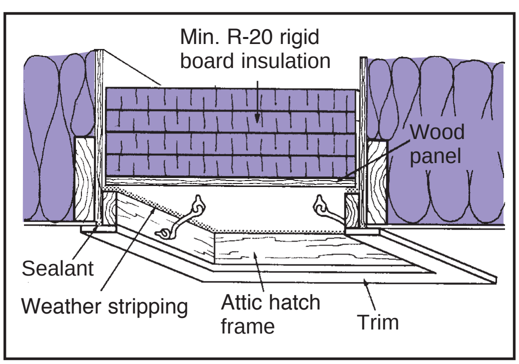


Fig. E-25: Insulated attic hatch

Cathedral and vaulted ceilings

Cathedral and vaulted ceilings should receive the same amount of insulation as open attics. State codes require that a minimum 1-inch deep airspace must be maintained above fibrous insulation.

Perforated venting strips are typically installed at the top and bottom of each rafter bay to allow airflow between the insulation and the roof sheathing.

When planning cathedral or vaulted ceilings, 12- to 14-inch-wide rafters should be specified. This will allow enough space to achieve a minimum R-value of 38 (if 12-inch thick fiberglass batting is used) and will still leave room for the required 1 inch air space (see Figure E-26). Proper vents should be installed to the underside of the roof sheathing in each rafter cavity to ensure at least a 1-inch air space.

If less than 12- to 14-inch rafters are specified, you can achieve an equal or higher R-value by insulating with a spray-in-place foam insulation. These products are classified as rigid insulation, which means they can be sprayed directly

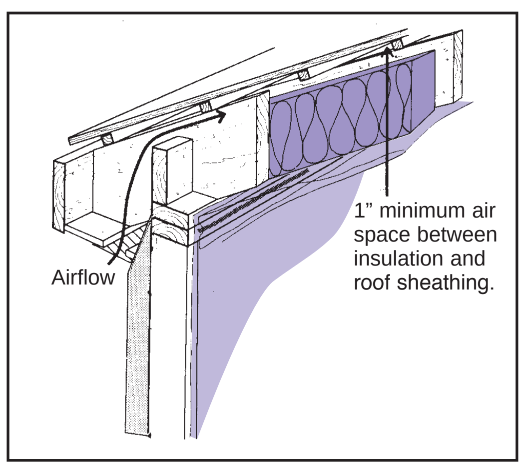


Fig. E-26: Cathedral ceiling insulation against the underside of the roof sheathing. A 1-inch airspace is not required when rigid insulation is used.

Recessed lights should be avoided in cathedral or vaulted ceilings if you are planning to build a high-performance home. These lights are recessed into the ceiling insulation increasing the potential for warm moist air to escape into the attic where it can condense and create problems. There have been many cases of homeowners reporting water dripping from nonsealed fixtures. It was caused by moisture-laden air that had escaped into the attic insulation, froze, and melted when it got warmer. Cold air can also enter your home through the nonsealed fixtures creating uncomfortable drafts. Also, because of limited space, there is not an effective way to insulate above them. Consider a surface-mounted or "track" lighting system for these ceilings.

Hot roof

A roof can either be designated as "hot" or "cold." A hot roof is a flat, cathedral, or shed roof insulated with foam insulation on the underside of the roof decking between the rafters, with no natural ventilation in the roof cavity (see Figure E-27). A cold roof maintains a continuous air space between the underside of the roof and the insulation (see Figure E-28).

In a cold roof, which is the standard way in insulating the vast majority of roofs, the air space allows an exit path for moist air that has leaked into the insulation. It also provides a thermal break between the insulation and the roof sheathing that helps reduce the possibility of ice dams.

A hot roof relies on high levels of insulation to slow down heat transfer to the exterior. Also, the air barrier provided by the spray foam reduces the chance that moist air will enter the insulation cavity and cause problems. For this method to work it is important that a continuous vapor retarder be installed under the drywall and there should not be any penetrations in the drywall such as recessed lights.

Hot roofs have been used successfully for over 15 years in northern climates; however, use of this method has raised much debate in the building industry. It is said that because hot roofs don't include ventilation, there could be problems with moisture and heat build-up in hot summer months.

There is also a concern that hot roofs may have a negative impact on the life of asphalt shingles. Studies have shown that color differences in shingles will actually have a larger impact on the

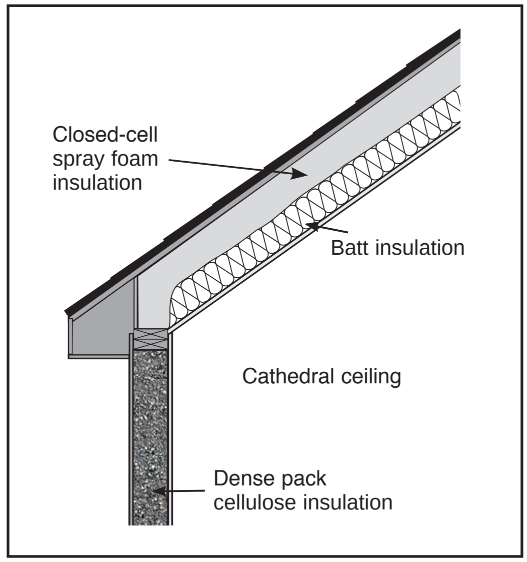


Fig. E-27: Hot roof, non-vented attic

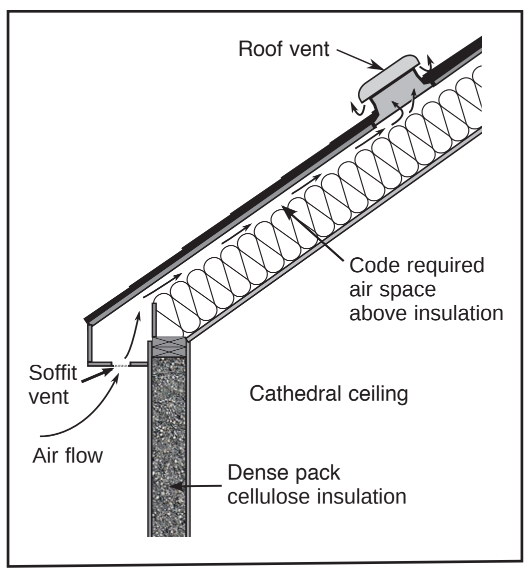


Fig. E-28: Cold roof, vented attic

temperature of roofs than the difference between a ventilated and a hot roof. A 'hot' roof will typically only be a couple degrees warmer than a ventilated roof. Some shingle manufacturers have approved the use of the hot roof system with their products but others have not, so it's best to check the warranty.

Cost may be the biggest limiting factor. Batts usually cost about one-third the cost of foam, but the foam performs much better having about double the insulation value per inch and virtually eliminating air leakage and attic by-passes.

Ice dams

An ice dam is a ridge of ice, usually accompanied by ice sickles, that forms and builds up on the lower edge of the roof over the eaves during the winter. Ice dams usually occur after a heavy snow-fall and several days of freezing tempera-tures. Snow can block the attic vents and warm air inside your home leaks into the attic and warms the underside of the roof causing snow and ice on the roof to melt. When the snow melts, it runs down the roof to the edge where it pools and refreezes. Ice is forced under the shin-gles where it can melt and cause costly structural and interior moisture damage to walls, ceilings, insulation, and other areas. Ice dams can be prevented by following procedures for air sealing and insulation outlined in this publication.

Windows/skylights

Windows

Choosing windows for your new home is one of the most difficult decisions you have to make. The major issues affecting window decisions are:

- Aesthetics.
- Maintenance.
- Cost.
- Style.
- Energy efficiency.
- Size.
- Placement.
- Frame type (wood, clad, vinyl, fibrex, fiberglass).

Your decisions inevitably affect how you feel when you are inside your new home. Windows provide natural light, view of the outdoors, natural ventilation, security, and protection from the cold in winter and heat in summer. The windows you choose must also harmonize visually with the outside of your home.

Windows are available in an incredible range of styles and sizes. This wide variety of options fits into three basic window categories:

- Stationary
- Double-hung
- Casement

All windows are really variations of the double-hung and casement types (see Figure E-29).

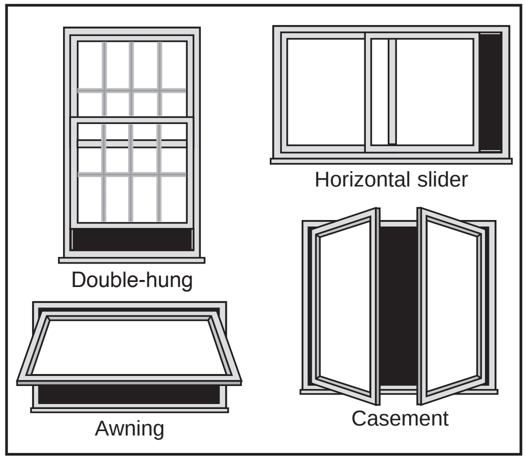


Fig. E-29: Common types of windows

Stationary windows

Also known as "picture" windows, these windows have inoperable sashes and are not meant to open. Picture windows are to enhance views and typically are installed in conjunction with one or two smaller windows with operable sashes for ventilation. Since they are not intended to open or close, they can be sealed in place to prevent air infiltration. A station-ary window is more energy efficient than its operable counterpart. When a group of windows is specified, stationary windows are used in combination with windows that open to help achieve a reasonable compromise between ventilation and energy efficiency.

Double-hung windows

Also known as “vertical sliders,” double-hung windows date back to colonial times and represent the traditional look most often associated with older homes. One window sash hangs above the other. Either sash can be moved up or down to open or close the window as desired (see Figure E-30). Significant improvements in the energy efficiency of double-hung windows have been made in recent years. But the natural mechanics of these windows make them more susceptible to air infiltration and less energy efficient than casement or picture windows. Double-hung windows are generally chosen in relationship to the “look” they provide and lend themselves to certain styles of construction. We recommend low-E, gas-filled windows with a storm panel when double-hung windows are specified (see low-E glass coatings).

A variation on the double-hung window is the horizontal slider. Commonly called “sliders,” each sash moves horizontally to open and close rather than up and down. Basement utility windows typically are the horizontal sliding type.

Casement windows

Casement windows utilize sliding and pivoting hardware that swing the sash outward like a door, except without hinges. A rotating handle adjusts the window to the opened or closed positions. Most casements have high- and low-mounted locking hardware that not only secures the sash but also provides a tight seal to the weather stripping.

Casements have distinct advantages over double-hung windows. Because most casements open a full 90% outward, they are well suited to directing airflow into your home for ventilation in summer months. This feature also allows the window to be cleaned on both sides from inside the house.

Casement windows are considered to be the most energy-efficient operable windows, at least in terms of air infiltration. The harder the wind blows against them, the tighter the sash seals against the weather stripping (see Figure E-31).

Casement windows are not without disadvantages:

- In rainstorms, open casement windows are susceptible to damage since the top of the sash is unprotected.
- The screen is mounted on the inside of the window, so bugs and airborne debris can become trapped between the screen and glass during summer months.

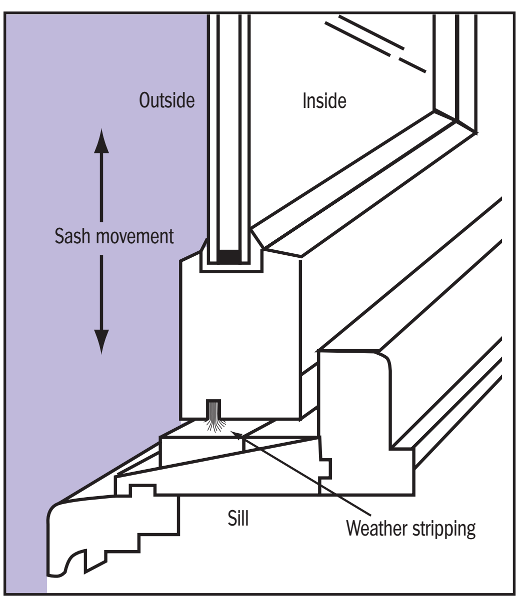


Fig. E-30: Double-hung window

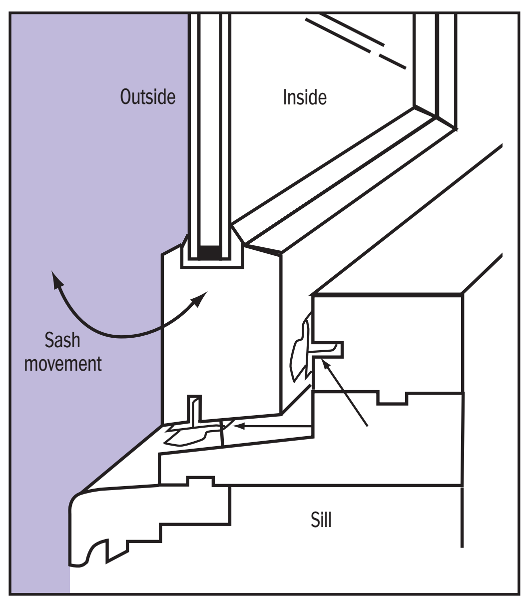


Fig. E-31: Casement window

A variation of the casement window is the "awning" window. This window utilizes a sliding pin mechanism which is located at the top of each side of the window sash. Awning windows are not common in new construction in the Madison area because most will not open wide enough to meet fire escape clearance codes.

Window glass

Historically, window sashes were glazed with a single sheet of glass held in place with flexible putty (glazing compound). As the price of heating fuel increased, a separate storm window became a standard part of window construction. Two panes of glass are better than one, but even windows with two panes of glass have very little insulating value. Windows can account for about 15% to 20% of the total heat loss in homes.

As concerns about energy costs and efficiency have grown, the window industry has made its products more energy efficient. Significant improvements have been made in weather stripping, edge spacers, locking mechanisms, and in the insulating capabilities of the glazing.

When selecting your windows, always use the overall U-factor, not the center of glass U-factor, as a basis for comparing thermal energy efficiency. The lower the U-factor the greater a window's resistance to heat flow and the better its insulating value. (The U-factor is simply the reciprocal of the R-value. See Glossary for definition.)

Also, look for a moderately high solar heat gain coefficient (SHGC). The SHGC is a number that represents the amount of heat that is transferred though the glass. For example, glass with a .60 SHGC will allow 60% of the sun's heat to pass through and 40% will be reflected away.

The National Fenestration Rating Council (NFRC) publishes the Certified Products Directory, which provides accurate energy performance ratings for fenestration products such as windows, doors, and skylights. They developed a window energy-rating labeling system based on "whole-window" performance. It is the only reliable way to compare the basic energy-related properties for different windows, doors, and skylights (see Figure E-32). Only products bearing an NFRC energy performance label are certified. These ratings also can be used to determine whether a product meets code or other requirements. The rating takes into account heat loss characteristics of the frame, spacers, edge of glass, and center of glass to come up with the overall U-factor. The NFRC rating label also compares solar heat gain, visible light transmittance, and infiltration. NFRC rates all products in two standard sizes so that consumers and others can be sure they are comparing products of the same size. On the label, these two sizes are listed as "Res" and "Non-Res."

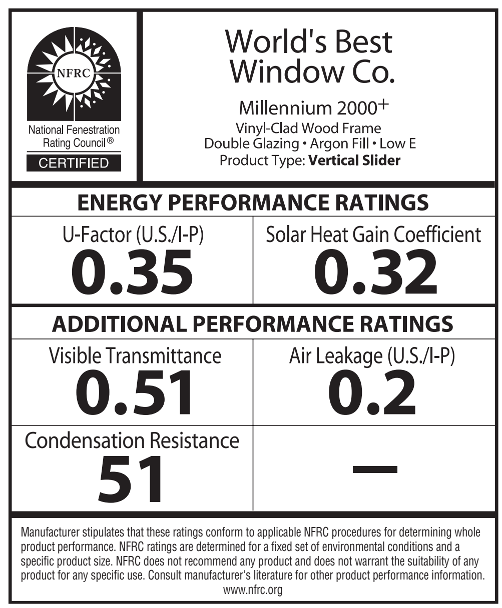


Fig. E-32: NFRC label

Low-E glass coatings

Low-E glass is treated with a very thin transparent coating of metallic oxide. This chemical coating slows down the emission of infrared energy (heated air) and also reduces the transfer of ultraviolet light (fabric-fading rays from the sun). Consequently, when low-E windows are specified, heating and cooling costs are reduced. Manufacturers now offer a wide range of low-E glass that is termed "spectrally selective" because they reduce summer heat gain as well as winter heat loss. It is not unusual to specify one type of low-E glass for the north side of the home and a different type for the south, west, and east.

Gas-filled windows

Inert gases (typically argon gas) improve the energy efficiency of windows. When two panes of glass are sealed together to form a double-glazed window, gas is injected into the airspace between the two panes. Because this gas is denser than the air it has replaced, R-value is improved, and the result is a slower rate of heat loss through the glass. Most manufacturers of low-E-coated windows include injection of an inert gas as an option (see Figure E-33).

Window condensation

Windows, being the weakest thermal part of a wall, are prone to condensation forming on the inside surface. Assuming high-performance windows are installed, the cause is usually excessive humidity levels in the home. But, extremely cold temperatures could be the cause, even if humidity levels in the home are normal. For example, at 40% relative humidity in the home and a double pane w/low-E and argon gas window, condensation would occur at -40°. At 50% relative humidity, condensation would occur at -20° (see figure E-34).

If condensation occurs persistently, at less than extreme winter temperatures, the solution is to lower the relative humidity in the home. The point being that window condensation is usually not the fault of the window, but rather too high humidity in the home.

Window number and placement

The quantity and placement of windows is determined by a number of factors. Building codes have to be considered because Wisconsin State code requires the total glass area per habitable room equal at least 8% of the room's livable floor area to provide natural light and an emergency exit.

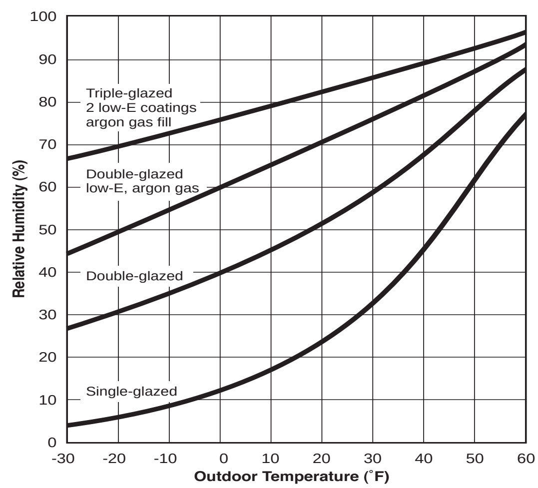


Fig. E-34: Relative humidity/temperature/condensation chart

Glazing	R-Value (center of glass)	U-Value (center of glass)
Single glazing	0.85	1.18
Double glazing:		
1/2" airspace	2.04	0.49
1/2" airspace with low-E coating	2.78	0.36
1/2" airspace with low-E coating and argon gas filled	3.25	0.31
3/4" airspace with low-E coating and two 3/8" airspaces	3.29	0.30
3/4" airspace with low-E coating and two argon filled 3/8" airspaces	4.03	0.25
Triple glazing and two 3/8" airspaces	2.78	0.36

Fig. E-33: Approximate R-value and U-factor values for various glazing options (not to be confused with the NFRC rating).

A rule-of-thumb goal to shoot for – limit the total glass area of the home (windows, skylights, and glass doors) to no more than 15% of the total exterior wall and ceiling area.

Window placement has a major effect on energy efficiency. The greatest percentage of windows should be placed on the south side of the house. An extended soffit (roof overhang) and/or some type of window covering will help to reduce heat buildup from the summer sun.

Place just enough windows on the north, east, and west walls to balance interior light levels; capture any views; create an attractive house; and allow for natural cooling. But be sparing, because windows placed in these orientations are energy drains in cold months and, in the summer, east and west windows let in unwanted hot morning or afternoon sun, unless they are shaded. For balanced lighting and ventilation, place windows on opposite or at least two sides of each room. Limit the use of skylights, which admit too much sun in the summer and are difficult to shade. Instead, install solar tubes (also known as tubular skylights) in interior rooms without windows, which let in some light, but less heat (see Figure E-35). If skylights are installed, they should be at least double-paned, low-E, argon-filled windows with a U-factor and solar heat gain coefficient (SHGC) of 0.30 or below.

Specify different U-factors and SHGC's for the different orientations.

- South-facing windows should have a SHGC in the range of 0.40 to 0.65 to maximize solar heat gain during the winter, a U-factor of 0.30 or less to reduce conductive heat transfer, and a high visible transmittance (VT) for good visible light transfer. If you can't find windows with a high SHGC, a reasonable option is to install triple-paned clear glass which lets in large amounts of sun while limiting heat loss.
- North-facing windows should have a low U-factor of 0.30 or below and since they collect little solar heat, the SHGC can be lower.
- East- and west-facing windows should have a U-factor and SHGC of 0.30 or lower and/or be shaded using deciduous trees or interior blinds or window quilts.

The importance of a high SHGC

In a northern climate, choosing windows with a high SHGC for the southern exposure can save money on utility bills. For example, assuming a typical home heated with a 92% efficient natural gas furnace at $1/therm and cooled with a 13 SEER A/C at $.13/kWh, there is a net annual heating and cooling savings of about $43 using windows with a SHGC of 0.55 on the south orientation instead of standard 0.30 SHGC windows. Unfortunately, low solar heat gain windows have become "standard" in northern climates to the point where high SHGC windows are either hard to find or only available by special order and may cost extra.

Selecting windows

Aesthetics and cost, in addition to energy efficiency, will be important factors in selecting the windows for your new home. You should also consider:

- Ease of cleaning.
- Availability of parts and service.
- Warranties.

Before purchasing or placing an order for windows, ask the distributor or your contractor for installation references. Talk with homeowners about what they like or don't like about the windows. It will help make your decision easier. And you can call 252-7117 and ask an MGE representative for additional information.

Skylights

If you plan to install skylights, it's best to limit their size and number. Installed skylights typically have higher effective U-factors (greater heat loss) than the same type of window installed in a wall, resulting in 35% to 45% greater heat losses during cold weather. The more skylights you specify, the greater the potential heat loss. As a rule of thumb, the skylight area should never be more than 5% of the floor area in rooms with many windows and no more than 15% of the room's total floor area for spaces with few windows.

A south-facing roof is the best place to locate skylights and provides the greatest potential for winter passive solar heat gain but often allows unwanted heat gain in the summer. You can prevent unwanted solar heat gain by installing the skylight in the shade of deciduous (leaf-shedding) trees or adding a movable window covering on the inside of the skylight, which is not always easy to do.

Some units have special glazing that can help control solar heat gain. Manufacturers use various glazing technologies to reduce these impacts. The most common technologies include those also used for window glazing are heat-absorbing tints, insulated glazing (double-glazed, triple-glazed), and low-emissivity (low-e) coatings. Some manufacturers even install a translucent insulation material between several glazing layers to create a more thermally efficient assembly.

Here are some tips on what to look for:

- Double-paned, low-E, argon-filled.
- Low U-factors (0.30 or lower) to minimize heat losses – and, for additional protection, movable insulating devices.
- Low SHGC (0.30 or lower) to moderate the sun's heat.
- Well-constructed skylights that are sealed properly in the roof opening to reduce infiltration.

Fixed skylights are more energy efficient than operable ones, but operable skylights, in some applications, are practical for ventilation purposes and for reducing heat buildup in summer months.

A good alternative to skylights are called "solar tubes" or "light pipes" (see Figure E-35). They are installed in the same area as a skylight and can provide about the same amount of natural light. These tubes capture sunlight on the roof of your home through a small dome and reflect the light down a tube which runs through the attic. The light comes through a diffuser on the ceiling in the living area. On the ceiling, the solar tube resembles a recessed light fixture. Some solar tubes come equipped with energy-efficient lightbulbs to allow them to provide light when it is dark.

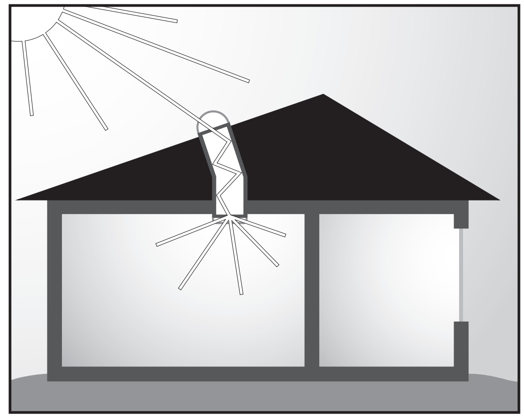


Fig. E-35: Solar tube lighting

For more window information

The Efficient Windows Collaborative is a useful source of information about the benefits of energy-efficient windows, descriptions of how they work, and recommendations for their selection and use. http://www.efficientwindows.org/

Entrance systems

Steel-clad doors

The entrance door preferred by most builders and new homeowners in Madison at this time is an insulated, steel-clad door. These doors are constructed of a metal or wood frame with a steel skin. Their cores are typically insulated with rigid or expanded polyurethane foam. They are strong and durable and require little maintenance and will not shrink, expand, or warp. They are generally installed prehung in their frame with magnetic weather stripping and adjustable thresholds. Steel-clad doors have R-values ranging from 7 to 12.

Fiberglass-clad doors

Fiberglass-clad doors have the same basic features as steel-clad doors. The door is prehung and offers the same range of R-values as steel-clad. Some homeowners choose fiberglass over steel cladding because it feels warmer to the touch and is available with a simulated wood grain texture.

Solid wood doors

Solid wood entrance doors are favorites for aesthetic reasons. However, wood doors are susceptible to warping and do not maintain an airtight seal as well as steel- or fiberglass-clad doors. Even when used in conjunction with good weather stripping and a quality storm door, a solid wood door only has an R-value of about 2. We recommend that you consider a storm door and a vestibule when a solid wood entrance door is specified.

There are some companies that manufacture wood-clad (veneered) doors. These doors provide the look of solid wood while offering the same energy-efficient features as steel- or fiberglass-clad doors.

Patio doors

There are two standard types of door assemblies referred to as patio doors – sliding and swinging doors. The swinging patio door usually has a complementary stationary door beside it, but two swinging doors are not uncommon. Patio doors usually have the same kind of R-value options as windows. They are available with low-E coatings and gas-fill options. Many window manufacturers also produce their own line of patio doors and entrance systems. You may save money by purchasing windows and doors from the same company.

Sliding patio doors allow more air infiltration for the same reasons as double-hung windows. Shop for a sliding patio door that has very low air-infiltration rates and/or limit installation to one sliding unit on the south side of your home. And to reduce the potential for air infiltration and heat loss, specify a sliding storm door as well.

A better alternative is to install a swinging patio door where one door is stationary and one door swings open. However, due to the relatively poor insulating abilities of glass, installation of these doors should be limited as much as possible. The best location for them is on the south side of the house. These doors are less taxing on energy costs if they are installed as an entry into a three-season porch or an unheated sun space. Shelter them from direct weather.

Storm doors

While steel- and fiberglass-clad doors offer insulating values superior to that of solid wood doors, consider the value of a storm door. Storm doors increase the total insulating value and help reduce air infiltration. In addition, they protect the primary door's finish against the weather and with a screen insert provide ventilation during summer months.

Make certain to check the primary door manufacturer's warranty before installing a storm door. Depending on where the door is located, heat from the sun can cause door decoration warpage. Some manufacturers' warranties are voided when a storm door is installed.

Exterior door placement

Exterior doors, like windows, offer less insulating value and have greater potential for air infiltration than the surrounding walls. The guidelines for window placement should also be followed for exterior doors.

Interior pocket doors

Although interior doors generally do not affect energy efficiency, the pocket door is an exception. Pocket doors are installed when space would be compromised by a swinging door. A pocket door slides into a wall cavity instead of swinging on hinges. If the cavity the door slides into is not sealed properly, heated air can escape and cold drafts can occur. If you are planning to install pocket doors in your new home, ask your contractor how to remedy this problem.

Seal up/tighten up

Controlling airflow

It may appear counterproductive to spend money to eliminate naturally occurring air leakage through the building shell and then spend more money to install a mechanical system to ventilate the house. But several benefits accrue from the house-tightening measures and techniques mentioned in this book.

- Reduced heating bills: Unwanted airflows can account for up to 30% of total heating load.
- Improved comfort: Drafts will be reduced and temperatures will be constant.
- Increased durability for shell components: Air that moves from inside to outside in winter contains moisture that can shorten the life of shell components such as framing and insulation.
- Improved thermal integrity of existing insulation materials: Air movement through fibrous insulation can reduce the effective R-value by as much as 50%.
- Increased operating efficiency for a balanced ventilation system: If shell tightening is not addressed, homes are over ventilated in the winter and under ventilated in the summer.
- Reduced noise levels.

Air flows from a high pressure area (positive) to a relatively lower pressure area (negative). Several factors cause a pressure difference across the building envelope:

- Wind: Probably the greatest influence to unwanted airflows through the building (see Figure E-36).
- Temperature: The greater the temperature difference, the greater the airflow. Warm air tends to rise toward the top of the building. This is referred to as the "stack effect" (see Figure E-37). The stack effect creates a positive pressure along the ceiling and the upper areas of the exterior walls causing air to leak out any cracks or holes. The rising air creates a negative pressure in the lower region of the house causing outdoor air to be drawn in through any holes or cracks. The house, in effect, acts like a chimney. Air-tightening measures will help reduce the stack effect to a point where drafts are generally not noticeable, although the effect can never be completely eliminated.
- Operation of chimneys and exhaust-only ventilation equipment: A negative pressure is created when furnaces, water heaters, fireplaces, and exhaust systems are operating. Air is being forced out of the structure and is replaced by cold outside air through cracks around doors, windows, outlets, switches, and other penetrations on the outside shell.

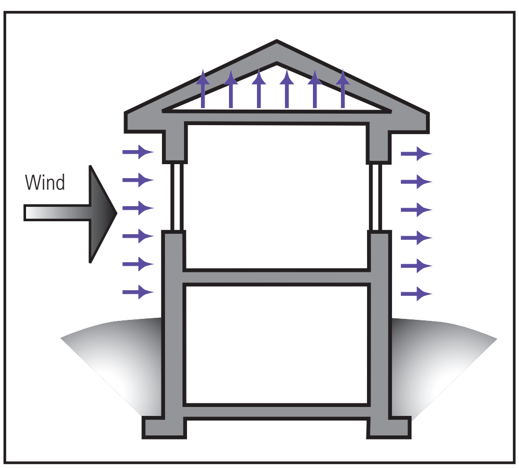


Fig. E-36: Wind effect

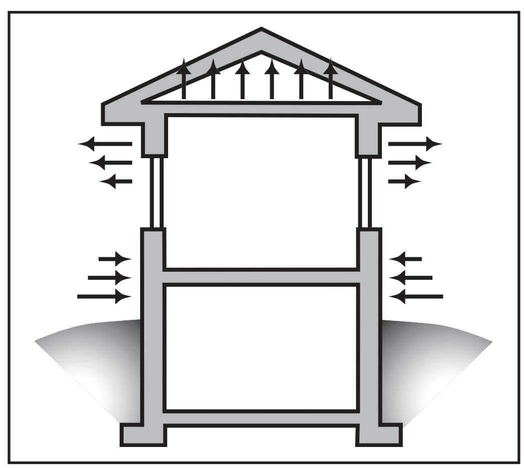


Fig. E-37: Stack effect (winter)

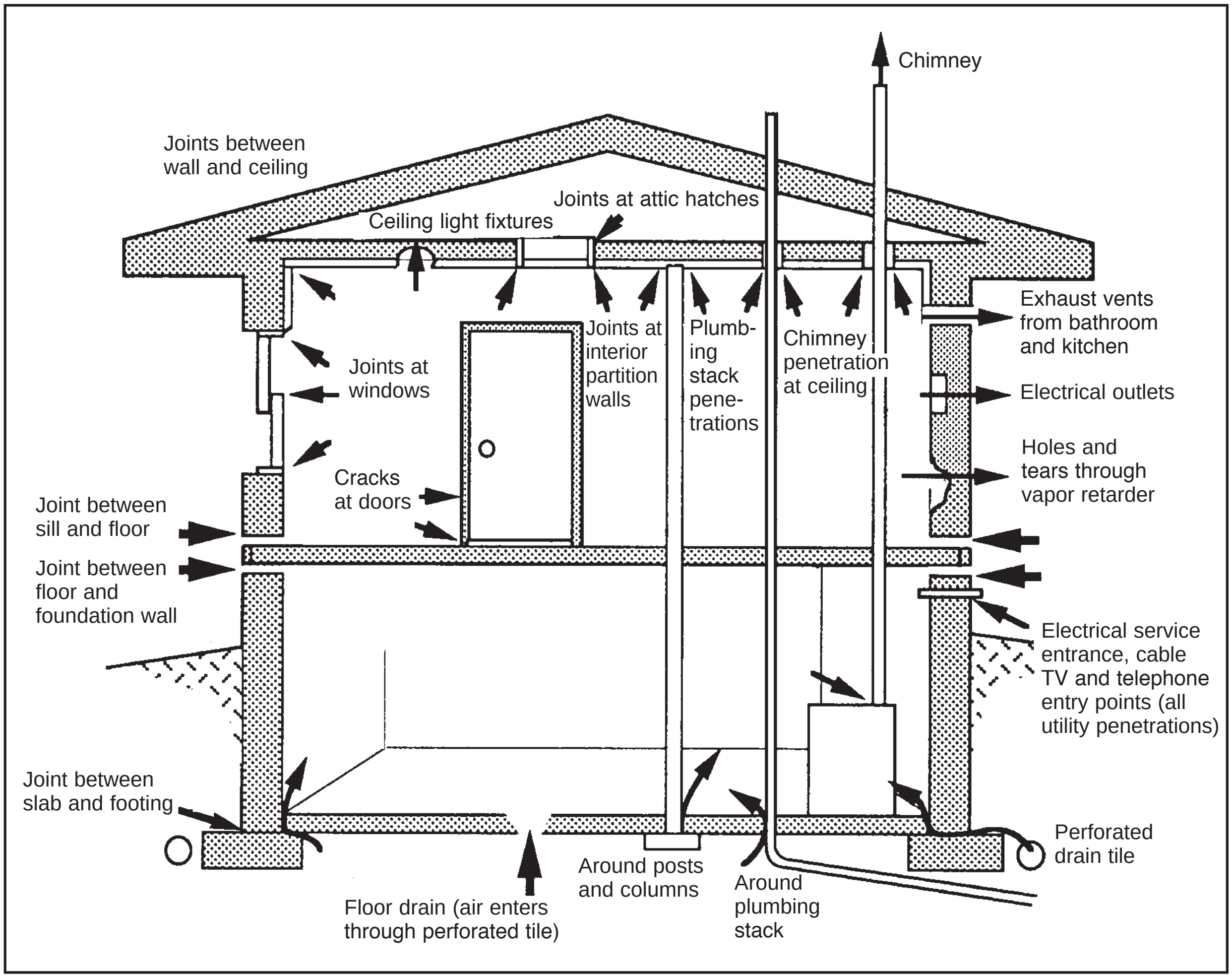


Fig. E-38: Typical air-infiltration locations

To ensure a comfortable, healthy place to live, fresh air is necessary. We recommend tight home construction and a balanced whole house ventilation system. This gives you control of the ventilation for your home. A complete discussion of home ventilation can be found in the Mechanicals section of this book under the heading "Ventilation."

Reducing airflow

There are a number of specifications that you can write into your building contract to help prevent unwanted airflow.

The best strategy to reduce airflow is to specify air-sealing measures in the building contract. Ask your builder what air-sealing measures are employed during construction. The only way to check if adequate air-sealing measures were performed is to specify an air-infiltration or blower-door test when construction is complete. By then, it's too late to fix most air-leakage problems, so make sure the air sealing is done during construction.

Also, the type of wall and sill box insulation will have a huge bearing on how tight the house will be. See the Insulation section in this chapter for specifics.

If you choose to build under the Focus on Energy New Homes Program, you'll have third-party help to ensure air-sealing measures are employed during construction and a blower-door test is also included in the package. For help with locating a New Home Program consultant, call us at 252-7117.

Figure E-38 shows typical locations in new homes where airflow control is necessary. Following are measures to reduce airflow at these locations.

Basements

- Sump pump pits: Install sealed sump pit covers.
- Basement utility windows: Eliminate or install windows with storms or specify insulated glass.
- Ring joist/sill boxes: Install foam sill sealer on top of foundation wall and caulk where plate meets foundation wall around perimeter. Use spray-in-place foam insulation to seal and insulate.
- Sill box penetrations: These include furnace, water heater, and dryer vents as well as air conditioner, water, gas, and electric service lines. Specify sealing around all service penetrations and exhaust vents (see Figure E-39).

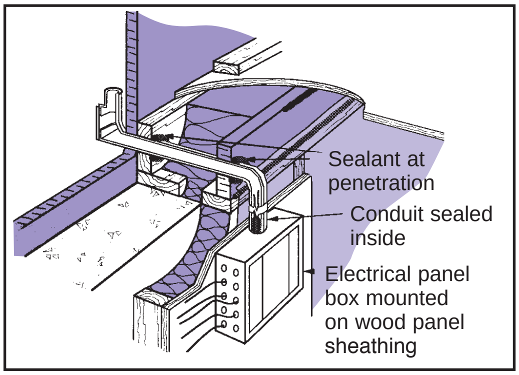


Fig. E-39: Main electric in basement

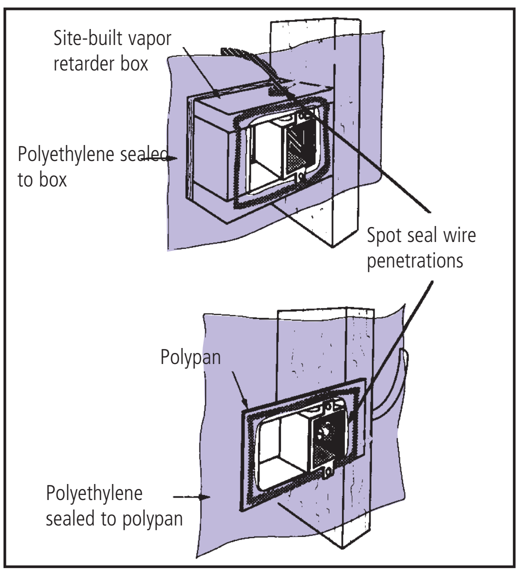


Fig. E-40: Examples of sealed outlet boxes

Wall and floor penetrations above grade

- Electric outlet and switch boxes: Specify sealed outlet/switch boxes or use polypans and require insulation contractor to foam-in boxes, seal wire penetrations, and seal vapor retarder to boxes (see Figure E-40).
- Central vacuum connections: Install sealed connectors and sealed vacuum canisters.
- Penetrations that run from heated to unheated space: Seal around heating ducts, plumbing pipes, and electric wire where they exit the heated space.
- Plumbing pipes under sinks: Specify sealing around waterlines before gypsum board or cabinets are installed (see Figure E-41).
- Fireplaces: Specify combustion air kits with spring-loaded backdraft dampers and/or positive-lock chimney dampers. Seal around perimeter of fireplace where brick or stone meet gypsum board. Install gasketed doors. Specify insulated and sealed chimney chaseways. Install sealed combustion or direct-vented gas-burning fireplaces.
- Windows/doors: Use foam sealant in conjunction with fiberglass between rough opening and jambs.

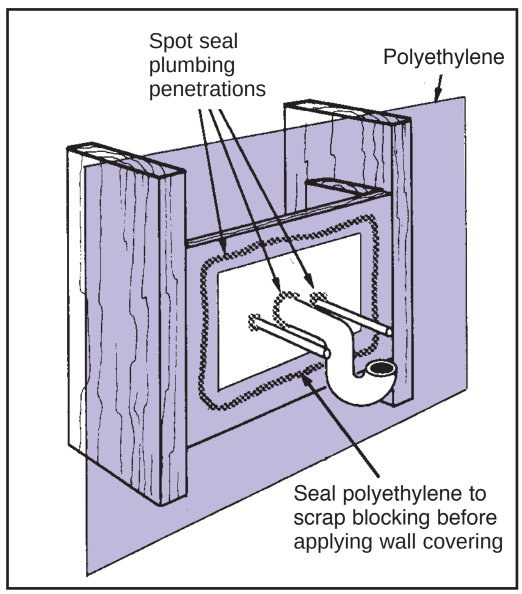


Fig. E-41: Sealing plumbing penetrations

- Bay/bow/box windows: Seal these window units around perimeters where they meet the walls and wrap or seal window seat from exterior side. Install layers of rigid board insulation under window seat from exterior side to minimum R-30 or as much as space will permit. (Window trim may need to be modified to create more depth for insulation under seat.)
- Pocket doors: Segregate pocket door cavities from unheated space, insulate, and seal around cavity.

Ceiling penetrations (see Figure E-42)

- Attic access panels: Insulate snugly with a minimum of R-20 rigid board insulation, add weather stripping, and secure to ceiling trim. Ideally, specify garage access if possible (see Figure E-42).
- Plumbing vent stacks: Install flexible collar at upstairs ceiling on attic side and seal (see Figures E-43a and E-43b).

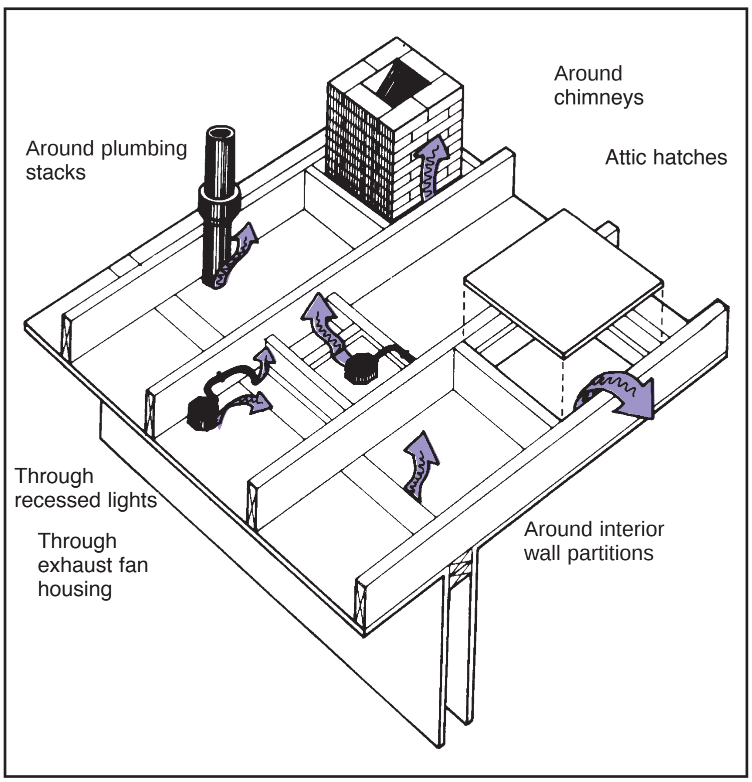


Fig. E-42: Potential air-infiltration/heat-leakage points in attics

- Skylights: Select a skylight that does not open or feature locking sashes. Seal window flashing to roof deck. Consider insulated window covering to reduce heat loss.
- Exhaust fans: Install exhaust fans with exterior spring-loaded backdraft dampers. Seal the fan duct where it connects to the fan housing and seal perimeter of box to gypsum board on attic side.

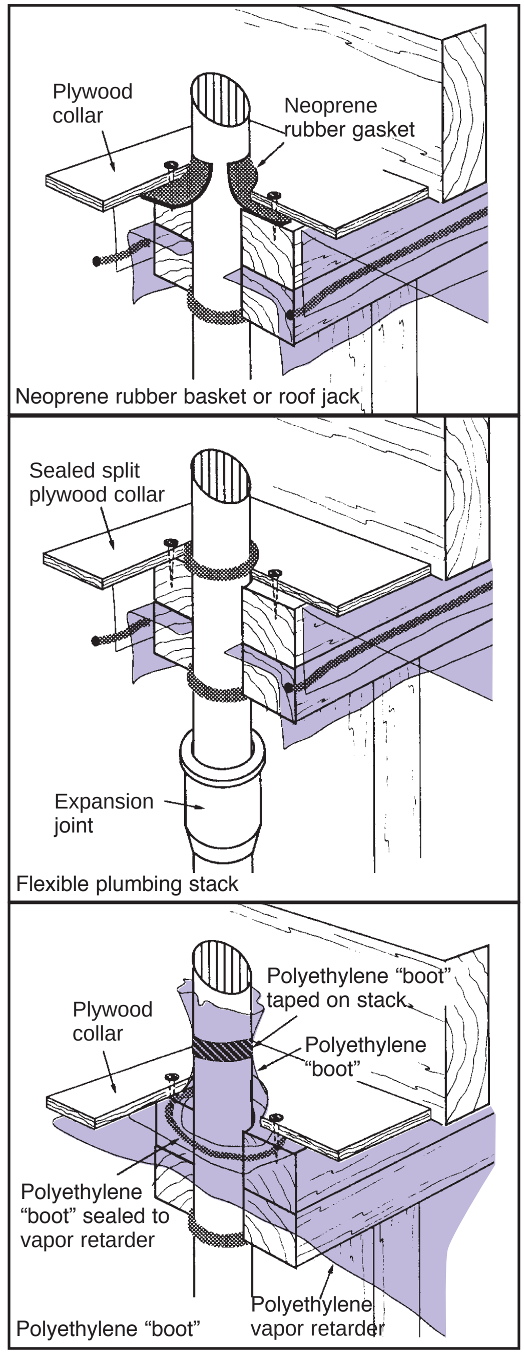


Fig. E-43a: Sealing vent stacks

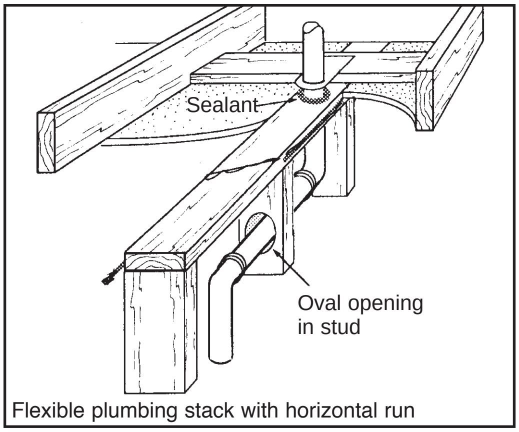


Fig. E-43b: Sealing vent stacks

- Recessed lights: Avoid use in cathedral or vaulted ceilings. In other ceiling areas, specify sealed fixtures or fabricate sealed boxes of rigid board or other scrap material as containers for the light housings. After the light housing is installed, seal wire penetrations and seal box to exterior side of ceiling.
- Kitchen/bathroom soffits, bulkheads, dropped ceilings: Insulate, install vapor retarder, and seal exterior walls before constructing and installing bulkhead, soffit, or dropped ceiling.
- Fireplace chimney connections: Seal with high-temperature sealant where chimney exits heated space (see Figure E-44).

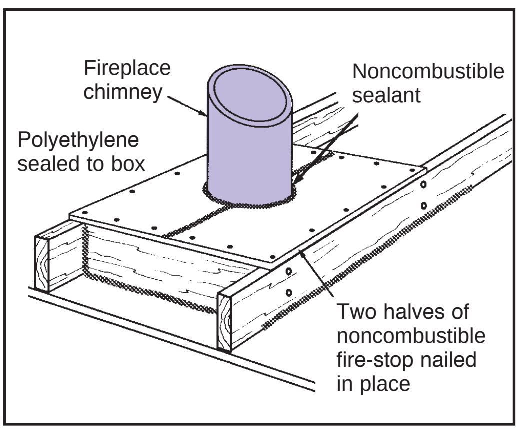


Fig. E-44: Sealing factory-built chimneys where they exit heated spaces

The movement of moist air

To help understand the role of air barriers and vapor retarders in controlling the movement of moisture, it is helpful to review some basic laws of physics.

Vapor diffusion is the movement of moisture in the vapor state through a material as a result of a vapor pressure difference or a temperature difference. Vapor diffusion occurs from areas of higher vapor pressure to lower pressure and from the warm side to the cold side. Vapor pressure is directly related to the concentration of moisture at a given location. The higher the relative humidity inside the house in winter, the greater the vapor pressure to get outside.

Vapor will move from an area of higher air pressure to an area of lower pressure only if there is a hole for it to go through. The greater the temperature difference, the greater the pressure for movement.

Heat loss always occurs from the warmer side to the colder side. The greater the temperature difference, the greater the heat loss.

Given these dynamics, there is pressure during the heating season to propel warm, moist air through the building shell to the outside. When moisture encounters a cold surface on its journey through the building shell, condensation can occur. If this situation occurs regularly, without the chance to dry, the possibility of structural damage to the building shell is increased and insulation effectiveness is dramatically reduced.

Air barriers (airflow retarders)

Air barriers keep outside and inside air out of the building envelope. They can be located anywhere in the building envelope – at the exterior surface, the interior surface, or any place in between. In heating climates, it is generally desirable to install both interior and exterior air barriers. Interior air barriers reduce the entry of moisture-laden air into the wall and ceiling, whereas exterior air barriers control infiltration of exterior air and wind washing through the insulation which degrades the effectiveness of the insulation.

Air barriers can be any type of material that is air impermeable, durable, and continuous. Plywood, OSB, building paper, styrofoam, polyethylene, and house wraps can all be used as air barriers.

Studies indicate that approximately 100 times more moisture enters the building shell by airflow than by diffusion.

Vapor retarders (vapor diffusion retarders)

The function of a vapor retarder is to reduce the entry of water vapor through building materials (e.g., drywall) and into building assemblies by diffusion. In heating climates, vapor retarders are installed on the interior or warm side of the insulation to prevent moisture diffusion through the drywall and into an insulated cavity. Vapor retarders should not be confused with air retarders because vapor diffusion and air transport of water vapor act independently of one another. However, some materials can be used as both (see Air/vapor retarders below). Vapor retarders are rated in "perms." The lower the perm rating, the less water vapor will go through it. Wisconsin State code requires an aboveground vapor retarder with a perm rating of 1.0 or lower. A 6 mil (six thousands of an inch) polyethylene has a perm rating of 0.1.

Humidity-controlled vapor retarder

A new type of vapor retarder appeared on the market in 2003. The material consists of a 2-mil-thick nylon-based high-tensile-strength sheeting which is as strong as a 6-mil sheet of polyethylene. It is being called the "smart vapor retarder" because it changes permeability according to relative humidity and can increase the drying potential of wall assemblies. Its moisture permeability varies from less than 1 perm at low relative humidity (such as during winter) to more than 20 perms at high (95%) relative humidity. This means that at higher humidity more moisture can escape. This is important because with higher moisture comes the greater possibility for mold formation and indoor air-quality problems. The goal of this system is to keep moisture from entering from the outside and to allow any air-carried moisture that is carried into the wall from the inside to dry out. This material is intended for use in heating and mixed climates, and is not suitable for cooling climates with high outdoor humidity or in buildings with high constant indoor relative humidity. Interior finish materials and cavity-fill insulation must also be highly permeable. This new product helps to reduce the risk and liability concerns due to excess moisture in homes and buildings.

Air/vapor retarders

Air/vapor retarders are materials that act as both air barriers and vapor retarders. A number of different products can be used as air/vapor retarders. The most common in use in Madison is a polyethylene membrane known as "visqueen," "plastic," or "poly." It is installed on the interior between the drywall and the framing.

A continuous application of the air/vapor retarder should be specified. Where overlaps or splices occur, the polyethylene should overlap a minimum of 16 inches (to the next stud or framing member). Always secure overlaps to framing members with staples. Ideally, seams created by overlaps should be taped or sealed with an acoustical sealant. The junction between the wall and ceiling should be sealed as well. Where penetrations occur (electrical outlets, fan housings, etc.), attach and seal the air/vapor retarder to the object making the penetration.

House wraps

House wraps are made from cross-woven, tear-resistant fibers that form very strong, flexible membranes and function as an exterior air barrier. They allow water vapor to exit to the exterior but prevent air or liquid water from entering from the exterior.

This material is literally wrapped around the house over the sheathing before the windows and doors and siding are installed. All overhangs and floors over unheated spaces should also be wrapped. Seams and tears should be sealed with a suitable tape or a flexible caulk before the windows, doors, and siding are installed.

House wraps are available through several different manufacturers and are typically sold in rolls of 9-feet wide by 100-feet long.

responsiblenergy

mechanicals

mechanicals

Heating

Efficiency and sizing

All central-heating equipment is rated for efficiency. Efficiency is expressed as AFUE (Annual Fuel Utilization Efficiency). The higher the AFUE rating, the more energy efficient the heating system.

Proper sizing matches the heating capacity of the equipment to the heat loss of the home. If the unit is sized properly, it should run 100% of the time at “design” conditions. In the Madison area, design condition sizing is based on an indoor temperature of 70ºF and an outdoor temperature of -13ºF, or a temperature difference of 83º.

Oversizing can cause uncomfortable temperature swings and the rated efficiencies will not be attained. Undersized equipment will not be able to maintain the desired design temperature on the coldest days.

Forced-air vs. hydronic heating

The choice of which system to choose is a difficult one. Each system has advantages and disadvantages (see Figure F-1). It is important to weigh the options and choose the system that best suits your home, your environment, your family, and your lifestyle. The most commonly used system in the United States is forced air; however, hydronic heating is gaining wider acceptance.

	Advantages	**Disadvantages**
Forced air	Less expensive to install Air is easily filtered and humidified	Noisier Requires furnace filters that need to be replaced regularly
Hydronic heating	Quiet Easily zoned No airborne dust	More expensive to install Separate system and ducting is required for cooling

Fig. F-1

Hydronic/boilers

Hydronic heat can be either a hot water boiler or steam generator. Boilers pump heated water through a network of piping to radiators where the heat is delivered. Boilers are rated by the same AFUEs as furnaces. Efficiencies in the 80% range are common, and boilers with efficiencies over 90% and sealed combustion are available.

Most Madison-area new homebuyers want central air-conditioning systems installed. Currently, about 80% to 90% of new homes nationwide include air-conditioning. This preference adds extra cost to a boiler system because separate ducts for delivery of cooled air may need to be installed.

Despite this disadvantage, boiler systems offer some distinct advantages:

- Boilers deliver comfortable, even, consistent heat distribution.
- Warm air doesn’t blow out of registers so there is less airborne dust, and homeowners comment that their homes are easier to keep clean.
- Boilers are quieter than their forced-air counterparts.
- They can be zoned to heat only portions of the home.
- In-floor and ceiling-radiant heating systems are possible options with a boiler. Radiant floor-heating systems employ a boiler and pumps to circulate warm water through flexible plastic tubing laid in loops underneath the floor. This type of heating works best under concrete, stone, tile, or hardwood floors. The plastic pipes can also be connected into heat transfer plates which can then be installed above the areas to be heated.

Forced-air furnaces

Forced-air furnaces (see Figure F-2) employ a powerful fan to push heated air through a system of ducts that distribute heat to all parts of the house. In the Madison area, natural gas forced-air furnaces are the most common equipment installed in new homes. The cost of heating with gas is relatively low, and high-efficiency levels can be achieved.

High-efficiency gas or condensing furnaces have an AFUE of between 90% and 96%. This means only 4% to 10% of the heat is wasted. By comparison, older forced-air furnaces have an AFUE of 55% to 65%. Lower or "mid efficiency" furnaces, also known as non-condensing, offer AFUEs from 78% to about 80%. Some mid- and high-efficiency furnaces offer additional features that provide greater comfort as well as additional energy savings. These are known as "two speed" or "variable heat output" or "variable capacity furnaces." Contractors normally offer a choice between mid- and high-efficiency furnaces. MGE recommends an AFUE rating of 90% or higher for forced-air natural gas furnaces.

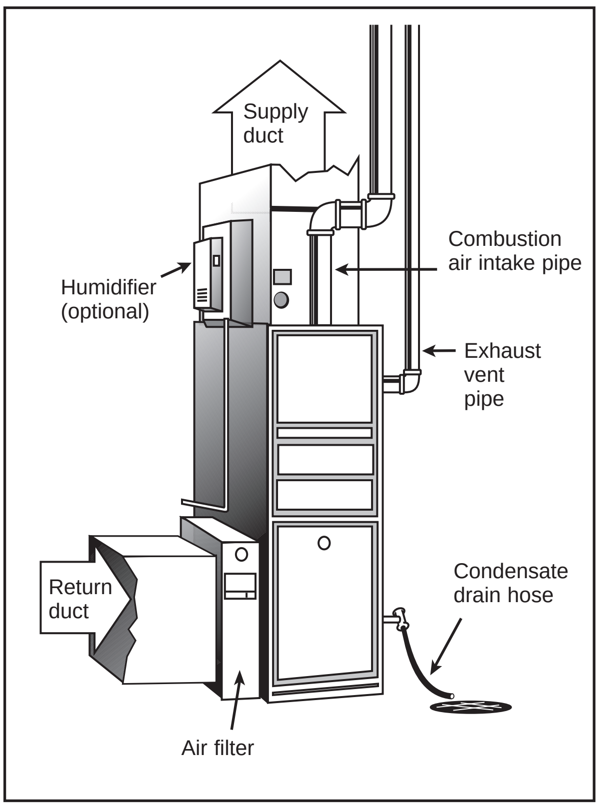


Fig. F-2: Condensing gas furnace

The least expensive forced-air system usually includes a single-stage furnace with a single-speed blower motor. The entire house is ducted as a single zone and therefore has just one thermostat.

A quality forced-air system would probably include a two-stage furnace with a variable-speed blower motor. The house would be separated into several zones with separate thermostats, and the air would be distributed through well-sealed ducts.

Variable heat output furnaces

These forced-air furnaces provide the ultimate combination of comfort, efficiency, and quiet performance. The blower motor uses direct current rather than the standard alternating current. These are normally called ECM motors. Variable heat output furnaces also have two-stage or variable gas valves with the lower input about 70% that of the higher input. On average, the lower stage operates 70% to 85% of the time. The blower automatically adjusts to match fan speed with the heat output. The result is quieter operation, slower airflow from registers, and better temperature control.

Hybrid furnaces

Hybrid furnaces, sometimes called dual fuel furnaces, combine a forced air furnace with an electric heat pump, which heats and cools the home. During moderate winter weather, heat pumps are more economical to operate than furnaces. As the temperature drops, a point is reached where the heat pump can no longer keep up with the heating demands economically and the pre-programmed thermostat automatically switches over to the gas furnace. A hybrid furnace generally costs from 30% to 50% more than a standard high-efficiency gas furnace and air conditioner but can save money depending on the cost of gas and electricity.

Standard furnace features

- Intermittent (pilotless) ignition. All high-efficiency furnaces come equipped with an intermittent ignition device. “Spark” or “hot surface” igniters are two types of intermittent ignition systems that have replaced wasteful pilot lights.
- Filters or air cleaners. You’ll have a choice of several levels of particulate removal with a forced-air furnace – standard fiberglass unpleated filter, pleated 1- or 2-inch thick filters, 9-inch deep-pleated filters, and electronic air cleaners (see Figure F-3). High-efficiency particulate air (HEPA) filters are also available. Filters reduce the amount of airborne dust, help avoid repairs by keeping the furnace clean, and the more sophisticated models provide a cleaner and healthier indoor environment. MGE recommends installing at least the 9-inch deep-pleated filters.
- Safety shutoff control. High-efficiency furnaces also feature a safety shutoff control as standard equipment. If the furnace malfunctions or if the combustion air intake becomes blocked, the furnace will automatically shut off.

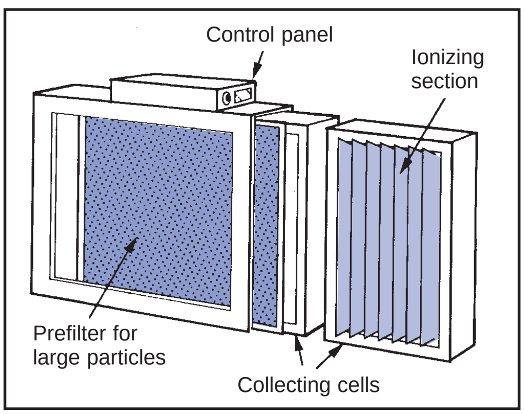


Fig. F-3: Electronic air cleaners

Optional furnace features

Features available as options when you select a new furnace:

- Programmable thermostats. Allow you to preprogram the temperature settings and times you want the furnace or air conditioner to operate. Wake up (or come home) to a comfortable home.
- Humidifiers. Automatic furnace-mounted humidifiers are available. A tightly constructed home retains more of the moisture produced by normal household activities so you may not need a humidification system. Humidifiers are mounted in the ductwork above the furnace and should be serviced yearly, as leaks can severely damage the furnace.
- Zoning. Allows the temperature in different areas (zones) of the house to be controlled by individual thermostats or sensors for increased comfort and efficiency. Mechanical dampers in the ducts control airflow to the different zones.
- Sealed combustion. Sealed-combustion furnaces use 100% outside air for combustion. The exhaust gases are vented directly to the outside without the need for a draft hood or damper.
- Many furnace manufacturers offer “dual certified” furnaces. This means the furnace can either be installed to draw combustion air from the inside or from the outside. Unfortunately, even when outside air is specified, truly sealed combustion is not possible because the combustion air pipe is not totally sealed to the combustion chamber.
- MGE recommends completely sealed combustion furnaces. 100% outside air:
    - Reduces the possibility of primary and secondary heat-exchanger damage due to corrosive household contaminants being drawn into the combustion chamber. Laundry products, paints, and solvents are all possible sources of contaminants.
    - Avoids using indoor air for combustion that you have already paid to heat.
    - Reduces the possibility of backdrafting (pulling exhaust gases down a chimney by means of a negative pressure).

Duct sealing

Sealing ducts can save energy but more importantly can improve comfort.

It is important to distinguish between duct leakage to the outdoors and leakage to conditioned spaces. In parts of the country where ducts are run through unconditioned crawl spaces, duct leakage has been shown to account for 15% to 30% of heating and cooling costs. In Madison, most homes have full basements and most ducting is within conditioned or semi-conditioned space. Little heat is lost to outside, but it may not get to where it is intended and there may be cold spots in the home. We recommend using a butyl-backed foil tape or water-based duct sealant to seal the duct seams and joints during installation. Common duct tape does not seal well and is not recommended.

Furnace installers are responsible to certify that the proper amount of heated air reaches each room. This is called "balancing" the system. If the system is not balanced properly, rooms closest to the furnace may be much warmer than rooms further away. We recommend you specify "balancing" the heating system.

If it is absolutely necessary to route ductwork through unheated spaces such as attics, crawl spaces, or garages, it is very important to pay special attention to sealing and insulating these ducts.

Other types of heating equipment

Electric resistance

Electric resistance heating systems are expensive to operate and rarely used for central heating in new homes in the Madison area. The cost to heat with electricity, given comparable homes, is about 200% to 250% greater than with natural gas.

Heat pumps

Heat pumps, which are refrigerant based, remove heat from one area and transfer it to another (a refrigerator is one type of heat pump). A heat pump can provide both heating and cooling for the home.

Conventional air-source heat pumps are not recommended for heating in the Madison area because they are usually more expensive to operate than a high-efficiency gas furnace. As the outside temperature drops, so does the efficiency of the heat pump. When the temperature drops below a certain point, usually around 27˚F, the system switches over to expensive electric resistance heat.

Recently, cold weather heat pumps were introduced into the market. At least two manufacturers are selling heat pumps that maintain better heating performance at lower outside temperatures than conventional air-source heat pumps. These low temperature optimized models make heat pumps more practical for cold climates.

Ground-source heat pumps (GSHP), sometimes called geothermal heat pumps, are an alternative because they use the relatively constant ground temperature as a heat source in winter and a heat sink in summer (see Figure F-4). There are two types of system configurations, closed loop and open loop. Closed loop systems circulate water or nontoxic antifreeze through plastic pipes buried below the frost line. Open loop systems can be installed in areas where an adequate supply of water is available (wells, ponds, or lakes) and open discharge is feasible.

In winter the liquid absorbs heat from the earth or water as it passes through the ground loop and then transfers that heat to the heat pump's evaporator and carries it to the relatively cooler ground or water. In summer, the liquid in the ground loop absorbs heat from the heat pump's evaporator and carries it to the relatively cooler ground or water.

Ground-source heat pumps are substantially more expensive to install than conventional heating systems. The trenching or drilling required is the main reason for the cost difference.

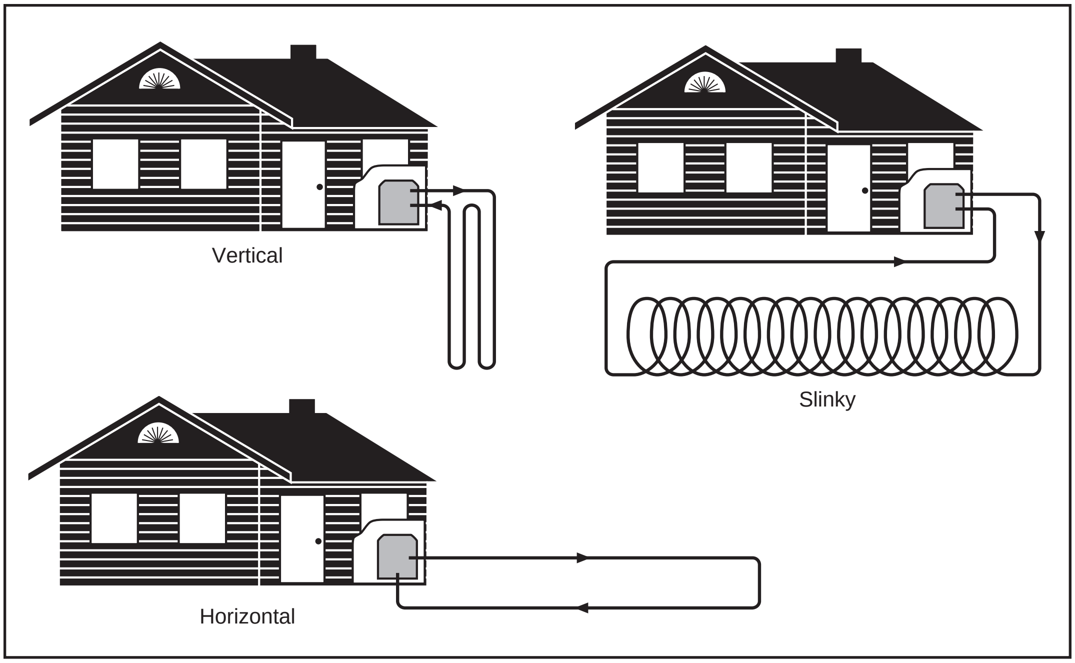


Fig. F-4: Ground-source heat pumps

Efficiency information on some different types of heat pumps:

- Air-source electric heat pump. Heating efficiency for air-source electric heat pumps is indicated by the heating season performance factor (HSPF), which is the ratio of the seasonal heating output in Btu divided by the seasonal power consumption in watts. Cooling efficiency is indicated by the seasonal energy efficiency ratio (SEER), which is the ratio of the seasonal heat removed in Btu per hour to the seasonal power consumption in watts. Look for the ENERGY STAR® label, which is awarded to those units with SEERs of 13 or greater and HSPFs of 8 or greater. The unit with the higher rating will be more efficient. These units are meant to be used in warmer climates and should not be used in cold climates such as Madison, Wis.
- Ground-source or water-source electric heat pumps. The heating efficiency of ground-source and water-source heat pumps is indicated by their coefficient of performance (COP), which is the ratio of heat output in Btu's per Btu of energy input. Their cooling efficiency is indicated by the energy efficiency ratio (EER), which is the ratio of the heat removed (in Btu per hour) to the electricity required (in watts) to run the unit. Look for the ENERGY STAR label, which indicates a heating COP of 3.0 or greater and an EER of 13 or greater.
- Gas-fired air-source heat pump. The efficiency of gas-fired air-source heat pumps is indicated by their COP. Look for the ENERGY STAR label, which indicates a heating efficiency of 1.2 COP or greater and a cooling efficiency of 1.25 COP or greater.

Integrated or combination systems

"Combo systems" use a single appliance such as a water heater or boiler for both space and water heating. The system, which consists of a heating module and air-handling module, works like a furnace and water heater. Together they provide high-efficiency home and water heating. They can be installed as a forced-air system or integrated with in-floor radiant heating.

Air-conditioning can also be added and works in the same manner as a standard furnace. The sealed combustion design uses 100% outside air to operate the burner. These units have a combined annual efficiency rating of around 90%. They also provide virtually unlimited hot water at an operating cost that is about 30% less than conventional water heaters.

Micro combined heat and power (MCHP) systems

A MCHP system, also called cogeneration, is comprised of a furnace and a small piston engine that runs on natural gas, propane, or oil, which produces electricity. The waste heat from the small engine can be used to supplement water heating or home heating.

MCHP is mainly a heating system so that in seasons you don't need heat, the machine turns off and you pay your utility for electricity, and during cold months it generates electricity for use in your home.

The sizes range from 1.2 kilowatts (kW) (1,200 watts) to 6 kW (6,000 watts). In a smaller home with average electric use, the 1.2-kW system can supply one-third to one-half of all electric use.

This technology has provided heat and electrical energy efficiently at commercial and industrial sites for many years. However, after hundreds of successful residential installations in Japan and Europe, several manufacturers are now offering models in the U.S.

Currently, the largest barrier to wide implementation is the high cost of these systems. The smallest system is about twice the cost of a standard high-efficiency furnace and the larger systems can be three to four times more expensive.

Fireplaces

A fireplace will probably be a consideration as you plan your new home. The decision to include a fireplace involves lifestyle, room appeal, and the expected value it will add. Fireplaces vary greatly in efficiency. Some wood and gas log fireplaces operate at very low efficiencies while a higher end direct-vent gas fireplace can be over 90% efficient.

Wood-burning fireplaces

There are various types and efficiencies of wood-burning fireplaces and stoves. From masonry open hearth to the most efficient wood stove, choose one that offers features such as safety, energy efficiency, and ambiance. In general, open hearth wood fireplaces waste 80% to 90% of the usable heat as exhaust and conventional wood stoves waste from 50% to 70%. These types of fireplaces are not recommended in a tightly constructed energy-efficient home because of the potential for backdrafting to occur. The only wood-burning fireplace that should be installed is one that has fully gasketed doors and 100% outside combustion air.

Consider the availability, the cost, and the inconvenience of wood. Seasoned firewood can be expensive and difficult to obtain. Firewood also has to be stacked and stored in a dry location and can be messy when moved from the storage area to the fireplace.

Burning wood releases carcinogens and other pollutants into the air. The smog and pollution caused by wood-burning fires has become an issue in some parts of the country. The Environmental Protection Agency (EPA) sets emission standards for wood stoves. (Some municipalities have standards that are more stringent and even regulate when stoves can be used.) The EPA regulations apply to freestanding wood stoves and fireplace inserts that have air-supply controls and tight-fitting doors.

What to look for:

- 100% outside combustion air. This reduces drafts and the competition for air with other exhaust appliances.
- Fully gasketed doors. In tightly constructed homes, fireplaces with fully gasketed doors are less prone to backdrafting when the doors are closed. If the doors are kept closed when the fireplace is not in use, cold outside air cannot be drawn back into your home via the chimney chaseway or through

the outside combustion air duct. Typical fireplace doors are not gasketed. While operating, the fireplace will draw up to 40% of the air needed for combustion from inside your home even if the outside combustion air duct is open.

- Catalytic combustor. These honeycomb discs are made of glass or ceramic with a thin metal coating. They usually are located near the top of the stove, just above the main fire area. When hot exhaust gases rise from the firebox, they pass through the combustor and react with the catalytic metal coating. As a result, the combustion temperature of the exhaust is lowered, which causes the gases to reignite. The wood burns once, and the exhaust burns again. The combustor has to reach at least 600°F to operate efficiently. But it can be damaged by direct exposure to flame. That's why modern combustor stoves include a flame deflector plate to protect the honeycomb disc. They decrease emissions by at least 30% and increase overall fuel efficiency at the same time by 30% or more. New models carry EPA approval, emit up to 90% less smoke than older models, and produce overall fuel efficiencies that range from 60% to 75%.
- Freestanding wood stove (see Figure F-5). Freestanding wood stoves are designed to radiate heat in all directions. A quality wood stove is equipped with a fully gasketed door, a catalytic converter, and outside combustion air. They require relatively little combustion air and can be dampered to sustain longer burn times. Combustion of seasoned hardwoods in a wood-burning stove is virtually complete, resulting in very little ash. A wood stove installed in a central location in conjunction with an open floor plan will provide much greater heating potential than a typical fireplace built into an outside wall.

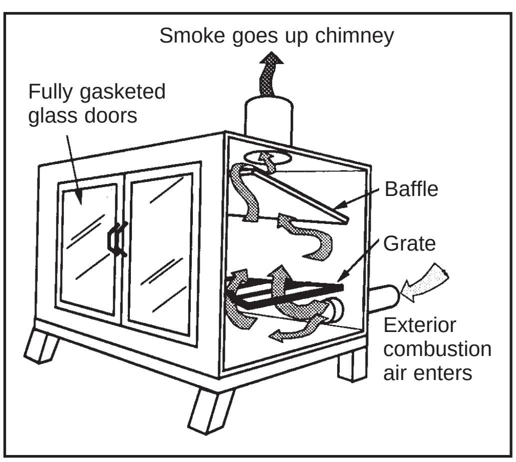


Fig. F-5: Energy-efficient wood stove

Natural gas fireplaces

Consider a natural gas fireplace as a clean and efficient alternative to wood-burning. Natural gas can be piped directly to the fireplace and is always ready when you want it. Also, it is safer for the environment and does not produce creosote to clog chimneys or smoke that can back up into your home.

Direct-vent gas fireplaces

This type of fireplace is best suited for todays tightly constructed energy-efficient homes. All openings are sealed with thermal or ceramic glass. No interior home heat can be lost through combustion in the direct-vent system. All oxygen for combustion is drawn down into the fire chamber through the exterior pipe of a double wall-venting system. All by-products of combustion are exhausted through the interior pipe of the system. Most direct-vent fireplaces will have efficiency ratings between 60% and 80%. A new entry into the direct-vent gas fireplace market improves the efficiency to over 90%.

What to look for:

- Ask about energy efficiency first. Most of today's gas fireplaces have an AFUE rating which takes into account all the energy used (gas and electricity) as the fireplace cycles on and off. This rating allows for a more accurate estimate of yearly operation. Another rating is the Steady State Efficiency rating, which measures their efficiency at maintaining a steady temperature in the area they are heating. As a rule, the Steady State Efficiency figures will always be higher than their AFUE figures and are not intended to estimate yearly cost of operation.

- Direct-vent design. Uses 100% outside air for combustion and can be vented directly through a sidewall. You avoid the added cost to run a chimney up through the roof.
- Electronic ignition system. Consider a gas fireplace that does not have a continuous pilot.
- Radiation-transparent ceramic glass front. Efficiently transfers radiant heat into the room.
- Variable setting control or turndown. Allows you to adjust the heat output by regulating the rate of gas consumption. Look for a model that has a wide turndown range. Turndown ranges can vary from only about 70% of full load to about 20% of full load.
- Automatic thermostat control. Helps keep room temperature constant by automatically adjusting the firing rate. Reduces energy consumption while maintaining comfort and continuous viewing pleasure.
- Secondary heat exchanger. Many units have a primary heat exchanger through which room air will naturally circulate by convection. Some units have a secondary heat exchanger that extracts more heat from the combustion gasses and transfers it to the room.
- Quiet variable-speed circulating fan. Blows heat from the heat exchanger into the room.
- Insulated outer casing. Prevents heat loss through the walls to the outside if located on an exterior wall.

Sizing

Sizing is determined by input and output ratings. The input rating is the amount of gas the fireplace can consume in one hour (Btu/h). The output rating is the amount of heat delivered to the house in one hour. For example, a 20,000 Btu/h input fireplace operating at 70% efficiency will provide the same amount of heat as a 40,000 Btu/h input unit operating at 35% efficiency and it will use only half the fuel.

High-efficiency direct-vent gas fireplaces are widely available. These fireplaces offer a means to significantly reduce energy use and CO2 emissions while maintaining a comfortable home with an attractive fire.

Pellet stoves, corn stoves, and multi-fuel stoves

Pellet stoves look similar to wood stoves or fireplace inserts, but instead of burning wood, they burn small pellets typically made from recycled wood shavings or sawdust. Although you can use pellets to run a whole house heating system, the fuel is more commonly used to feed fireplace inserts and freestanding stoves serving as supplemental heating appliances.

All pellet stoves have a hopper which typically holds one 40-pound bag of pellets. One bag should last about a day under normal operating conditions. A feeder device, like a large screw, drops a few pellets at a time into the combustion chamber for burning. How quickly pellets are fed to the burner determines the heat output. More advanced models have a small computer and thermostat to govern the pellet feed rate.

Like a modern gas appliance, pellet stoves use a draft-inducing fan to supply combustion air and vent combustion gases. The exhaust gasses can be vented horizontally through an outside wall, up through the roof or into a chimney with an approved chimney liner.

Regular maintenance includes daily hopper filling and checking/cleaning the burn pot to keep air inlets open and weekly or monthly ash removal depending on the type of unit and the fuel burned. Also, the flue vent should be cleaned seasonally to prevent soot building up, and unused pellets should be removed from the stove hopper and feed system at the end of the heating season.

It will be necessary to purchase the pellets in large amounts at a time to get the cheapest price. This means you'll need a place to store 2 to 3 tons of pellets (100 to 150 40-pound bags), which hopefully won't be too far away from the stove.

These stoves, under normal usage, consume about 100 kilowatt-hours (kWh) of electricity per month to run fans, controls, and the fuel feeders.

Corn stoves are designed for whole kernel, shelled corn combustion. Functionality and maintenance required are similar to that of a pellet stove. The chief difference between a pellet stove and a dedicated corn stove is the addition of metal stirring rod within the burn pot or an active ash removal system. An active ash removal system consists of augers at the bottom of the burn pot that evacuate the ash and clinkers. During a normal burn cycle, the sugar content within corn (and other similar bio-fuels) will cause the ashes to stick together, forming a hard mass. The metal stirring rod, which is usually connected to a motor by a simple chain system, will break apart these masses, causing a much more consistent burn.

Multi-fuel stoves can burn corn and pellets and can be adapted to burn other fuels, such as soy beans, olive pits, cherry pits, biomass fuel grains, and processed silage. While there is a push to create stoves that are able to burn multiple fuels with minimal adjustments, some pellet stoves are not designed to stir fuel and will not burn corn or other fuels.

Some of these stoves/fireplaces may save energy dollars when heating your home, but, do some calculations to see if staying with a natural gas home-heating system is more cost effective. You may be surprised to find out that a 90%+ efficient gas furnace will probably save you more money. See Appendix A for a table that compares the cost per million Btu's of usable energy for different fuels.

For these heating appliances to work as part of a system in a tightly constructed home, outside combustion air needs to be installed.

It is wise to first identify a reliable supplier of the fuel to be used before making a purchase. These heating appliances require time and attention to run properly. If you are someone who likes to "set it and forget it," then these are not for you.

Fireplace recommendations for a tightly constructed home

In a tightly constructed home, a direct-vented natural gas fireplace is your best option.

- Safety. You eliminate any possibility of backdrafting combustion gases into the living space.
- Energy efficient. Efficiencies range from 60% to over 90%. Outside air is used for combustion so air heated by your furnace is not escaping up the chimney.

Air-conditioning

Central air units efficiency

The efficiency of air conditioners is measured in relationship to the equipment's cooling and dehumidifying capabilities. Efficiency is stated in terms of the equipment's SEER. The higher the SEER, the more efficient the air conditioner.

The SEER changes with different condensing unit and coil combinations. Ask contractors to verify the SEER of the combination they recommend.

High SEER models usually offer:

- Top-of-the-line quality and features.
- Quieter operation.
- Better warranties.

MGE recommends installation of air conditioners with a minimum SEER of 13 (see Figure F-6).

Sizing

Like heating equipment, the air conditioner size depends on the volume of living space to be cooled, the amount and location of door and window glass, how well your home is insulated, and the tightness of construction. The heating

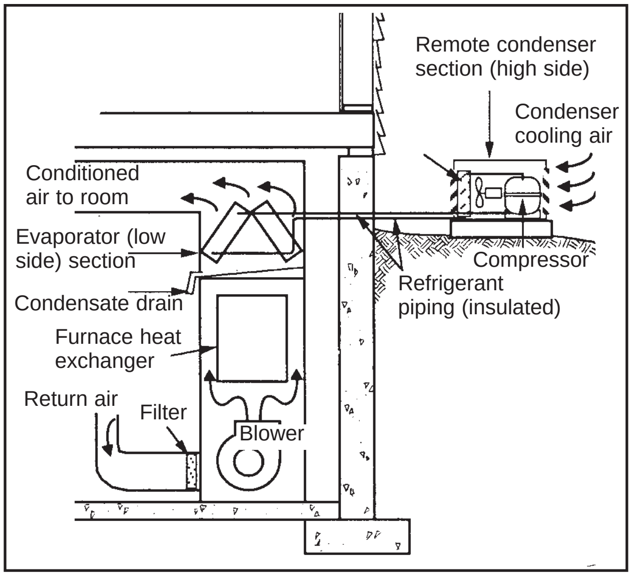


Fig. F-6: Air-conditioning system

contractor should "size" the air conditioner in relationship to these factors.

Central air conditioners are sized by the ton (1 ton = 12,000 Btu/h). Don't worry about contractor bids that differ by 6,000 Btu/h (or 1/2 ton). If the difference is a full ton or more, ask the contractors why they chose that size. Ask for a copy of their cooling load calculations.

Greatly oversizing the cooling system will jeopardize the energy efficiency you expect. An oversized air conditioner is capable of cooling down the house very rapidly, but the moisture or latent heat in the air does not get removed. This lingering moisture makes the air feel cold and "clammy." An accurately sized air conditioner will effectively remove latent heat and will cost you less to purchase and to operate.

A properly sized air conditioner will take a little longer to cool your home. If the air conditioner is off during a hot day, don't expect the air conditioner to lower the temperature by 20°F within an hour of the time you get home. Program your clock thermostat to start the air conditioner two to three hours before you get home.

When you know the weather is going to be hot and humid, make sure that doors and windows are closed. Keep window shades, blinds, and/or curtains drawn to prevent overheating from the sun. A thermostat setting of 78°F should maintain comfort.

In addition, your air conditioner, like your furnace, requires regular maintenance to function efficiently. Outside condenser coils should be checked periodically as well. Shrubs and bushes or fallen leaves should be kept from blocking airflow through the condenser coils.

Ductless systems (mini-split air conditioner)

They're called ductless because they use no ductwork or air distribution systems. Ductless systems are made up of two main components: the condensing unit (compressor), located outside the building, and the indoor fan unit(s), which is wall- or ceiling-mounted in the rooms they are to cool. Refrigerant lines connect the outdoor unit to the indoor unit(s). Models are available with multiple indoor fan units connected to one outside condensing unit. A typical indoor fan unit is 32 inches wide by 11 inches high by 7 inches deep and weighs about 18 pounds.

Other features:

- Wireless remote that allows you to control the entire system
- Thermostatic control
- Variable-speed blower
- Moving vanes to distribute the cool air evenly
- Built-in filters for removing larger allergen particles

Ductless systems can be a good solution for homes with hot water radiant heat (no hot-air ductwork). Depending on the number of fan units installed, these systems can be used for whole house cooling or for cooling just one room.

Water heating

In a typical American home, about 10% to 15% of the energy budget is used for heating water for showers, baths, cooking, laundry, and cleaning purposes. When choosing among different water heater models, it is wise to analyze the lifecycle cost – the total of purchase price and energy use during its estimated lifetime. A water heater may be more expensive to purchase, but if it's more efficient, it may cost less in the long run.

Water heater efficiency

A water heater's efficiency is measured by its energy factor (EF). EF is based on recovery efficiency, standby losses, and cycling losses. The higher the EF, the more efficient the water heater. Electric-resistance water heaters have an EF ranging from 0.7 and 0.95, gas water heaters from 0.5 to 0.65, heat pump water heaters from 1.5 to 2.0, and demand (tankless) water heaters around 0.8.

Each .01 increase in the EF would save about $4 per year at $1.00/therm. For example, for a family of four, a 40-gallon tank-type gas water heater with an EF of 0.65 would save about $20/year over the same water heater with a 0.60 EF.

Types of water heaters

There are four basic types of water heaters:

- **Conventional storage tank:** Offers a ready reservoir (storage tank) of hot water.
- **Demand (tankless or instantaneous):** Heats water as needed without the use of a storage tank.
- **Solar:** Uses the sun's heat to provide hot water and store it in a tank.
- **Integrated:** Combines both water-heating and space-heating into one appliance.

Conventional storage tank water heaters

Historically, storage tank water heaters have been used in the vast majority of new homes. Most have a 40- to 50-gallon tank. The temperature of the water is raised and maintained to usually between 120°F to 140°F. A 40- or 50-gallon water heater should easily meet the needs of a one- to four-member household.

If you plan to install a whirlpool bathtub or spa that requires 100 gallons or more of hot water, your plumbing subcontractor may suggest a large-capacity water heater. These water heaters are generally in the 80- to 120-gallon capacity range. Although many consumers make water heater purchase decisions based only on the size of the storage tank, the first-hour rating (FHR), provided on the EnergyGuide label, is actually more important. The FHR is a measure of how much hot water the heater will deliver during a busy hour. Before you buy a water heater, estimate your household's peak-hour demand and look for a unit with an FHR in that range. Beware that a larger tank doesn't necessarily mean a higher FHR or higher efficiency. Storage tank water heaters have an average life span of 7 to 12 years.

There are four basic types of gas-fired storage tank water heaters:

- Conventional. Conventional water heaters are vented into a chimney (see Figure F-7).

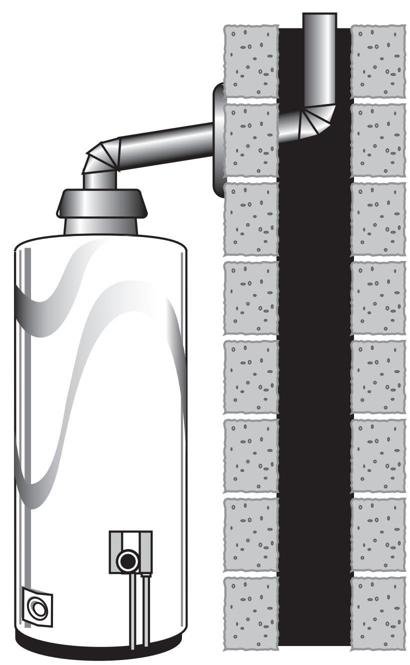


Fig. F-7: Conventional gas water heater

- Side-vented (vented straight out the wall using approved vent piping). There are two types: power-vent and direct-vent. Power-vent gas water heaters use a small fan to exhaust flue gases, and some models can be vented up to 45 feet. These water heaters need an electrical connection. Electricity for the fan costs only a few dollars per month for a family of four. Power-vent water heaters have safety shutoffs that turn off the burner if the fan fails to operate properly (see Figure F-8). Direct-vent gas water heaters use outside air for combustion. Concentric-pipe models need to be located near an outside wall and don't utilize an exhaust fan (see Figure F-9). Two-pipe systems permit combined horizontal and vertical venting runs up to 45 feet using PVC pipe and come with an electric venting fan.
- Integrated. These units combine water- and space-heating functions into one appliance. Most integrated water heaters provide large amounts of continuous hot water. Compare the cost and performance of an integrated heater versus separate furnace and water-heater units.
- Companion tank. This system heats the water in conjunction with another energy use, usually for space heating. If you will heat your house with a high-efficiency boiler, heat from the boiler is transferred to the tap water through an efficient water-to-water heat exchanger coil located either inside of the boiler or a separate storage tank. Companion tank water heaters have a very low operating cost and a long life.

There are two main types of electric storage tank water heaters to choose from:

- Conventional. To heat water, conventional electric water heaters use resistance-heating elements located inside the water tank. High-efficiency units feature more insulation to help reduce heat loss.
- Heat pump. These units use electricity to pull heat from the surrounding air to heat the water in the storage tank. Heat pump water heater systems typically have higher initial costs than conventional storage water heaters. However, they have lower operating costs, which can offset their higher purchase and installation prices. Heat pumps also have a beneficial dehumidifying effect (see Figure F-10).

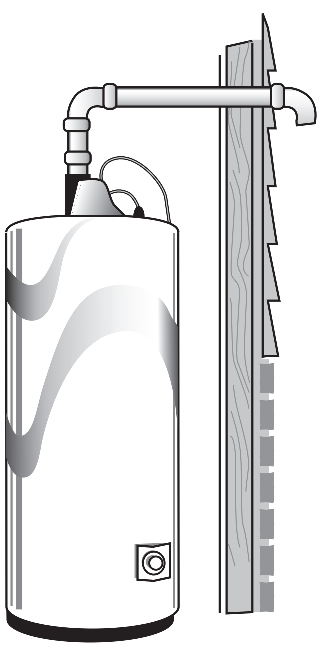


Fig. F-8: Power-vent gas water heater

Fig. F-9: Direct-vent gas water heater

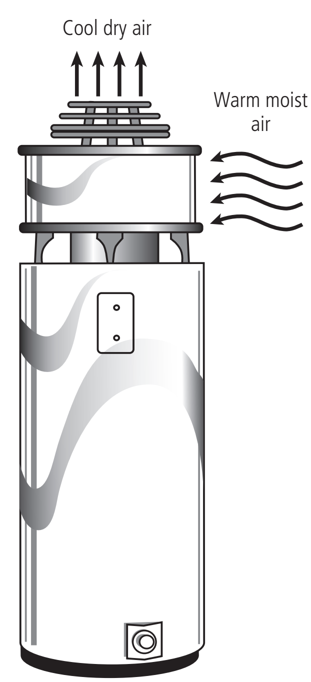


Fig. F-10: Electric heat pump water heater

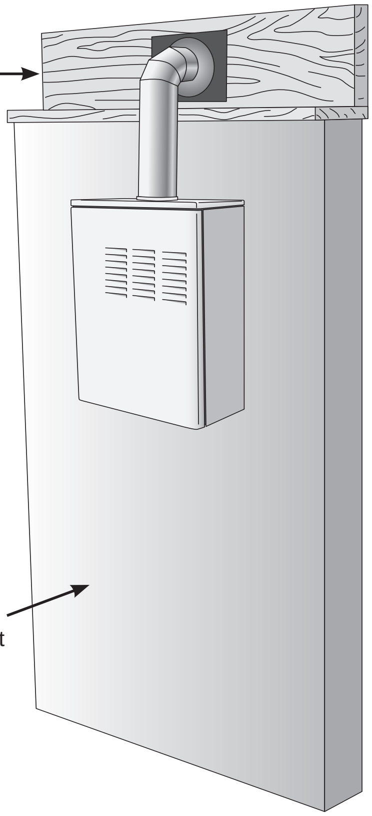


Fig. F-11: Demand water heater

Demand (tankless or instantaneous) water heaters

Demand water heaters are common in Japan and Europe. They began appearing in the United States in the late 1970s. Unlike storage tank water heaters, demand water heaters heat water only as it is used. When the hot water faucet is turned on, water is drawn through a series of coils passing over a heating element. As a result, only water needed on demand is heated (see Figure F-11).

Demand water heaters are available in propane (LP), natural gas, or electric models. They come in a variety of sizes for different applications, such as a whole house water heater or for a hot water source for a remote bathroom or hot tub. They also can be used as a booster for dishwashers, washing machines, and a solar or wood-fired domestic hot water system.

Demand water heaters:

- Have a life expectancy of about 20 years.
- Eliminate standby losses.
- Can save between 15% and 25% on operating costs over comparable tanks with the same fuel type.
- Must be used with a water softener if hard water is prevalent.
- Purchase cost is usually two to three times more expensive than comparable tanks.

Electric-demand water heaters are very efficient and take up very little space. However, they are about twice as expensive to operate as a gas unit and may require a larger electric service.

Solar water heating

A thermal solar hot water heating system can reduce water heating costs by 50% to 70% per year. Flat plate collectors are installed on the roof as a stand-off system or designed to blend into the roof line for a more aesthetically pleasing look. A typical system uses two 4x8 collector panels, an 80-gallon water storage tank, a heat exchanger, and a pump to move the heat transfer liquid through the system. The collectors should face directly south and receive full sun from 9 a.m. to 3 p.m. throughout the year and be positioned at an angle of 43° to 45° relative to the horizon.

Integrated water heating

There are two types of integrated or combination systems:

- Tankless coil
- Indirect

Tankless coil and indirect water heaters use a home's space heating system to heat water. They're part of what's called integrated or combination water- and space-heating systems.

Tankless coil water heaters use a heating coil or heat exchanger installed in a main furnace or boiler. Whenever a hot water faucet is turned on, the water flows through the heat exchanger. These water heaters provide hot water on demand without a tank, like a demand water heater, but because they rely on the furnace or boiler to heat the water directly, tankless coil water heaters work most efficiently during cold months when the heating system is used regularly.

Indirect water heaters offer a more efficient choice for most homes, but are more expensive because they require a storage tank. An indirect water heater uses the main furnace or boiler to heat a fluid that's circulated through a heat exchanger in the storage tank. The energy stored by the water tank allows the furnace to turn off and on less often, which saves energy. Therefore, an indirect water heater is used with a high-efficiency boiler and well-insulated tank can be the least expensive means of providing hot water.

Indirect systems can be fired by gas, oil, propane, electric, solar energy, or a combination of any of these. Tankless systems are typically electric or gas-fired. Also, these integrated or combination water heating systems not only can work with forced-air systems but also with hydronic or radiant floor heating systems.

Both of these systems usually cost more than a separate water heater and furnace or boiler, but installation and maintenance costs may be less and yearly energy costs may be lower.

To determine the energy efficiency of a combination water- and space-heating system, use its combined appliance efficiency rating (CAE). The higher the number, the more energy efficient the water heater. Combination appliance efficiency ratings vary from 0.59 to 0.90.

Ventilation

Obviously, you would like your new home to be a comfortable, healthy place to live. You want to breathe fresh air without pollutants, odors, or excess moisture, but you don't want uncomfortable drafts and high heating and cooling costs.

The increasing national concern about indoor air quality has led to new developments and attitudes about home building. They help justify the construction of tightly built, well-insulated homes that are centrally ventilated for health, comfort, and protection of your investment.

Indoor air pollutants

A primary source of indoor air pollutants comes from building materials used in the construction and decoration of your new home. Many of these materials contain chemicals which, through a process called "off-gassing," can contribute to poor indoor air quality.

Some typical volatile organic compounds (VOC) found in residences include formaldehyde, benzene, and toluene. They are used to manufacture particle board, carpets, vinyl flooring, paneling, upholstery fabric, floor varnish, adhesives, caulking, drywall, wallpaper, and paint. These materials can release VOCs for up to two years inside your home (see Figure F-12).

In addition, occupants of the home also contribute to indoor air pollution through the use of cleaning materials, arts and crafts, food preparation, and everyday housekeeping activities.

Besides pollutants that may be harmful to your health, there are unpleasant odors produced by everyday activities including hobbies, the disposal of food, some forms of cooking, the keeping of pets, and bathroom use.

Some individuals may be sensitive to these pollutants but may not realize it until they move into a new home. If you feel you may be sensitive or allergic to VOCs, specify no- or low-emitting building materials.

Moisture

Everyday activities that produce large amounts of moisture within the home include cleaning, cooking, bathing, washing dishes and clothes, animal and plant care, and exhaling. If not controlled in some way, this moisture can accu-

Pollutant	Description	Health Effects	Sources In Houses	Ways to Reduce Exposure
Radon	Odorless, colorless, radioactive gas, a decay product of radium, occurs naturally in the Earth's crust.	Believed to be responsible for 5% to 20% of all lung cancers.	Air infiltration from the ground beneath the home, well water, construction products (e.g., concrete, stone).	• Increase ventilation – Install a whole house ventilation system – Install sub-slab ventilation • Seal cracks and openings in basement.
Formaldehyde	Strong-smelling, colorless, water-soluble gas, a component of some glues used in making plywood, particle board and textiles.	Nose, throat, and eye irritation, possibly nasal cancer.	Outgassing from synthetic materials such as particle board, plywood, furniture, drapes, and carpets.	• Specify materials that do not contain formaldehyde.
Carbon monoxide	Colorless, odorless, tasteless gas released during combustion.	Lung ailments, impaired vision and functioning. Fatal in high concentrations.	Kerosene heaters, wood/gas-burning fireplaces, unvented gas appliances, attached garages.	• Vent fireplaces properly. • Do not use unvented appliances. • Learn how to properly operate all appliances. • Ensure attached garages are sealed away from living spaces.
Nitrogen dioxide	Colorless, odorless, tasteless gas formed during combustion.	Lung damage, lung disease after prolonged exposure.	Unvented combustion appliances.	• Do not install unvented appliances.
Particulates	Tiny particles known as respirable-suspended particulates (RSPs).	Lung cancer, emphysema, heart disease, irritation of respiratory tract, respiratory infections.	Tobacco smoke, wood smoke, unvented appliances, kerosene heaters.	• Be sure venting systems are leakproof. • Do not install unvented appliances. • Install air-filtration system. • Clean/change air filters regularly.

Fig. F-12: Indoor air pollutants, potential health effects, and ways to reduce exposure.

mulate rapidly in your home. The first sign of high moisture levels might show up in late autumn as condensation on your windows. Or it might show up in the basement as a musty smell or damp spots on the walls or floor.

Moisture levels are usually much greater in a new home since building materials are in the process of drying out. This includes the concrete in the basement, which releases moisture as it cures for up to two years after construction. In many cases, moisture problems in new homes will persist beyond this so-called drying out period.

Indoor air pollutants, excessive moisture, and unpleasant odors can be easily controlled by specifying the installation of a whole house ventilation system.

Air infiltration or whole house ventilation?

Many question the value of whole house mechanical ventilation systems. They contend that a house can be built too tightly and that houses should be loose enough to "breathe." When this philosophy is applied to the construction of new homes, problems with moisture and air pollutants may develop, and these homes will cost more to heat and cool. Since air infiltration can account for as much as 30% of heating and cooling costs, you can expect to pay more annually on utility bills if you adhere to this philosophy.

For clarification, the difference between "natural" and "mechanical" ventilation should be explained to point out a com-

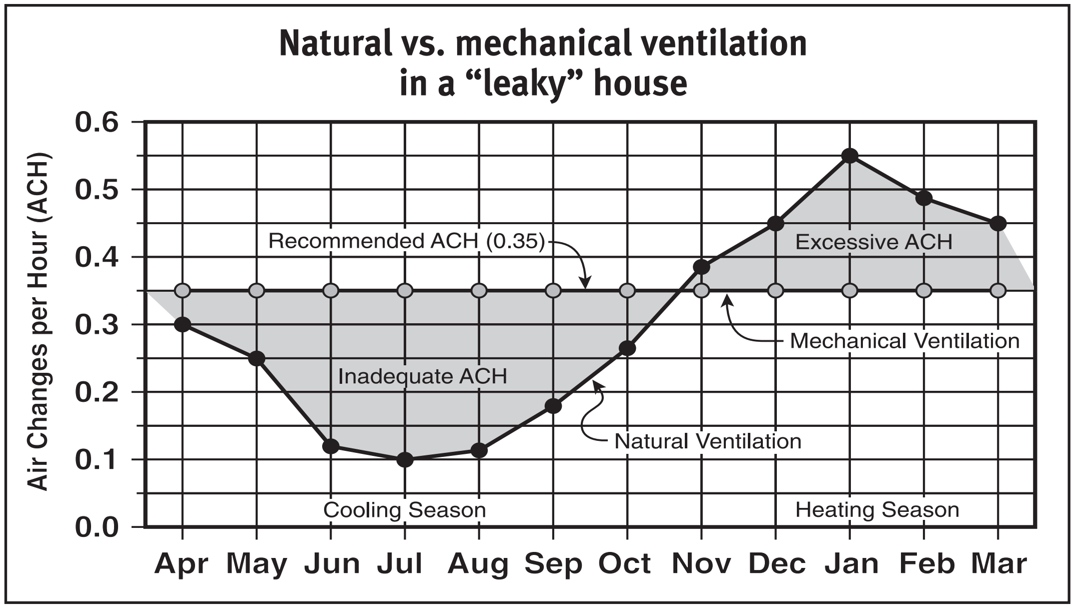


Fig. F-13: There is less air change in summer resulting in stale air and poor indoor air quality. More air change in winter causes dry interior air and excessive energy bills.

mon misconception. It is largely assumed that if the home's natural ventilation rate is found to be 0.35 ACH (the recommended air change per hour), then ventilation will be adequate. In truth, it will be inadequate.

Natural ventilation refers to the average yearly air change rate of the house as influenced by wind, temperature differentials, and occupancy. In a leaky house, the natural ventilation rate is very low during mild weather and very high during cold weather (see Figure F-13). In the winter months, excessive ACH causes drafts, lower-than-recommended humidity levels, and higher heating bills. In the fall and spring, there is not enough ACH to ensure good indoor air quality and moisture can build up.

Mechanical ventilation is constant and can be relied on to assure good indoor air quality and control moisture levels. It is accomplished by employing some type of fan system to ventilate the house.

This is a good example of the "whole house" philosophy where different parts of the house interact with each other to form a working system. If the house is loosely constructed, adding a ventilation system is of little value and it will be drafty and less comfortable to live in. If the house is tightly constructed with no ventilation system, chances are there will be moisture and indoor air-quality problems.

Control your living environment

Finally, there is the issue of control. The basic concept of shelter, the reason we build homes, is to provide control over our living environment. Most homeowners take control of heating and cooling their home for granted. Control of ventilation is also important.

A ventilation system gives you control of when, where, and how much ventilation you want.

We recommend you construct your new home as tightly as possible and install a whole house, balanced, heat recovery, mechanical ventilation system ("Build Tight, Ventilate Right").

Filtration

Filtration devices are intended to remove pollutants from indoor air. This discussion concentrates on devices designed to be installed in the ductwork of a home's central heating, ventilating, and air-conditioning (HVAC) system to clean the air in the whole house. Portable room air cleaners can be used to clean the air in a single room or specific areas, but they are not intended for whole house filtration.

Indoor air pollution is among the top five environmental health risks. In reference to the previously mentioned three-pronged approach to good indoor air quality, the first step is to control or eliminate the sources of pollutants and to ventilate a home with clean outdoor air. The ventilation method may, however, be limited by weather conditions or undesirable levels of contaminants contained in outdoor air. If these measures are insufficient, an air cleaning device may be useful.

There are several types of air cleaning devices available; each designed to remove certain types of particles and pollutants.

Two types of air cleaning devices can remove particles from the air – mechanical air filters and electronic air cleaners. **Mechanical air filters** remove particles by capturing them on filter materials. High-efficiency particulate air (HEPA) filters are in this category. **Electronic air cleaners** such as electrostatic precipitators use a process called electrostatic attraction to trap charged particles. They draw air through an ionization section where particles obtain an electrical charge. The charged particles then accumulate on a series of flat plates called a collector that is oppositely charged.

Gas-phase air filters remove gases and odors by using a material called a sorbent, such as activated carbon, which adsorbs the pollutants. These filters are typically intended to remove one or more gaseous pollutants from the air stream that passes through them. Because gas-phase filters are specific to one or a limited number of gaseous pollutants, they will not reduce concentrations of pollutants for which they were not designed. Some air cleaning devices with gas-phase filters may remove a portion of the gaseous pollutants and some of the related hazards, at least on a temporary basis. However, none are expected to remove all of the gaseous pollutants present in the air of a typical home. For example, carbon monoxide is a dangerous gaseous pollutant that is produced whenever any fuel such as gas, oil, kerosene, wood, or charcoal is burned, and it is not readily captured using currently available residential gas-phase filtration products.

Some air cleaners use ultraviolet (UV) light technology intended to destroy pollutants in indoor air. These air cleaners are called ultraviolet germicidal irradiation (UVGI) cleaners and photocatalytic oxidation (PCO) cleaners. Ozone generators that are sold as air cleaners intentionally produce ozone gas to destroy pollutants. Ozone, however, is a lung irritant that can cause adverse health effects and is therefore not recommended.

- **UVGI cleaners** use ultraviolet radiation from UV lamps that may destroy biological pollutants such as viruses, bacteria, allergens, and molds that are airborne or growing on HVAC surfaces (e.g., found on cooling coils, drain pans, or ductwork). If used, they should be applied with, but not as a replacement for, filtration systems.
- **PCO cleaners** use a UV bulb, along with a substance called a catalyst that reacts with the light. They are intended to destroy gaseous pollutants by converting them into harmless products, but are not designed to remove particulate pollutants. UV bulbs must be replaced about once a year.
- **Ozone generators** use UV light or an electrical discharge to intentionally produce ozone. Ozone is a lung irritant that can cause adverse health effects. At concentrations that do not exceed public health standards, ozone has little effect in removing most indoor air contaminants. Thus, ozone generators are not always safe and effective in controlling indoor air pollutants. Consumers should instead use methods

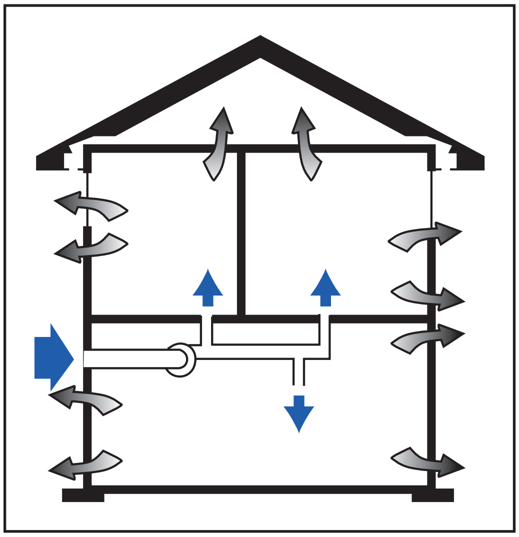


Fig. F-14: Supply-only system

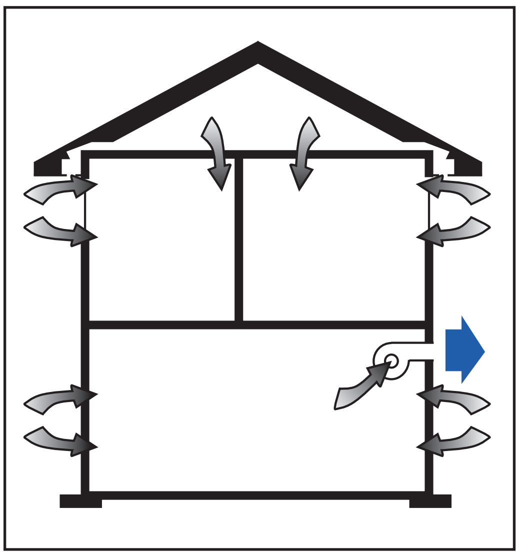


Fig. F-15: Exhaust-only system

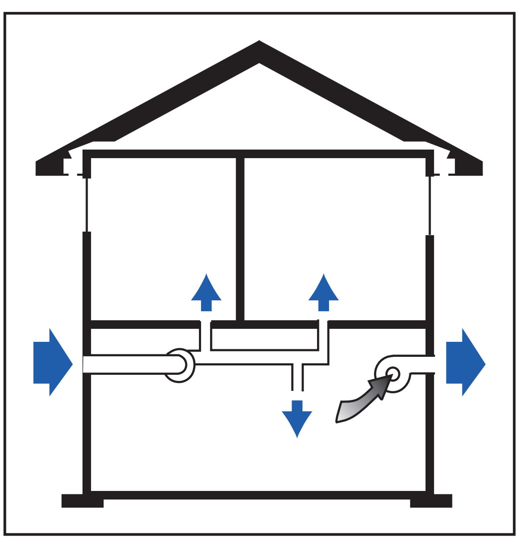


Fig. F-16: Balanced system

proven to be both safe and effective to reduce pollutant concentrations, which include eliminating or controlling pollutant sources and increasing outdoor air ventilation. Visit www.epa.gov/iaq/pubs/ozonegen.html for more information on ozone generators sold as air cleaners.

Whole house ventilation systems

The purpose of a whole house mechanical ventilation system is to provide a regular supply of clean, dry air to all areas of your home and exhaust stale, polluted air and moisture. Fresh, dry outside air can be supplied to the house by:

- Venting outside air directly to the cold-air return on the furnace.
- Through air inlets installed in the walls.

Removal of pollutants and moisture is accomplished by installing exhaust ducts (pickups) to all bathrooms, the kitchen, and a main living area. A 2,400-square-foot home would have three to four exhaust pickups but could have more depending on the number and location of bathrooms or other ventilation needs.

Whole house ventilation systems can eliminate the need for dedicated bathroom exhaust fans, but an outside-vented exhaust fan is still recommended in the kitchen for rapid removal of odors and excess moisture (see Spot ventilation). Whole house exhaust pickups located in the kitchen should not be placed over cooking appliances and, as a general rule, should be placed a minimum of 6 feet away from them to prevent grease from being drawn into the system.

Whole house ventilation can be accomplished in a number of different ways, from a simple in-line centrifugal fan system to the more elaborate heat recovery ventilator.

There are three basic types of whole house ventilation systems:

- **Supply-only.** A supply-only system (see Figure F-14) creates a positive pressure within the house. Fresh air is pushed into the house forcing stale air out through chimneys and unintentional openings in the building shell. This type of system minimizes the possibility of backdrafting and ensures that contaminants like radon are kept out of the living space. However, the positive pressure forces moisture-laden interior air into cracks in the building shell and leads to concealed condensation in the walls and attic. The cold air pumped into the house during the winter may cause discomfort to occupants unless it is preheated and properly distributed throughout the house. For these reasons, a supply-only system is not recommended.

- **Exhaust-only.** Exhaust-only systems (see Figure F-15) employ a centrally located exhaust fan and ducted exhaust pickups to remove air from moisture/pollutant-producing areas in the house. There are a variety of exhaust-only systems. One of the most popular and effective is the centrifugal in-line fan. The unit is installed in the basement or attic for extremely quiet operation. Two or three stale air "pick-ups" are placed in bathrooms and the general living area. Another type is the multiport exhaust-only system. These systems have one exhaust port and three or four ports that are ducted throughout the house to pick up stale air. Most operate at two or more speeds. Several manufacturers sell complete kits with all the ducts and accessories. These may cost a bit more, but the kits simplify installation.

  As these systems exhaust stale air, the house becomes negatively pressured. Negative pressure induces fresh air into the house through leaks around doors and windows, sill areas, and outlets. When other exhaust appliances are operating at the same time (dryer, central vacuum, and Jenn®-air type ranges), drafts and cold spots develop that may increase your heating bill.

  If the negative pressure is great enough, backdrafting occurs. In other words, more air is exhausted from the house than is supplied to the house. Smoke, moisture, and combustion gases can be drawn back into the house through the water heater, furnace, or fireplace chimneys creating a potentially hazardous situation. In some situations, the negative pressure may increase the possibility that radon gas will be drawn from the soil into the house.

  Exhaust-only ventilation systems in tightly constructed homes need a source of makeup air or pressure-balancing measures. This ensures proper operation of the system and avoids the possibility of backdrafting.

- **Balanced.** There are two types of balanced systems: heat recovery and non-heat recovery. Both types bring in as much air as is exhausted. This ensures the same amount of fresh air supplied as stale air exhausted (see Figure F-16). A balanced system maintains a neutral pressure inside the house.

Features of balanced systems

There are two types of balanced systems:

Heat-recovery systems. These systems have been referred to as air-to-air heat exchangers but are more commonly known as heat-recovery ventilators (HRVs) or energy-recovery ventilators (ERVs).

The heart of these systems is the heat-exchanger core. Its function is to transfer heat from the exhaust air to the supply air without letting the air streams mix. During the cold months, fresh, dry, outside air is brought into the house through the HRV and is preheated by the warm, stale air as it passes through the core. The fresh air is distributed to the house and the stale air is exhausted to the outside. Approximately 75% of the heat that would normally be exhausted is recovered from the stale air.

One of the main drawbacks of air-to-air heat exchangers, compared to other ventilation strategies, is their cost. The installed cost of a unit, depending on house size, can be approximately $1,500 to $3,000. A manufacturer located in Madison, Wis., designed a unit for residences under 2,700 square feet that is as effective as other units but is about half the cost and installs in less than half the time required for other air-to-air heat exchangers. This unit is designed to be used with

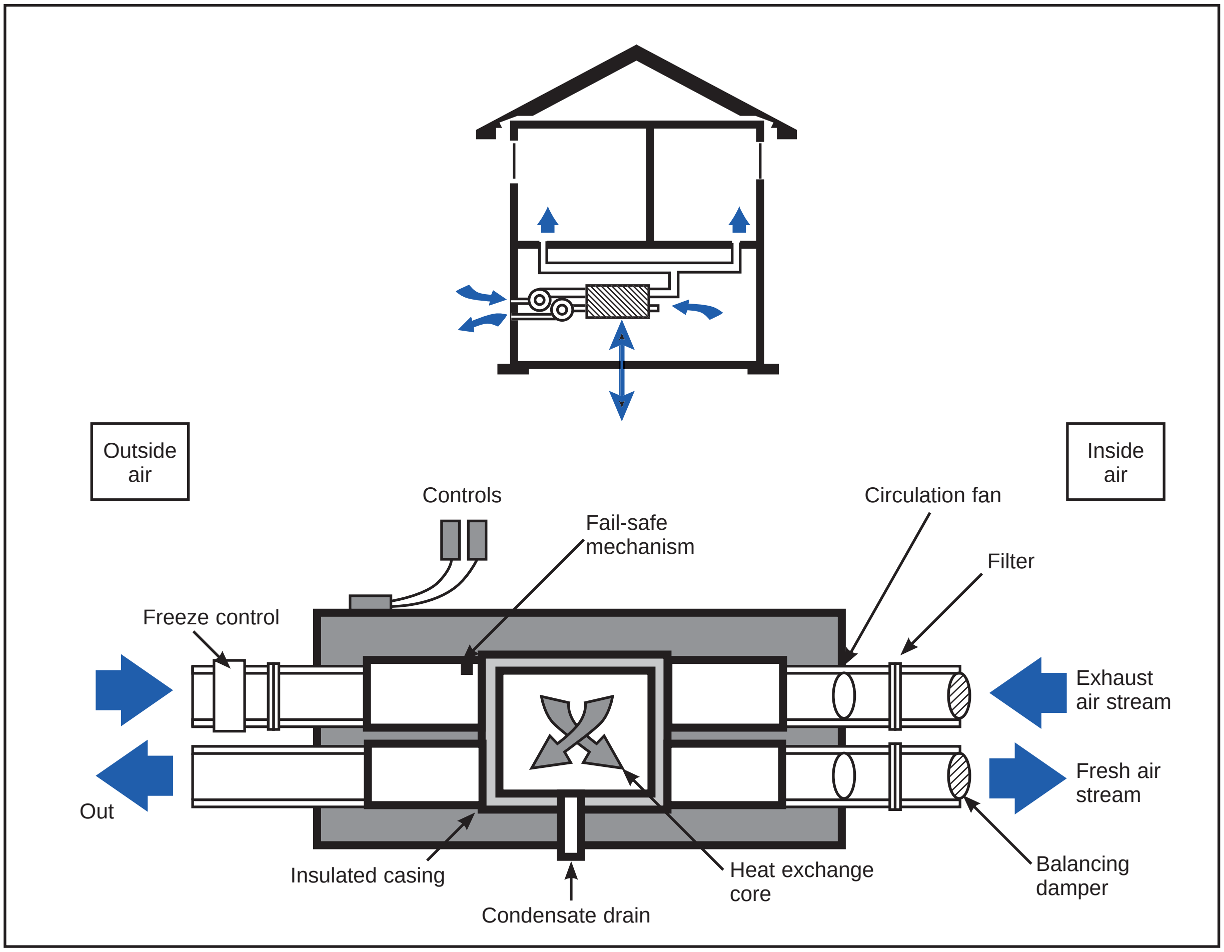


Fig. F-17: Typical AAHX system

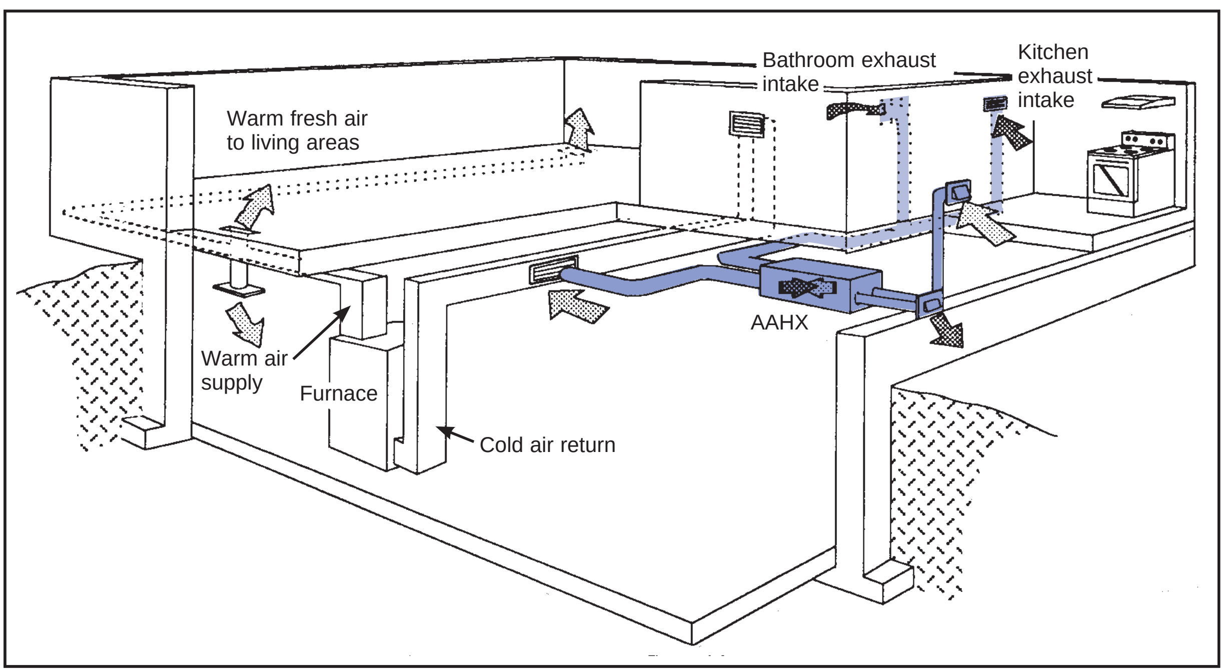


Fig. F-18: AAHX with fresh air supplied to furnace cold-air return a furnace with an electronically commutated motor (ECM). It uses the furnace fan to pick up stale air and distribute fresh air. It costs about 75% less to run an ECM fan than the standard furnace fan. This unit can be installed directly onto the cold-air return, eliminating the need for fresh air and stale air pickup ducting.

HRVs use a heat exchange core made of aluminum or plastic which exhausts 100% of the moisture in the air being exhausted. This can be good in very humid situations but has the drawback of requiring a defrost strategy to counter freeze-ups. In winter, the water vapor from the exhaust air of an HRV can freeze the core and the outdoor exhaust vent. When this happens, ventilation ceases until the core is defrosted. Some systems have an electric heating element for defrosting the exterior vent and some use a bypass strategy where an automatic damper cuts off the outside air and indoor air is circulated through the unit until the frost is gone.

An ERV has a unique heat-exchange core that not only transfers temperature across the plate, separating the two air streams, but also transfers water vapor based on the absolute humidity difference between the two air streams. There are also rotating wheel-type ERVs which use desiccant materials to transfer humidity.

ERVs also operate without condensation or frosting in almost all conditions, eliminating the need for condensate pans and drains and defrost cycles in most applications. If you run an air conditioner in the summer, an ERV generally offers better humidity control than an HRV and can save money on air-conditioning costs.

Non-heat-recovery systems. These systems are the same as the heat-recovery systems except they don't employ a heat-exchanger core. They provide balanced whole house ventilation but no heat is recovered. Although the initial expense of these systems is lower than an HRV, the long-term cost is higher. We recommend the heat-recovery method of ventilating (see Figure F-17).

Most balanced systems supply fresh incoming air directly into the cold air return on the furnace where it is preheated before being distributed through the ducts to all parts of the house (see Figure F-18). A system of dedicated stale air pickups is installed during rough framing in moisture-producing areas in the house.

When a boiler is specified as the heating system, individual supply air ducts are installed. This configuration is more effective in terms of supplying fresh air to the house (as opposed to using the furnace ducts) but costs more to install.

Ventilation system controls

For either a balanced or exhaust-only system, there are a few controls to choose from. The recommended control is a proportional or percentage runtime control where you set a dial to the percentage of time you want the system to run. For example, if you set it to 50%, the system will run 30 minutes out of every hour.

Another strategy is using a clock timer to centrally control the system. Either a 24-hour or 7-day timer can be used. Clock timers allow routine ventilation depending on your needs and/or lifestyle.

Dehumidistats will also work as a central control but need to be more closely monitored in relation to the weather conditions. Dehumidistats are governed by moisture in the air, so setting it to 40% will activate the system when relative humidity is greater than 40%.

Bathrooms are typically individually controlled by installing "twist" timers (15-minute to 60-minute timers are common). Twist timers activate the ventilation system as needed if the central control is off cycle. And some systems have the potential of boosting the ventilation system to a high speed for faster removal of moisture. Twist timers work well in darkrooms, bedrooms, sun spaces, hobby areas, or for other areas that need individual ventilation.

Ventilation system sizing

Ventilation systems are sized to the volume of living space. They should have the capacity to supply your home with an amount of fresh air that is adequate for your lifestyle.

The capacity of a ventilation system is measured in ACH. The system should be able to ventilate the house to 0.35 ACH. For example, to supply 0.35 ACH for a 2,000-square-foot house, the HRV would need to supply at least 93 CFM. The formula is volume x 0.35 divided by 60 minutes. At this rate, the ventilation system would completely replace the air in your home about every three hours. This air-change rate ensures fresh air and a healthier environment.

With any ventilation system, the relative humidity should be monitored to determine whether any changes should be made to the ventilation rate. A good quality humidity gauge will help determine whether the ventilation rate should be changed.

"Spot" ventilation

Also known as "point source" ventilation, it is accomplished by the installation of exhaust fans at spots in the house where moisture or unpleasant odors are produced. These areas include the kitchen, bathroom, and occasionally enclosed laundry areas. While spot ventilation is important for ridding these areas of unpleasant odors, excess moisture, and other pollutants quickly, standard exhaust fans do not have the capacity in most cases to remove polluted moist air equally from all other areas of the house.

If you don't install a whole house mechanical ventilation system, specify outside-vented exhaust fans in all bathrooms and in the kitchen instead. Ideally, exhaust fans should have sone (sound level) ratings of 1.5 or less to ensure quiet operation.

It also is important to make certain that the fans are sized correctly. We recommend fans with a minimum capacity of 100 CFM of air movement for average-sized bathrooms and 50 CFM for small bathrooms or powder rooms. Bathrooms with whirlpool tubs should have fans with a capacity of 150 CFM or more. Your kitchen should be equipped with an exhaust fan rated at a minimum of 150 CFM. Down-vented or island-type kitchen exhaust fans are capable of moving large amounts of air (in some cases from 200 to 900 CFM).

If you plan to install a range hood, specify it be vented to the outdoors. Recirculating-type fans move air around but do not provide any ventilation.

MGE ventilation recommendations

Effective ventilation cannot be overemphasized for a tightly constructed, energy-efficient home. We recommend installing a whole house balanced heat-recovery ventilation system that is properly sized to your home. It should meet ventilation codes and industry standards and be reflective of your living habits.

For more information about ventilation or ventilation systems, call 252-7117.

responsiblenergy

appliances

appliances

Home appliances consume approximately 25% to 35% of all electricity produced in the United States. Now that you've made your home energy efficient, continue that efficiency through the purchase of energy-efficient appliances. To compare the efficiencies of new appliances, look for the yellow and black EnergyGuide label.

Here are some appliance selection tips.

Refrigerator and freezer

Compare those EnergyGuide labels! There can be up to a 50% difference in electricity costs for the same size refrigerator over its 15-year life. That's equal to about $900! The following amenities require more electricity:

- Side-by-side doors
- Automatic defrost
- Through-the-door water/ice dispensers

Chest freezers use less electricity than upright freezers. Locate your refrigerator out of direct sunlight and away from the range and dishwasher.

Range, oven, and microwave

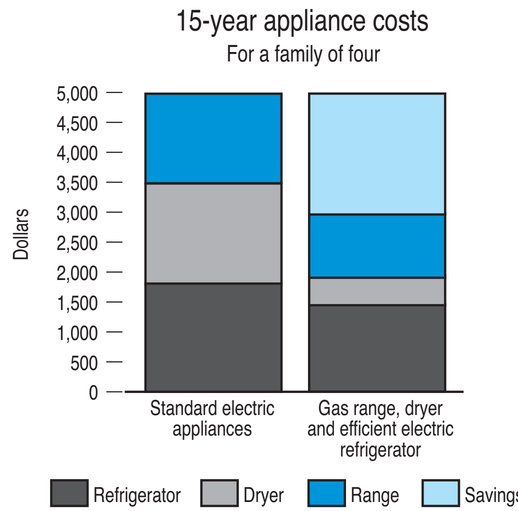
Cooking with natural gas costs at least 50% less than electricity. Microwave ovens are more efficient than electric ranges or electric ovens. Place them away from your refrigerator.

Dishwasher

Choose one that has a water-heating booster element and a short cycle. Locate it away from your refrigerator.

Clothes washing machine

Wash clothes in cold water, and use detergent designed for cold water. Front-loading models use less energy and less water than top-loading models.



Look at the savings with gas!

Dryer

Drying clothes with gas costs at least 50% less than electricity. Invest in a model with a moisture-sensing cycle. It will automatically turn off when your clothes are dry.

Look for this symbol when you shop

ENERGY STAR® labeled products use less energy than other products. They reduce your energy costs and help to protect the environment. We're an ENERGY STAR partner. Learn more about qualifying products at www.energystar.gov or call MGE at 252-7117.

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responsiblenergy

lighting

lighting

Lighting

It's hard to imagine that lighting is a significant portion of your energy bill. After all, how much energy can a light-bulb use? In the average household, lighting constitutes approximately 15% of total energy consumption (see Figure H-1). If you want an energy-efficient home, specify energy-efficient lighting during the planning stage. Energy-efficient lighting can reduce lighting costs by up to 75%.

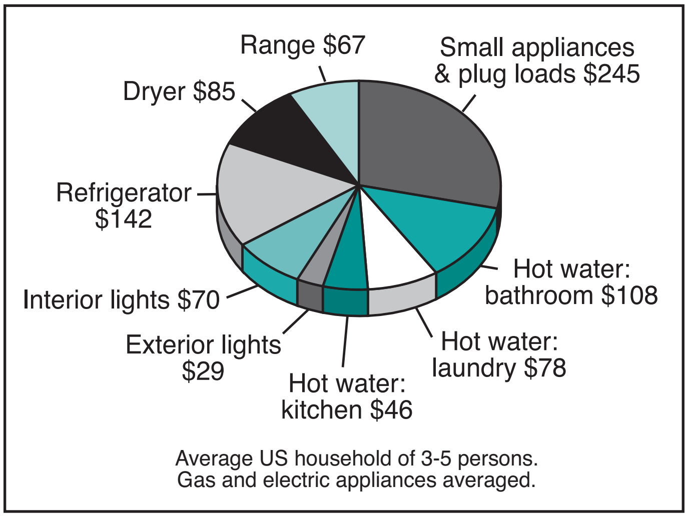

Fig. H-1: Annual water heating, appliances, and light costs for an average family of four (total = $870).

Types of lighting

There are three basic types of lighting for home use: incandescent, fluorescent, and high-intensity discharge.

- Incandescent lighting has been the most common home lighting but is gradually being phased out. The majority of incandescent bulbs won't be manufactured after 2014 due to new government lighting efficiency standards. The reason for this is incandescents are not very energy efficient. 90% of the energy you pay for becomes heat rather than light. Low-voltage incandescent lighting is often used outdoors for landscape or decorative lighting and is more energy efficient than standard incandescent. Also more efficient are low-voltage halogen or quartz halogen lighting for indoor use in recessed and track-lighting systems.
- There are a wide variety of different types of fluorescent lightbulbs available in stores today. Most common in home use are the tube type and the compact fluorescent bulbs (CFL). Fluorescent lighting is up to five times more energy efficient than standard incandescent, lasts about 10 times longer, and comes in a variety of warm and cool tones to complement interior color schemes. CFLs now look much like their incandescent equivalents including standard, globe, candelabra, flood, and spot bulbs. three-way, dimmable and outdoor bulbs for cold weather also are available. Be sure to recycle fluorescent bulbs when they burn out. They contain a small amount of mercury which is toxic. The mercury poses no risk as long as the bulbs remain unbroken and are properly disposed. Stores that sell CFLs in Dane County are required to collect and recycle them.
- High-intensity discharge lighting is the most efficient outdoor security lighting for the home. There are two types of bulbs—high-pressure sodium and metal halide. Each provides more light at significantly lower wattage than incandescent.

Specialty lighting

Light-emitting diodes (LEDs)

A LED is a semiconductor device that converts electricity into light. LED lighting has been around since the 1960s but is just now beginning to appear in the residential market for space lighting.

Widespread consumer use of LEDs, as a replacement for conventional lighting, is currently hampered by a number of issues. Initial cost is higher than that of CFLs. LEDs have lower light levels than other bulbs, although the continuing development of LED technology has caused their light output to increase exponentially, with a doubling occurring about every 36 months since the 1960s. Also, light output can decline as much as 30% toward the end of its rated lifetime.

LED lightbulbs are slated to be the lighting of the future once the technology is improved and the costs come down. Currently, there are a limited number of LED fixture manufacturers, but this is changing.

Well-planned and controlled lighting equals energy-efficient lighting

Carefully plan your lighting needs to help control use and save energy. Determine the primary function lighting will serve in each area in and around your home as general, decorative, task, or security lighting. Choose the best type of lighting for that purpose. Add lighting controls to make lighting more energy efficient.

- Dimmers. Control the brightness of light. As brightness is reduced, less electricity is used.
- Timers. Turn lights on and off at preset times.
- Motion detectors. Turn lights on when they sense motion in the immediate vicinity and off when the motion stops or after a preset time.
- Photocells. Turn lights on or off when they sense changes in natural light levels. Used to turn outdoor lights on at dusk and off at sunrise and can be used for indoor security lighting as well.

The Lighting Pattern Book for Homes

By Russell P. Leslie and Kathryn M. Conway

To help you plan your lighting, we purchased several copies of this book for the Dane County Library system. Check it out!

Lighting savings

How much can you expect to save if you install energy-efficient lighting? Figure H-2 compares purchase price and operating cost for readily available energy-efficient bulbs. Use this chart to calculate total savings over the life of the bulb.

Savings from using high-efficiency lighting

	Life span (hours)	No. of bulbs*	Operating cost**	Purchase price***	Life-cycle cost	Net savings
9-watt compact fluorescent	8,000	1	$ 10.08	$ 2.00	$ 12.08	$ 36.72
40-watt incandescent	1,000	8	$ 44.80	$ 4.00	$ 48.80	-
14-watt compact fluorescent	8,000	1	$ 15.68	$ 4.00	$ 19.68	$ 53.52
60-watt incandescent	1,000	8	$ 67.20	$ 6.00	$ 73.20	-
16-watt compact fluorescent reflector	8,000	1	$ 17.92	$ 9.00	$ 26.92	$ 81.08
75-watt incandescent R-40/flood	2,000	4	$ 84.00	$ 24.00	$108.00	-
23-watt compact fluorescent	10,000	1	$ 32.20	$ 4.00	$ 36.20	$117.13
100-watt incandescent	750	13.3	$140.00	$ 13.33	$153.33	-
42-watt compact fluorescent	10,000	1	$ 58.80	$ 9.00	$ 67.80	$195.53
150-watt incandescent	750	13.3	$210.00	$ 53.33	$263.33	-





* The energy-efficient bulbs shown in this chart have a longer life than standard incandescent bulbs. An equivalent number of incandescent bulbs are included in each comparison.
** Electricity cost used to calculate operating cost is $.08/kilowatt-hour (kWh).
*** Prices listed are current local retail for the total number of bulbs. Prices may vary.

Fig. H-2: The electricity that a lightbulb consumes costs far more than its purchase price. Investing in an energy-efficient bulb makes sense over time.

responsiblenergy

insulation / equipment

recommendations

recommendations

MGE recommendations for new single-family construction:

I. Basements.

A. Waterproofing recommendations.

1. Treat the exterior side of concrete walls, at finished grade to footings, with a rubber polymer, spray-on coating.
2. Install perforated drain tile around the inside and outside perimeter of the foundation wall footings and connect the two in three to four places.
3. Install a sealed sump-pump basin and connect it to the drain tile.

B. Foundation wall insulation recommendations (exterior application).

1. Install minimum R-5 rigid board insulation vertically around the perimeter to the footings.
2. Include insulation on the foundation wall between attached garages and slabs on grade.
3. Secure sheets of tongue-and-groove rigid board with metal fasteners spaced on 16-inch centers to footings.
4. Install a protective coating/shield to the rigid board that will remain exposed after backfilling.
   a. Protective coating/shield should extend a minimum of 6 inches below finished grade line to ensure protection of the insulation after settling.
   b. Acrylic cement coatings should be installed to a 1/8-inch minimum thickness.

C. Foundation wall insulation recommendations (interior application).

1. Install minimum R-5 rigid board extruded polystyrene to the concrete wall.
2. Install a minimum 2x4 stud wall.
   a. Use treated 2x4 for stud wall bottom plate.
   b. Insulate stud wall with minimum R-11 batting.
   c. Do not install vapor-barrier material on or within the wall.
   d. Cover with 15-minute fire-stop material.

D. Sillbox/ring joist recommendation. This area can account for a large portion of the total air infiltration in your new home. To ensure high R-value without air infiltration:

1. Install spray-in-place polyurethane foam in sillbox cavities after all utility penetrations have been made (if foam is used here, other air-sealing measures will not be necessary).

E. Radon-proofing recommendations.

1. Install a sub-slab passive-stack radon reduction system.

F. Basement floor insulation recommendations (for areas in the basement intended for living space).

Note: Basement floor excavation will need to be 5 to 8 inches deeper than normal if radon-protection measures and insulation beneath the floor are planned.

1. Install minimum 1-inch thick rigid board insulation over washed stone (or over leveled sand if radon-proofing measures are not specified) and tape seams.
2. (Optional) Install a minimum 6-mil-thick vapor retarder over the rigid board insulation before the concrete is poured.

G. Air-sealing recommendations.

1. Seal around all utility service and exhaust vent penetrations through the sillbox with flexible silicone sealant. (Does not apply if spray foam is used to insulate the sillbox.)
2. Seal around perimeter of sump basin covers.
3. Seal around sewer pipe where it enters concrete floor.
4. Seal around perimeter of basement where floor meets wall and all other cracks or joints in floor or walls.

II. Insulation recommendations for concrete slabs on grade.

A. Insulate under concrete slabs with minimum R-10 rigid board.

B. Insulate with minimum R-10 rigid board from top edge of slab to bottom of frost walls around perimeter (frost walls are typically 4-feet deep in this area). Include side of slab that abuts garage or basement walls.

Note: Floating slabs with shallow frost walls less than 4-feet deep should be insulated vertically to a 2-foot depth and then horizontally 2 feet away from the vertical piece (2´ down, 2´ away).

III. Insulation recommendations for floors over unheated space.

A. Garage ceilings with heated space above.

1. Completely fill ceiling space with minimum R-30 insulation (more if space permits).
2. If webbed truss joists are specified for framing the garage ceiling, a spray-in-place insulation should be specified to completely fill areas between webbed-support pieces. (This cannot be accomplished using batts.)
3. If heating ducts run through the unheated space, specify insulated “flex ducts” for heating/cooling runs to registers. Tape ducts to register boots securely.

4. Installation of a polyethylene vapor retarder above the garage ceiling is not necessary. Tightly assembled subflooring fastened with construction adhesive meets vapor-retarder requirements.
5. To avoid freezing pipes, do not run water lines through garage ceilings.

B. Overhangs, bay, bow, and box windows.

1. Cantilevered floors and overhanging window areas should be completely filled with a minimum of R-30 insulation.
2. Install a minimum of R-5 rigid board from outside before soffit material or finished board is installed.
   a. In most cases, overhanging windows will need to be "framed down" below the window seat (from exterior side) to make room for recommended insulation levels.
   b. In some cases, achieving a higher R-value by installing successive layers of rigid board or installing spray foam is more practical than framing down underneath the window.
3. Avoid running water lines or heating ducts through cantilevered floors.

IV. Above-grade wall recommendations.

A. Design the wall to include the four elements of a "water managed wall":

1. A drainage plane.
2. An airspace to drain the water down.
3. Flashing connected to the drainage plane.
4. Weep holes to shed water to the outside.

B. Fill the wall cavity with one of the spray-in-place insulation systems.

C. Install minimum R-5 extruded polystyrene rigid board insulation as sheathing (corner bracing is required).

1. Tape all seams and corners of the rigid board insulation.

D. Seal all outlets, switches, and fixtures on exterior walls (not necessary if spray foam or dense pack insulation is used).

1. Specify air-tight outlets/switches using gasketed electrical boxes or the Lessco® air-vapor barrier box (polypan). Note: Typically, the electrician would install the polypans when the house is roughed in but the builder or homeowner can install them before the electrician is called in.
2. As part of the insulation contract, specify that all wiring penetrations into polypans, through all top plates, and from exterior walls into interior walls are spot foamed.
3. Also, as part of the insulation contract, specify the installation of a 6-mil continuous vapor retarder. Note: "Continuous" meaning that the insulation contractor should be directed to seal all the overlaps at ceiling and wall junctures and seal the vapor retarder to the polypans and all other wall or ceiling penetrations. An acoustical sealant, spray adhesive, or tape can be used as sealers.

E. **Insulate "framing headers" by sandwiching rigid board insulation between the supporting members.**

F. **Framing members (nailers) should be minimized at the corners and at the interior wall junctions to maximize R-value potential. Or use a 2-stud corner with drywall clips/backers.**

V. Open attic/cathedral ceiling insulation recommendations.

A. Accessible open attics.

1. Specify at least 10-inch-high raised-heel energy trusses to ensure uniform R-value across attic ceiling.
2. Install minimum 6-mil sealed vapor retarder over the ceiling.
3. Install air baffles (proper vents) against roof sheathing in all rafter bays at eaves to prevent insulation from blocking soffit airflow.
4. Specify continuous ridge-venting system to achieve balanced outside airflow through the attic.
5. Install minimum R-44 to R-50 attic insulation.
6. Fasten minimum R-20 rigid board insulation (four 1-inch thick pieces) to attic hatch and specify weather stripping around hatch perimeter.
7. Avoid the use of recessed lighting unless sealed units are used or site-built sealed boxes are installed.

B. Cathedral ceilings.

1. Specify enough space between the roof sheathing and the drywall to allow for a minimum of R-38 insulation.
2. Specify continuous soffit/fascia and ridge-venting systems to achieve balanced outside airflow between fibrous insulation and roof sheathing.

   Note: A minimum 1-inch deep airspace between insulation and roof sheathing must be maintained when fibrous insulation is used.
3. Specify a continuous 6-mil vapor retarder in the ceiling.
4. Install track lighting or surface-mounted fixtures for lighting. Avoid recessed lights.
5. A spray-in-place foam or rigid board insulation can be specified to maximize R-value and reduce air infiltration in cathedral ceilings.

   Note: An airspace between the roof sheathing and insulation is not required if a foam insulation is installed to the underside of the roof sheathing. This is called a "hot roof."
6. Require the insulation contractor to spot-foam all wire and other penetrations into open attics and cathedral ceilings.

VI. Windows and doors.

A. Windows/skylights.

1. Specify NFRC-rated, double-pane, low-E, gas-filled windows with a U-factor of 0.35 or lower.
2. Specify same minimum for skylights, side lights, and for sliding/swinging glass doors.
3. Limit total square footage of window/door glass area to less than 15% of the above-grade envelope surface area (i.e., walls and ceiling). To maximize passive solar, the south-facing glass should be 7% to 12% of the total finished floor area.
4. Specify 50% to 60% of the windows be installed on walls facing within 10 degrees of due south.
5. Limit the number of skylights or use solar tubes as an energy-efficient alternative.

B. Doors.

1. Specify minimum R-7 insulation for your main entrance and the door leading from the house to an attached garage.
2. Avoid solid wood entrance doors unless storm doors are also specified.
3. Specify French doors with double-pane, low-E, gas-filled glass instead of sliding glass patio doors.
4. Do not install any type of entrance door on a north/northwest-facing wall unless the entrance can be sheltered with a vestibule, a sun porch, an attached garage, etc.

VII. Mechanical equipment.

A. Furnaces/Boilers.

1. Install a sealed combustion furnace or boiler.
2. Specify a furnace with a minimum AFUE of 90% or a boiler with a minimum AFUE of 87%.
3. Consider a furnace equipped with an electrically commutated motor (ECM). Comfort is enhanced and electricity costs are reduced.
4. Install a programmable thermostat.

B. Air conditioners.

1. Install a central air conditioner with a minimum SEER of 13.
2. If possible, locate the condenser on the north side of the house.

C. Water heaters.

1. Install a direct-vented natural-gas water heater with a minimum energy factor of 0.58.
2. For whirlpools/spas, install a 50-gallon, rapid-recovery model.

D. Ventilation systems.

1. Install a balanced, whole house ventilation system represented by an energy recovery ventilator (ERV) or a heat-recovery ventilator (HRV).
2. Install a variable proportional controller, a seven-day clock timer, or a dehumidistat to centrally control the ventilation system.
3. Install 15- to 60-minute twist timers for spot ventilation in your bathrooms or other designated rooms to individually control moisture or odors in these areas.
   a. Specify an outside-vented exhaust fan for the kitchen for rapid removal of odors and moisture.

E. Exhaust fans.

1. Install remotely located, in-line exhaust fans to ensure quiet operation.
2. Specify spring-loaded backdraft dampers to reduce cold air drafts when the exhaust fan is idle.
3. Specify correct sizing of individual exhaust fans by room size. Exhaust-fan ducting should be insulated and run the most direct route to the outdoors.

F. Fireplaces.

1. Install a direct-vented, sealed-combustion, natural-gas fireplace.
2. If you require a wood-burning appliance, install a freestanding wood stove in a central location.

   Note: Freestanding wood stoves are your best buy for heating purposes when they are equipped with fully gasketed door(s) and are supplied with outside combustion air.
3. If you install a zero-clearance, framed-in fireplace:
   a. Install on an inside wall. Avoid “bump outs” on outside walls.
   b. Specify fully gasketed doors and/or a positive-lock chimney damper.
   c. Specify outside air ducting for combustion with positive-lock damper.
   d. Specify constructing airtight chimney chase ways represented by continuously sealed vapor retarders, finished wall covering, and sealed chimney collar to the chimney connection where chimney enters unheated space (use noncombustible sealants).

VIII. Air-infiltration testing.

Note: Air infiltration can account for up to 30% of heating and cooling costs in the average home. Reducing air infiltration enhances comfort and saves you money on monthly utility bills.

A. Air-infiltration testing, using a blower door, should be specified as part of your building contract for the following reasons:

1. The results indicate how much attention was paid to sealing the house shell as it was constructed.
2. The results indicate specific places where more work should be done to reduce/eliminate air infiltration.

B. MGE recommends setting an air-tightness goal for the builder to meet.

1. If you choose to build under the Focus on Energy New Homes program, the allowable infiltration rate, as measured by a blower door, is 0.25 CFM@50 pascals per square foot of envelope area.

IX. Appliances

A. Choose ENERGY STAR® labeled products

X. Lighting

A. Choose energy-efficient lighting such as compact fluorescent fixtures and bulbs for the majority of your lighting needs.

If you have any questions about these recommendations, call MGE's Home Energy Line at 252-7117 and ask for Home Construction Services.

responsiblenergy

glossary

glossary

A/C. An abbreviation for air conditioner or air-conditioning.

ACH50. Air changes (number of times air is replenished in a given space) per hour at 50 pascals pressure.

ACQ (alkaline copper quartenary). A waterborne pesticide that is forced into wood under high pressure to protect it from termites, other wood-boring insects, and decay caused by fungus.

Active solar heating systems. A solar water- or space-heating system that uses pumps or fans to circulate the heat-transfer fluid from the solar collectors to a storage tank subsystem.

Air change. A measure of the rate at which the air in an interior space is replaced by outside (or conditioned) air because of ventilation and infiltration (usually measured in cubic feet per time interval [hour] divided by the volume of air in the room).

Air infiltration measurement. A building energy auditing technique used to determine and/or locate air leaks in a building shell or envelope. The measurement is done with a blower door.

Air lock. The area/hall between a heated room and the outdoors that provides a temperature insulation between the two spaces. It prevents excessive heat loss each time an outside door is opened.

Airflow retarder. A material or structural element that inhibits airflow into and out of a the building's envelope or shell. Airflow retarders can be located anywhere in the building envelope – at the exterior surface, the interior surface, or at any location in between. Wherever they are located, airflow retarders should be impermeable to airflow, continuous, and durable over the life of the building. Drywall, polyethylene, extruded polystyrene, building paper and wrap, and exterior sheathing material can all be used as airflow retarders.

Air-source heat pump. A type of heat pump that transfers heat from outdoor air to indoor air during the heating season and works in reverse during the cooling season.

Air-to-air heat exchanger (AAHX). See Heat Recovery Ventilator (HRV) or Energy Recovery Ventilator (ERV).

Annual Fuel Utilization Efficiency (AFUE). The measure of seasonal or annual efficiency of a residential heating furnace or boiler. It takes into account the cyclic on/off operation and associated energy losses of the heating unit as it responds to changes in the load, which in turn is affected by changes in weather and occupant controls.

Argon. A colorless, odorless inert gas sometimes used in the spaces between the panes in energy-efficient windows. This gas is used because it will transfer less heat than air. Therefore, it provides additional protection against conduction and convection of heat over conventional double-pane windows.

ASHRAE. Abbreviation for the American Society of Heating, Refrigeration and Air-Conditioning Engineers.

Attic access. An opening that allows access to the attic.

Attic ventilators. Screened openings provided to ventilate an attic space. See Eave Vents and Roof Vents.

Backdrafting. The reverse flow of chimney gases into a building through the chimney flue, draft hood, or burner unit. Backdrafting can be caused by chimney blockage or it can occur when the pressure differential (negative pressure) is too high for the chimney to exhaust. A pressure differential can be created by operating exhaust-only appliances such as bath fans, kitchen range hoods, dryers, and central vacuums located outside the building shell.

Backfill. The replacement of excavated earth into a trench around or against a basement/crawl space foundation wall.

Batt. A section of fiberglass or rock-wool insulation measuring 15″ or 23″ wide of various thickness' and lengths. Can be "faced" (paper covering on one side) or "unfaced" (without paper).

Blower door. A device used by energy auditors to pressurize or depressurize a building to locate places of air leakage and energy loss.

Bottom plate. The "2 by 4's or 6's" that lay on the subfloor upon which the vertical studs are installed. Also called the sole plate.

British thermal unit (Btu). The amount of heat required to raise the temperature of one pound of water 1%F (equal to 252 calories).

Building envelope. The structural elements (walls, roof, floor, foundation) of a building that encloses conditioned space (the building shell).

Building overall heat loss rate. The overall rate of heat loss from a building by means of transmission plus infiltration, expressed in Btu per hour, per degree temperature difference between the inside and outside.

Building permit. Authorization to build or modify a structure.

Cantilever. An overhang. Where one floor extends beyond and over a foundation wall. For example at a fireplace location or bay window cantilever. Normally, not extending over 2 feet.

Carbon monoxide. A colorless, odorless but poisonous combustible gas with the formula CO. Carbon monoxide is produced in the incomplete combustion of carbon and carbon compounds such as fossil fuels (i.e., coal, petroleum) and their products (e.g., liquefied petroleum gas, gasoline) and biomass.

Casement window. A window with hinges on one of the vertical sides and swings open like a normal door.

Catalytic converter. An air-pollution control device that removes organic contaminants by oxidizing them into carbon dioxide and water through a chemical reaction using a catalysis, which is a substance that increases (or decreases) the rate of a chemical reaction without being changed itself (required in all automobiles sold in the United States and used in some types of heating appliances).

Caulking. (1) A flexible material used to seal a gap between two surfaces, e.g., between pieces of siding or the corners in tub walls. (2) To fill a joint with mastic, asphalt, or plastic cement to prevent leaks.

C-A (Copper Azole, sometimes formulated as CBA, copper boron azole). A waterborne pesticide that is forced into wood under high pressure to protect it from termites, other wood-boring insects, and decay caused by fungus.

CCA (Chromated Copper Arsenate). A waterborne pesticide that is forced into wood under high pressure to protect it from termites, other wood-boring insects, and decay caused by fungus. In 2004, CCA was voluntarily restricted by industry. Alternative treatments are C-A (Copper Azole, sometimes formulated as CBA, copper boron azole), ACQ (Alkaline Copper Quartenary), MCQ (Micronized Copper Quatenary), and Sodium Borates (SBX/DOT).

Ceiling joist. One of a series of parallel framing members used to support ceiling loads and supported in turn by larger beams, girders, or bearing walls. Also called roof joists.

Ceiling, cathedral. A ceiling plane that is higher at one end than the other (as opposed to a flat ceiling).

Ceiling, vaulted. Three or more intersecting ceiling planes that join and rise to a central apex.

Cellulose insulation. A type of insulation composed of waste newspaper, cardboard, or other forms of wastepaper and a fire retardant.

CFM (cubic feet per minute). A rating that expresses the amount of air a blower or fan can move. The volume of air (measured in cubic feet) that can pass through an opening in one minute.

Chlorofluorocarbon. A family of chemicals composed primarily of carbon, hydrogen, chlorine, and fluorine whose principal applications are as refrigerants and industrial cleansers and whose principal drawback is the tendency to destroy the Earth's protective ozone layer.

Coefficient of performance (COP). A ratio of the work or useful energy output of a system versus the amount of work or energy inputted sent into the system as determined by using the same energy equivalents for energy in and out. It is used as a measure of the steady-state performance or energy efficiency of heating, cooling, and refrigeration appliances. The COP is equal to the Energy Efficiency Ratio divided by 3.412. The higher the COP, the more efficient the device.

Cold air return. The ductwork (and related grills) that carries room air back to the furnace for re-heating.

Combustion air. Air required to provide adequate oxygen for fuel-burning appliances.

Combustion chamber. Any wholly or partially enclosed space in which combustion takes place.

Combustion gases. The gaseous byproducts of the combustion of a fuel.

Compact fluorescent lamps (CFLs). A smaller version of the tube-type fluorescent lamps bent into compact shapes. Most CFLs come with an integral ballast, but two-piece designs have a separate ballast that lasts through four or five lamps (40,000 to 50,000 hours). They are 75% more efficient than standard incandescent bulbs.

Condensation. The beads or drops of water (and frequently frost or ice in extremely cold weather) that accumulate on the inside of the exterior covering of a building (most often on windows). Condensation occurs when warm, moisture-laden air from the interior contacts a colder surface. The air cools and can no longer hold as much moisture.

Condensing furnace. A type of heating appliance that extracts so much of the available heat content from a combusted fuel that the moisture in the combustion gases condenses before it leaves the furnace. Also, this furnace circulates a liquid to cool the furnace's heat exchanger. The heated liquid may either circulate through a liquid-to-air heat exchanger to warm room air or it may circulate through a coil inside a separate indirect-fired water heater.

Condensing unit. The outdoor component of a central air conditioner that is designed to remove heat absorbed by the refrigerant and transfer it outside the conditioned space.

Conduction. The direct transfer of heat energy through a material.

Conductivity. The rate at which heat is transmitted through a material.

Convection. The transfer of heat from one point to another (e.g., air or water) by mixing one portion of the air with another. A cold wall will create a convective air current in which the cascading warmer air from the ceiling is mixed with the cooler air next to the wall and falls to the floor.

Cooling degree-day (CDD). A unit for measuring the extent that the outdoor daily average temperature (the mean of the maximum and minimum daily dry-bulb temperatures) falls above a base temperature (usually 65°F). One degree-day is counted for each degree the average temperature falls above the base for each calendar day. For example, if the day's high is 90 and the day's low is 70, the day's average is 80. 80 minus 65 is 15 cooling degree-days. Total CDD is the cumulative total for the year/cooling season. The higher the CDD for a location, the warmer the daily average temperature(s).

Cooling load. The amount of cooling required to keep a building at a specified temperature during the summer, usually 78°F, regardless of outside temperature.

Creosote. A brownish, sticky residue produced from burning unseasoned firewood. In wood-burning fireplaces, creosote buildup can cause chimney fires.

Damp proofing. The black, tar-based material applied to the exterior of a foundation wall to resist the passage of water.

Dampers. Adjustable blades within an air duct to control the flow of air.

Daylighting. The use of direct, diffuse, or reflected sunlight to provide supplemental lighting for building interiors.

Degree-day. A unit for measuring the extent that the outdoor daily average temperature (the mean of the maximum and minimum daily dry-bulb temperatures) falls below (in the case of heating, see Heating Degree-Day) or falls above (in the case of cooling, see Cooling Degree-Day) an assumed base temperature, normally taken as 65°F, unless otherwise stated. One degree-day is counted for each degree below (for heating) or above (in the case of cooling) the base for each calendar day on which the temperature goes below or above the base.

Dehumidistat. An electronic sensing and control device used to regulate mechanical ventilation according to the relative humidity in the building. When the relative humidity surpasses a preset limit, the dehumidistat activates the ventilation system in order to exhaust house air.

Demand (tankless) water heater. A type of water heater that has no storage tank thus eliminating storage tank standby losses. Cold water travels through a pipe into the unit, and either a gas burner or an electric element heats the water only when needed.

Dewpoint. The temperature at which a given air/water vapor mixture is saturated with water vapor (i.e., 100% relative humidity). If air is in contact with a surface below this temperature, condensation will form on the surface.

Diffusion. The movement of individual molecules through a material. The movement occurs independent of airflow and increases as the temperature increases.

Direct gain. A term referring to a type of solar heating system where the solar collection area is an integral part of the building's usable space (e.g., windows).

Double glass. Window or door in which two panes of glass are used with a sealed air space between. Also known as insulating glass.

Double-hung window. A window with two vertically sliding sashes, both of which can move up and down.

Drainage plane. A water-repellent material, overlapped to drain downward, and continuous over the whole building exterior. The drainage plane, coupled with an airspace, provides drying capability to the wall.

Drip cap. A molding or metal flashing placed on the exterior topside of a door or window frame to cause water to drip beyond the outside of the frame.

Drywall (or gypsum wallboard, sheet rock, or plasterboard). Wall board or gypsum. A manufactured panel made out of gypsum plaster and encased in a thin cardboard. Usually 1/2″ thick and 4´ x 8´ or 4´ x 12´ in size. The panels are nailed or screwed onto the framing and the joints are taped and covered with a "joint compound." "Green board" type drywall has a greater resistance to moisture than regular (white) plasterboard and is used in bathrooms and other "wet areas."

Drywall clips (also called drywall stops). Small pieces of hardware that function as backing to fasten drywall. The clips eliminate the need for an additional stud in a corner.

Duct. A round, oval or rectangular pipe-like passageway for transporting air.

Eaves. The horizontal exterior roof overhang.

Eave vent. Opening located in the soffit under the eaves of a house to allow the passage of air through the attic and out the roof vents.

EER (energy efficiency ratio). A measure of steady-state or instantaneous efficiency – i.e., the efficiency of the air conditioner once it is up and running. The Air-Conditioning and Refrigeration Institute standardized this rating, which reports central air-conditioning efficiency as the cooling capacity in Btu/hour divided by the watts of power consumed at 80°F indoors and 95°F outdoors. The higher the EER, the more efficient the air conditioner.

Emissivity. The ratio of the radiant energy (heat) leaving (being emitted by) a surface to that of a black body at the same temperature and with the same area. Expressed as a number between 0 and 1.

Energy factor. The measure of overall efficiency for a variety of appliances. For water heaters, the energy factor is based on three factors: (1) the recovery efficiency, or how efficiently the heat from the energy source is transferred to the water, (2) standby losses, or the percentage of heat lost per hour from the stored water compared to the content of the water, and (3) cycling losses. For dishwashers, the energy factor is defined as the number of cycles per kWh of input power. For clothes washers, the energy factor is defined as the cubic-foot capacity per kWh of input power per cycle. For clothes dryers, the energy factor is defined as the number of pounds of clothes dried per kWh of power consumed.

Energy recovery ventilator (ERV). A type of mechanical ventilation equipment that is similar to a HRV but features an enthalpic-type heat exchanger that enables the transfer of small amounts of moisture as well as heat. This system can reduce air-conditioning load by pre-cooling and removing excess moisture from incoming fresh air during the summer.

Energy-efficient mortgages. A type of home mortgage that takes into account the energy savings of a home that has cost-effective, energy-saving improvements that will reduce energy costs, thereby allowing the homeowner more income for the mortgage payment. A borrower can qualify for a larger loan amount than otherwise would be possible.

Evaporator coil. The part of a cooling system, usually located in the furnace plenum, that absorbs heat from air in your home.

Exfiltration. The uncontrolled leakage of air out of a building.

Expanded polystyrene (EPS). Beads of styrofoam that are pressed under high pressure to form rigid insulation panels.

Exterior insulation and finish systems (EIFS). Multilayered exterior wall systems that are used on both commercial buildings and homes. EIFS consist of insulation board that is secured to the exterior wall surface with a specially formulated adhesive and/or mechanical attachment; a durable, water-resistant base coat which is applied on top of the insulation and reinforced with fiberglass mesh for added strength; and a durable finish coat.

Extruded polystyrene (XPS). A type of insulation material with fine, closed cells containing a mixture of air and refrigerant gas. The plastic is heated to the melting point and injected into a mold. This insulation has a high R-value, good moisture resistance, and high structural strength compared to other rigid insulation materials.

Fan depressurization (blower door). A large fan is used to exhaust air from a building in order to create negative inside pressure. An analysis of the flow rate through the fan at varying pressure differences provides a measurement of airtightness.

Fascia. Horizontal boards attached to rafter/truss ends at the eaves and along gables. Roof drain gutters are attached to the fascia.

Fibrex. A proprietary blend of wood fiber and vinyl made from postindustrial waste from manufacturing wood and vinyl windows. It is sometimes used to make window frames.

Floor trusses. A single framework of individually structured members connected at their ends to form a series of triangles to span a large distance. Floor trusses can be constructed in virtually any length or thickness unlike dimensional lumber.

Flue. Large pipe through which fumes escape from a gas water heater, furnace, or fireplace. Normally these flue pipes are double walled, galvanized sheet metal pipe and sometimes referred to as a “B Vent.” Fireplace flue pipes are normally triple walled. In addition, nothing combustible shall be within 1″ from the flue pipe.

Fluorescent light. The conversion of electric power to visible light by using an electric charge to excite gaseous atoms in a glass tube. These atoms emit ultraviolet radiation that is absorbed by a phosphor coating on the walls of the lamp tube. The phosphor coating produces visible light.

Footer, footing. Continuous 8″ or 10″ thick concrete pad installed before and supports the foundation wall or monopost.

Formaldehyde. A chemical used as a preservative and in bonding agents. It is found in household products such as plywood, furniture, carpets, and some types of foam insulation. It is also a by-product of combustion and is a strong-smelling, colorless gas that is an eye irritant and can cause sneezing, coughing, and other health problems.

Foundation waterproofing. High-quality below-grade moisture protection. Used for below-grade exterior concrete and masonry wall damp-proofing to seal out moisture and prevent corrosion. Normally looks like black tar.

Frost line. The depth of frost penetration in soil and/or the depth at which the earth will freeze and swell. This depth varies in different parts of the country.

GFCI or GFI (ground fault circuit interrupter). An ultra sensitive plug designed to shut off all electric current. Used in bathrooms, kitchens, exterior waterproof outlets, garage outlets, and "wet areas." Has a small reset button on the plug.

Gypsum board. Typically referred to in the Madison area as drywall, wallboard, or sheetrock, it is the most common material used to cover interior walls and ceilings. Gypsum board panels are available in 1½″ or 5/8″ thickness and in full sheet sizes of 4´ x 8´ or 4´ x 12´. Other sizes are available for 9´ ceilings.

HVAC. An abbreviation for heat, ventilation, and air-conditioning.

Header. The horizontal structural member over an opening (for example over a door or window).

Heat exchanger. A device used to transfer heat from a fluid (liquid or gas) to another fluid where the two fluids are physically separated.

Heat pump. A mechanical device which uses compression and decompression of gas to heat and/or cool a house.

Heat-recovery ventilator (HRV). A type of mechanical ventilation equipment that features a heat exchanger for providing controlled ventilation into a building. It provides fresh outdoor air while recovering energy from the exhaust air stream. See also ERV.

Heating degree-day (HDD). A unit for measuring the extent that the outdoor daily average temperature (the mean of the maximum and minimum daily dry-bulb temperatures) falls below a base temperature (usually 65˚F). One degree-day is counted for each degree the average temperature falls below the base for each calendar day. For example, if the day's high is 40 and the day's low is 20, the day's average is 30. 65 minus 30 is 35 heating degree-days. Total HDD is the cumulative total for the year/heating season. The higher the HDD for a location, the colder the daily average temperature(s).

Heating load. The amount of heating required to keep a building at a specified temperature during the winter, usually 65ºF, regardless of outside temperature.

Home Energy Rating System (HERS). A nationally recognized energy rating program that gives builders, mortgage lenders, secondary lending markets, homeowners, sellers, and buyers a precise evaluation of energy-losing deficiencies in homes. Builders can use this system to gauge the energy quality in their home and also to have a star rating on their home to compare to other similarly built homes.

House wrap. Any of several spun-fiber polyolefin rolled sheet goods for wrapping the exterior of the building envelope.

I-beam. A steel beam with a cross section resembling the letter 'I'. It is used for long spans as basement beams or over wide wall openings, such as a double garage door, when wall and roof loads bear down on the opening.

I-joist. Manufactured structural building component resembling the letter 'I'. Used as floor joists and rafters. I-joists include two key parts: flanges and webs. The flange of the I-joist may be made of laminated veneer lumber or dimensional lumber, usually formed into a 1½″ width. The web or center of the I-joist is commonly made of plywood or oriented strand board (OSB). Large holes can be cut in the web to accommodate duct work and plumbing waste lines. I-joists are available in lengths up to 60´ long.

Ice dam. A ridge of ice that forms and builds up on the lower edge of roofs above the soffit and prevents melting snow (water) from draining off the roof. The major cause of ice dams is warm air leaking into the attic.

Impermeable. Not permitting water vapor or other fluid to pass through.

Incandescent lamp. A lamp employing an electrically charged metal filament that glows at white heat. A typical lightbulb.

Infiltration. Air flowing into a building through a hole, crack, or other opening.

In-floor radiant water heat. A boiler-driven forced-water system that delivers heated water through a network of piping either imbedded in concrete or wood subflooring.

Insulating glass. Window or door in which two panes of glass are used with a sealed air space between. Also known as double glass.

Insulation. Any material high in resistance to heat transmission that, when placed in the walls, ceiling, or floors of a structure, will reduce the rate of heat flow.

Insulated header. Insulation added to the horizontal structural member over an opening such as a door or window to resist heat loss or gain.

Jamb. The finish material surrounding and securing a window sash or door. Doors and windows are typically installed prehung to their jambs.

Joists. Parallel beams used to support floors and ceilings.

Kiln-dried lumber. Any lumber placed in a heated chamber or "shed" to reduce its moisture content to a specified range or average under controlled conditions. For softwood framing lumber, the moisture content of kiln-dried lumber is somewhat based on regional conventions but is most often an average of 12% by weight. In comparison, the moisture content of thoroughly air-dried softwood framing lumber is 15% to 20%.

Kilowatt (kW). A standard unit of electrical power equal to 1,000 watts or to the energy consumption at a rate of 1,000 joules per second.

Kilowatt-hour (kWh). A unit or measure of electricity supply or consumption of 1,000 watts over the period of one hour. Equivalent to 3,412 Btu.

Laws of Thermodynamics. Describes the transport of heat and work in thermodynamic processes. These laws have become some of the most important fundamental laws in physics and other sciences associated with thermodynamics.

Lifecycle analysis (LCA). A process used to compare products to determine if they are "green" or "sustainable" is to look at a product's lifecycle environmental impacts. An LCA of a building product covers its environmental impacts "cradle to grave" through six basic steps: (1) raw material acquisition, (2) product manufacturing process, (3) home building process, (4) home maintenance operation, (5) home demolition, and (6) product reuse, recycling, or disposal.

Lighting, recessed. A popular type of ceiling light that allows placement of the lamp (lightbulb) above the ceiling surface. The lens can be adjusted flush, or nearly so, with the ceiling.

Lineal foot. A unit of measure for lumber equal to 1″ thick by 12″ wide by 12″ long. Examples: 1″ x 12″ x 16´ = 16 board feet, 2″ x 12″ x 16´ = 32 board feet.

Load-bearing wall. Includes all exterior walls and any interior wall that is aligned above a support beam or girder.

Long-wave radiation. Infrared or radiant heat.

Low-E (low-emissivity coating). Low-E coatings allow light to pass through but reflect heat. This improves energy efficiency year-round. A double-pane window with low-E coating can insulate as well as a triple-pane window without low-E coating. Some low-E coatings perform better than others, so check the NFRC rating.

Lumens. Unit of measure for total light output. The amount of light falling on a surface of one square foot.

Lumens/watt. A measure of the efficacy (efficiency) of lamps. It indicates the amount of light (lumens) emitted by the lamp for each unit of electrical power (watts) used.

Manufactured wood. A wood product such as a truss, beam, gluelam, microlam, or joist which is manufactured out of smaller wood pieces and glued or mechanically fastened to form a larger piece. Often used to create a stronger member which may use less wood. See also Oriented Strand Board.

Masonry. Any assemblage of individual concrete, clay, or stone building units which are bonded together with mortar.

MCQ (micronized copper quatenary). A waterborne pesticide that is forced into wood under high pressure to protect it from termites, other wood-boring insects, and decay caused by fungus.

Mechanical ventilation. Controlled, purposeful introduction of outside “fresh” air to the conditioned space.

Microlam. A manufactured structural wood beam. It is constructed of pressure and adhesive bonded wood strands of wood. They have a higher strength rating than solid-sawn lumber. Normally comes in 1½″ thickness and 9½″, 11½″, and 14″ widths.

Natural ventilation. Ventilation that is created by the differences in the distribution of air pressures around a building. Air moves from areas of high pressure to areas of low pressure with gravity and wind pressure affecting the airflow. The placement and control of doors and windows alters natural ventilation patterns.

Negative pressure. A pressure below atmospheric pressure. Negative pressure exists when the pressure inside the house is less than the air pressure outside. Negative pressure encourages infiltration.

NFRC (National Fenestration Rating Council). A nonprofit organization that provides performance ratings on windows, doors, and skylights. NFRC administers a certification and labeling program for the energy efficiency of windows, doors, and skylights.

OC or On Center. The measurement of spacing for studs, rafters, and joists in a building from the center of one member to the center of the next.

Oriented Strand Board or OSB. A manufactured 4´ x 8´ wood panel made out of 1″ to 2″ wood chips and glue. Often used as a substitute for plywood.

Outgassing. The process by which materials expel or release gasses.

Particle board. Plywood substitute made of course sawdust that is mixed with resin and pressed into sheets. Used for closet shelving, floor underlayment, stair treads, etc.

Pascal. A unit measurement of pressure in the metric system. House airtightness tests are typically conducted using a blower door with a pressure difference of 50 pascals between the inside and outside. Fifty pascals is roughly equivalent to a 20 mph wind blowing against all surfaces of the home.

Passive solar. Refers to the use of the sun's energy for the heating and cooling of living spaces. In this approach, the building itself or some element of it takes advantage of natural energy characteristics in materials and air created by exposure to the sun. Passive systems are simple, have few moving parts, and require minimal maintenance and require no mechanical systems. Operable windows, thermal mass, and thermal chimneys are common elements found in passive design. Operable windows are simply windows that can be opened.

Perimeter drain. 4″- 6″ perforated flexible tubing that goes around the perimeter (either inside or outside) of a foundation wall (before backfill) and collects and diverts groundwater away from the foundation. Generally, it is connected to a sump pit inside the home, and a sump pump is sometimes inserted into the pit to discharge any accumulation of water.

Permeability. A measure of the ease with which water penetrates a material.

Permeance rating or perm rating. A measurement of the transmission of water through a material. The lower the number, the more resistance to the passage of water.

Permeance. A unit of measurement for the ability of a material to retard the diffusion of water vapor at 73.4°F (23°C). A perm, short for permeance, is the number of grains of water vapor that pass through a square foot of material per hour at a differential vapor pressure equal to 1″ of mercury.

Photocatalytic oxidation (PCO). An emerging technology in the HVAC industry usually coupled with other filtering technologies for air purification in a forced-air heating/cooling system. PCO is not a filtering technology as it does not trap or remove particles.

Photovoltaic device. A solid-state electrical device that converts light directly into direct current electricity. Solar photovoltaic devices are made of various semiconductor materials including silicon, cadmium sulfide, cadmium telluride, and gallium arsenide and in single crystalline, multicrystalline, or amorphous forms.

Plenum. The main hot-air supply duct leading from a furnace.

Plumbing stack. A plumbing vent pipe that penetrates the roof.

Polypans. Builder slang for a manufactured plastic box that is used to form a continuous vapor retarder around electric receptacles in walls and ceilings (e.g., Lessco® Air/Vapor Barrier Boxes).

Polyurethane. A large family of plastics used as coatings or for flexible and rigid-foamed products.

Positive pressure. A pressure above atmospheric pressure. Positive pressure exists when the pressure inside the house is greater than the air pressure outside. A positive pressure difference encourages exfiltration.

Post-and-beam. A basic building method that uses just a few hefty posts and beams to support an entire structure. Contrasts with stud framing.

Precast concrete foundation and wall panels. A concrete wall cast in a factory and assembled in the field that can be used below or above grade.

Pressure difference. The difference in pressure of the volume of air enclosed by the house envelope and the air surrounding the envelope.

Pressure-treated wood. Lumber that has been saturated with a preservative. See C-A, CCA, ACQ, and MCQ.

PVC (polyvinyl chloride) or CPVC. A type of white or light gray plastic pipe sometimes used for water supply lines and waste pipe.

R Value. A measure of a materials resistance to the passage of heat. The higher the R value, the more insulating value it has.

Radiant barrier. A thin, reflective foil sheet that exhibits low-radiant energy transmission and, under certain conditions, can block radiant heat transfer installed in attics to reduce heat flow through a roof assembly into the living space.

Radiant ceiling panels. Ceiling panels that contain electric resistance heating elements embedded within them to provide radiant heat to a room.

Radiant energy. The energy of electromagnetic waves that transmits away from its source in all directions.

Radiant heat transfer. The transfer of heat energy from an area of higher temperature to an area of lower temperature by electromagnetic radiation.

Radiant heating. A method of heating, usually consisting of a forced hot water system with pipes placed in the floor, wall, or ceiling. Also electrically heated panels.

Radiation. The transfer of heat through matter or space by means of electromagnetic waves.

Radon system. A ventilation system beneath the floor of a basement and/or structural wood floor which can be either passive or utilize a fan to exhaust radon gas to the outside of the home.

Radon. A naturally occurring radioactive gas found in the United States in nearly all types of soil, rock, and water that can migrate into buildings.

Rafter. Lumber used to support the roof sheeting and roof loads. Generally, 2 x 10’s and 2 x 12’s are used. The rafters of a flat roof are sometimes called roof joists.

Rafter bay. The space between each roof rafter or roof truss.

Ranch. A single story, one level home, with or without a basement.

Rebar, reinforcing bar. Ribbed steel bars installed in foundation concrete walls, footers, and poured in place concrete structures designed to strengthen concrete. Comes in various thickness’ and strength grades.

Refrigeration capacity. A measure of the effective cooling capacity of a refrigerator, expressed in Btu per hour or in tons, where one ton of capacity is equal to the heat required to melt 2,000 pounds of ice in 24 hours or 12,000 Btu per hour.

Relative humidity. The amount of moisture in the air compared to the maximum amount of moisture that the air could retain at the same temperature. This ratio is expressed as a percentage.

Rim joist. A joist that runs around the perimeter of the floor joists and home. Also called the band joist.

Roof joist. Lumber used to support the roof sheeting and roof loads. Generally, 2 x 10's and 2 x 12's are used.

Roof sheathing or sheeting. The wood panels or sheet material fastened to the roof rafters or trusses on which the shingle or other roof covering is laid.

Roof valley. The "V" created where two sloping roofs meet.

Roof vent. An opening, either a continuous ridge vent or a louver/small dome mounted near the ridge of the roof to allow the passage of air through the attic. Works in conjunction with the eave vents.

Rough opening. The horizontal and vertical measurement of a window or door opening before drywall or siding is installed.

R-value. A measure of the capacity of a material to resist heat transfer. The R-value is the reciprocal of the conductivity of a material (U-factor). The higher the R-value of a material, the greater its insulating properties.

Sealant. A compound used to fill and seal a joint.

Sealed combustion heating system. A heating system that uses only outside air for combustion and vents combustion gases directly to the outdoors. These systems are less likely to backdraft and to negatively affect indoor air quality.

SEER (seasonal energy efficiency ratio). A rating that denotes the overall seasonal efficiency of air-conditioning equipment. It is the total cooling delivered by a system during the cooling season, measured in Btus, divided by the total electric energy input in watt-hours for the same period. The higher the SEER, the more efficient the air conditioner. An air conditioner must have a SEER of at least 10 to be sold in the United States.

Semi-permeable. The term vapor semi-permeable describes a material with a water-vapor permeance between 1 and 10 perms. Water vapor can pass through a semi-permeable material but at a proportionally slower rate.

Sensible cooling load. The interior heat gain due to heat conduction, convection, and radiation from the exterior into the interior and from occupants and appliances.

Setback thermostat. A thermostat with a clock which can be programmed to turn the heating or cooling system on or off at preset times and temperatures.

Sheathing, sheeting. The structural wood panel covering, usually OSB or plywood, used over exterior stud walls, floor joists, or rafters/trusses of a structure.

Shed roof. A roof containing only one sloping plane.

Sheet rock (drywall, wall board, or gypsum). A manufactured panel made out of gypsum plaster and encased in a thin cardboard. Usually 1/2″ thick and 4´ x 8´ or 4´ x 12´ in size. The "joint compound." "Green board" type drywall has a greater resistance to moisture than regular (white) plasterboard and is used in bathrooms and other "wet areas."

Shingles. Roof covering of asphalt, asbestos, wood, tile, slate, or other material cut to stock lengths, widths, and thickness'.

Siding (lap siding). Slightly wedge-shaped boards used as horizontal siding in a lapped pattern over the exterior sheathing. Varies in butt thickness from 1/2″ to 3/4″ and in widths up to 12″.

Sill plate. A 2″ x 6″ or 8″ framing member that is fastened flat to the top of the foundation wall. The floor assembly, which is made up of a ring joist and floor joists, is then fastened to the sill plate (also referred to as a mudsill).

Sill sealer. Material used to provide a seal at the top of the foundation wall before the sill plate is fastened down. Typically, a flexible foam material is used here to provide a weather-tight seal between the sill plate and foundation wall.

Skylight. A more or less horizontal window located on the roof of a building.

Slab on grade. A type of foundation with a concrete floor which is placed directly on the soil. The edge of the slab is usually thicker and acts as the footing for the walls.

Soffit. The area below the eaves and overhangs. The underside where the roof overhangs the walls. Usually the underside of an overhanging cornice.

Soil stack. A plumbing vent pipe that penetrates the roof.

Solar constant. The average amount of solar radiation that reaches the Earth's upper atmosphere on a surface perpendicular to the sun's rays (equal to 1,353 watts per square meter or 492 Btu per square foot).

Solar heat gain coefficient (SHGC). The SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits. A window with a SHGC of 0.30 lets in only 30% of the sun's heat energy.

Solar tube. A tube, lined with highly reflective material, used for distributing natural daylight from the exterior to the interior space. A small dome is installed on the roof and the tube is terminated at an interior ceiling with a light diffuser.

Sole plate. The bottom, horizontal framing member of a wall that's attached to the floor sheeting and vertical wall studs.

Spec home. A house built before it is sold. The builder speculates that he can sell it at a profit.

Stack effect. Pressure differential across a building caused by differences in the density of air relative to the difference in temperatures between indoors and outdoors.

Stick built. A house built without prefabricated parts. Also called conventional building.

Stud. A vertical wood framing member, also referred to as a wall stud, attached to the horizontal sole plate below and the top plate above. Normally 2 x 4's or 2 x 6's, 8´ long (sometimes 92 5/8″). One of a series of wood or metal vertical structural members placed as supporting elements in walls and partitions.

Stud framing. A building method that distributes structural loads to each of a series of relatively lightweight studs. Contrasts with post-and-beam.

Subfloor. The framing components of a floor to include the sill plate, floor joists, and deck sheeting over which a finish floor is to be laid.

Sump. A basin installed in the basement floor designed to collect ground water from a perimeter drain system.

Sump pump. A submersible pump located beneath the surface of the basement floor (in a sump basin) that removes infiltrating groundwater or backed-up sewer water.

T&G, tongue and groove. A joint made by a tongue (a rib on one edge of a board) that fits into a corresponding groove in the edge of another board to make a tight flush joint. Typically, the subfloor plywood is T&G.

Therm. A unit of heat containing 100,000 Btu.

Thermal mass. Refers to materials such as masonry and water that can store heat energy for extended time. Thermal mass will prevent rapid temperature fluctuations.

Thermodynamics. The study of energy conversion between heat and mechanical work, and subsequently the macroscopic variables such as temperature, volume, and pressure.

TJI or TJ (truss joist). Manufactured structural building component resembling the letter 'I'. Used as floor joists and rafters. I-joists include two key parts: flanges and webs. The flange of the I-joist may be made of laminated veneer lumber or dimensional lumber, usually formed into a 1½″ width. The web or center of the I-joist is commonly made of plywood or oriented strand board (OSB). Large holes can be cut in the web to accommodate duct work and plumbing waste lines. I-joists are available in lengths up to 60´ long.

Ton (of air-conditioning). A unit of air-cooling capacity (12,000 Btu per hour).

Top plate. Top horizontal member of a frame wall supporting ceiling joists, rafters, or other members.

Trombe wall. A wall with high thermal mass used to store solar energy passively in a solar home. The wall absorbs solar energy and transfers it to the space behind the wall by means of radiation and by convection currents moving through spaces under, in front of, and on top of the wall.

Truss. An engineered and manufactured roof support member with "zig-zag" framing members. Does the same job as a rafter but is designed to have a longer span than a rafter.

U-factor or U-value. The rate of heat flow through a material expressed in Btu per hour per square feet per degree. The U-factor is the inverse of an R-value (e.g., a U-factor of 0.5 equals an R-value of 2, or 1 divided by 0.5. Conversely, an R-value of 0.5 equals a U-factor of 0.2, or 1 divided by 5). The lower the number, the greater the heat transfer resistance (insulating) characteristics of the material.

Utility easement. The area of the earth that has electric, gas, or telephone lines. These areas may be owned by the homeowner, but the utility company has the legal right to enter the area as necessary to repair or service the lines.

Valley flashing. Sheet metal that lays in the "V" area of a roof valley.

Valley. The "V" shaped area of a roof where two sloping roofs meet. Water drains off the roof at the valleys.

Vapor barrier. An impermeable membrane primarily used to stop water vapor transmission into wall, ceiling, and floor assemblies of buildings. It is defined as a material with a permeance of less than 0.01 perms as defined by ASTM F 1249 or ASTM E 96 testing protocols. The term 'vapor barrier' is often used interchangeably with the term 'vapor retarder' to describe all membranes used to resist water vapor transmission. Technically, many of these materials are only vapor retarders as they have varying degrees of permeability.

Vapor retarder. A material used to slow the rate of water vapor diffusion into the thermal envelope of a structure. It is installed under the drywall on the warm side of exterior walls and its purpose is to prevent insulation and structural wood from becoming damp and metals from corroding. Normally, 6 mil polyethylene sheeting is used. A vapor retarder is classified by ASTM E 1745 as a plastic material having a permeance of less than 0.1 perms as tested by ASTM F 1249 or ASTM E 96.

Variance. An approved deviation from a zoning law.

Visible transmittance (VT). Measures how much light comes through a product. The VT is an optical property that indicates the amount of visible light transmitted. VT is expressed as a number between 0 and 1. The higher the VT, the more light is transmitted. A VT of 0.75 allows 75% of the light to be transmitted through the glass.

Visqueen. A 4 mil or 6 mil plastic sheeting.

Volatile organic compound (VOC). A highly evaporative, carbon-based chemical substance that produces noxious fumes. Found in many paints, caulks, stains, adhesives, and manufactured building materials.

Water vapor pressure. The pressure exerted by water vapor in the air. Water vapor moves from an area of high pressure to an area of low pressure.

Water-managed wall system. An exterior above-grade wall construction strategy that is designed to shed water and allow the wall to dry. It consists of four elements: (1) a drainage plane, (2) an airspace between the drainage plane and the cladding, (3) flashing connected to the drainage plane, and (4) weep holes to allow water to escape to the outside.

Waterproofing. Treating the exterior surface of a foundation wall to resist the passage of water. Waterproofing, unlike damp-proofing, uses a tar-like material that contains rubber and is capable of stretching to cover cracks as the house settles. It is usually applied from the footings up to grade level.

Whole house fan. A mechanical/electrical device used to pull air out of an interior space. Usually located in the highest location of a building (in the ceiling) and venting to the attic or directly to the outside.

Window sash. The operating or movable part of a window. The sash is made of window panes and their border.

XPS. See Extruded polystyrene.

Zone valve. A device, usually placed near the heater or cooler, which controls the flow of water or steam to parts of the building; it is controlled by a zone thermostat.

Zoning. The combining of rooms in a structure according to similar heating and cooling patterns. Zoning requires using more than one thermostat to control heating, cooling, and ventilation equipment.

Zoning\Use permit. Authorization to use a property for a specific use, e.g., a garage or a single-family residence.

appendix

heating fuel comparison table

One way to compare the delivered cost of different heating fuels is the cost/million Btu method. This method takes into account the Btu content and the cost of the fuel plus the efficiency of the delivery system. Use this method to compare the relative cost difference between different heating fuels and heating system efficiencies.

The formula is:

$$\textbf{Energy cost/million btu (MMBtu)} = \frac{\textbf{Cost per unit of fuel X 1,000,000}}{\textbf{Energy content per unit X AFUE/COP}}$$

Cost per million BTUs of usable energy
(sorted by Cost/million Btu's)

		Btu's per unit	Cost per unit[1]	AFUE/ COP	Cost/million Btu's
Natural gas	therm	100,000	$1.00	92%	$10.87
Electric (GSHP)[2]	kWh	3,413	0.13	330%	11.54
Natural gas	therm	100,000	1.00	80%	12.50
Wood[3] (efficient stove)	cord	20,000,000	200.00	70%	14.29
Propane (own tank)	gallon	91,600	1.78	92%	21.12
Corn[4]	bushel	392,000	6.00	70%	21.87
#2 Fuel oil	gallon	138,200	2.80	92%	22.02
Pellet fuel	40# bag	320,000	5.00	70%	22.32
#2 Fuel oil	gallon	138,200	2.80	80%	25.33
Electric (residential rate)	kWh	3,413	0.13	100%	38.09
Wood (open hearth)	cord	20,000,000	$200.00	20%	$50.00

[1]Fuel costs are a snapshot in time and will vary seasonally and over time.

[2]Ground-source heat pump.

[3]Seasoned firewood - 20% moisture content (wet basis).

[4]Shelled corn - 15% moisture content.

If you would like to input different fuel prices for your particular situation, we recommend downloading the heating fuel calculator spreadsheet from the U.S. Department of Energy at http://www.eia.doe.gov/neic/experts/heatcalc.xls.

we put our energy into helping you

Check with MGE, your community energy company, for information about:

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