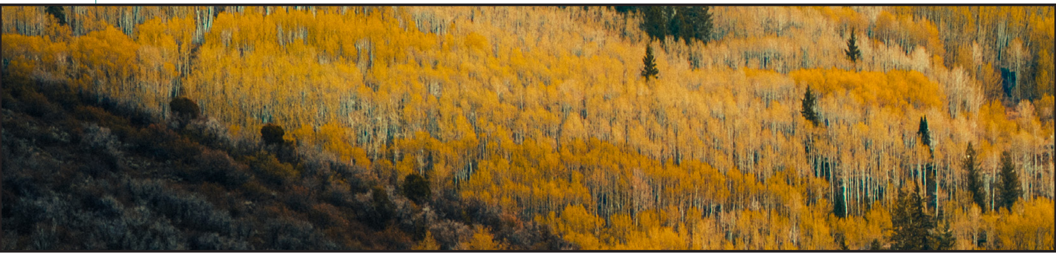
M O N T A N A

Next Home

Planning Guide to Energy Efficiency



Next Home Planning Guide to Energy Efficiency

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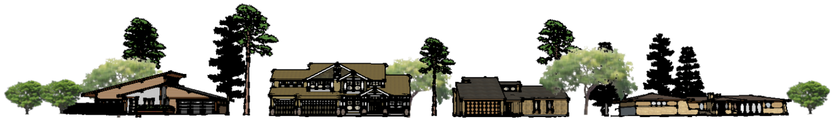
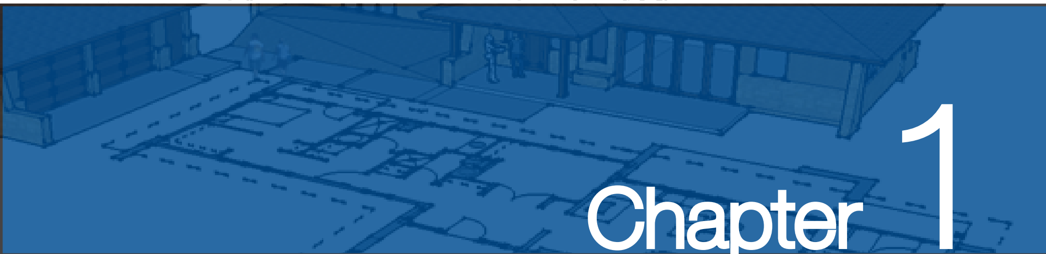




Chapter 1 Introduction

This guide is designed to help new home buyers learn the benefits of energy-efficient design and construction. Our homes are the center of family life. We trust that a new home is healthy, safe, and comfortable. A new house is not only a major financial investment it is also a significant investment in energy and other natural resources. The average single family home in the NorthWestern Energy service area is 49 years old. Many of those homes will be used for well over 100 years. By making new homes energy efficient we save energy for generations of occupants.

Shelter is a fundamental human need. Without shelter our survival in harsh environments would be impossible. The early inhabitants of Montana created shelter from locally available materials. The style and building techniques of early Montana inhabitants evolved over centuries. Knowledge of how to create shelter was a part of the traditional knowledge shared from one generation to the next. In the generations since the industrial revolution our relationship to home building has changed. Building techniques have become increasingly more complicated requiring sophisticated new skills and training. Adding to the complexity of modern home building are the codes and standards that permeate the industry. It has become rare for someone to build their own home. Most of us must rely on informed designers, builders, subcontractors, trades workers, and suppliers for assistance in creating new homes that meet our expectations for comfort, health, safety, and energy efficiency.

Green Building

Modern homes consume electricity, natural gas, or propane in addition to the natural resources used in building construction. Today many designers and builders strive to minimize the use of those natural resources and reduce pollution associated with construction activities. These "green" builders are having a major influence on how new homes are designed and constructed today. Green building principles contributes to a healthier environment both inside and outside the home. Significant home buyer interest in green building has spawned numerous new products and services that improve our homes and contribute to the economy. Green building includes many aspects of house construction such as resource efficiency, the environmental impacts of materials used, water efficiency, the health related characteristics of materials, and equipment. Given concerns about energy availability and climate change many green building advocates consider energy efficiency the most important characteristic of today's green homes.

Reducing a building's energy use is the best protection against an uncertain energy future. Regardless of where energy comes from or its future price, using less is better. Energy efficiency is the term we use for doing more with less energy. It benefits your family, your country, and the environment. Energy efficiency improves your quality of life by helping build a more comfortable and healthy home. Energy efficiency saves you money. A recent study showed that American families earning a gross income of $50,000 experienced an average after-tax energy cost increase from 12% in 2001 to 21% in 2012.

How Energy is Used in Homes

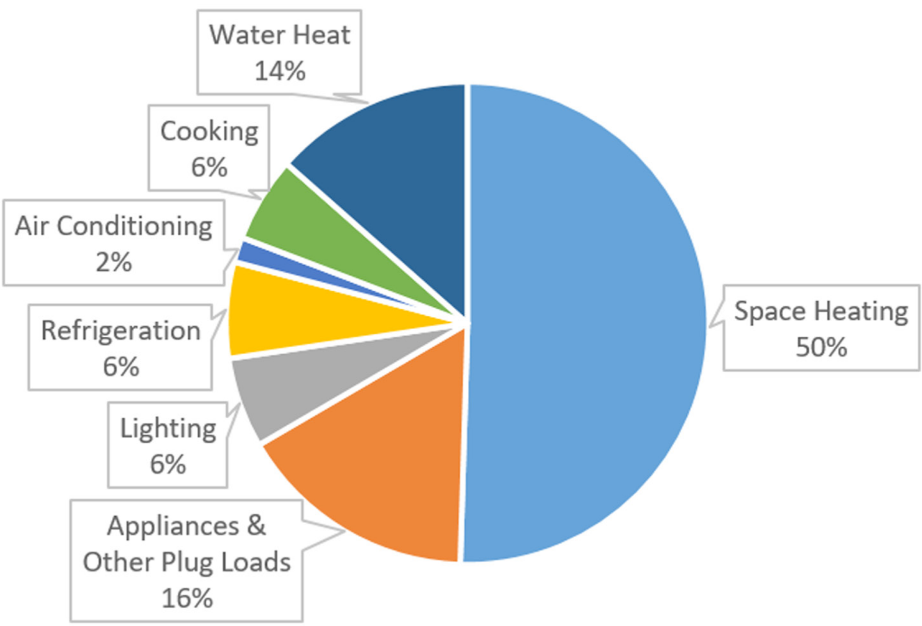
Our homes can be kept at any temperature we choose, a luxury that wasn't possible 100 years ago. But keeping our homes comfortable uses a lot of energy. Electric lighting has revolutionized the way we live, work, and play. Some homes still use the traditional incandescent bulbs invented by Thomas Edison. These bulbs convert only about 10% of the electricity they use into light; the other 90% is converted into heat. Compact fluorescent bulbs, or "CFLs," have made major inroads into home lighting in the last 15 years. These bulbs last much longer and use much less energy than incandescent bulbs. Now LED lamps are replacing CFLs because they are so much more efficient and can produce significant savings over the life of the lamp.

Appliances such as refrigerators, washing machines, and dryers are also more energy efficient than they used to be. Congress passed and subsequently amended the National Appliance Energy Conservation Act that requires new appliances to meet strict energy efficiency standards.

The graph on the following page shows how homes in the NorthWestern Energy service area use energy. Space heating is the greatest use by far. Appliances and miscellaneous plug load energy use now is more significant than consumption for water heating, lighting, or refrigeration.

Over the past 30 years the U.S. population grew by 30% while the number of homes grew by about 40%. Energy consumption, however, grew at a slower rate, due to improvements in building insulation and efficiencies of heating and cooling equipment, water heaters, refrigerators, and other major appliances. However, these efficiency gains were offset by increases in the number of homes with cooling equipment, clothes washers and dryers, and dishwashers. Additionally, a growing number of U.S. households now have multiple televisions, computers, and refrigerators.

How Energy Is Used In Homes

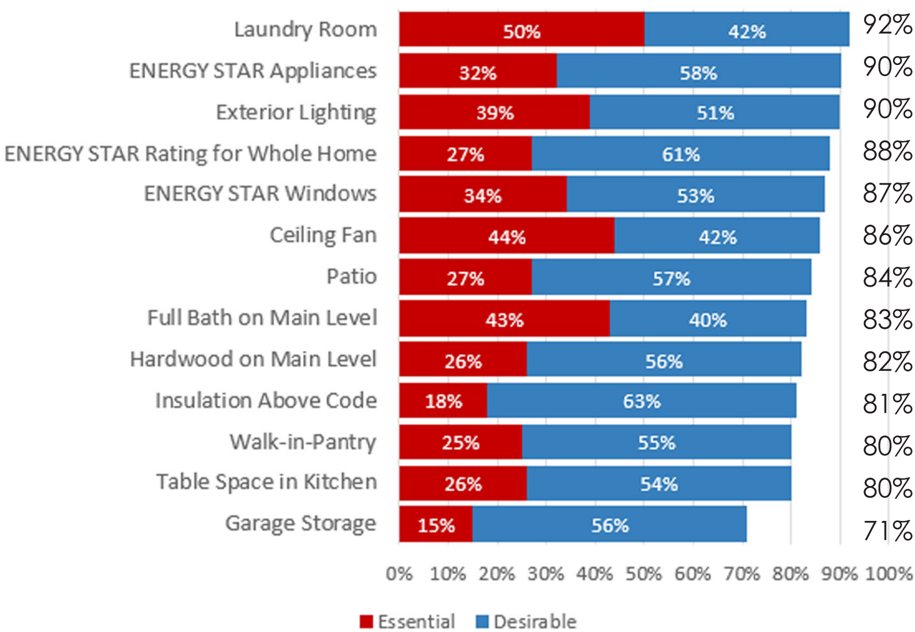


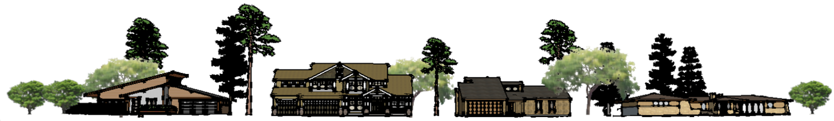
In 2009, 76% of U.S. homes had at least one computer, 8% more than just four years prior, and 35% had multiple computers. Also, most households had only one television in 1978. In 2009, the average household had 2.5 televisions. Over 45% of homes have at least one television with a screen size of 37 inches or larger. Screen size and average energy consumption per television have continued to grow over time.

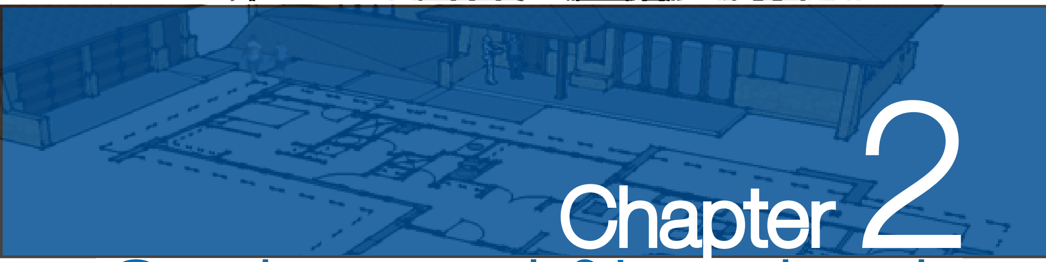
What Home Buyers Want

The National Association of Home Builders (NAHB) recently released its latest study tracking home buyer preferences, titled *Housing Preferences of the Boomer Generation: How They Compare to Other Home Buyers*. Potential home buyers consider features that help them save energy and keep the home organized as most essential and desirable. ENERGY STAR® appliances and windows, insulation higher than required by code, a laundry room, garage storage, and a walk-in pantry positively influence the home buying decision.

Homebuyers' Most Wanted List







Chapter 2

Codes and Standards

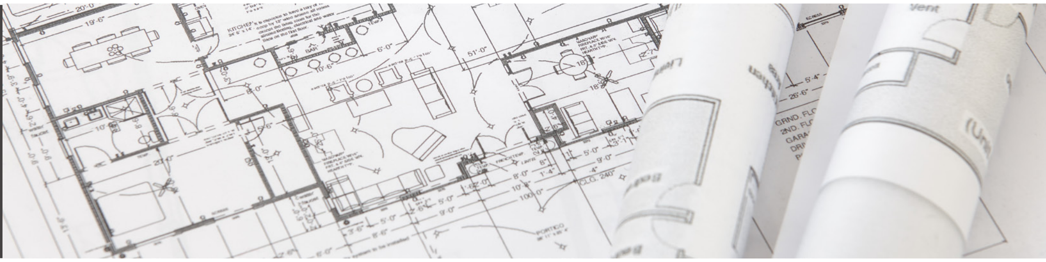
Montana Energy Code

Home buyers in the state have a right to expect a minimum level of energy efficiency in the homes they buy. That right is established by the Montana law. Within local government jurisdictions that choose to enforce the building code, these minimum energy efficiency features are assured by the inspection process required for each new home. Outside local code enforcement jurisdictions the energy code is enforced on residential buildings through Montana's self-certification program.

The Montana energy code is applicable to all new residential buildings constructed in the state, with the exception of garages and storage buildings.

Montana law requires, as an element of the self-certification program, that the builder provide a signed document to the building owner stating that the house complies with the state energy code.

The energy code also applies to additions, alterations, renovations, and repairs. However, the energy code is not retroactive. Unaltered portions of the original building do not need to comply. A good rule of thumb is that if it is new, then it has to meet the energy code. There are several exceptions, such as storm windows installed over existing windows and glass-only replacements. The residential energy code also applies when unconditioned space becomes conditioned, such as when a garage is converted to living space.



The energy code establishes legal minimums for some energy-related features of new homes. The main areas regulated by the energy code are building envelope, mechanical systems, and lighting systems.

What the energy code does not regulate is equally or more important. For example, the code does not regulate appliances and plug loads. In a codes context, appliances are defined as anything governed by the U.S. Department of Energy's Appliances and Commercial Equipment Standards Program. Critically, the federal legislation prohibits individual states from adopting more stringent standards. The federal equipment standards apply not only to what we normally think of as appliances such as refrigerators and clothes washers, but also to residential and commercial furnaces, heat pumps, water heaters and air conditioners, commercial clothes washers, linear fluorescent lamps, boilers, walk-in coolers and freezers, and more.

Plug loads refer to any energy consuming item that is brought into a building or home after construction is finished. Examples of plug loads are computers, copiers, printers, refrigerator heaters, pottery kilns, washers and dryers, and the now ubiquitous large flat screen televisions.

Energy codes do not control other fundamental aspects of house design that strongly impact energy use such as building orientation and layout. Finally, energy codes do not regulate what are probably the major determinants of a building's ultimate energy use: construction and installation quality; equipment maintenance; and occupant behavior.

More than anything, of course, the performance of a building is dependent on how it is used by the occupants and the people who control and maintain the energy systems. Lighting left on during unoccupied hours consumes energy without serving any useful purpose. Space cooling systems without controls set to take advantage of outside air for free cooling will sacrifice unnecessary energy. Doors and windows left open will render the best insulation irrelevant, and a teenager taking thirty-minute showers will offset attempts at reducing energy for hot water. Energy codes control none of this. Refer to the later chapter titled *After You Move In* for more information about how to assure your home achieves its energy saving potential.

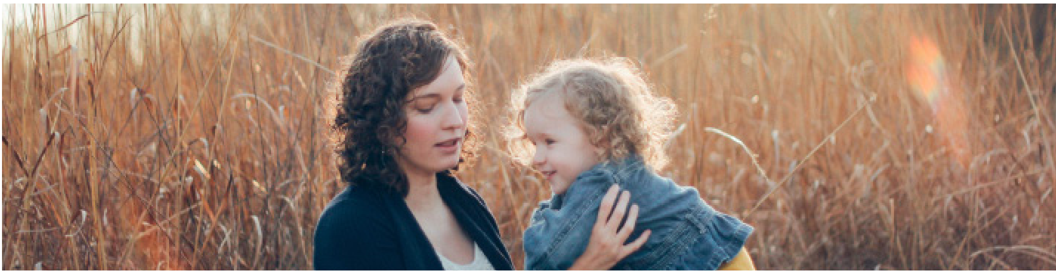
Benefits to Home Buyers

Energy codes and above-code energy standards play an important role in improving home performance. The benefits provided by the energy code and above-code standards such as ENERGY STAR, Indoor airPlus, Zero Energy Ready Home (ZERH) are summarized below.

Lower Energy Costs. The most recent changes to Montana's energy code are expected to result in a 15% improvement in energy efficiency over the previous version. A study by the U.S. Department of Energy (USDOE) found that, on average, the latest code will result in a seven-year average simple payback for a new Montana home. Another analysis by the Montana Department of Environmental Quality (DEQ) estimated the average simple payback at thirteen years. The Energy Savings from an ENERGY STAR Home are about 15% above code while the savings from ZERH homes are even greater.

Increase Home Value. Increasing the energy efficiency of your home will not only keep more dollars in your pocket, but it can also dramatically improve the market value of your home. Along with the tight financial climate comes a wave of buyers who are not only fiscally savvy, but also care about the impact their lives have on the environment.

Improve Comfort. Homes that are built to energy code requirements or above provide greater year-round comfort. A comfortable home is warm in the winter, cool in the summer, and free from drafts and cold spots. Better windows reduce the occurrence of condensation on window surfaces. Well-designed



ventilation systems keep the indoor air home fresh and safe. Homes are more durable and last longer when built according to recognized building science principles.

Improve Health and Safety. Inefficient buildings can contribute to serious health concerns, especially for children, the elderly, and those suffering from illness. Energy code-compliant homes can reduce health risks such as mold, dust and dust mites, radon, pollen, and combustion by-products. The Indoor airPlus program provides health safeguards well beyond those provided by the building and energy codes.

Reduce Maintenance Costs. Energy-efficient homes can reduce maintenance problems associated with mold growth and rot from condensation; heating and cooling equipment maintenance/ replacement due to excessive run times; and insect, rodent, and other pest infestation due to improper sealing. The ENERGY STAR program includes many design features that will assure that the home is durable.

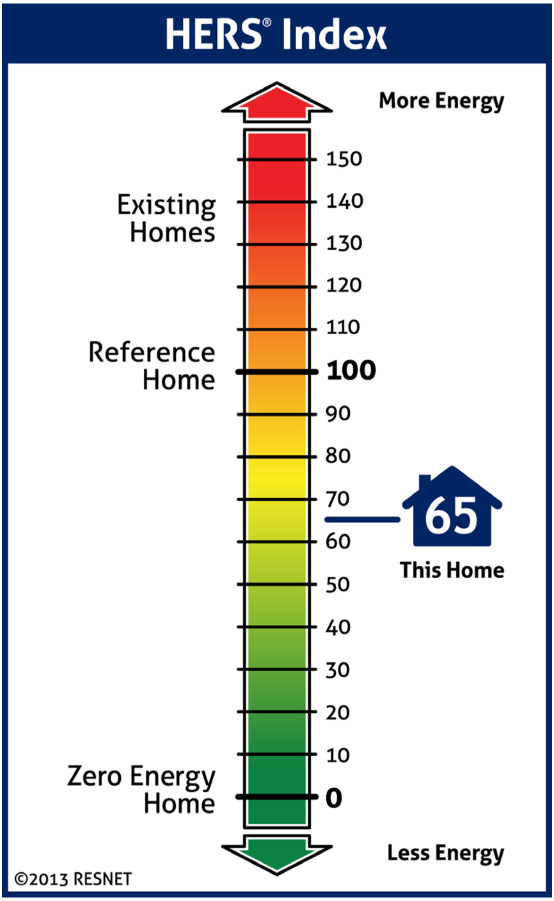
Above-Code Programs & Standards

When Barely Legal Isn't Good Enough

The energy code specifies the minimum new home energy efficiency features allowed by state law. The reference section at the end of this document includes links to websites that summarize the energy code requirements.

A number of programs provide energy-efficiency standards and testing protocols for those home buyers interested in their home exceeding the minimums for energy efficiency, comfort, and health. Most of the above-code programs involve third-party evaluation and inspection by a Home Energy Rater (HERS Rater). Home Energy Raters have become the nationally recognized home energy experts who provide energy-efficiency strategies and performance testing for new residential construction.

Home Energy Ratings



A home energy rating measures how energy-efficient your home is compared to other homes. It consists of an analysis conducted by a certified Residential Energy Services Network (RESNET) Home Energy Rater and, based on those results; your home is given a score also known as the HERS Index. This is a nationally recognized system for calculating a home's energy performance, with a lower score equaling a more energy-efficient home.

A comprehensive HERS home energy rating, conducted by a certified RESNET Home Energy Rater, is an in-depth energy performance assessment of a home. It consists of diagnostic testing using specialized equipment, such as a blower door test, duct leakage tester, and when appropriate a combustion analyzer and infrared camera to determine the amount and location of air leaks in the building envelope, the amount of leakage from HVAC distribution ducts, the effectiveness of insulation inside walls and ceilings, and potential combustion safety issues.

Government agencies such as the Department of Energy (DOE), Department of Housing and Urban Development (HUD) and the Environmental Protection Agency (EPA) recognize the HERS Index as an official verification of energy performance.

ENERGY STAR New Homes

The materials and techniques used in building a new ENERGY STAR Home will significantly increase home comfort and provide even temperatures through every season. Providing proper ventilation, minimizing air leaks and installing point-source ventilation in bathrooms, kitchens, and laundry rooms for moisture management ensures clean, healthy indoor air. While some of these features are included in the state energy code, ENERGY STAR sets a much higher standard for installation details and third-party verification.

ASK ABOUT ENERGY STAR CERTIFIED HOMES

To earn the ENERGY STAR label, a new home is performance tested throughout the building process by an independent HERS Rater who verifies that the required building specifications and equipment performance levels were met. ENERGY STAR is a program of the US EPA. Features of an ENERGY STAR Home include:

High-Efficiency Heating and Cooling. High–efficiency systems are engineered and installed to deliver more comfort, better moisture control, improved indoor air quality, and quieter operation.

Proper Design and Quality Installation Practices. Trained HVAC professionals design and install the heating and cooling systems in ENERGY STAR certified homes in accordance with best practices established by the leading industry association and equipment manufacturers.

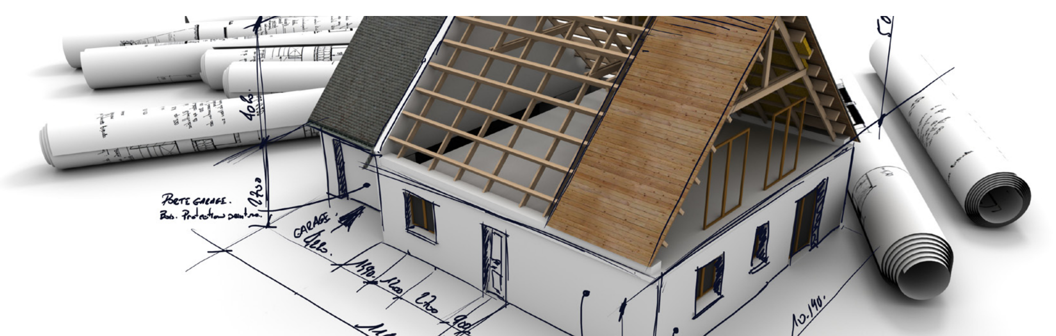
Whole–House Mechanical Ventilation. The living space in ENERGY STAR certified homes has a constant source of filtered air to reduce indoor air pollutants in your home.

Complete Thermal Enclosure System. Comprehensive air sealing, properly installed insulation, and high–performance windows work together to enhance comfort, improve durability, reduce maintenance costs, and lower monthly utility bills. Tried–and–true building practices, such as flashing, moisture barriers, and heavy–duty membranes, are employed to effectively drain water from the roofs, walls, and foundations of ENERGY STAR certified homes.

Properly Installed Insulation. It's not just the amount of insulation; it's the quality of installation that makes all the difference. Proper installation includes careful placement to eliminate gaps, voids, and compression; complete air barriers that prevent air from bypassing the insulation; and building techniques that minimize heat flow through framing. This ensures consistent temperatures throughout the house, reduced energy use, and increased comfort.

Advanced Lighting and Appliances. ENERGY STAR certified light fixtures and bulbs come in many shapes and sizes. This gives home buyers a wide range of lighting choices that allow them to create the atmosphere they want for their homes. ENERGY STAR lighting offers significant cost savings and longer lifetimes than standard products. Household appliances account for nearly 20 percent of energy use in an average house. A comprehensive package of ENERGY STAR certified appliances can reduce energy costs, while offering improved performance, quality, and durability. ENERGY STAR certified homes often include ENERGY STAR certified dishwashers, refrigerators, washing machines, ceiling fans, and ventilation fans.

Independent Inspections & Tests. The label that comes with every ENERGY STAR certified home may look small. It measures just three by five inches. But what it stands for is really big. It means that a home has undergone a better process of independent inspections and testing to



ensure it meets strict requirements set by the EPA.

How New Homes Earn ENERGY STAR

Step 1: Builder Become an ENERGY STAR Partner

Step 2: Builder and Rater Work Together to Select Climate-appropriate Energy Efficiency Features

Step 3: Builder Constructs Home and Rater Performs Field Verification and Quality Assurance

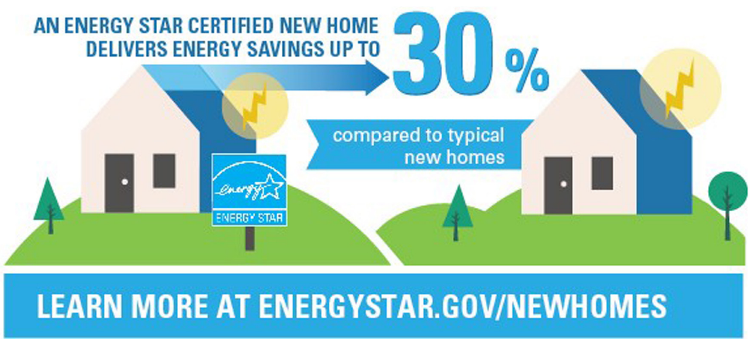
Step 4: Rater Certifies the Home and Issues an ENERGY STAR Label

Indoor airPLUS

Indoor airPLUS is a voluntary partnership and labeling program that helps new home builders improve the quality of indoor air by requiring construction practices and product specifications that minimize exposure to airborne pollutants and contaminants. Clean air is good for everyone's health, but it can be especially important to those that have chronic respiratory conditions.

EPA created Indoor airPLUS to help builders meet the growing consumer preference for homes with improved indoor air quality. Indoor airPLUS builds on the foundation of EPA's ENERGY STAR requirements for new homes and provides additional construction specifications to provide comprehensive indoor air quality protections. Every Indoor airPLUS home must first earn the ENERGY STAR Certified Home label. Home Energy Raters who certify a home to ENERGY STAR may also certify a home to Indoor airPLUS.

Why Indoor Air Quality is Important. Home buyers today are increasingly concerned about the indoor air quality of their homes.



ask about

EPA Indoor airPLUS

QUALIFIED HOMES

Issues like mold, radon, carbon monoxide and toxic chemicals have received greater attention than ever as poor indoor air quality has been linked to a host of health problems. Poor indoor air quality can lead to eye irritation, headaches, allergies, respiratory problems such as asthma, and other serious health problems. Since most people spend close to 90% of their time indoors, keeping indoor pollution levels as low as possible is the right thing to do for you and your family.

DOE Zero Energy Ready Home

A U.S. Department of Energy (DOE) Zero Energy Ready Home (ZERH) is a high performance home which is so energy efficient, that a renewable energy system can offset all or most of its annual energy consumption. Launched in 2012, the DOE Zero Energy Ready Home a new way to easily identify leading edge builders who construct to the program's strict guidelines are so energy efficient - at least 40%-50% more energy efficient than a typical new home - that a small renewable energy system can offset most or all of the annual energy consumption. By building homes with extraordinary levels of energy efficiency, comfort, safety, health and durability, DOE Zero Energy Ready Home partners are saving Americans energy and money, creating jobs and protecting the environment.

A DOE Zero Energy Ready Home is a high performance home which is so energy efficient, that a renewable energy system can offset all or most of its annual energy consumption. In Montana the renewable energy system does not have to be installed at this time. The program requires that provisions are made for installations at some future date if and when such systems become cost effective. Launched in 2012, the DOE Zero Energy Ready Home™ is a new way to easily identify leading edge builders who construct to DOE's strict guidelines for zero net-energy

ready homes. DOE Zero Energy Ready Homes are so energy efficient - at least 40%-50% more energy efficient than a typical new home - that a small renewable energy system can offset most or all of the annual energy consumption. By building homes with extraordinary levels of energy efficiency, comfort, safety, health and durability, DOE Zero Energy Ready Home partners are saving Americans energy and money, creating jobs and protecting the environment.

To qualify as a DOE Zero Energy Ready Home, a home must meet the minimum requirements specified, be verified and field-tested in accordance with HERS Standards by an approved verifier, and meet all applicable codes. Builders may meet the requirements of either the Performance Path or the Prescriptive path to qualify a home. Buildings eligible for qualification are: single family detached and attached dwelling units; dwelling units in multifamily buildings with three stories or fewer above-grade; dwelling units in multifamily buildings with four or five stories above-grade, that have their own heating, cooling, and hot water systems separate from other units and where dwelling units occupy 80% or more of the occupiable square footage of the building.

DOE Zero Energy Ready Home Prescriptive Path. The prescriptive path provides a single set of measures that can be used to construct a DOE Zero Energy Ready Home labeled home. Modeling is not required, but no trade-offs are allowed. All homes certified through the Prescriptive Path shall be submitted to DOE Follow these steps to use the prescriptive path:

1. Assess eligibility by using the number of bedrooms in the home to be built to determine the conditioned floor area of the Benchmark Home. If the CFA of the home to be built exceeds this value, the performance path must be used.

2. Build the home using the mandatory requirements for all labeled homes, and all requirements of the DOE Zero Energy Ready Home Target Home.

3. Verify that all requirements have been met using an approved verifier.

DOE Zero Energy Ready Home Performance Path. While all mandatory requirements must be met, the performance path provides flexibility to select a custom combination of measures that meet the performance level of the DOE Zero Energy Ready Home HERS Target Home. Computer modeling is required, but energy efficiency measures can be optimized for each particular home or builder. All homes certified through the Performance Path shall be submitted to DOE. Follow the steps below to use the performance path with RESNET-accredited Home Energy Rating Software programs:

Step 1. The HERS Index of the DOE Zero Energy Ready Home Target Home is determined. The DOE Zero Energy Ready Home Target Home is identical to the home that will be built, except that it is configured with the energy efficiency features of the DOE Zero Energy Ready Home Target Home. The HERS Index of the Target Home is automatically calculated in accordance with the RESNET Mortgage Industry National Home Energy Rating Standards.

Step 2. A size modification factor is next calculated.

Step 3. The HERS Index of the DOE Zero Energy Ready Home Target Home is calculated based on the HERS Index of the DOE Zero Energy Ready Target Home and the Size Modification Factor.

Step 4. Complete HERS software calculations for preferred set of energy measures and verify resulting HERS Index Score at or below DOE Zero Energy Ready Home Target Home HERS Index Score modified, as required, for house size.

Step 5. Construct the home using measures that result in a HERS Index at or below the DOE Zero Energy Ready Home HERS Target.

Step 6. Verify that all requirements have been met using an approved verifier.

Summary of DOE Zero Energy Homes Requirements:

- ENERGY STAR Qualified Home
- ENERGY STAR qualified windows and doors
- All ducts located within thermal air boundary
- Hot water delivery systems meets requirements of the EPA WaterSense
- Installed refrigerators, dishwashers, and clothes washers are ENERGY STAR Qualified
- 80% of lighting is ENERGY STAR qualified
- Installed ceiling fans and bathroom ventilation fans are ENERGY STAR qualified
- House is certified under the EPA Indoor airPlus program
- Compliance with the Consolidated Renewable Energy Ready Home (RERH) Checklist
- AFUE minimum 94%
- SEER minimum 13
- HSPF minimum 10
- Compliance with ASHRAE 62.2 Whole House Mechanical Ventilation System with minimum 1.2 cfm/Watt fans and a minimum 60% heat exchange efficiency
- Grade I insulation required per RESNET Standards
- Envelope infiltration maximum of 2 ACH50

Chapter 3
Home Design

Constructing energy-efficient, durable, and comfortable homes makes economic sense—for the homeowner, the builder, the real estate professional, and the environment. Builders across the country have already discovered that it isn't difficult to build energy-efficient homes that are more healthy, durable, and comfortable to live in, while cutting energy bills. The next few pages will introduce the design features that differentiate a high performance home. While many of these design features are just common sense, other features call on the latest developments in building science and technolgy.

Climate Responsive Design

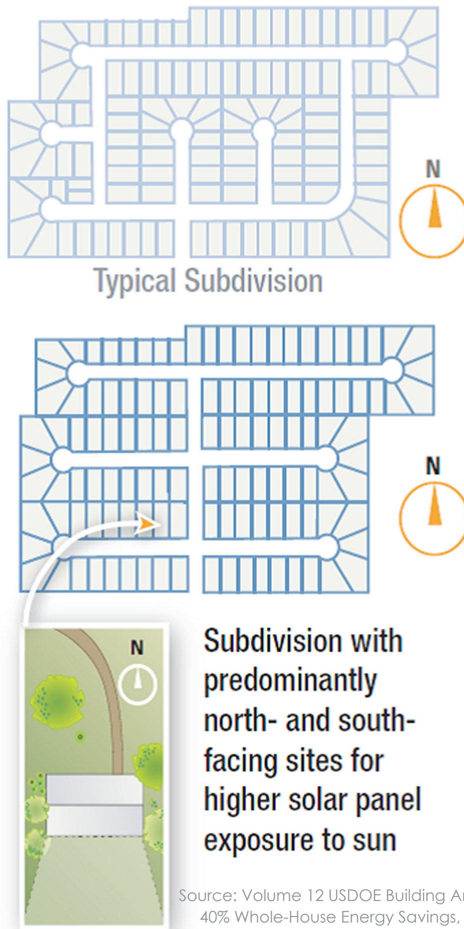
When solar energy is mentioned, most people think of photovoltaic (PV) panels that generate electricity. Unfortunately many home buyers, designers, and builders don't realize that solar electric systems are more costly than most energy efficiency and climate responsive design strategies. The first step in solar design for a new house is energy efficiency. Energy efficiency should be given the highest priority. After energy efficiency the next step is that the building shape and orientation which includes window placement and selection of glazing characteristics.

Building Shape and Orientation. By facing the long side of a home to the south and the short sides to the east and west, the building will capture solar heat in the winter and block solar gain in the summer. In the heating-dominated cold climate regions, builders can use solar orientation to take full advantage of the sun's natural heat.

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

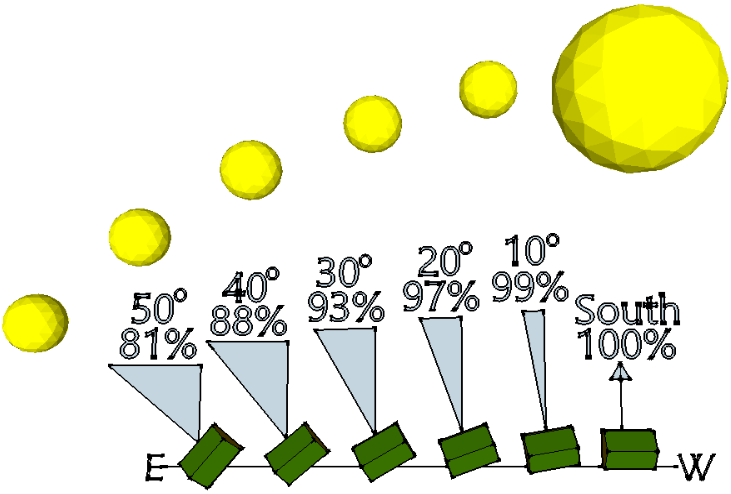
One virtually no-cost option for improving energy performance is to subdivide for solar orientation. Subdivision lot lines and roads should be designed for predominantly north-south orientation.

While the ideal orientation would be to face the home's long side directly into the sun, it can be oriented up to 30 degrees away from due south and lose less than 10% of the potential heating savings. Locating windows on the home's south side will enhance its solar performance. If the south-facing window area reaches 8% to 10% of floor area, the home is called "sun tempered." A home with south-facing glass area of greater than 10% of floor area would be called a "passive solar" home; this much south-facing glass typically requires thermal storage mass and mitigate summer heat gains. Providing appropriate shading for both sun tempered and passive solar homes is very important.



Source: Volume 12 USDOE Building America: 40% Whole-House Energy Savings, 2011

A study done in the Pacific Northwest by the Bonneville Power Administration placed passive solar home space-heating savings between 10% and 20%. To minimize overheating during spring and fall, builders should limit the amount of west-facing glass.



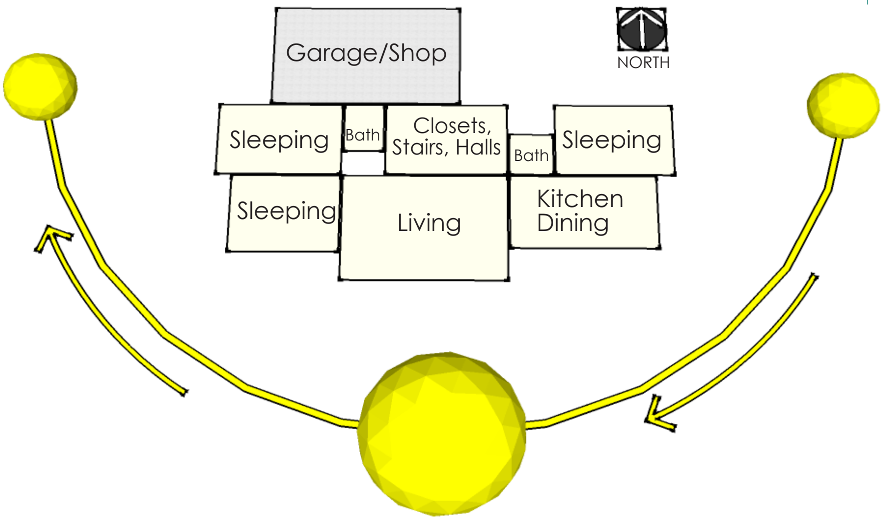
Window Orientation and Solar Heat Gain

As window orientation deviates from due south solar heat gain is reduced. Illustration shows degree deviation from south and resultant reduced solar heat based on vertical double-pane Low-E glazing during the heating season for Helena.

The optimum orientation may be influenced by several factors including views, floor plan layout, local weather patterns, and shading from vegetation, other buildings, and topographic features. Generally, an orientation slightly east of south is preferred. This provides greater solar gain earlier in the morning when the outdoor air temperatures are low. Orienting the long axis of the house east of south will reduce afternoon solar heat gain when overheating potential is at its greatest. Orienting the long axis of the house west of south will increase afternoon solar gain but allow that heat to carry longer into the night.

When positioning buildings to get the maximum solar benefit, overhangs can help manage heat gain and glare. Windows should be selected to manage heat loss and solar gain. Proper building orientation, proper window location, design for natural ventilation, and provisions to shade windows and walls can eliminate the need for mechanical cooling in most homes.

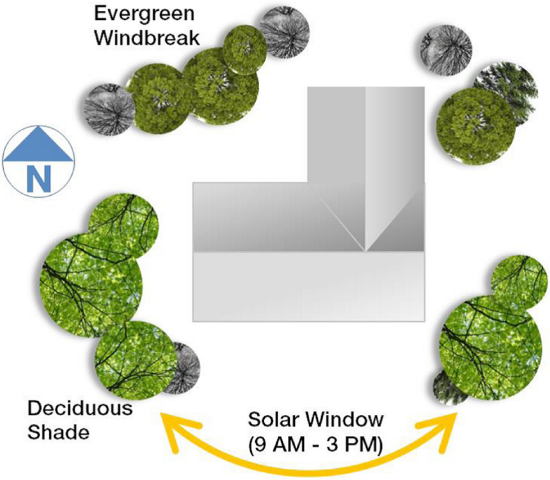
Optimum solar orientation and views do not necessarily coincide. As the views become further off south, obtaining solar heat from that window becomes more challenging. North windows provide no significant solar heat. For windows that provide minimum solar contribution, lower U-factors should be considered.



Plan Room Functions to Coincide with the Sun's Movement

Energy consumption for space heating can be reduced by locating rooms so that the daily sequence of activities align with the path of the sun. By relating rooms to the movement of the sun solar energy can be used when it is most available. For example, the kitchen and breakfast eating areas can most benefit from early morning sun. The south side of the house is a good place for spaces that are continually occupied during the day. Utility spaces and spaces that do not need sun light should be placed on the north side of the house.

Windows. Montana has a heating-dominated cold climate. It is preferable to use windows with a lower U-factor and a higher solar heat gain coefficient (SHGC). The U-factor is a measure of heat transfer. The lower the U-factor, the better the window performs at stopping heat flow. The SHGC measures how well the window blocks heat caused by sunlight. The lower the rating, the less solar heat the window transmits. The Montana energy code prescriptive compliance path requires a window U-value of 0.32 or lower. The energy code does not regulate the SHGC in the Montana climate zone. Typically, a double-pane Low-E wood or vinyl window has a SHGC of about 0.50. The south windows of sun-tempered home would benefit from a higher SHGC. For more information about windows, see the Efficient Windows Collaborative website at www.efficientwindows.org.



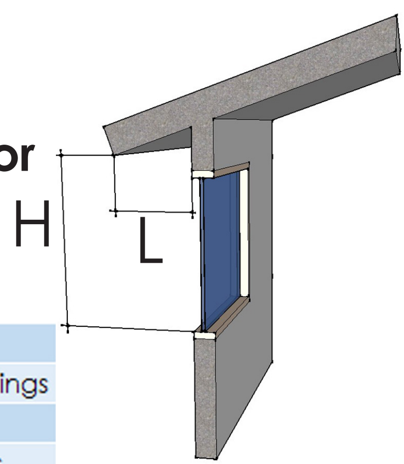
Solar Site Planning

Window Overhangs and Shading. Installation of overhangs is critical to maximize solar heat gain without creating uncomfortable overheating and glare. Overhangs provide protection from rain, hail, and ultraviolet radiation on siding and windows. Overhangs may take the form of eaves, porches, awnings, pergolas, or trellises. Overhangs should be sized to account for differences in sun angles, elevation, window height and width, wall height above the window, and amount of shading desired based on time of day and time of year. Free and low-cost computer programs are available for sizing overhangs based on location. An online sun shading calculator is available at www.susdesign.com/. SketchUp, 3D modeling software commonly used by designers, allows simulation of building and overhang hourly shadows each day of the year.

The following diagram provides another simple approach to designing window overhangs:

L = H / Overhang Factor

	Overhang Factor (100% Shading at Noon)		
Latitude	June 21	August 1	
45	2.58	1.93	Dillon, Red Lodge
46	2.45	1.85	Butte, Bozeman, Billings
47	2.33	1.78	Helena, Missoula
48	2.20	1.70	Kalispell, Great Falls
49	2.10	1.65	Cut Bank, Havre



Shade can also be provided by intentional planting or preservation of existing trees on the site. While evergreen trees may provide better wind protection, deciduous trees are ideal for summer shading in the cold climate because their lack of leaves in the winter will not block desirable solar gain during the heating season. Trees reduce cooling requirements, particularly when located on the south and west side of the home to block low-angle, late-afternoon, peak solar-gain sun. There is obviously a trade-off between providing shade in the summer and solar heat gain during the spring and fall that must be addressed for each solar-tempered house.

Planning for Roof-Mounted Solar Electric Panels. Designing a home to provide significant south-facing roof area will faciliate adding solar electric panels in the future. A due-south building orienation is not absolutely necessary. In the Montana climate, the optimal solar electric panel tilt is between 40° and the site latitude. With an orientation of due south, the tilt can vary from 20° all the way to a roof pitch of 60° and still receive 90% of available solar energy. If the tilt is at the optimum of 40° for total annual kWh production, the azimuth could vary by 50° either east or west of due south and still receive 90% of the available solar energy.

Building Envelope

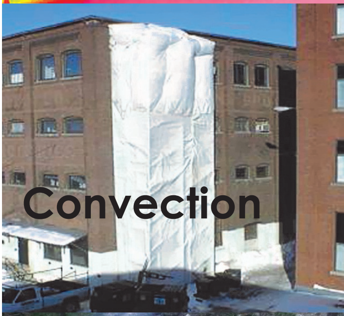
The walls, roof, and floor of a house protect occupants from the rain, snow, sun, and wind. We refer to these components of a house as the *building envelope*. By installing insulation in the building envelope, we minimize heat transfer from the house in the winter and into the house in the summer. By installing an air barrier in the building envelope, we reduce the movement of air from inside the house to the exterior, also reducing heat loss in the winter.

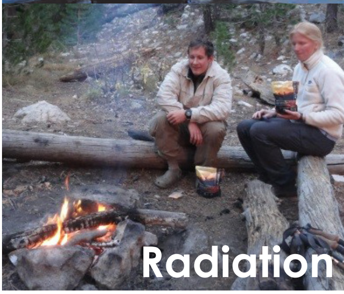
By building efficient envelopes (walls, roofs, and floors), the amount of heating and cooling energy required will be minimized. More efficient building envelopes may also reduce the size of the heating and cooling system.

While heating systems are often replaced over the life of a home, the building envelope of a modern home is rarely improved. The costs of adding insulation to walls and roofs that are already insulated is too great. For that reason, the energy efficiency of walls, roofs, and floors deserve extra attention when the house is first built.

The building envelope of a home is subjected to a wide range of conditions caused by the wind, sun, air temperatures, and humidity. Periods of greatest heat loss and heat gain occur when temperature difference between the inside and outside is the greatest.

To design building envelopes that are durable and energy-efficient, it is important to understand the way heat, air, and water vapor move through the building envelope. All heat transfer can be explained by three heat-transfer mechanisms: *conduction*, *convection*, and *radiation*. These mechanisms explain heat transfer and also offer insights into why some buildings and spaces are more comfortable than others.



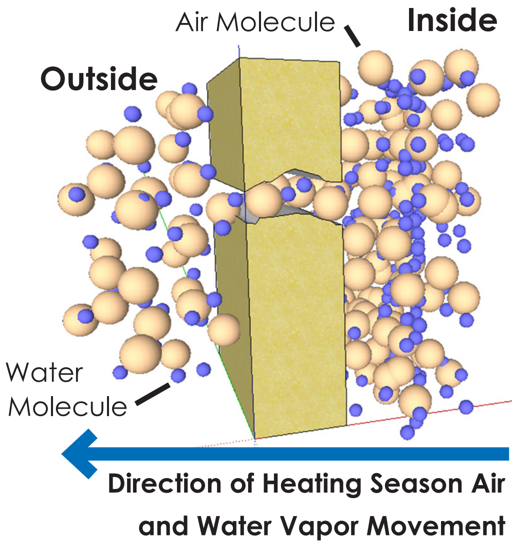


Conduction is heat flow through solid objects and materials. Heat is transferred from molecule to molecule. This is generally the slowest of the three heat-transfer mechanisms. The infrared scan photo to the right of a front door shows conduction of heat through the door. The dark blue sections of the door are colder, indicating greater heat loss than through the thicker portions of the door, which have a greater resistance to heat transfer by conduction.

Convection is heat transfer by a moving gas or fluid such as air or water. This heat movement is caused by the density difference between warmer and cooler molecules. Warm air rises to the top of a building where it either escapes to the attic, and eventually outside, or is cooled and falls.

Heat transfer by **radiation** occurs when heat is transferred through space or air from one object to another. Heat transfer by radiation requires a temperature difference between objects, a gap, and an unimpeded "line of sight." We can feel the effect of heat transfer by radiation when we are warmed by a campfire on a cool night or are uncomfortable sitting near a cold window in an otherwise warm room.

It's in the Air. Water vapor is always present, in varying quantities, in the air around us. That water vapor is invisible until it condenses on cold window surfaces or is seen as a mist rising from a boiling pot of water. The movement of air and water vapor from inside our home into the building envelope is an important factor when it comes to the long-term durability of a home.



Air and water vapor move from areas of high pressure to areas of low pressure. During the heating season in Montana, the air pressure inside the home is generally greater than outside. Under these conditions, house air, along with water vapor, are forced into the walls and ceiling.

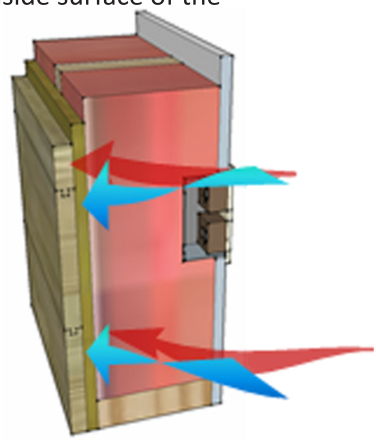
R-Values and U-Factors. Understanding a few basic energy terms and concepts will help in understanding building energy efficiency. *R-value* is a measure of thermal resistance. The greater the R-value, the better the insulator. R-values may be added to each other to determine the total R-value of an assembly. *U-factors* on the other hand, cannot be added. U-factors are used when calculating heat loss through materials and assemblies. R-values are the inverse of U-factors and U-factors are the inverse of R-values.

R-Values Measure Thermal Resistance

- R-Values are additive (R-1 + R-1 = R-2); U-factors are not
- R-value is the inverse of U-factor: R=1/U and U=1/R
- The higher the R-value, the greater the thermal resistance
- The lower the U-factor, the greater the thermal resistance
- U-factors are used for windows, doors, and skylights

One of the most important roles of the building envelope is to control the movement of liquid water and water vapor. There are many sources of water that affect buildings. They include exterior moisture (rain), interior moisture (water vapor from people using the building), and moisture in construction materials. It is important to minimize the movement of warm-moist interior air into the wall or ceiling. Water vapor moves into a wall by air transport and by diffusion. Water vapor movement by air transport is much more significant than by diffusion. Where air molecules can move, so can smaller water molecules. The solution to preventing excessive diffusion is to install a vapor retarder on the warm side of above-grade walls. The solution to minimizing water vapor movement by air transport into the building envelope is to install a continuous sealed air barrier.

Water vapor inside a wall can condense if the inside surface of the exterior sheathing is cool enough. If the wall cavity is filled with air-permeable insulation, such as fiberglass, cellulose, or low-density foam, condensation occurs on the exterior sheathing. One strategy to reduce the potential for condensation is to raise the temperature of the inside face of the sheathing. This can be accomplished by adding continuous insulation to the exterior of a wall. This is a key reason future energy codes will likely require continuous exterior sheathing.



Warm air and water vapor move through air barrier leaks into the building envelope.

Note: High-density foam insulation is generally not air-permeable and thus prevents water vapor from entering the wall or roof cavity.

Allow the Wall to Dry. No matter how hard we try to eliminate moisture from walls, some moisture is likely to occur either from initial construction or later from water leaks or a compromised air barrier. For that reason, it is important to provide a way for walls to dry. In Montana's climate, drying has generally occurred primarily to the outside, but walls also will dry to the inside during the warmer portion of the year. The solution to allowing walls to dry is to never install Class I vapor retarders (0.1 perms or less) on both sides of the wall. A Class II vapor retarder (greater than 0.1 perms but less than 1.0 perm) meets the code requirement and allows the wall to dry to the inside.

If continuous foam insulation is installed on the wall exterior, there will be little drying to the outside. In this case, it is critically important that no Class I vapor retarder, such as a polyethylene sheet, be installed on the inside of the wall to prevent drying to the interior.

How Much Insulation? The Montana Energy Code includes several building envelope compliance options. The most widely used compliance option is the prescriptive approach, which specifies the minimum energy-efficiency characteristics for different envelope components. The following table includes the minimum prescriptive requirements.

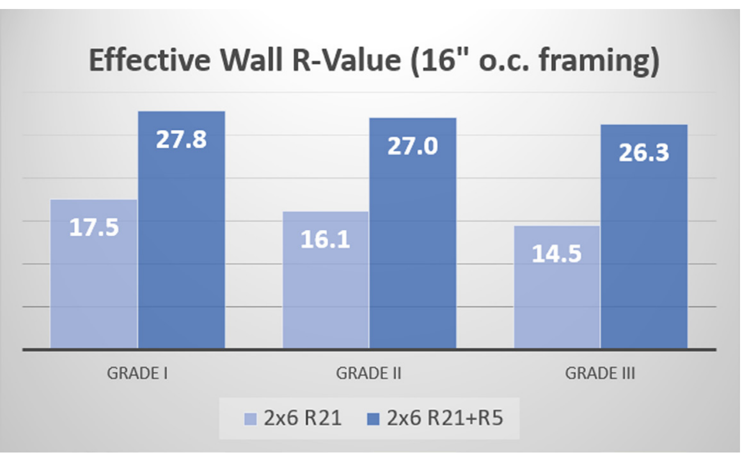
Energy Code Prescriptive Building Envelope Requirements

Windows & Doors	**U-0.32**	
Skylights	**U-0.55**	
Ceiling	**R-49**	**R-38 complies if uncompressed insulation extends over top of exterior wall top plate.**
Wood Frame Wall	**R-21 or R-13+5**	**First value is cavity insulation, second value is continuouse sheathing.**
Mass Wall	**R-15/R-20**	**Second value applies if more than half of R-value is on the interior of the mass wall.**
Floor	**R-30**	
Basement Wall	**R-15/R-19**	**First value is continous, second value is cavity.**
Slab Floor	**R-10 for 4'**	**Insulation must extend downward continuously from top of slab 4 feet vertically or horizontally.**
Crawlspace Wall	**R-15/R-19**	**First value is continous insude or outside, second value is cavity insulation on the inside.**

Vented attic roofs allow greater levels of cost-effective insulation than cathedral ceilings where added depth is more costly. Increasing the R-value in walls is even more costly, in part because wider walls means reduced house floor area. While fiberglass and cellulose insulation cost less per R-value, foam insulation offers greater R-value per inch. The final choice of insulation materials for walls or roof will have to balance installation cost with insulation R-value. Insulation material decisions affect other key wall performance factors, such as air and water vapor permeability.

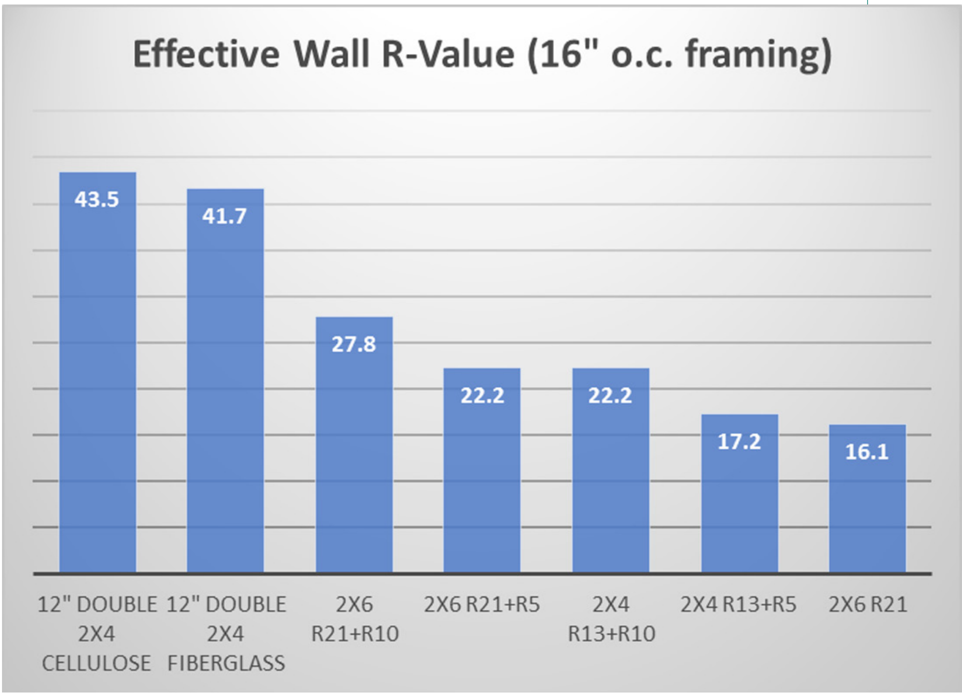
Installation quality plays an important role in insulation effectiveness, especially with batt insulation which is prone to defects such as gaps and areas of compression. RESNET, the organization that certifies ENERGY STAR homes, has created an insulation installation grading system, with Grade I being best and Grade III being worst. The insulation grade is determined by the gaps and areas of compressed insulation.

The percentage of the wall or roof assembly that is framing also impacts the effective R-value of the wall or roof assembly. The insulation values shown in table on the previous page are “nominal.” This means the other components of the assembly, such as framing members and wall finishes, are not included. The graph below shows the effective wall R-value when all components of the wall are considered. The two walls compared are a 2x6 frame wall with nominal R-21 insulation and a 2x6 frame wall with nominal R-21 insulation plus a continuous layer of R-5 rigid foam insulation. The effective R-value of a 2x6 wall with R-21 insulation and moderate quality installation (Grade II) is only R-16. Notice that poor installation has a greater impact on the walls without continuous insulation.



Above-code programs such as ENERGY STAR have encouraged designers and builders to consider advanced wall designs that provide greater levels of insulation.

The table on the next page presents the effective insulation value of a number of walls. Each design has its benefits and challenges that need to be carefully considered. It is important to understand that increasing the R-value of an assembly has diminishing returns. In other words, the greater the R-value, the less the benefit that will be obtained by adding an additional R-value. At some point it is more cost-effective to invest in



better windows or ventilation air heat recovery than adding insulation to a wall.

Windows. Highly efficient windows will increase comfort, durability, and energy savings. The National Fenestration Rating Council (NFRC, www.nfrc.org) provides window labeling that is required by the energy code. The two most significant performance values included on the NFRC label are the U-factor and Solar Heat Gain Coefficient (SHGC).

U-factor measures heat transfer. The lower the U-factor, the better the window performs at stopping heat flow. The maximum U-factor allowed by the Montana energy code is 0.32 which is equivalent to about R-3.

The SHGC measures how well the window blocks heat from the sun. The lower the SHGC rating, the less solar heat the window transmits. This rating is expressed as a fraction between 0 and 1. Most double-pane windows with a Low-E coating have a SHGC of about 0.5. The Montana energy code does not regulate the SHGC.

Building Envelope Tightness. Today's high-performance homes are built tight and then controlled mechanical ventilation is provided. This saves energy and provides fresh air under all weather conditions. To assure that the home's envelope is tight, the energy code requires that every home pass a house tightness (blower door) test, as well as comply with a checklist of building air barrier details.

The air barrier must be continuous and sealed. The energy code requires sealing all joints and penetrations. It is common for the air barrier to be a combination of materials. At walls and ceilings, the primary air barrier is usually either the gypsum board or sheet polyethylene




installed behind the gypsum board. The key feature of a code-compliant air barrier is that all seams and joints are sealed with manufacturer approved compatable sealant, gasket, or tape.

House Tightness Testing. In a blower door test, an exterior door is fitted with a nylon skirt that has an opening for a large fan. For new construction, a depressurization blower door test is typical. The blower door exhausts air from the house until the home has a negative pressure of 50 Pa with reference to the outside. The amount of air that flows out of a house is equal to the amount of air that leaks into the house.

The blower door fan includes the fan housing and several rings to adjust the size of the fan opening. The nylon skirt is held in the doorway by a metal frame. The motor speed controller allows the technician to control the speed of the fan. The blower door test procedure includes closing all exterior doors and windows and disabling all combustion appliances and exhaust fans. The air-flow measurement at 50 Pa is then used to calculate the air change rate for the house. While the blower door testing process is not complex, it takes care to properly set up the house and configure the digital manometer.

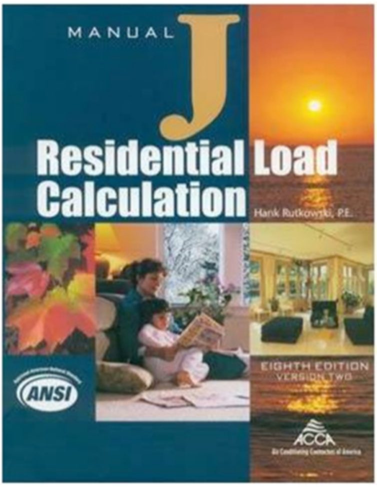
Efficient Heating and Cooling Systems

Today's high-efficiency heating and cooling systems are engineered and installed to deliver more comfort, improved indoor air quality, and quieter operation. This guide identifies key factors that home buyers, designers, and builders should consider when selecting heating and cooling systems appropriate for a particular home. For smaller, more energy-efficient homes, there are alternatives to the traditional central forced-air space-conditioning systems. HVAC is an acronym that stands for "heating, ventilation, and air conditioning." The next section in this guide discusses mechanical ventilation.

Air Changes per Hour at 50 Pascals (ACH50) – The number of times in an hour that the total air volume of a home is exchanged for outside air with the house depressurized by a blower door to 50 pascals with reference to the outside.

Pascals – A measurement of air pressure. One inch of water column is equal to 249 pascals.

An HVAC system must first be designed. Then the system must be installed. A critical, but often overlooked, third step in the process is commissioning. Commissioning of HVAC systems is important to assure that the system has been installed as designed and is operating properly. Proper duct design and installation is also important to achieve best results in comfort, efficiency, and durability. For example, ducts should be installed within the building thermal envelope to save energy. When ducts are located outside the thermal envelope, it suggests a lack of planning and coordination on the part of designers and HVAC contractors.



System Design. The Air Conditioning Contractors of America (ACCA) produces a set of manuals (*Manuals J, S, and*

D) that provide the industry standard for all three steps in the system design process. In the first step of the design process the system designer calculates the heating and cooling loads according to Manual J. Accurate heating and cooling load calculations are critically important for HVAC system design. Load calculations dictate the size of the HVAC system needed. The consequences of choosing the wrong-sized system include: noisy operation, discomfort, a failure to maintain proper moisture control, and the longevity of the system. A home's heating and cooling loads depend on a number of factors including the climate, house size, house orientation, tightness of the building envelope, and the thermal characteristics of the envelope.

Most available furnaces are oversized for a small energy efficient house. The smallest available furnaces from major U.S. manufacturers are rated at about 40,000 Btu per hour or more. Over the past 30 years, building envelopes have become tighter and better insulated, but U.S. furnace manufacturers haven't adjusted. Installing furnaces that are larger than necessary can result in comfort complaints. In such houses the central area thermostat will be satisfied but the bedroom at the end of a long duct run is still cool. Small furnaces, even when available, can be more expensive. This has led energy efficient home builders to look for alternatives to the central forced air system.

The second step in the design process is selection of the equipment that meets the calculated loads. The Montana energy code requires that Manual S, or its equivalent, be used when selecting heating and cooling equipment.

The final step, at least for central forced-air systems, is design of the duct system based on Manual D. Air ducts move air from the heating and cooling equipment to the rooms in the house, and then from the rooms back to the air handler. In a central forced air system proper airflow is needed to deliver or remove the correct amount of heat from each room. Factors that influence duct system design include: duct length, duct diameter, duct type, duct turns, and other components such as filters.

Heating and Cooling System Options. Many different appliances can be used to heat a house, including furnaces, boilers, water heaters, heat pumps, and wood stoves. Most traditional space conditioning systems use central forced air to distribute the conditioned air to the rooms of the house. However space conditioning systems that do not require duct work such as radiant systems, space heaters, and ductless heat pumps are becoming more common, especially for smaller homes. For the best results in comfort, efficiency, and durability, HVAC systems and

Efficiency Ratings. Following are the most common terms used to define the efficiency of HVAC equipment:

Annual Fuel Utilization Efficiency (AFUE). AFUE is the amount of fuel converted to heat at the furnace or boiler outlet in proportion to the amount of fuel entering. This is expressed as a percentage. A furnace with an AFUE of 90 is said to be 90% efficient.

Seasonal Energy Efficiency Ratio (SEER). SEER is a measure of air-conditioning equipment energy efficiency over the cooling season. It is the total cooling of a central air conditioner or heat pump in Btus during the normal cooling season divided by the total electric energy input in watt-hours. Central air-conditioning systems use SEER, while window units use EER.

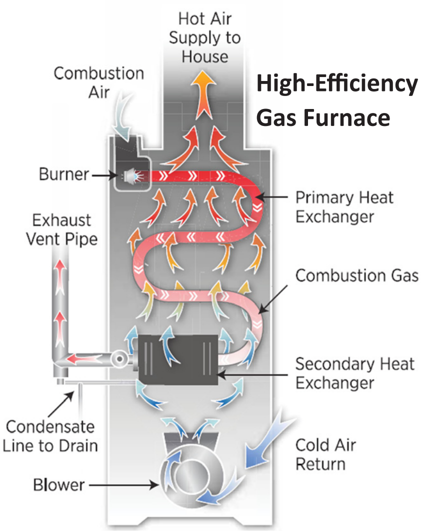
Energy Efficiency Rating (EER). EER is a rating of a central air conditioner's steady-state efficiency at 80°F indoors and 95°F outdoors, measured once the air conditioner is running. EER is similar to SEER except it measures the "instantaneous" efficiency rather than the efficiency over an entire season.

Heating Season Performance Factor (HSPF). HSPF is a measure of a heat pump's energy efficiency over the heating season. It is the total heating output of a heat pump, including supplementary electric heat, during the normal heating season in Btu's divided by the total electricity consumed in watt-hours.

duct design must be integrated in the overall building design. Builders should work closely with their HVAC engineer to properly size and select the HVAC equipment and ducts. With the advent of air-source heat pumps, the use of electric furnaces has declined sharply.

Forced-Air Systems. Forced air systems use duct work to distribute conditioned air throughout the house. Forced-air systems are equipped with a filter that removes airborne particles.

Gas-Fired furnaces are the most common heating system installed in homes today. A high-efficiency (≥90% AFUE), variable-speed, sealed



Source: Volume 14 USDOE Building America: Energy Renovations HVAC, 2011

combustion, natural gas-fired furnace provides the lowest-cost of delivered heat. Sealed combustion means an appliance acquires all air for combustion through a dedicated sealed pathway, usually a PVC pipe, from the outside to a sealed combustion chamber, and all combustion products are vented to the outside through a separate, dedicated sealed vent. Sealed combustion appliances eliminate the potential for back-drafting.

Furnaces should not be installed in a vented attic, vented crawl space, or garage where they would waste a lot of heat. Instead they should be installed in a basement mechanical room or a mechanical room near the center of the house.

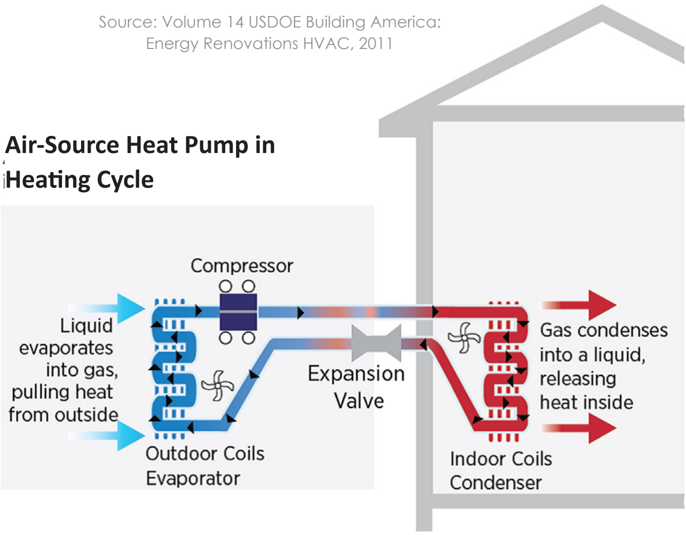
The federal government requires residential gas-fired furnaces to have a minimum efficiency of 80%. Medium-efficiency furnaces have efficiencies in the range of 80% to 82%. High-efficiency furnaces are designed to condense flue-gas moisture. High-efficiency furnaces are also called *condensing furnaces* and have AFUE ratings between 90% and about 97%. Condensing furnaces require a drain to dispose of the liquid condensate.

Condensing furnaces are power-vented and most are *sealed-combustion*. Sealed-combustion furnaces don't use any indoor air for combustion. An important advantage of a sealed-combustion furnace is that it is much less likely to suffer from back drafting problems.

Electric Heating and Heat Pumps. Electric resistance heat is used sparingly in today's new homes. It is largely limited to providing supplemental heat in bedrooms and bathrooms in homes equipped with non-ducted space heaters or ductless heat pumps. In Montana, standard air-source heat pumps typically use electric resistance back-up heat during very cold periods. Backup natural gas heat is a cost-effective alternative for larger homes. Heat pumps can be an energy-efficient alternative to propane furnaces and standard air conditioners where natural gas is not available. Heat pumps are often installed as a forced air system. A heat pump operates similar to a refrigerator. During the heating season, heat pumps move heat from the cool outdoors into the house; during the cooling season, heat pumps move heat from the house to the outdoors. Because they move rather than generate heat, heat pumps can provide up to four times the amount of energy they consume. Proper controls and commissioning are critical to achieving the efficiencies offered by heat pumps.

Source: Volume 14 USDOE Building America: Energy Renovations HVAC, 2011

Air-Source Heat Pump in Heating Cycle



Ground-Source Heat Pumps. Unlike air-source heat pumps, which draw heat from the air, ground-source heat pumps use the moderate temperature below ground to achieve high efficiencies. Geothermal, or ground-source, heat pumps can be very efficient for heating and cooling because they use the constant temperature of the earth as the exchange medium instead of the outside air temperature. This allows the system to reach fairly high efficiencies (300% or more) on the coldest of winter nights, compared to 175% to 250% for air-source heat pumps on cool days. Disadvantages include their initial cost and the need for yard space to install piping in the ground.

In a closed-loop system, piping loops can be laid horizontally, vertically, or looped in the ground or in ponds. These collector options are shown in the diagram in heating mode with fluid circulating to collect heat (red) from the ground, release it to the indoor heat pump through a heat exchanger, and return cooled fluid (blue) to collect more heat.

Ductless Heat Pumps. Ductless heat pumps are a more efficient


Source: Volume 14 USDOE Building America: Energy Renovations HVAC, 2011

alternative to standard air-source heat pumps. Ductless heat pumps are sometimes referred to as *mini-split heat pumps* or just *mini-splits*. Ductless heat pumps consist of a single outside compressor/condenser unit connected to one or more wall- or ceiling-mounted indoor air handler units to provide zone heating and cooling without ducts.

Ductless heat pumps provide increased energy savings over standard heat pumps in several ways – because they are ductless and mounted inside conditioned space, there are no losses to the attic or crawlspace or through leaky ducts; they provide zonal heating; and advances in technology in recent years have increased performance to the point that HSPF 12/SEER 26 units are now available.

These high-performing heat pumps also perform at a much wider temperature range than standard heat pumps: some models can operate at an outdoor temperature range of 5°F to 75°F for heating and 14°F to 115°F for cooling, eliminating or significantly reducing the need for backup heat sources in many locations.

A quality ductless heat pump installation results from attention to details, including tools, installation, and homeowner education. Several years ago, the Northwest Energy Efficiency Alliance developed a program to displace existing electric resistance heat with energy-efficient ductless heat pumps. Some builders of small energy-efficient homes have begun to use these units as the primary space-conditioning system.

Single-point space-conditioning systems such as ductless heat pumps provide no heat to bedrooms and bathrooms except through open doors. DOE Building America research suggests one possible strategy for providing conditioned air to those rooms when the bedroom doors are closed. Transfer fans can be installed above the bedroom doors but this approach requires coordination between the electrician and HVAC installer to ensure electrical service is provided. Using transfer fans allows heating and cooling energy to reach the bedrooms in lieu of duct work.

Cooling Equipment. The cooling season is shorter in Montana than in many other parts of the country. In a well-designed and well-insulated home, summer heat may be adequately controlled by ventilation combined with climate-responsive design to minimize summer solar heat gain. Mechanical cooling options include central air conditioning as part of a central gas furnace forced-air system, wall unit air conditioners, and heat pumps. Evaporative cooling is also an option in Montana with our dry climate. Heat pumps are more efficient than standard electric air-conditioning and new models of ductless heat pumps offer SEER ratings as high as 26 at a wide temperature range. The EPA reports that 75% of installed air conditioners had the wrong amount of refrigerant when tested. Incorrect refrigerant levels can lower efficiency by 5% to 20% and can cause premature component failure, resulting in costly repairs. Based on these findings, the ENERGY STAR New Homes program requires extensive commissioning for all heat pumps.

Duct Design and Installation Best Practices. Duct design and installation is often taken for granted by builders and home buyers. Following are several design factors that will improve the performance of a central forced-air duct system.

Install ducts inside the thermal envelope. An important consequence of locating duct work or air handler outside the conditioned space is code required tightness testing. The current energy code allowable duct leakage of 4 cfm per 100 ft^2 of conditioned floor area is a very tight standard. If duct tightness testing is required, locating supply registers under cabinets without a duct boot to the toe-kick register becomes a major problem. If the air handler and ducts are located within the thermal envelope, no tightness testing is required by code.

Do not use framing cavities for supply or return ducts. The energy code prohibits use of building cavities for supply ducts. Framing cavities like stud bays or panned floor joist spaces are leaky and very difficult to seal. The Montana energy code allows building cavities to be used as return ducts; however, leaky return ducts can depressurize the combustion appliance zone and potentially cause back drafting of atmospherically vented water heaters.

Install branch duct balancing dampers. Every branch duct running to a register needs a balancing damper. These dampers allow adjustment during the commissioning process to make sure that each room gets the proper air flow.

Use of galvanized ducts is preferable to flex duct. The corrugations in flex ducts cause turbulence that reduces airflow through the duct.

Locate supply registers to reduce length of duct work. Supply registers were usually located near cold outside walls, often under windows, to minimize discomfort from winter air infiltration and cold surface temperature. In today's well-insulated tight homes equipped with high-quality windows, it is feasible to install supply registers on interior walls.

Provide return-air pathway. Inadequate return-air pathways can create pressure imbalances from room to room that cause problems in a home. Most homes are equipped with supply ducts that deliver conditioned air to every room but often there is no dedicated return-air pathway from each room back to the furnace. The result of inadequate return-air is

temperatures, negative pressures in the combustion appliance zone potentially cause back drafting of atmospherically vented appliances and increased movement of warm humid air into building cavities causing moisture problems in walls and ceilings.

System Commissioning. *Commissioning* is the term used to describe testing the HVAC equipment to determine if it has been installed and is operating properly. Commissioning is the "exception" and not the "rule" in new home construction. Following are the most important elements of the HVAC commissioning process.

Forced-air duct work. Commissioning duct work includes:

- Visual inspection of joints and duct sealing
- Visual inspection of the duct insulation
- Duct tightness test
- Verification of airflow at each supply register
- Verification of return-air pathways from every room that has a supply register

The Montana energy code requires a duct tightness test unless all duct work and the air handler are located in conditioned space. But it is good practice to conduct such test regardless of duct location.

Combustion appliances. It's important to perform combustion safety checks on all combustion appliances like furnaces and water heaters. If there are any atmospherically vented appliances in the house, it is good practice to perform a worst case depressurization test to determine if back drafting of the appliance is a possibility.

Air conditioner or air-source heat pump. If the house has central air conditioning, it's important to verify the equipment's refrigerant charge and the airflow rate across the cooling coil. According to the ACCA, airflow across the cooling coil should be within the range recommended by the equipment manufacturer and within 15% of the airflow specified by the system design.

Ground-source heat pumps. The HVAC systems where commissioning is most critical are ground-source heat pumps (GSHPs). These systems often require five or six different contractors to be involved with the installation. With this many different trades involved, it is not uncommon that the system as a whole does not perform properly.

Mechanical Ventilation

In the past, we have assumed that "fresh air" would be provided to our homes through operable (openable) windows and leaks in the building envelope. Building science has taught us that we can't rely on natural forces to provide ventilation. In the meantime, we have introduced thousands of chemicals into our houses through building materials, finishes, packaging, furniture, carpets, clothing, and other products. This is in addition to the allergens and occupant-generated airborne chemicals.

As we have built tighter homes with more insulation, the relative humidity in the home has increased and the potential for condensation on cool or cold surfaces has increased as well. The presence of moisture condensation has been a leading cause of mold and mildew in both new and existing construction. Asthma has also increased as interior relative humidity has gotten higher. Therefore, it has become critical to install mechancial ventilation in our homes.

All new houses in Montana must be tested to no more than 4 air changes per hour at 50 pascals (4 ACH50) pressure. Building and testing a tight envelope is fairly straightforward. In fact, if properly ventilated a house building envelope can't be built too tight. Getting ventilation right is by far the more difficult challenge. While building science experts agree that mechanical whole-house ventilation is critical, those same experts differ on exactly how much ventilation air is required and how to design an effective ventilation system. The Montana building code requires both a whole-house mechanical ventilation system and local exhaust ventilation.

Whole-House Mechanical Ventilation System. A code-compliant whole-house ventilation system may or may not provide effective energy-efficient ventilation. But since whole-house mechanical ventilation is mandated by the Montana residential building and energy codes, and is thus the legal minimum, let's summarize those requirements.

Since the fans associated with a whole-house mechanical ventilation system will be operating continuously in most cases, the energy code calls for the use of energy-efficient fans. A table in the energy code specifies the minimum efficacy for the whole-house ventilation fans.

The building code specifies the minimum exhaust air flow, in cubic feet per minute (cfm), that must be provided based on the conditioned floor area and number of bedrooms in the house. Typically this ventilation exhaust air flow is between 40 and 100 cfm operated continuously. The whole-house mechanical ventilation system must be provided with controls that allow manual override.

The Importance of Moisture and Pollutant Source Control

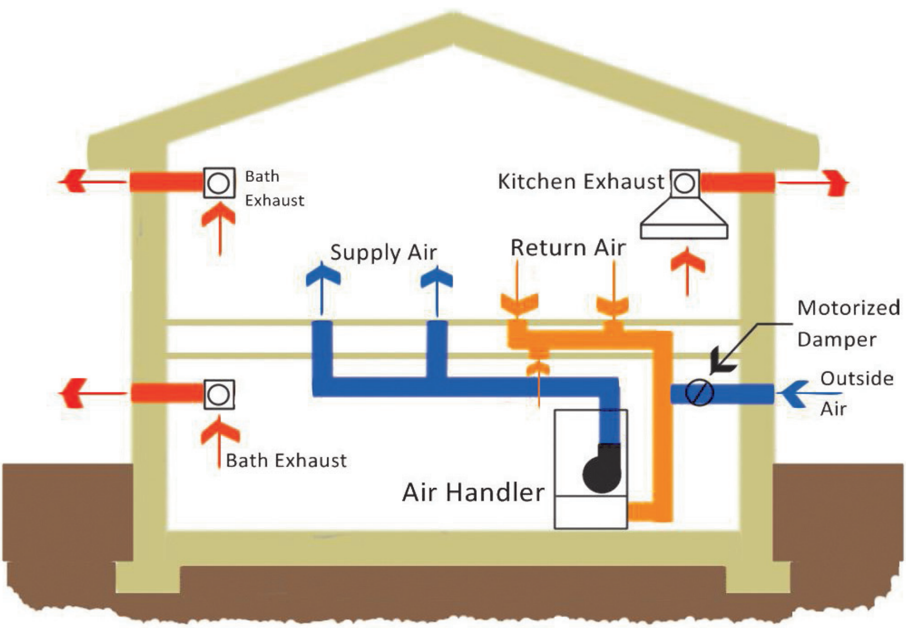
Whole-house ventilation systems introduce outside air to dilute unavoidable pollutants. But the first defense against poor indoor air quality should be eliminating the sources of indoor air pollution and moisture. Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources release pollutants intermittently such as: smoking; the use of unvented or malfunctioning stoves, furnaces, or space heaters; the use of solvents in cleaning; and hobby activities.

While many pollutant sources can be eliminated by design decisions and lifestyle choices, there will always be sources of moisture. Liquid water and water vapor are not inherently dangerous but, if uncontrolled, excessive moisture can lead to both health problems and deterioration of the building structure.

Local Exhaust Ventilation. In addition to a whole-house ventilation system, the code also requires minimum local (also called *spot* or *point source*) exhaust capability in kitchens and bathrooms. Kitchens must have a 100-cfm, intermittent exhaust, or a 25-cfm continuous exhaust. The fans must exhaust to the outside. Recirculation fans do not comply. Bathrooms must have either a 50-cfm intermittent controlled exhaust or a 20-cfm continuous exhaust. If continuous exhaust is used to comply with the local exhaust requirement, it may also be counted toward the whole-house mechanical ventilation.

Exhaust-Only Ventilation Systems. One or more simple exhaust fans, usually located in a bathroom, pulls air out of the house. Make-up (replacement) air is drawn into the bathroom from hallways and other rooms in the house which, in turn, draws outside air through envelope leaks into those spaces. Other intermittently controlled local exhaust fans in bathrooms, kitchen, and laundry room provide local exhaust. Control of the local exhaust fans may be by timer switch or dehumidistat. Bathroom fans switched with lights turn off too soon to adequately remove moisture buildup from showers of baths. Because replacement air is drawn through uncontrolled leaks, fresh air is not evenly distributed in the home. Uneven distribution of fresh air is more pronounced when bedroom doors are closed.

Balanced Ventilation Systems. In balanced ventilation systems, there is a dedicated make-up air pathway designed into the system. A balanced ventilation system is more likely to provide design air quantities. Make-up air is provided through planned pathways, which improves air quality. Balanced systems may also be designed to provide heat recovery with a heat recovery ventilator (HRV). The two most common balanced ventilation system types are the air handler integrated system and the

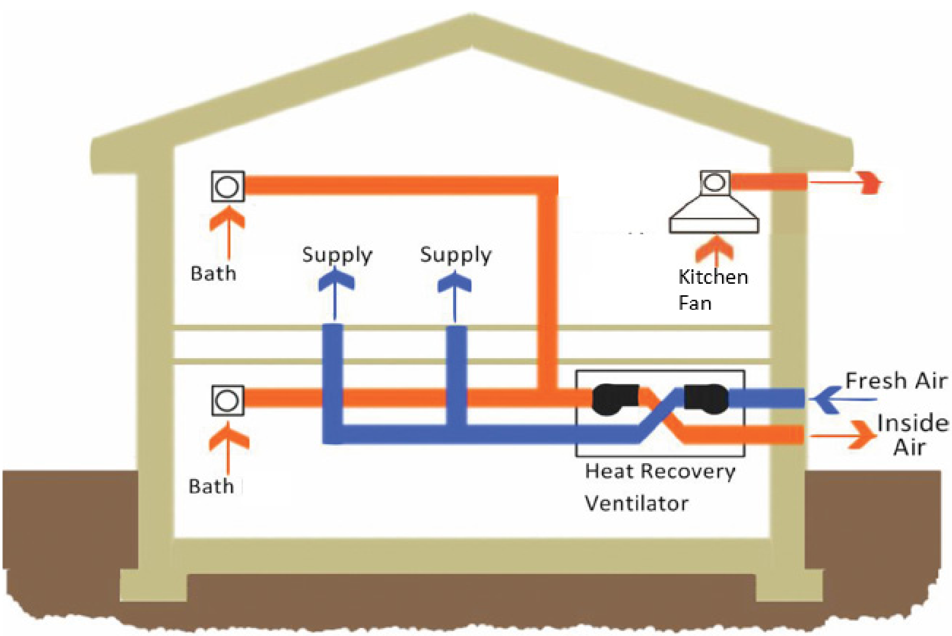


Balanced Exhaust Ventilation Integrated with Central Air Handler

heat recovery ventilator (HRV).

The diagram on the previous page shows a balanced ventilation system without heat recovery. Air is exhausted from fans located in the kitchen and bathrooms. Fresh air is provided through a make-up air duct connected to the return side of the air handler. This make-up air duct is equipped with a motorized damper that is operationally integrated with the air handler and exhaust fans.

The operation of the central air-handler fan pulls air into the return air duct. The motorized damper in the make-up air duct adds a fixed amount of outside air into the central system and its operation can be integrated with the operation of the primary exhaust fan. This approach allows the central air-handler system to distribute and temper outside air. The outside air duct should be insulated and sloped to the outside to deal with possible condensation. Use of flex duct should be avoided to reduce the chance of reservoirs that can collect condensation. As noted by Joseph Lstiburek in the *Builder's Guide to Cold Climates*, the mixed return air temperature should not be allowed to drop below 50^{o} F in order to control condensation of combustion gases on the heat exchanger surfaces.



Balanced Ventilation System with Standalone HRV

Heat Recovery Ventilators. The diagram on the previous page shows a balanced central exhaust ventilation system with a standalone HRV. An HRV transfers heat from the exhaust air to the intake air. In this system, air is collected from spaces in the home that are most likely to produce moisture or pollutants and is then exhausted at a central point. Fresh air is supplied by the central ventilation system to one or more spaces.

When an air handler is present, the fresh air supply from the HRV can be connected to the return side of the air handler and the low-speed air handler fan is interconnected with the operation of the HRV. Typically, an HRV will transfer 60% to 90% of the heat in the stale air being exhausted from the home to the fresh air entering the home. While it is possible to integrate an HRV with a central air handler, it is difficult to balance the HRV is this configuration because of the ducting and operating conditions of the central air distribution system.

Effective, Efficient Ventilation. Following are some design and operation considerations that improve the effectiveness and energy efficiency of the ventilation system.

A mechanical ventilation system must be used to be effective. Factors that discourage use and cause occupants to disable the systems include noise, blowing cool air on occupants, complex controls, lack of understanding of system operation by occupants, controls not being labeled.

Simplify and label controls. The mechanical ventilation system manual control should be clearly and permanently labeled, especially the required override switch.

Exhaust air from source locations. Air should be exhausted from the rooms where most pollutants, odors, and moisture are generated, such as bathrooms, laundry rooms, and kitchen.

Supply air to occupied rooms. Supply and returns to each bedroom will assure that each is well ventilated, even when doors are closed.

Distribute fresh air directly to occupied rooms. Good distribution means fresh air is supplied to the rooms where occupants spend most of their time, such as living room and bedrooms.

Exhaust kitchen range hoods to exterior. Kitchen range hoods should exhaust outside to remove moisture, odors, and pollutants.

Recirculation hoods allow grease vapors and odors to remain in the house and should be avoided.

Install quiet fans. Fan noise can be a major factor in whether occupants use the ventilation system provided. If fans are rated over one sone, there is a good chance the system will be deactivated by the occupants. A sone is a measure of loudness. The higher the sone rating the louder the sound.

Beware of back-drafting. Back drafting is the spillage of combustion gases, including carbon monoxide, from a combustion appliance such as fireplace, woodstove, atmospherically vented gas furnace, or atmospherically vented gas water heater. Installing sealed combustion, power vented, direct vented, and induced draft appliances will assure back drafting is not a problem. A combustion appliance zone worst-case depressurization test is used to determine if back-drafting is a possibility from atmospherically vented combustion appliances such as furnaces and water heaters. Several appliances and design factors can contribute to negative pressure in a house.

Testing exhaust and supply flow. Flow hoods and other testing equipment are available to test the air flow at ventilation devices. The test is usually quick and easy. Actual fan flow depends not only on the fan capacity but also on the length and character of the duct. If the duct to the exterior is long, compressed, or has sharp bends, then then flow will be significantly reduced.

Beware of Radon. Radon enters a home through cracks in concrete, joints in construction below grade, and through poorly sealed crawl space construction. You can’t test for radon before construction. That is why the U.S. EPA recommends that all homes built in Zone 1, which includes Montana, have radon-mitigation systems installed at time of construction.

Advanced Lighting

The typical incandescent lamp wastes 90% of the energy it uses, producing heat rather than light. High-performance lighting, including CFL and LED products, provides excellent visual quality that is also very energy-efficient.

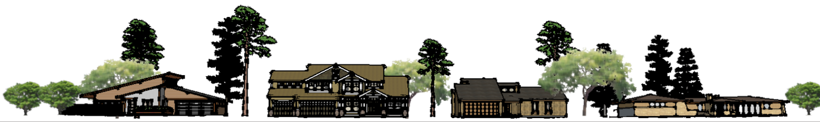
Compact fluorescent lamps (CFLs) use 70% to 75% less energy than their incandescent equivalents with comparable brightness and color rendition. They cost more, but last 10 to 13 times longer than incandescent lamps, making them cost-effective if used at least two to three hours per day. CFLs come in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

Light emitting diode (LED) lights are becoming more commonplace as new models are developed with better lighting performance, higher efficiency, and lower cost. ENERGY STAR criteria for solid-state lighting (LED) went into effect in September 2008. To earn the ENERGY STAR label, LED products have to offer a three-year warranty and meet stringent performance requirements for color rendering, luminaire efficiency, and light output over the life of the lamp, which is at least 25,000 hours for indoor, residential products. The Montana energy code requires that at least 75% of the lamps in permanently installed lighting fixtures be high-efficacy lamps.

Recessed "can" ceiling fixtures, or downlights, that are recessed into insulated ceilings are required by the energy code to be rated for insulation contact (so that insulation can be placed over them). The housing of the fixture should be airtight to prevent conditioned air from escaping into the ceiling cavity or attic, and unconditioned air from infiltrating from the ceiling or attic into the conditioned space. But even code-acceptable recessed can fixtures are not really air-tight. When installed in insulated ceilings they allow air and water vapor to pass through the ceiling.

Residential lighting controls represent a significant opportunity for energy savings. Lighting controls generally refer to technologies that turn off (or turn down) lighting systems when they are not needed. Examples include occupancy sensors, vacancy sensors, photo sensors, dimmers, and timers.

Lighting is typically considered as functioning in three layers: *ambient*, *task*, and *accent*. Ambient lighting, the principal component of high performance lighting, is the light needed for basic circulation and occupancy of a room. Task lighting meets the visibility needs of specific functional tasks such as food preparation or grooming. Accent lighting provides visual relief, visual attraction , and emphasis.

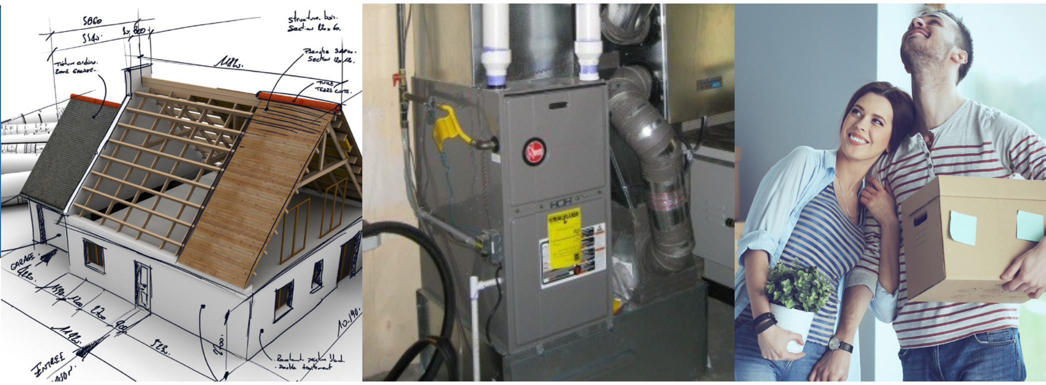


Chapter 4
After You Move In

There are three primary factors that determine home energy consumption. First, the building and its energy systems must be efficient. Second, the home occupants must operate the home efficiently. Third, the homeowner must be attentive to basic maintenance needs of the home. To ensure your home is operating at its highest efficiency implement the following tips.

Lighting. Use ENERGY STAR-certified light bulbs, such as CFLs or Light Emitting Diodes (LED) to provide bright, warm light while using 75% less energy, and lasting up to 10 times longer than traditional incandescent bulbs. This means more money in your pocket. Homes that use incandescent bulbs waste $400 a year on utility bills when compared to homes that install ENERGY STAR lighting throughout. Turn off lights when the room is unoccupied. Consider installing motion sensors in appropriate spaces.

Use Programmable Thermostats (when installed). If you have a programmable thermostat, make sure it is set properly. As much as half of the energy used in your home goes to heating and cooling. One simple way to ensure you don't waste money is by correctly programming your home's programmable thermostat. You can then schedule the space conditioning to turn on prior to your return. By using your programmable thermostat correctly, you won't waste money heating and cooling your home when you're not there.



The energy performance of a home is determined by the building envelope, the energy systems, and occupant behavior.

Outlets and Electronics. In the average U.S. home, 25 percent of electricity used by home electronics occurs while the products are off. In the United States alone, "vampire power" costs consumers more than $3 billion a year. Reduce unnecessary costs on your utility bill by unplugging electronics such as cell phone chargers and power strips when they're not in use. Other energy savings tips include:

- Even when they're turned off, home electronics in "standby" mode use energy to power features like clock displays. Consider using power strips to turn off unnecessary electronics.
- Purchase ENERGY STAR-qualified televisions; they're up to 30% more efficient.
- Set your computer to sleep mode instead of using a screen saver.
- Unplug battery chargers when the batteries are fully charged or the chargers are not in use.

Automatic Mechanical Ventilation System. Your home has been constructed with a whole-house mechanical ventilation system to ensure that the household has a constant supply of fresh air. Discuss with your builder what type of ventilation system you have and how to operate and maintain it effectively.

HVAC Equipment. Keep your cooling and heating system at peak performance by having a qualified contractor conduct tune-ups in the spring prior to a hot summer and in the fall before a cold winter. Maintaining your heating, ventilation, and air conditioning (HVAC) equipment can have a big effect on your utility bills, and your comfort. Catch small issues before they become expensive problems. This can have a big effect on your utility bills—and your comfort.

Check your air filter monthly and change it as recommended so your HVAC system will operate at peak efficiency. The air filter is designed to catch particles, which reduce the amount of air delivered through ducts. A dirty filter can even cause the air handler to shut down. So, it's important that your HVAC fan is able to blow air freely throughout the duct system so that you are getting the correct amount of air throughout your home.

Windows and Doors. Check the weatherstripping around your doors annually and replace as needed. Weatherstripping keeps drafts from coming in; over time, it eventually wears down. During summer months,

use blinds and curtains to block unwanted heat from the sun shining through windows.

Laundry. Wash full loads of laundry; most machines use the same amount of energy regardless of the load size. Use cool or cold water whenever possible. 90% of the energy used for washing clothes comes from heating the water. Dry one load of clothes after another. The residual heat from the first load helps dry the second one faster. Use the moisture sensor option on your dryer. It automatically shuts off the machine when your clothes are dry.

Kitchen. The freezer works best when it is filled to capacity. If necessary, place covered, plastic containers of water in your freezer to take up extra space. Operate dishwasher only with full loads. Avoid use of the pre-rinsing feature – dishwashers today don't require pre-rinsing to effectively clean dishes. By skipping this step, you'll save as much as 20 gallons per load, or 6,500 gallons per year. Avoid the heat-dry, rinse-hold, and pre-rinse features, and try the air-dry option instead.

Note: Many of these recommendations are included in the *ENERGY STAR® Certified Homes Maintance Guide*.

References

Internet Resources:

ENERGY STAR New Homes, U.S. Environmental Protection Agency
www.energystar.gov/newhomes/?s=mega

Zero Energy Ready Home, U.S. Department of Energy
energy.gov/eere/buildings/zero-energy-ready-home

Indoor airPlus, U.S Environmental Protection Agency
www.epa.gov/indoorairplus

Residential Energy Services Network (RESNET)
www.resnet.us/

National Fenestration Rating Council (NFRC)
www.nfrc.org

Efficient Windows Collaborative
www.efficientwindows.org/

Building America Program: Bringing Building Innovation to the Market
energy.gov/eere/buildings/building-america-bringing-building-innovations-market

Energize Montana (Energy Codes), MT Dept. of Environmental Quality
http://deq.mt.gov/Energy/EnergizeMT/EnergyCode

Sustainable by Design (online solar design tools)
http://susdesign.com/index.php

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