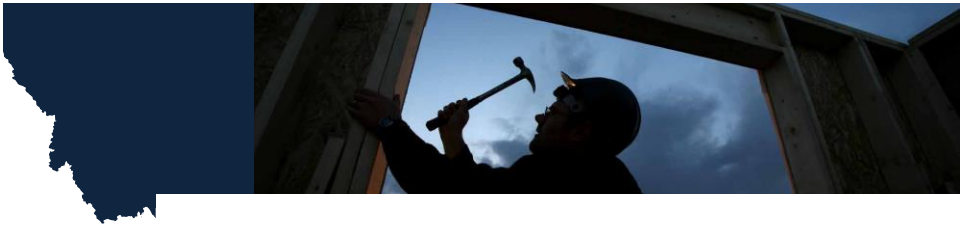


Montana



New Home Buyers Guide to Energy

An Introduction to Energy
in New Homes

This document was produced by the
National Center for Appropriate Technology



Contents

| | |
|---|----|
| Introduction | 1 |
| Montana Energy Code Is Applicable Statewide | 2 |
| Energy Codes Create Better Homes | 3 |
| Above-Code Programs | 4 |
| Climate Responsive Design | 6 |
| Building Science Basics | 7 |
| Energy Code Compliance | 11 |
| Mechanical Ventilation Systems | 16 |
| Heating and Cooling Systems | 22 |
| Lighting | 30 |
| After You Move In | 31 |

Cover photo and header graphic source:
Northwest Energy Star Homes Program



Source: EPA Indoor airPlus Program



Source: Northwest ENERGY STAR Homes

Introduction

The purpose of this guide is to inform new home buyers of the benefits of energy-efficient design and construction. This introduction to residential energy efficiency will explain a few building science fundamentals and related design features that help determine a home's comfort, durability, and affordability. Since all Montana homes are required by state law to comply with the state energy code, this guide will highlight some of those code requirements.

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 you, your country, and the environment. Energy efficiency improves your quality of life by



Source: ENERGY STAR
New Homes



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.

Montana Energy Code Is Applicable Statewide

Energy codes benefit home buyers by requiring contractors to provide a minimum set of efficiency features. Within government jurisdictions that choose to enforce the building code, these features are assured by the inspection process required for each new home. The energy code is enforced on residential buildings located outside local code enforcement jurisdictions through Montana's *dwelling self-certification program*. 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.

In Montana, the state decides the specific energy code language that will be applied throughout the state. Local government jurisdictions can choose whether to enforce the state code but may not modify the code language itself. The Montana state energy code is applicable to new residential buildings constructed in Montana, with the exception of garages and storage buildings.

The energy code applies to additions, alterations, renovations, and repairs, as well as to new construction. 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.





Energy Codes Create Better Homes

Energy codes play an important role in improving home performance. The benefits provided by the energy code include:

Lower Energy Costs. Cost-effectiveness is an important consideration in the energy code development process. 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 13 years.

Increase Home Value. Increasing the energy efficiency of your home will not only keep more dollars in your pocket today, but it can also dramatically improve the market value of your home. Rising energy costs continue to be a leading driver of energy efficiency awareness and action. 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 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.

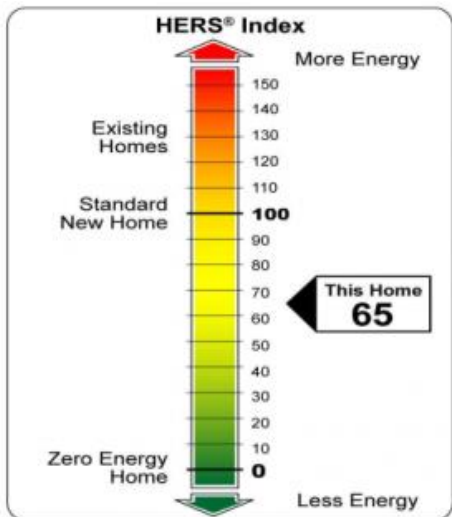
Reduce Maintenance Costs. Energy-efficient homes can reduce maintenance problems associated with mold growth and rot from condensation; heating and cooling equipment maintenance/replacement due to excessive run times; and insect, rodent, and other pest infestation due to improper sealing.

Above-Code Programs – When Barely Legal Isn't Good Enough

The energy code specifies the minimum new home energy efficiency allowed by law. A number of programs provide energy-efficiency standards and testing protocols for those homebuyers interested in more efficient homes.

Home Energy Ratings

A home energy rating measures how energy-efficient your home is as 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 on the *Home Energy Rating System*, 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.



For more about home energy ratings: www.resnet.us/energy-rating.



ENERGY STAR New Homes

ENERGY STAR New Homes are designed to use substantially less energy for heating, cooling and water heating.

The materials and techniques used in building a new ENERGY STAR Home will significantly increase your 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.



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 Environmental Protection Agency (USEPA).

Find out more about ENERGY STAR New Homes at www.energystar.gov.

Indoor airPLUS

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.



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. Indoor airPLUS is a program of the US Department of Energy (USDOE).

Find out more about Indoor airPLUS at www2.epa.gov/indoorairplus.

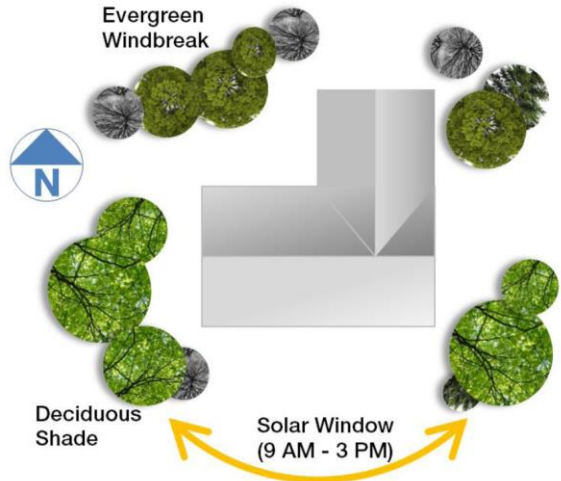


Climate Responsive Design

Solar energy is a hot topic today. But when solar energy is mentioned, most people think of photovoltaic (PV) panels mounted on the roof to produce electricity. Most homebuyers, designers, and builders don't realize the energy-savings potential of 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. Too much south-facing window area requires the addition of thermal storage mass to limit high interior temperatures during summer. To minimize overheating during spring and fall, designers should limit the amount of west-facing glass.

When positioning buildings to get the maximum solar benefit, overhangs can help manage heat gain and glare. Windows should be selected to manage the quantity of 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.



Climate Responsive Design Site Planning





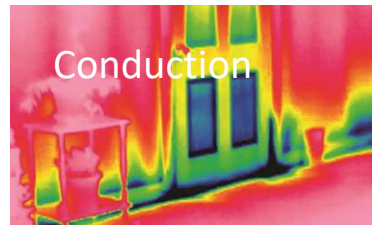
Building Science Basics

The term *building science* refers to the physics of how buildings work. As homes have become tighter and better insulated the building industry has recognized the need to be much more aware of building science principles. Programs such as ENERGY STAR for New Homes and the USDOE Building America program have expanded our knowledge of building science. Many of these principles have been incorporated into the current Montana energy code.

The Basics of Heat Transfer

All heat transfer and movement into and out of a building can be explained by three heat-transfer mechanisms: *conduction*, *convection*, and *radiation*. These mechanisms 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. The adjacent infrared scan photo illustrates relative conduction of heat through the door. The dark blue sections of the door are cooler, indicating greater heat loss through these thinner areas. The yellow areas of the door are thicker and provide greater resistance to heat flow.



Convection is heat transfer by a moving liquid such as water or gas such as air. This heat movement is caused by the density difference between warmer and cooler parts of the fluid. Warm air rises to the top of a building where it either escapes to the outside, or is cooled and falls. It is then warmed again by either solar gain or the building's heating system and the process repeats itself. In buildings, this process creates high pressure at the top of building and low pressure at the bottom of the building.





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 or are uncomfortable sitting near a cold window surface in an otherwise warm room.



About R-Values and U-Factors

R-Values Measure
R-Values are additive
R-Value is the inverse
The higher the R-Value
The lower the U-Factor

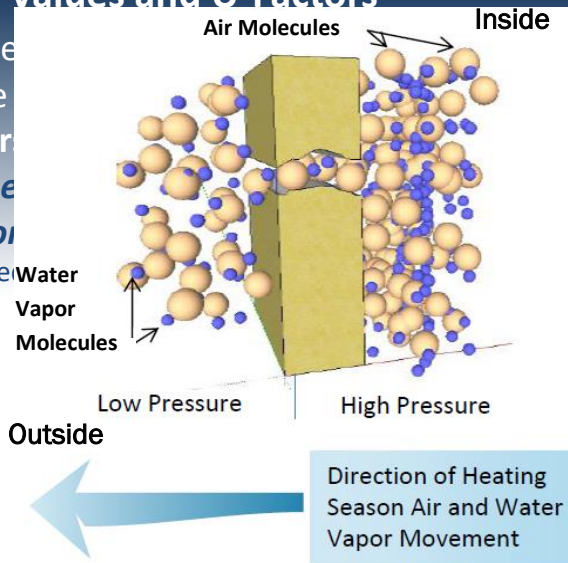
U-Factors are used

It's in the Air

Water vapor is always present, in varying quantities, in the air of our homes. 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 into the building walls and ceiling 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.





Building Envelope Functions

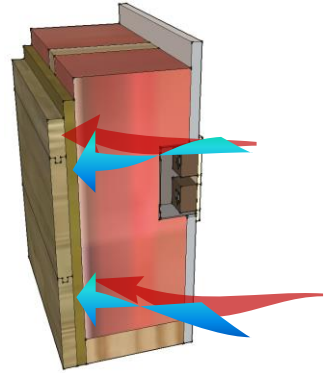
The primary role of the building envelope is to control the movement of heat, air, liquid water, and water vapor. There are many sources of water that affect buildings. They include exterior moisture (rain), interior moisture (water vapor from people using the building), and moisture in new construction materials. The following general principles apply to walls as well as to the ceiling and roof.

Keep the Interior Air and Water Vapor Out of the Wall

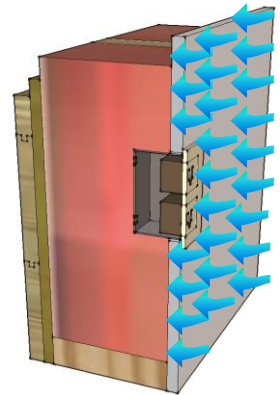
It is important to minimize the movement of warm, moist interior air into the wall. Where air molecules can move, so can smaller water molecules. Water vapor moves into a wall by *air transport* and by *diffusion*. Water vapor movement by air transport is much more significant than by diffusion.

The movement of water vapor through air leaks is called *air transport*. If water vapor is allowed to enter the wall and if the temperature of the inside face of the exterior sheathing is cold enough, then the water vapor will condense, potentially resulting in mold and damage to the structure. To minimize air and water vapor movement into the wall, it is necessary to install a continuous sealed *air barrier*.

In diffusion, water vapor molecules move through seemingly solid materials. The permeability, or *perm rating*, is a measure of how much diffusion a material allows. The solution to preventing excessive diffusion is to install a *vapor retarder*. In order to control vapor diffusion into the building envelope, the



The **air barrier** reduces vapor movement by air transport.



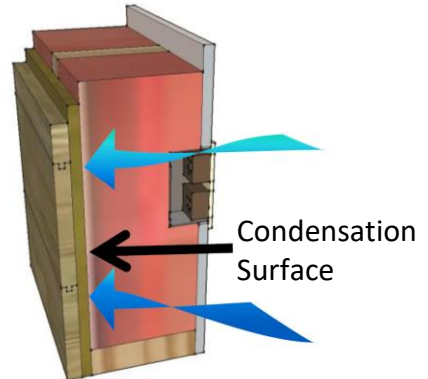
The **vapor retarder** reduces vapor movement by diffusion.



building code requires that a vapor retarder be installed on the warm side of above-grade walls. While diffusion may allow water vapor to enter the wall, it also allows a wall to dry under certain climatic conditions. Choosing the appropriate type of vapor retarder is an important design decision to assure wall durability.

Increase Condensation Surface Temperature

Water vapor inside a wall can condense if the inside surface of the exterior sheathing reaches dew point temperature. One strategy to reduce the potential for condensation is to raise the temperature at the inside face of the sheathing. This can be accomplished by adding continuous insulation to the exterior of a wall. If the wall cavity is filled with fiberglass batt insulation, or other air permeable insulation, condensation occurs on the exterior sheathing which is referred to as the *condensation surface*.



Adding exterior insulation increases the temperature of the exterior sheathing.

Allow the Wall to Dry

No matter how hard we try to eliminate moisture from walls, some moisture is likely to occur. For that reason, it is important to provide a way for walls to dry. In the Montana climate, drying occurs primarily to the outside, but walls also will dry to the inside during a 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 but allows the wall to dry to the inside.

Energy Code Compliance

All new residential buildings in Montana must comply with the “mandatory” provisions of the energy code and at least one of the building envelope



compliance methods. By providing multiple envelope compliance methods the code provides flexibility to the designer and builder. The most familiar but least flexible compliance method is the prescriptive *R-value Method*. The next most common compliance method, the *Total UA Method*, is more flexible, allowing tradeoffs between the different building envelope components. Free software from the USDOE, RESCheck™, is based on the Total UA Method.

The intent here is not to detail all code requirements but rather to educate new home buyers about the key minimum energy features to expect in a new home. Special attention will be given to building tightening and mechanical ventilation, which have become more stringent in the current energy code.

Energy Code Compliance Label

The Energy Code Compliance Label or certificate is required in all new homes and additions. The label is a way for the builder to certify that the house complies with the energy code. The label must be permanently affixed to the electrical breaker panel by the builder. If the home is not supplied with this label then the builder is not complying with the state energy code.

| ENERGY CODE COMPLIANCE LABEL | | |
|---|--|--------------|
| Address: _____ | | |
| Ceiling: | Flat | R- _____ |
| | Vaulted | R- _____ |
| Walls: | Above grade walls | R- _____ |
| | Basement walls | R- _____ |
| | Crawlspace walls | R- _____ |
| Floors: | Over unheated spaces | R- _____ |
| | Perimeter slab for _____ feet | R- _____ |
| | Under slab for _____ feet full | R- _____ |
| Exterior doors: _____ R- _____ | | |
| Windows: | NFRC unit rating | U- _____ |
| Water heater: | Energy factor (EF) rating | _____ |
| Heating system: | Energy efficiency rating | _____ |
| (AFUE for gas; HSPF heat pump) | | |
| Cooling system: | EER _____ SEER _____ | |
| Heating ducts: | Systems sealed _____ | Yes per code |
| | In non-conditioned areas insulated to | |
| | Supply R- _____ Return R- _____ | |
| | Leakage test at rough-in _____ or finished _____ | |
| | Leakage to outside _____ or total leakage | |
| results _____ | CFM 25 per 100 sq. ft. | |
| or N/A | | |
| Air Sealing: | Blower door test results _____ | ACH 50 |
| | Visual inspection _____ | Yes per code |
| Whole house mechanical ventilation: _____ Yes per code | | |
| Other (i.e., radon mitigation) _____ | | |
| Builder: _____ | | Date: _____ |
| Signature: _____ | | |
| <p><i>The home builder or representative certifies compliance with ARM 24.301.162 and MCA50-60-802, by completing and signing this label. November 2014</i></p> | | |
| <p>THIS LABEL MUST BE PERMANENTLY AFFIXED BY HOME BUILDERS TO THE BREAKER PANEL ON ALL NEW RESIDENTIAL BUILDINGS, AS REQUIRED BY SECTION 50-60-803, MONTANA CODE ANNOTATED AND 2012 IECC – SECTION 401.3</p> | | |

Installation per Manufacturer's Instructions



All materials, systems, and equipment must be installed according to the manufacturer's installation instructions. In the two top photos at the right, the fiberglass batt insulation does not meet code because the gaps and compressions do not meet the manufacturer's specifications. Manufacturer's installation specifications are an enforceable extension of the code.



Building Envelope Requirements

Requirements for the prescriptive *R-value Method* are shown in the table below.



The R-values in this table refer only to the insulation and not to other components of the wall, ceiling, or floor. Log, concrete block, and insulated concrete form (ICF) walls must comply with the “mass” wall requirements.

| Component | Insulation, Window, Door, and Skylight Requirements | Remarks |
|-----------------|---|---|
| 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 (if present) is continuous sheathing |
| Mass Wall | R-15/R-20 | Second value applies when more than half of R-value is on interior of mass wall |
| Floor | R-30 | Insulation that fills cavity (R-19 minimum) also complies |
| Basement Wall | R-15/R-19 | First value is continuous, second value is cavity |
| Slab | R-10, 4' | Insulation must extend downward continuously from top of slab for 4 feet vertically or horizontally |
| Crawlspace Wall | R-15/R-19 | First value is continuous inside or outside, second value is cavity insulation on inside |






Building Tightness

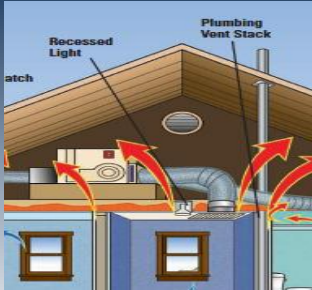
The energy code is based on the premise that homes must be built tight and that mechanical ventilation must be provided. To assure that the home's envelope is tight, the code requires that every home pass a blower door test **as well as** complying with a checklist of building tightening details. That checklist is titled the *Air Barrier and Insulation Installation Table* and is sometimes referred to as the *visual checklist*.

Building Tightness Code Requirements



Blower Door Test

+



Air Barrier and Insulation Installation Checklist

Air Barrier

The visual checklist begins with requiring a continuous sealed air barrier around the entire building envelope. It goes on to detail sealing at all penetrations. An *air barrier* is a material or assembly of materials that provide a barrier to air leakage through and into the building envelope. It is common for the air barrier to be a combination of materials that are sealed at the joints. At walls and ceilings, the primary air barrier is usually either the gypsum board or sheet polyethylene installed under the gypsum board. The key feature of a code-compliant air barrier is that all seams and joints are sealed with appropriate sealant or gasket.





A **vapor retarder** limits the amount of moisture that passes through a material or assembly by diffusion. The building code defines classes of vapor retarders. The code requires that a Class I or II vapor retarder be installed at the warm side of exterior above grade walls unless a specified level of exterior wall insulation is provided. A Class I vapor retarder is essentially impermeable. Sheet polyethylene is one example. Some paints meet the permeability characteristics of a Class II vapor retarder when applied to gypsum board. Typically, latex paint is considered a class III vapor retarder.

| Class | Definition | Examples | Remark |
|-------|--|--|-----------------------------|
| I | 0.1 perm or less | Sheet polyethylene, sheet metal, vinyl | Impermeable (vapor barrier) |
| II | Greater than 0.1 perm but less than 1.0 perm | Kraft-faced fiberglass batts or low-perm paint | Semi-impermeable |
| III | Greater than 1.0 perm but less than 10 perm | Latex or enamel paint | Semi-permeable |

The term **vapor barrier** is no longer used in the codes.

House Tightness Testing (Blower Door)

House tightness is measured by a **blower door test**. In a blower door test, an exterior door is fitted with a nylon skirt with an opening for a large fan. For new construction, it is most common to perform a depressurization blower door test. 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 through the envelope and exterior ducts. A digital



Source: The Energy Conservatory



manometer is used to measure the pressure difference and the air flow out of the fan.



Depressurization Blower Door Test

Mechanical Ventilation Systems

In recent years, the building industry has been installing better windows, more insulation, high-efficiency furnaces, and reducing the amount of outdoor air leaking into homes. In the past, most building codes have assumed that “fresh air” would be provided through operable windows and normal leaks in the building envelope. Research with tighter houses has shown that we can’t rely on natural forces to provide adequate 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 occupant-generated allergens and other pollutants.



More insulation and tighter construction has led to problems with indoor air quality and moisture problems in walls and attics.

Natural ventilation using windows depends on weather and occupant behavior. However, there are many reasons why occupants may choose not to open



windows including cold outside temperatures, security, outdoor air quality, dust, and noise.

Good ventilation protects the home from damage by eliminating excess moisture from the air. Too much moisture rots window sills and attic eaves, peels paint, and invites insect infestation. Damp insulation in walls and ceilings means lost heat, higher fuel bills, and destructive mold growth. Carpeting, wallpaper, electronic equipment, and furniture can be damaged by excess moisture.

“Build Tight and Ventilate Right”

The building codes and building science experts have adopted the “Build Tight and Ventilate Right” approach to building energy-efficient and healthy homes. Energy codes now require tight construction. A well-sealed home is less expensive to heat and ventilate because you can control how much outdoor air comes in and where it goes. Just because a house meets the code requirements



Photo Source: EPA 402/F-08/008, “Care for Your Air: A Guide to Indoor Air Quality”

The Importance of Moisture and Pollutant Source Control

The first defense against poor indoor air quality is 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, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in house-keeping. Soil gases such as radon and pesticides can be significant pollution sources unless the house is designed properly.

for mechanical ventilation does not mean the installed system will inherently be effective and energy-efficient for a particular home or family.



The codes require whole-house mechanical ventilation systems in Montana with the minimum airflow based on house floor area and the number of bedrooms. 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 efficient fans as specified in an energy code table.

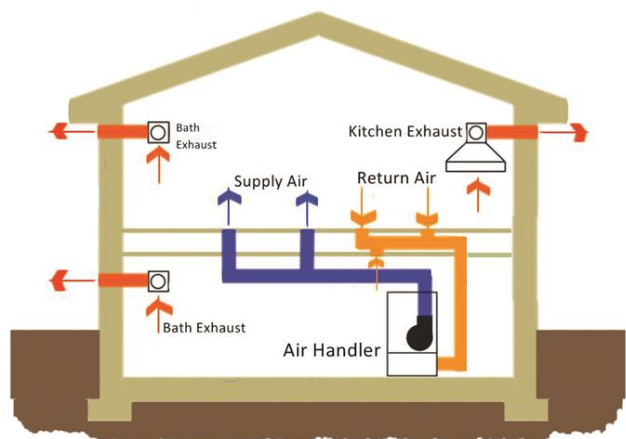
In addition to a whole-house ventilation system, the code also requires minimum local (also called “spot” or “point source”) exhaust ventilation capability in kitchens and bathrooms. Kitchens must have either 100-cfm, intermittent (manual) controlled exhaust or a 25-cfm continuous exhaust. Bathrooms must have either a 50-cfm intermittent (manual) controlled exhaust or a 20-cfm continuous exhaust.

Types of Mechanical Ventilation Systems

The two most common types of mechanical ventilation are *exhaust-only* and balanced systems. Exhaust-only systems depressurize the house without providing planned pathways for replacement or make-up air. The make-up air for exhaust-only systems is supplied by the air leaks in the building envelope. In balanced systems, make-up air pathways are designed into the system.

Exhaust-Only Ventilation Systems

A simple exhaust fan, 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



Exhaust-only Ventilation System



bathrooms, kitchen, and laundry room provide local exhaust. Control of the local exhaust fans may be by timer switch or humidistat. Bathroom fans switched with the lights turn off too soon to adequately remove moisture buildup from showers or baths. Because replacement air is drawn through uncontrolled leaks, fresh air is not evenly distributed in the home. Uneven distribution of fresh air is even more pronounced when bedroom doors are closed. Exhaust-only systems can contribute to depressurization in the combustion appliance zone which can lead to backdrafting of atmospherically vented appliances. A single central fan can exhaust air from several rooms.

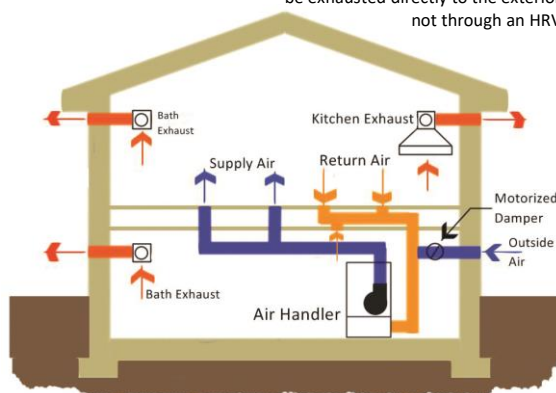
Balanced Ventilation Systems

In *balanced ventilation* systems, there is a dedicated make-up air pathway designed into the system. Providing this dedicated make-up air pathway minimizes problems of over-pressurizing and under-pressurizing spaces within the home. Make-up air is provided through planned pathways, which improves air quality. Heat recovery may be added to balanced systems. The ventilation system may be *stand-alone* or it may be *integrated* with the furnace or central air handler. Below is a diagram of a balanced ventilation system without heat recovery integrated with the air handler. 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.

While this approach allows the central air handler to distribute and temper outside air throughout the house, it has some significant disadvantages.

Note: A kitchen range hood should be exhausted directly to the exterior, not through an HRV.



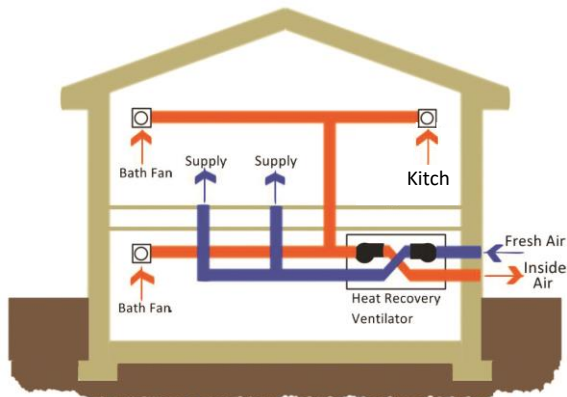
Balanced Exhaust Ventilation Integrated with Central Air Handler



The air- handler fan must operate in order to provide ventilation air which adds considerably to electric consumption. Design of the make-up air duct and controls is a challenge and the furnace may be damaged if the return air temperature becomes too cold.

The diagram below shows a balanced central exhaust ventilation system with a standalone heat recovery ventilator (HRV). In this type of 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 in the home.

Typically, an HRV will transfer 60% to 90% of the heat from the stale air being exhausted 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 due to the operating conditions of the central air system.



Balanced Ventilation System with Standalone HRV

HRVs have the potential to provide energy savings and effective ventilation but only if installed properly and only if the house is not over-ventilated. For small efficient homes, HRVs may not be cost-effective. If integrated with a central air handler the chances of an HRV providing cost-effective savings is reduced.





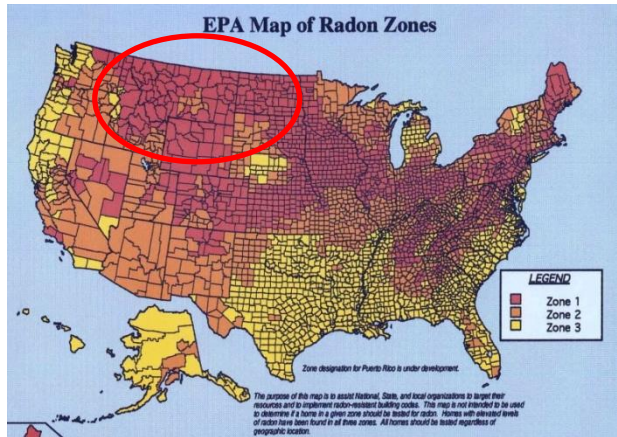
Ventilation Effectiveness Factors

- **A mechanical ventilation system must be used to be effective.** Factors that discourage use and lead occupants to disable the systems include noise, cool air blowing on occupants, overly complex controls, and lack of understanding of system operation by occupants.
- **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.** Install air supply and returns to each room where occupants spend most of their time, such as the living room and bedrooms. This will ventilate those rooms even when doors are closed.
- **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 unit of sound measurement.
- **Beware of backdrafting.** Backdrafting is the spillage of combustion gases, including carbon monoxide, from a combustion appliance such as an atmospherically vented water heater. Installing sealed combustion, power vented, direct vented, and induced draft appliances will minimize the changes that backdrafting will occur. Gas ovens and gas stovetops are other sources of combustion gases and should only be used with an exhaust hood directly vented to the exterior. By performing a worst-case depressurization test, a trained professional can determine if backdrafting can occur.
- **Testing Exhaust and Supply Flow.** Flow hoods and other testing equipment are available to test the air flow of ventilation devices. The test is usually quick and easy. Actual air flow depends not only on the fan capacity but on the length and character of the duct. If the duct to the exterior is long, compressed, or has sharp bends, 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 USEPA recommends that all homes built in Zone 1, which includes most of Montana, have radon-mitigation systems installed at time of construction.



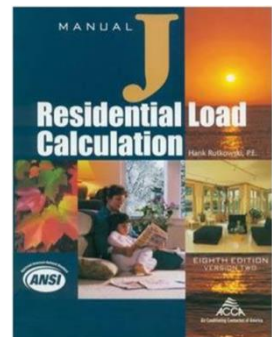
Heating and Cooling Systems

Reducing a building's energy use is the best protection against an uncertain energy future. More efficient building envelopes may reduce the size of the heating and cooling system.

System Design

An HVAC system must be designed, installed, and commissioned in order to perform well. Proper duct design and installation is also important to achieve best results in comfort, efficiency, and durability. There are three major steps to designing an HVAC system.

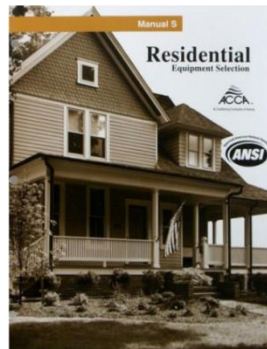
The first step is to calculate the heating and cooling loads. Accurate heating and cooling load calculations are critically important for HVAC system design. Load calculations dictate the size of the HVAC system needed. The consequences of choosing the wrong-sized system include noisy operation, discomfort, a failure to maintain proper moisture control, and decreased





system longevity. The Montana energy code requires that *Manual J*, or an equivalent methodology, be used when calculating building loads.

The second step is to select equipment that meets calculated loads. *ACCA Manual S* provides a reliable standard process for selecting heating and cooling equipment. The Montana energy code requires that *Manual S*, or its equivalent, be used when selecting heating and cooling equipment.



Finally, for central forced-air systems the third step is to design a duct system that moves air from the heating and cooling equipment to the rooms in the house, and then from the rooms back to the air handler. *ACCA Manual D* provides a reliable standard process for duct design but is not required by code.

System Commissioning

Commissioning is the term used to describe testing the HVAC equipment to determine if it has been installed and is operating properly. Following are the most important elements of the HVAC commissioning process:

- HVAC controls
- Combustion appliances
- Air conditioner or air-source heat pump
- Ground-source heat pumps
- Ventilation system

HVAC System Options

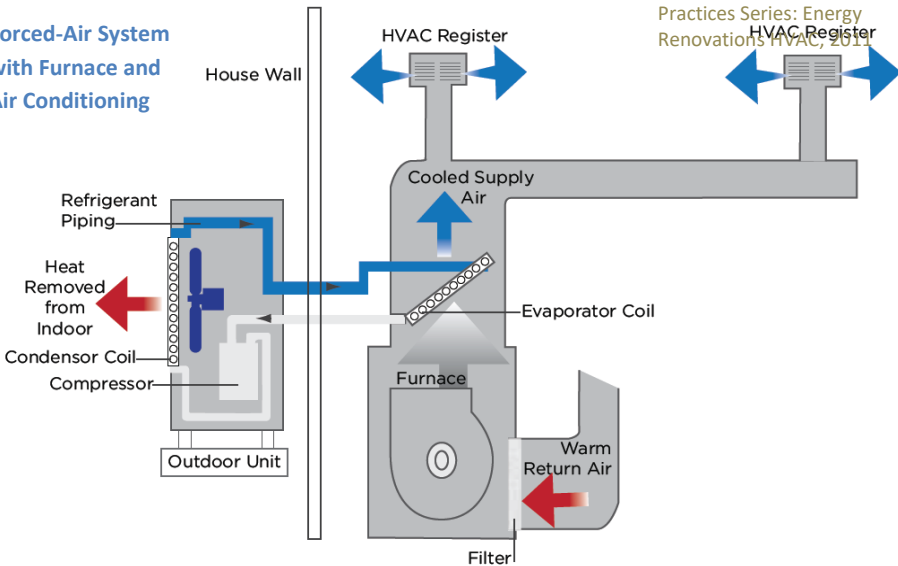
Many different appliances can be used to heat a house, including furnaces, boilers, water heaters, heat pumps, and wood stoves. Most traditional space-conditioning systems use central forced air to distribute the conditioned air to the rooms of the house. However space-conditioning systems that do not require ductwork such as radiant systems, space heaters, and ductless heat pumps are becoming more common, especially for smaller more efficient homes. Following is a brief introduction to the most common systems available.



Forced Air Systems

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

Forced-Air System with Furnace and Air Conditioning



Forced-air systems use ductwork to distribute conditioned air throughout the house. The most common forced-air system is a furnace that burns natural gas or propane and includes a fan to blow air through the duct system.

Gas-Fired Furnaces

A high-efficiency ($\geq 90\%$ AFUE), variable-speed, sealed-combustion, natural gas-fired furnace provides the lowest-cost of delivered heat. Sealed combustion means that 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.

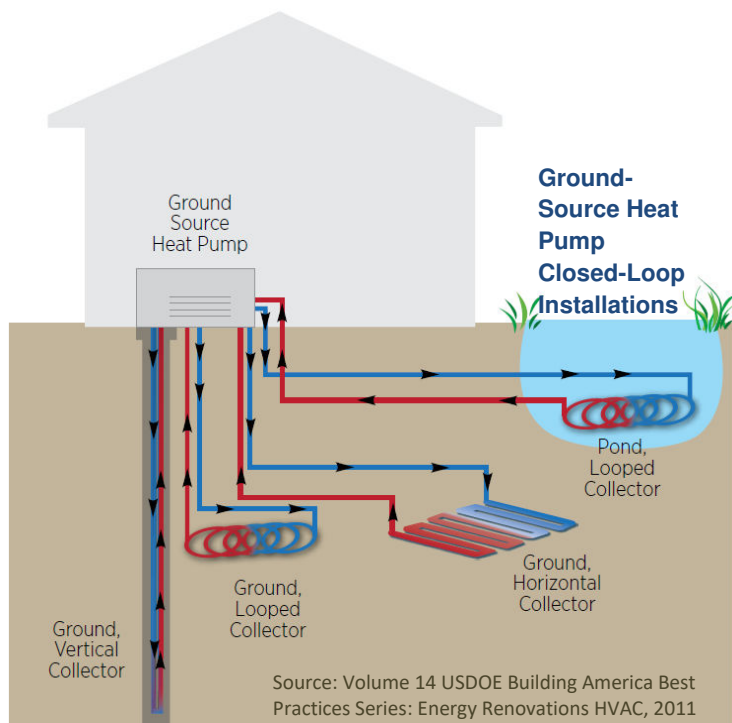
A low-efficiency furnace is less than 75% efficient. Medium-efficiency furnaces have efficiencies in the range of 80% to 82%. High-efficiency furnaces are designed to condense flue-gas moisture. High-efficiency furnaces are also called “condensing furnaces” and have AFUE ratings between 90% and about 97%.



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.

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 heat source instead of the outside air temperature. The disadvantages are their initial cost and the need for yard space to install the piping.



Boilers

In the United States, many people insist on central air conditioning in their homes for cooling. It's easier to provide whole-house cooling in a home with a ducted system. Once there is a duct system installed for cooling, it's cheaper to install a furnace for winter heating than to install a boiler with a separate distribution system. Hot water, often termed *hydronic*, heating is particularly suitable for space heating in a cold climate in areas where there is no need for air conditioning. The water is usually heated by a natural gas boiler. Hot water is piped through the house, which is heated by a radiant-floor system or by hot-water baseboard units.

Combination Systems

The term *combination system* usually refers to a system that uses a single water heater to provide both domestic hot water and space heating. The advantage is that only one appliance is required for both water and space heating. By adding an air conditioning coil at the air handler, central cooling can also be provided. Small air handlers with hydronic coils are readily available. Combination systems can be difficult to design and the right combination of contractors to install them may be hard to find.

Ductless Heat Pumps

Ductless heat pumps are a more efficient alternative to standard air-source heat pumps which use ducts and an air handler to distribute the hot or cool air. 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 units to provide zone heating and cooling without ducts.





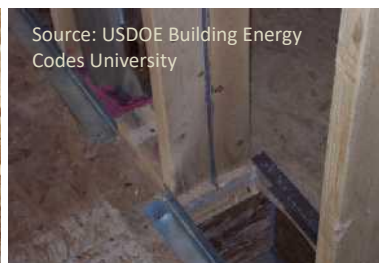
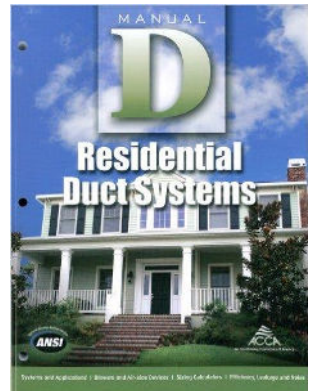
Ductless heat pumps provide increased energy savings over standard heat pumps in several ways – because they are ductless and mounted inside conditioned space, there are no losses to the attic or crawlspace or through leaky ducts; and they provide zonal heating. These high-performing heat pumps also perform at a much wider temperature range than standard heat pumps.

The main problem with ductless heat pumps is distribution of the conditioned air. This is often referred to as the *cold bedroom* problem. If room-to-room temperature variations are unacceptable, it's possible to design a system with very short ducts, but there is a loss of efficiency. For information on ductless heat pumps, visit <https://goingductless.com/>.

Duct Design and Installation Best Practices

Duct design and installation is often taken for granted by builders and homebuyers. It is good practice to use *ACCA Manual D* for designing the duct system. Following are several design factors that will improve performance:

- Install ducts inside the thermal envelope.
- Do not use framing cavities for supply or return ducts.
- Install branch duct balancing dampers.
- Use of galvanized ducts is preferable to flex duct.
- Locate supply registers to reduce length of ductwork.
- Provide return-air pathway.



Source: USDOE Building Energy Codes University



Inadequate return-air pathways can create pressure imbalances from indoors to outdoors or 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.

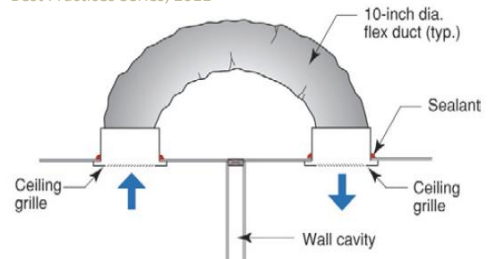
The result of inadequate return-air is room-to-room pressure imbalances that lead to uneven room temperatures; negative pressures in the combustion appliance zone, potentially cause backdrafting of atmospherically vented appliances; and increased movement of warm, humid air into building cavities, causing moisture problems in walls and ceilings.

There are four possible options to solve the pressurized-bedroom problem. Each bedroom needs one of the following:

- Dedicated return air ducted back to the furnace
- Door undercuts
- Transfer grilles
- Crossover ducts



Source: Volume 14 USDOE Building America Best Practices Series, 2011



Crossover Duct

Duct Tightness Testing

Two types of duct tightness testing are allowed by the Montana energy code. The *total duct leakage* test measures the duct leakage from the entire duct system regardless of whether it is located inside or outside the conditioned space. To conduct a total



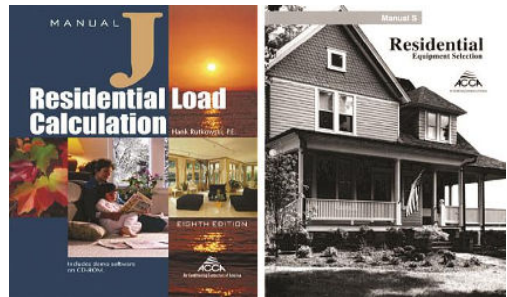


duct leakage test, all supply and return registers are sealed. The duct tightness tester fan is attached at the air handler cabinet or the return register nearest the air handler. The air flow required to bring the duct to the test pressure is equal to duct leakage.

The *duct leakage to the outside* test is more complex because the blower door fan must also be used to pressurize the house to 25 Pa with reference to outside. The duct tester fan is then used to bring the pressure in the duct system to zero with reference to the house.

Equipment Sizing

While not a code change, it is worth noting that heating and cooling equipment must be sized in accordance with ACCA Manual S and based on loads calculated according to ACCA *Manual J*. Oversizing equipment results in short cycling, which can reduce equipment life, reduce efficiency, reduce filter effectiveness, and results in poor dehumidification during the cooling season.





Lighting

The energy code requires a minimum of 75% of the all lamps or 75% of permanently installed lighting fixtures to be high-efficacy. In other words, there are two ways to comply, either by lamp count or fixture count. In either case, exterior lamps and fixtures are counted. There is an exception for low-voltage lighting, which is not required to utilize high-efficacy lamps. High-efficacy lamps are determined by their lumens per watt rating. A lumen is an amount of light produced by a light source.

**75% High-Efficacy by either:
1. Lamps Count; or**



So-called *airtight* recessed can lights are not actually airtight, but they do leak less air than recessed cans without weather stripping at the trim. Best practice for an energy-efficient house is to have no recessed can lights in an insulated ceiling.



After You Move In



There are two 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. Below are some tips about how to live in your new home to minimize energy waste.



Lighting

- Turn off lights when the room is unoccupied. Consider installing motion sensors in appropriate spaces.
- Replace burned out lamps with compact fluorescent or LED lamps.

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.

Heating and Cooling

- Use programmable thermostats to setback temperatures when the house is unoccupied. Many programmable thermostats are not set properly or used regularly.
- Keep your heating and cooling systems tuned up. These systems require periodic maintenance to ensure optimal performance. Make sure filters are changed regularly as suggested by the manufacturer.
- Most unwanted solar heat gain comes through the east and west windows, so plant deciduous trees on those two sides of the house. Shading your home with landscaping and window treatments can reduce indoor temperatures by as much as 20° F.

Electronics

- Avoid energy vampires. Even when they're turned off, home electronics in "standby" mode use energy to power features like clock displays.
- Purchase ENERGY STAR-qualified televisions - they're up to 30-percent 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.





Notes



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