E3A: Is Heating with Wood Right for Me?

Steps in the Wood Heat Series

E3A-WH
Printed April 2014

The following list may help you decide if heating with wood will work for you.

1. Have you considered the role that wood heat might play in your home? The type of heating unit, cost, and back-up heating fuel (propane, natural gas, electric, etc.) will vary according to how you intend to use wood. For example, if wood heat is the primary form of heat in your home you may purchase a larger unit and require a smaller back-up heating source than if you are looking to add wood as a part-time heat source or decorative addition to a room that will only be operated occasionally. These fact sheets will provide a general overview of wood heat, but you should be prepared to discuss your specific needs and objectives with a qualified installer.

2. Have you researched your community restrictions, home heating sources, and demands? There are many options for heating your home, especially if you are building a new house. You will be able to make a more informed decision about wood heat if you understand *what type* of energy you are currently using to heat your home, *how much energy* you are using, *how much* money you are spending, and *what* energy efficiency measures you could take to reduce your heating demand. Use the information at the end of this fact sheet to better understand your home heating consumption. Renewable energy systems, such as wood heating units, are more cost effective in markets where prices for fossil fuels are high and alternative energy sources abundant.

3. Do you have a good (legally accessible, abundant, suitable tree species, reasonable tree sizes, etc.) sustainable wood fuel resource available close by? Many factors determine the quality of a forest based-fuel resource. Transportation distance is a key consideration in the long-term economic viability of a wood heat system.

4. Are you willing to invest in a wood burning unit? A system that provides an average home's heating demand (53 Million BTU/year) will cost $5,000 or more before incentives. Some homeowners opt to reduce the total investment in the wood heat system by off-setting only a portion of their total heat needs. This reduces the system cost, but extends the economic payback period for the unit. You may have to finance the full cost as some incentives are tax credits or rebates received after installation.

5. Do you have the physical ability and time available to use wood? Unless you are considering a wood pellet system, heating with firewood takes time, resources and some hard physical labor. Research suggests that it requires about 15 hours of work to produce a standard cord of firewood (a stack of wood measuring 4ft x

4ft x 8ft) from cutting the standing trees to stacking the sized pieces at the point of use. These hours do not include hauling/transportation. Stove-tending time is about 10 hours/cord, resulting in a total of about 25 hours required to produce and use a cord of firewood. The average home's heat demand of 53 Million BTU/year would require between 3 and 5 cords of wood, depending on the wood species used and stove efficiency.

6. Does your area allow wood burning units? Some residential areas either do not allow solid wood burning devices or require special permits. Restrictions may limit emissions (thus the kind of fuel you are allowed to burn) or days you can burn (for example burning may be restricted on days when air quality is poor). Some areas prohibit the installation of wood burning units that emit more than a certain amount of particulates; others allow only the most efficient wood pellet stoves. Research and understand the restrictions in your area to ensure you will have adequate opportunities to burn and that your system design will not violate emissions standards.

7. Are you willing to maintain the system? Wood burning units require regular maintenance. Maintenance requirements are different for each system. You will need to bring in wood or pellets frequently, clean out ashes regularly, clean the flue/chimney and annually inspect and repair components of the stove and flue/chimney. Do not consider heating with wood if you are not willing to maintain your system or to hire someone to perform maintenance work on a regular basis.

8. What other motivations do you have to heat with wood? People invest in renewable energy for a variety of reasons. For example, you may be motivated to be less dependent on fossil fuels and its suppliers. Perhaps you are working to reduce your personal carbon footprint. Are you simply trying to reduce your current energy costs? Are you trying to hedge against future energy costs by using wood as a back-up fuel to your current system? Your reasons for exploring wood heat will influence your decisions about system size, economic benefit, and system type. Take time to think about your reasons for this investment before talking to a qualified installer.

Notes

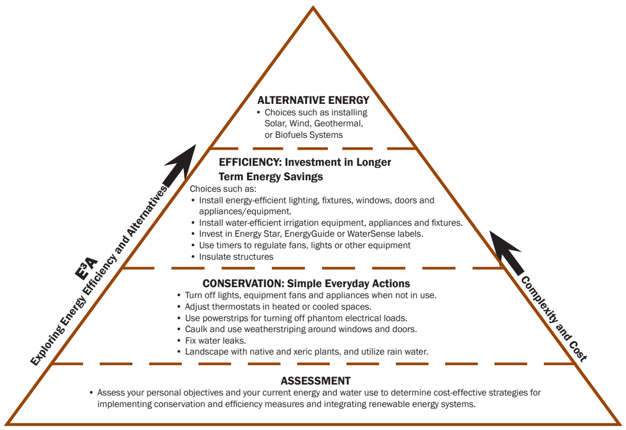
Montana State University Extension — Western SARE Sustainable Agriculture Research & Education — University of Wyoming Extension

STEP 1

Steps in the Wood Heat Series

E3A-WH.1
Printed April 2014

E³A: Introduction to Wood Heat

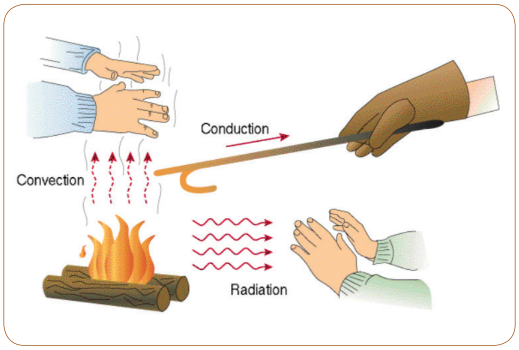


Contemporary wood-heating devices come in many shapes and sizes, from stand-alone stoves that heat their immediate surroundings in small spaces, to installations resembling mini district heating plants for combined central heating and domestic hot water. These fact sheets focus on small combustion units for homes and their ancillary components.

Every wood heating system design and installation should consider potential energy efficiency improvements to reduce the total heating demand (or load) first. A large, well-insulated, draft-free building can be heated comfortably with a relatively small unit, as compared to a building with no/low insulation levels, single-pane windows, and gaps and cracks in floors, walls and ceilings, and around pipes, window and door casings. Use the E3A Energy Management for the Home series to take energy conservation and efficiency measures prior to investing in a wood-burning device. Wood is usually used for space heating, so levels of insulation and air sealing are especially important to consider. Efficiency measures will reduce the size and cost of the system needed to heat the space.

It is especially important before installing wood heat to understand the energy use and air flow in the home. In considering energy use, evaluate the size of the space to be heated, the duration (number of months) of heating and the anticipated frequency of use of the wood combustion unit. Air flow is important as the heat "source" (combustion unit) and "sink" (home) need to interact as a system, rather than independent of each other. For example, the air "tightness" or availability of combustion air in the home will affect the ability of the combustion unit to draft and burn properly.

Heat Transfer



Wood heating, a thermal energy, is a form of energy associated with the motion of atoms and molecules. Wood heating systems transfer energy in three ways: 1) Radiation, 2) conduction, and 3) convection (warm air rises).

Heat moves as electromagnetic waves through empty space as *radiation*. *Conduction* occurs when heat energy is transferred through solid matter along a temperature gradient, from warmer to cooler. Convective heat transfer (often called *convection*) is the transfer of heat from one place to another by the movement of fluids (including gases, like air). When the molecules in the air come in contact with a hot surface, they separate and scatter, which makes the gas less dense. Cooler gases are denser and sink as the hot air rises. The exchange between hot and cold fluids results in circulation of the fluid and over time, the temperature of the entire fluid rises if minimal heat is lost. The following fact sheets will discuss both how the combustion units are designed to transfer heat as well as considerations for improving the thermal energy of wood heat in the design and installation processes.

Key Terms in Wood Heating

Room/Area Heat: A combustion unit that heats a single room or adjacent area. Usually has no ducting/piping to distribute heat to other parts of a building and is made of cast iron, steel, or stone. Examples are the common wood stove, pellet stove, or fireplace.

Central Heat: A combustion unit that commonly has ducting and blower (distributing air) or piping and pump (distributing water) to distribute heat to other parts of a building. Usually installed in basement, utility closet, or separate outbuilding.

Hydronic: These combustion units heat a heat-transfer liquid (water or antifreeze) that is piped to provide heat and hot water to occupied buildings such as homes, barns and greenhouses. May also be located indoors.

Single Fuel: Units that generate heat from one form of fuel.

Flex Fuel: Commonly refers to units that can generate heat from a variety of similar fuels (e.g., renewable solid fuels, like wood pellets, corn).

Multi Fuel: Commonly refers to units that can generate heat from a variety of dissimilar fuel sources like wood, coal, and even oil in a single unit.

Cordwood: The traditional "firewood", cut, split and stacked.

Pellets: Small, highly compacted wood residues made of mostly sawdust. Come in bags or bulk. In some part of the U.S., and in Europe, agricultural waste (e.g., corn stover), wild grasses, and dedicated energy crops (e.g., switchgrass, reed canary grass) are being used to make pellets.

Wood chips: Chipped wood, usually used on a commercial or industrial scale.

Notes

E³A: Combustion Technology

STEP 2

E3A-WH.2
Printed April 2014

Modern, high efficiency combustion systems create the conditions needed to burn all of the combustible components (solids, combustible gases and tar droplets) from the fuels before they leave the appliance. The technology includes the following characteristics:

- air tight doors allow for controlled supply of air;
- firebox insulation keeps temperatures inside the firebox, and thus combustion temperatures, high;
- preheated primary combustion air that does not cool the fire;
- preheated secondary air that is fed to the fire through sets of small holes in the gas-burning zone, above and behind the fuel bed;
- internal baffles that give the gases a long, hot enough route so that they can burn completely.

WOOD BURNING SYSTEMS

Wood Stoves

Non-Catalytic Wood Stoves

Non-catalytic wood stoves, in their most basic version, are a campfire in a box. These units rely on a controlled supply of pre-heated air to various points along a serpentine path in the combustion chamber for optimum conversion of fuel to heat. Advantages are a simpler construction, fewer/cheaper parts that need replacing, and lower, simpler maintenance. Disadvantages vs. a catalytic wood stove include: slightly lower efficiency due to necessary higher combustion temperatures, a narrower range of optimal firing rates, and relatively shorter burn times.

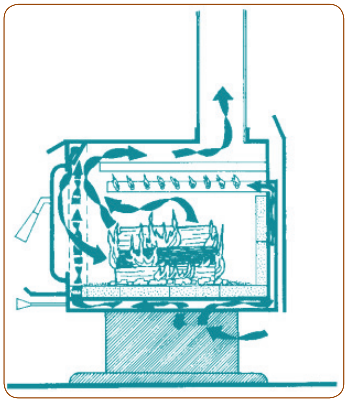


Figure 1. Non-Catalytic stove. (CMHC)

Catalytic Wood Stoves

Catalytic wood stoves have a brick-like catalyst, which increases the surface area and lowers the temperature where the combustible components in the wood smoke can be burned. While smoke usually ignites at approximately 1100 degrees F, the catalyst lowers that temperature to approximately 500 - 550 degrees F. Advantages are increased efficiency, longer burn time, and the ability of the unit to burn cleanly at lower firing temperatures. A disadvantage is the need to replace the catalyst roughly every 600 hours at a cost of between about \$100 and \$200. Learning to use the catalyst and adjusting the unit to optimize efficiency is slightly more complicated than the traditional non-catalytic stove.

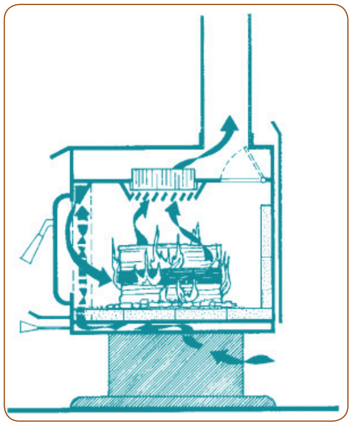


Figure 2. Catalytic stove. (CMHC)

Pellet Stoves

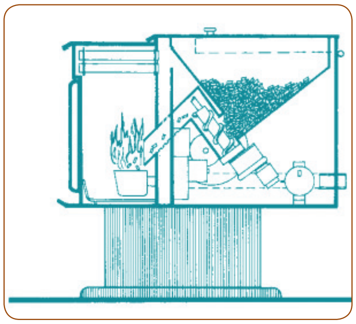


Figure 3. Pellet stove. Source: (CMHC)

Pellet stoves are similar in dimension to wood stoves. They use compressed pellets (made from wood or other biomass (made from plants, agricultural waste, or other vegetation)) for fuel. Pellet stoves have a variety of mechanical fuel-delivery and ash disposal systems, are equipped with sensors to help control air intake, and can be either fireplace inserts or free-standing stoves. The controlled air intake results in a relatively controlled and clean burn. If used correctly, pellet stoves produce very little smoke and creosote, the latter being the main cause of chimney fires. They are categorized into two types based on the pellet delivery systems: top-fed and bottom-fed. Bottom-fed units feed automatically into the stove, while top-fed units commonly have a hopper that is manually refilled with bagged pellets. Unlike wood stoves and fireplaces, pellet stoves need electricity to operate, but they can be easier to operate and maintain. Pellet burning involves no cutting, less hauling, and no splitting, stacking or waiting for the wood to dry, but requires the purchase of pellets.

Masonry Heaters

Masonry heaters have two features that set them apart from other types of combustion equipment. The first is apparent on the outside: they consist of a large amount of stone, bricks or refractory material. The second is concealed on the inside: they are designed with a system of channels through which the hot flue gasses travel before going up the chimney or stovepipe. Together, these design features make for very efficient, clean burning heaters. Masonry heaters still have a firebox, where wood is burned. But unlike wood stoves, they take a very long time to heat up, though. The large thermal mass (the bricks or stone cover a frame of firebrick) may take a full day to heat up. The thermal mass will also hold that heat for a very long time (and is warm to the touch, versus burning hot on a wood stove). One or two short duration but intense fires per day will maintain comfortable, even heat that radiates in all directions. Some masonry heaters have built-in cooking compartments ideal for baking bread or making stews.

The downside of masonry heaters is their higher price, size, and weight. Unless they are built on the house foundation, substantial reinforcements are needed for conventional buildings and a structural engineer is required. Commissioning someone to build a custom masonry heater can cost \$15,000 to \$30,000. Kits are available for the core of the heater (starting around \$5,000).

Fireplaces & Inserts

A conventional fireplace is typically a masonry or metal box with an attached flue and chimney. An open fire is built in the box and radiates heat into the room. These systems are typically very inefficient because the fire also causes a draft of conditioned room air to vent out the chimney, and because an open fire combusts fuel inefficiently. A fireplace insert is a wood stove that has been modified by its manufacturer to fit within the firebox of a masonry fireplace. Inserts are used to convert masonry fireplaces, into more effective heating systems. An insert consists of a firebox surrounded by a steel shell. Air from the room flows between the firebox and shell and is warmed. The outer shell ensures that most of the heat from the firebox is delivered to the room instead of being released up the chimney. Efficiency of inserts varies tremendously, with most only 50% of a wood stove.

Boilers

There are basically two kinds of wood-fired boilers: the standard hydronic heater, commonly known as an outdoor wood boiler, and two-stage gasification cord wood or pellet boilers. Within each category, there can be a wide range in terms of emissions, efficiency, cost, and heat output.

Boilers heat water or glycol (antifreeze), which is circulated through pipes to the space to be heated or into a heat exchanger in a forced-air system (though this is often less efficient).

Outdoor Wood Boilers

While Outdoor wood boilers (OWBs) are often advertised as a clean and economical way to heat one's house and water, OWBs can also be among the dirtiest and least economical modes of heating, when improperly used. Some suffer from design characteristics that make them notorious for having very high emissions and low efficiencies. They are based on a large firebox, surrounded

Source: Canada Mortgage and Housing Corporation (CMHC). A Guide to Residential Wood Heating, 2008 (About your House: Combustion Gases in Your Home, 2006; About your House: Efficient and Convenient Wood Heating, 2009).

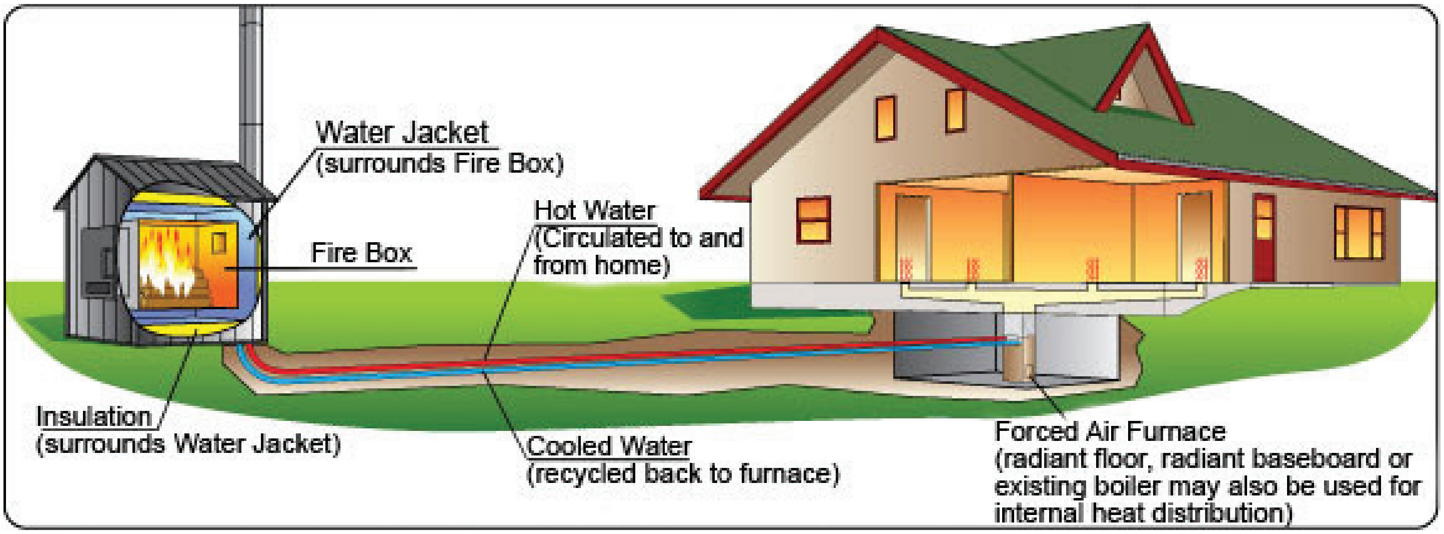


Figure 4. Source: Hearth, Patio and Barbecue Association (HPBA)

by a water jacket, which is often not well insulated; and they usually have low chimney stacks, which allow exhaust to hover close to the ground. Currently, there are no nationally established legal emissions limits for OWBs. When used improperly – such as burning wet wood or other inappropriate fuels – the hourly emissions of one (OWB) can be twenty times as high as the hourly emissions of an EPA-certified wood stove. They should be used with dry wood and adequate air intake to maximize efficiency and minimize emissions. While the EPA has initiated a voluntary regulatory program in an effort to encourage manufacturers to produce cleaner, more efficient units, there are still many unqualified, polluting boilers on the market. Be cautious when purchasing and installing one of these systems.

EPA Phase 2 cleaner burning hydronic heaters qualify for EPA's *Voluntary Hydronic Heater and Fireplace Programs.* The qualified level is 0.32 pounds of fine particles per million BTU of heat output (weighted average representing the range of burn rates expected in a year) and a maximum individual test run of 18.0 grams per hour. Typically, the maximum individual test run is the maximum heat output burn rate. A current list of Cleaner Hydronic Heaters can be found here: http://www.epa.gov/burnwise/owhhlist.html

Two-Stage GasificationWood Boiler

Two-stage gasification combustion systems are much more efficient and cleaner-burning than single-stage systems. All combustion of a solid material starts with gasification: the wood (or other material) is heated to the point where volatile gases are released, and it is these gases that burn. In a single-stage system, many of the gases are released up the chimney before they can be fully combusted (which means increased emissions and decreased efficiency). With two-stage combustion, the combustible material (in our case cord wood or wood pellets) is heated in one chamber in the relative absence of oxygen, and the gases are released into another chamber where fresh air is injected, for an almost complete combustion and at higher temperatures than can be reached in a standard wood stove, pellet stove, or traditional outdoor wood boiler systems (gasifying boilers can reach emissions of <1 gram of particulates per hour).

Europeans lead the world in the development and use of two-stage gasification boilers, and many of which are available for import. In addition, several domestic companies are now making very clean-burning, highly efficient units.

Thermal Storage

Many boilers employ thermal storage to improve efficiency by minimizing the frequency of on-off cycling. These are usually large, insulated buffer tanks that store heated water (such as a tank-style water heater) before circulating it throughout the building. Without thermal storage the heater would have to fire up any time there is demand, which means the heater cycles on and off frequently. With thermal storage, the boiler fires for a long period of time in order to heat the large amount of water in storage, and then shuts down for a long period of time while heat demand is satisfied through the stored heat energy. This greatly increases efficiency and reduces emissions.

Notes

E3A: Selection Criteria

STEP 3

Steps in the Wood Heat Series

E3A-WH.3
Printed April 2014

A wide variety of wood burning devices are available today. Designs as well as technology have dramatically improved over the last two decades. This publication will discuss differences in wood heating systems, especially those between EPA-certified units and those that are not certified. Most of the characteristics discussed below apply to both cordwood stoves and pellet stoves, but some are more specific to the particular fuel source.

Performance

Performance parameters and ratings are provided by the manufacturer both as information to consumers and marketing tools for salespeople.

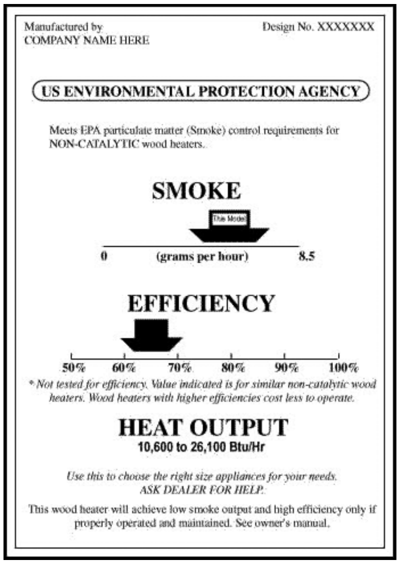
It is important to understand the information presented by manufacturers in the decision-making and purchasing process. Often performance parameters are used to describe performance of wood burning appliances in a similar fashion to the Environmental Protection Agency (EPA) fuel efficiency ratings (i.e. miles per gallon) for vehicles. However, not all of the data provided on product brochures are standardized and regulated. EPA certifies emission rates and high/low BTU (British Thermal Unit) output ranges for wood stoves. This information is very useful and specific to the stove model, but because models vary widely the information is not easily compared from one model to the next. Consumers should also be aware that EPA-approval indicates that the model has been tested in an EPA-certified laboratory as being able to meet certain uniform standards. However, consumers operating the equipment in the "real world" may not achieve the same standards the EPA achieved under controlled conditions.

Other performance parameters that may be listed in product literature include: efficiency, heat output, heating capacity and burn time (see table below). Test methods for calculating these parameters are not standardized or regulated – meaning manufacturers can define them differently. Hence, using these ratings to compare different models has to be approached with caution. These numbers may provide some initial information, but because of the difficulty in comparing models, and the fact that there are many other factors to selecting a wood burner for a specific site, the numbers should only be part of the selection criteria. A reputable dealer will likely be able to recommend the right stove for a particular situation and ensure consumer expectations of their new heating appliance are met.

Performance						
Stove Model	Peak Btu/hr* (On High)	Max. Burn Time (On Low)	Firebox Capacity (cu. ft.)	Max. Log Length	Emissions (g/hr)	Efficiency
Model 1	40,800	7-9 hrs	1.46	16"	2.1	78.5%
Model 2	51,100	10-12 hrs	2.0	18"/16" Ideal	1.1	77.2%
Model 3	56,000	12-14 hrs	2.4	20"/18" Ideal	1.1	79.5%

Example of performance parameters a consumer might find in a product brochure.

The following are some of the terms commonly found in manufacturers' brochures, and on appliance labels.



Efficiency

Efficiency ratings found on most, if not all, wood burning units are unspecific and can be fairly ambiguous. The reason is that assigning a single "efficiency" number when heating with a wood burning appliance is complex. For example, one measure, combustion efficiency, indicates how completely the wood burns. Another, heat transfer efficiency, is a measure of how much of the energy released is transferred to the space to be heated. These measures will both be influenced by when the wood is burned and whether the wood is properly seasoned (as described in Step 4), etc. The EPA certification of wood burning appliances provides a good guideline for efficiency. While EPA certification only assesses compliance with particulate emission limits (see factsheet on Emissions), higher overall efficiency is correlated with lower EPA limits for particulate emissions. Between 60% and 80% overall efficiency (combustion and heat transfer) is considered a reasonable range. Lower than 60%, and too much energy goes up the chimney rather than heating the space. Overall efficiency higher than 80% in woodstoves may have drawbacks. High efficiency units are designed to use as much of the stored wood energy as possible for heating, as opposed to allowing the energy to escape out the chimney. However, units with efficiencies above 80% utilize so much of the stored wood energy for heating that they have a low exhaust temperature, which could lead to a weak draft and increase the risk of water vapor condensation in the chimney.

Heat Output

Heat output is listed as maximum heat output in British Thermal Units per hour (BTU/hr). Typical heat output ranges are between 25,000 to 80,000 BTU. The measure, however, is a maximum output. Just like running a motor at maximum possible RPM for prolonged periods of time, running a wood or pellet stove at the maximum heat output can cause damage to the unit.

For consumers, some of the more valuable heat output numbers are the high and low BTU output ranges, which are reported on the EPA tag (label). The high/low output ranges tell a consumer how much heat a unit can produce and how low the temperature can go by design, while still burning cleanly. It is important to look for a unit with a broad a range so it can be used comfortably more days out of the heating season. As with all numbers, the high and low output ranges are estimates of real world conditions.

Heating Capacity

Heating capacity, usually provided as square feet of space the unit will heat, is a very subjective performance parameter because of the many non-stove related factors involved. Climate zones (e.g. California vs. Michigan), insulation levels/air tightness of the space to be heated, floor plans (open vs. fragmented), height of the space, as well as the kind of wood used, all need to be considered. These factors make the manufacturer-provided rating highly variable as a decision making tool.

Burn time

A factor that often does not appear in the numbers, but is important to consumers, is the burn time. In other words, consumers want to know how often they will need to add wood in the firebox or reload the hopper on a pellet stove in order to keep the space comfortably warm. Unfortunately, there is no perfect response. "How long will this stove burn on a single load/hopper full of wood/pellets?" is similar to, "How long will this car run on a tank of gas?" Burn time depends on three main factors: fuel quality (what kind of wood and its moisture content), heat demand, and the size and orientation of the firebox. Of these, fuel type and heat demand will have the largest influence. For example, dry Ponderosa pine burned with the vent wide open will provide moderate heat for several hours. Douglas fir will provide twice as much heat. A closed air supply vent will provide for less heat - though a burn time of 8+ hours. It also depends on other features of the unit. For example, due to their design and capability of burning with low emissions at lower temperatures, good catalytic stoves can deliver a lower burn rate over a longer period of time than their non-catalytic counterparts. A full automatic pellet stove controlled by a thermostat might need a refill of the hopper only once a day, depending on space heating demand and hopper size.

The best resource to make sense of all these ambiguous numbers and to recommend the right stove for a particular situation is to ask your local dealer for the pros and cons of each stove manufacturer and type. If possible, ask for references of people who have been using wood stoves and get their feedback.

EPA Emissions Standards

- An EPA certified wood stove or wood heating appliance has been independently tested by an accredited laboratory to meet a particulate emissions limit of 7.5 grams/hour for non-catalytic wood stoves (State of Washington 4.5 grams/hour) and 4.1 grams/hour for catalytic wood stoves (State of Washington 2.5 grams/hour). All wood heating appliances subject to the New Source Performance Standard for New Residential Wood Heaters under the Clean Air Act offered for sale in the United States are required to meet these emission limits. A current list of EPA Certified Wood Stoves can be found here: www.epa.gov/burnwise/woodstoves.html
- EPA Phase 2 cleaner burning hydronic heaters qualify for EPA's Voluntary Hydronic Heater and Fireplace Programs. The qualified level is 0.32 pounds of fine particles per million BTU of heat output (weighted average representing the range of burn rates expected in a year) and a maximum individual test run of 18.0 grams per hour. Typically, the maximum individual test run is the maximum heat output burn rate. A current list of Cleaner Hydronic Heaters can be found here: www.epa.gov/burnwise/owhhlist.html
- EPA Phase 2 units have a white tag and are about 90 percent cleaner than unqualified units. EPA's Phase 1 models are no longer considered "qualified" under the Program.
- Wood-burning appliances that are "qualified" under the EPA's Voluntary Hydronic Heater and Fireplace Program are NOT "certified" per EPA's New Source Performance Standard for New Residential Wood Heaters. Contact your state or local air quality agency for clarification on the type of wood-burning appliances, if any, which may legally be installed in your area.
- As of this writing, EPA with input from industry is in the process of developing new, tighter emissions standards for wood burning appliances. The proposed rules would tighten emissions standards in a two-step process: For new room heaters, which include pellet and wood stoves, the emissions levels proposed are 4.5 grams/hour in the first step, and 1.3 grams/hour in five years. The proposed rule also would eliminate separate emission targets for catalytic and non-catalytic stoves in favor of a single number, due to technology improvements that make separate standards unnecessary.
- For hydronic wood boilers, the step one-level is already met by a number of models with emissions of 0.32 pounds of particulate matter per million BTU heat output. The step-two level to be met in five years would cut that in half to 0.15 lb PM/MMBtu.

As with most things, certain parameters change for wood burning devices over their lifetime. According to the U.S. Environmental Protection Agency, certified woodstoves degrade with use, but they still burn cleaner than uncertified stoves, and on average, after about 7 years they still have lower emissions than uncertified conventional stoves.

Wood stove change-out programs, where the replacement of old, inefficient and polluting woodstoves with new, cleaner-burning technologies like gas, wood pellet, and EPA-certified wood stoves are encouraged and subsidized through direct grants, equipment donations and in-kind support, have been implemented across the country, including Libby (2008) and Seeley Lake (2012) in Montana. These programs commonly are offered in areas with elevated levels of air pollution caused by wood smoke.

CAUTION: "Meets EPA Requirements" or "EPA exempt" is not the same as "EPA-Certified" or "CSAB415.1 Certified" as some advertisements might suggest. These stoves do not meet EPA emissions standards. They just meet requirements to be *exempt* from emissions standards.

Notes

E3A: All About Wood

STEP 4

Steps in the Wood Heat Series

1. Introduction to Wood Heat
2. Combustion Technology
3. Selection Criteria
4. **All About Wood**
5. Economics of Heating with Wood
6. Installation and Maintenance
7. Agricultural Wood-Burning Applications

E3A-WH.4
Printed April 2014

How wood burns – Operation

Burning wood is a complex process, but it can be broken down into three steps, which happen in sequence and simultaneously in a given piece of wood:

1. **Water evaporation** – Properly dried firewood has a water content of less than 20%. Water in the wood needs to be boiled off (latent heat of evaporation) before temperatures can increase enough to release and ignite combustible gasses. The wetter the wood is, the more heat energy is consumed for this drying process; the poorer the combustion process and the more smoke and creosote are produced; and the catalytic converter in some types of wood stoves ages prematurely.

2. **Smoke formation** – Wood smoke is fuel! When the wood heats up, solid and liquid components in the wood turn into vapors - a cloud of combustible gases and tar droplets. Once it gets hot enough, with sufficient air supply, these gases and tar ignite and burn in a bright flame. If you can see grey smoke coming out of a chimney, not only is the air being polluted, but also energy is being wasted in the form of unburned vapors. A hot efficient fire will produce almost no smoke.

3. **Charcoals** – Once all the gases and tars are vaporized and burned off, what is left is charcoal; almost pure carbon that will burn easily, hot, and virtually smoke free, provided there is sufficient air supplied.

It takes some skill to start and maintain a comfortable, low-emission fire. Fine, dry wood will heat to the ignition point more quickly than large chunks of wood. Once critical temperatures are reached (around 1,000°F) wood will burn clean and efficiently. This requires sufficient oxygen - thus dampers should be wide open for start-up.

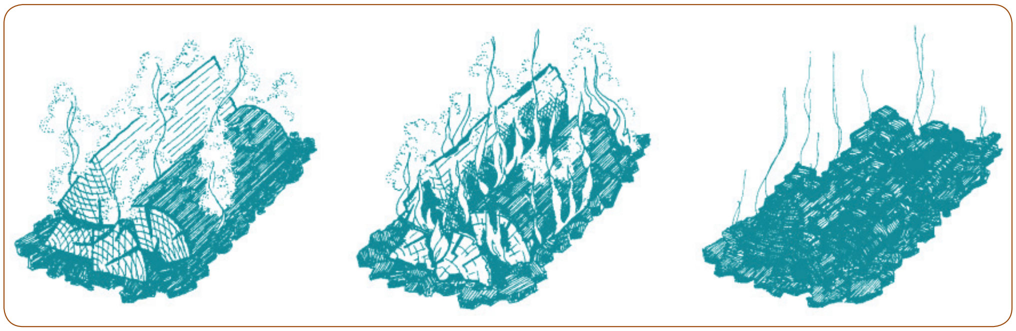


Figure 1. Three steps of wood burning. Source: A Guide to Residential Wood Heating. Canada Mortgage and Housing Corporation (CMHC)

Burn only dry, well-seasoned wood. Green or wet wood, paper (except a few sheets of newspaper, if necessary to start a fire), cardboard, and garbage may burn, but they compromise efficiency and contribute to higher emissions.

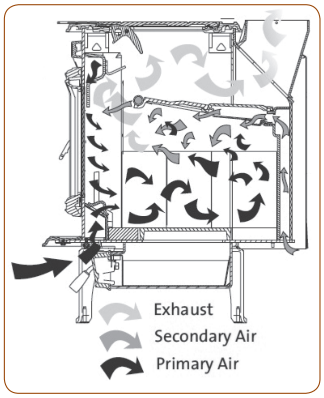


Figure 2. Combustion air paths. Source: Jøtul User Manual

Primary/Secondary Air System

Primary/secondary air is also referred to as single or dual stage combustion. Most modern wood burning units have a dual stage combustion process, where some combustion air is supplied more or less directly to the fuel source (primary air), usually through a grate or air vents, to enable gasification. A second stage (secondary air) supply allows pre-heated air to be injected into the smoke allowing for secondary, and almost complete combustion. Generally, primary air is controlled by the user, whereas the secondary air is controlled by the draw of the chimney.

Hazards of burning

Creosote deposits & chimney fires

Creosote is a highly combustible chemical by-product from incomplete combustion of carbon-containing compounds like wood. Chimney fires are commonly caused by creosote deposits in the flue pipe. Creosote condenses on cooler surfaces such as woodstove or fireplace flue pipes. Over time, these deposits can build up, and under the right circumstances (hot gases, embers in the flue) can ignite inside the flue.

Precautions: 1) Make sure the fire has sufficient air supply and maintains a high temperature. 2) Burn only dry, well-seasoned wood – nothing else. 3) Maintain sufficient flue gas temperatures (325°-400°F min). 4) Inspect and sweep the chimney at least once per year. 5) If used at all, make sure flue pipe mounted heat exchangers are properly installed.

Backdrafting

Backdrafting is when the path of exhaust gases is reversed from up and out to down and in. It is commonly the result of negative pressure in the building that contains the combustion unit or a wrong diameter/poorly designed flue.

An example would be running a powerful range hood that moves hundreds cubic feet per minute (cfm) of air. The volume of air that is exhausted has to be replaced by what is called "make-up air". Historically, buildings were less air-tight than today's energy efficiency standards require. In older structures, make-up air could be supplied through gaps and cracks in the building envelope. However, today's structures may not have sufficient "make-up air". Older buildings that have undergone energy efficiency measures or new structures may require additional ventilation in order to prevent back-drafting.

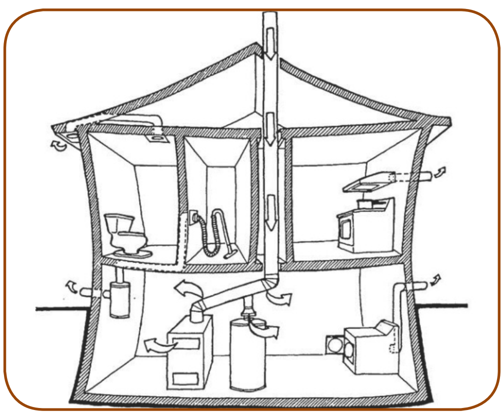


Figure 3. Backdrafting due to depressurization. Source: Combustion Gases in Your Home – Things You Should Know About Combustion Spillage. Canada Mortgage and Housing Corporation (CMHC)

Precautions: 1) Make sure a sufficient amount of make-up air is provided when bathroom fans, range hoods, whole house fans, and other appliances that exhaust large amounts of indoor air to the outdoors are running. A qualified installer should ensure that appropriate amounts of air are available. 2) Make certain the chimney or flue system is drafting properly - smaller diameter pipes tend to draft better. Smoke venting back into the room when the stove door is opened is a good indicator of a bad draft and may indicate a plugged chimney or poor design. 3) Pay attention to signs of back-spilling on other combustion units in the house. These are dark streaks of soot on the outside of an appliance with an open flame. 4) Install CO detectors on every floor of your home, include the basement.

Carbon Monoxide

Carbon Monoxide (CO), a poisonous and odorless gas is produced during most combustion processes. During oxidation (the combustion of a carbon-containing compound like wood), carbon monoxide formation occurs when inadequate oxygen is supplied. CO replaces oxygen in your blood, leading to death. Carbon monoxide is colorless, odorless, tasteless and slightly lighter than air.

Precautions: 1) Make sure the fire has sufficient air supply for complete combustion. In the presence of oxygen, carbon monoxide burns with a blue flame, producing carbon dioxide. 2) Install CO detectors on every floor of your home, including the basement. A detector should be located within 10 feet of each bedroom door, and near or over any attached garage. Detectors should be replaced every five to six years.

Hot embers in ash

There is a chance that hot embers are still hidden in clumps in a seemingly completely burned pile of ashes in the stove. If those ashes are cleaned out and moved to a place where combustible materials are close by, there is a chance of the embers reigniting and causing major damage, or releasing CO.

Precautions: 1) Carefully rake through the pile of ashes and watch for pockets of embers before disposing of it; or, use them to kindle the next fire. 2) Use only non-combustible implements to move ashes, such as a small closeable metal pail with a metal lid. 3) Ashes should be emptied into a metal garbage can stored outdoors away from combustible material, or in a damp soil pit.

Fuel type

All wood burning systems are strongly influenced by the type of wood that is burned. Very dense, dry wood burned with ample oxygen supply (wide open dampers) has the potential to overheat stoves and stoves and flue systems. If metal is red-hot - the heat is excessive.

Precautions: Special care must be taken when burning extremely pitchy wood (also known as "fat" wood) as pitch can result in excessive temperatures that can melt or burn through metal. Always monitor the type of fire in a wood burning device.

Wood Tips – size, moisture content, storage, etc.

A cord of wood is the standard unit of measurement for firewood, and measures 4ft x 4ft x 8ft. Because almost no one burns 4' long pieces of wood, fractions of cords, often called "face cords", "stove cords" or "furnace cords", are usually sold. These are piles of wood 4' high and 8' long and as wide as the length of the individual pieces. Make sure to convert the face cord back to a full cord when comparing prices for firewood.

The size of firewood most efficient for your stove is determined by a variety of factors, and will ultimately affect ease of use and burn properties. Length is commonly determined by the width and length of the fire box. It is advisable to cut the rounds to a few inches less than the shortest dimension of the two (length/width). This allows for loading the fire box in either east-west or north-south orientation depending on the changing heat demand throughout the heating seasons.

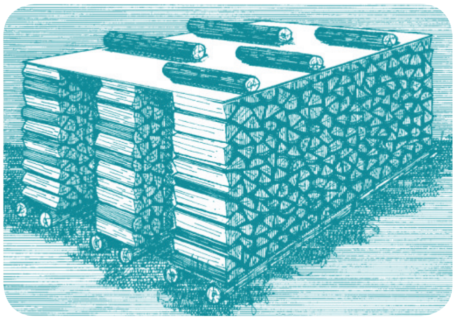


Figure 4. The firewood cord – Firewood is measured in cords. A full cord measures 4 ft. x 8 ft. x 4 ft. Many firewood dealers sell partial cords called face or stove cords. Pictured are three face cords with pieces measuring an average of 16 in. Together, these three face cords make up one full cord and should equal 128 cubic feet. Source: A Guide to Residential Wood Heating. Canada Mortgage and Housing Corporation (CMHC)

Another size factor to consider is ease of handling. While it is tempting to maximize the length and thus the amount of fuel per piece of wood as to reduce the frequency of reloading, there is a limit at which it becomes awkward and inconvenient to handle. Common lengths are between 12" and 20".

Firewood can be split to a variety of sizes, often ranging from 3" to 6" in diameter measured across the largest cross section. The different sizes will make it easier to build and maintain different fires to adjust to changing heat demands. Smaller, split pieces ignite and burn more efficiently than round wood. Larger pieces are best for longer time between refueling.

Drying Wood

Burning wet/green wood leads to incomplete combustion and thus creates significant smoke, potentially dangerous creosote deposits, and less heat. Green wood can contain up to 50% moisture by weight. Remember: before any heat can be released to heat a room, the energy stored in the wood is spent (and thus wasted) to evaporate moisture contained in the wood.

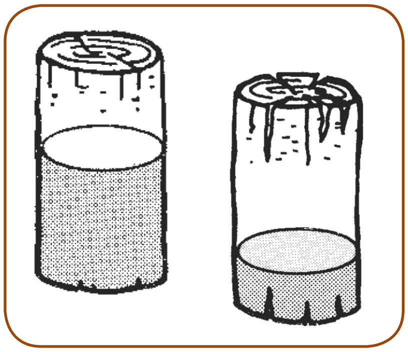


Figure 5. Wood water content before seasoning (left) and after seasoning (right). Source: Efficient, Convenient Wood Heating. Canada Mortgage and Housing Corporation.

An example: A small stack/big armload of properly seasoned pine firewood weighs about 40 pounds. At 20% moisture content, 8 pounds (or about a gallon of this wood) is water. Properly seasoned (dried) firewood has a moisture content of less than 20 percent, burns more efficiently, and produces less smoke and creosote.

In a live tree, the bark serves as a barrier that protects it from losing water that is transported up and down its trunk. To facilitate the drying process of firewood, this barrier needs to be broken or it will take twice as long. The wood should be cut to the desired length, split and stacked, off the ground, preferably in freestanding single rows, and exposed to wind and sun. Well dried, seasoned wood sounds hollow when it is rapped on and has cracks on the grayish colored ends. Depending on weather and wood species, this drying process can take from 6 months to two years.

After the wood is dry, it can be brought inside a shed or other building protected from the elements (but provided with some air circulation) until it is used.

Moving Firewood

DO NOT MOVE FIREWOOD OVER LONG DISTANCES. Besides becoming increasingly uneconomical, transporting firewood can drastically increase the spread of tree-killing insects and diseases. Examples of these insects and diseases include the native mountain pine beetle, and invasive species like the Asian longhorned beetle, emerald ash borer, and gypsy moth. Even without visible bugs, holes, burrows, sawdust, or other weird looking stuff on it, wood should not be considered "safe" to move. These tiny threats can significantly damage forests, and are spreading fast. While several states have firewood movement restrictions, others advocate leaving firewood at home. If you are buying firewood, ask the seller where they got the wood. If it is not nearby, or if they do not know where the wood is from, consider another firewood dealer. As a general rule of thumb, 50 miles is too far, and 10 miles or less is considered best. The closer to the property where it is actually burned the better, and that includes the firewood for your camping trip.

Buying wood pellets

Quality wood pellets are a convenient and very clean burning fuel source that can be used with automated fuel handling systems. Usually available as 40# bags or in bulk, they are produced with tight quality standards. They are small pills, made of mostly sawdust and a binding agent, usually lignin, and are highly compacted.

Characteristics of high quality wood pellets are:

a. Consistent size, ~ ¼” diameter, ¾” long.

b. Low moisture content, 5-10%.

c. Low amount of fines, <1%. The amount of fines influences the smoothness and flow of the pellets in the feeder as well as combustion properties.

d. Mechanically durable, as to be able to endure numerous handlings without breaking and producing fines.

e. No additives. Lignin, a natural component found in wood, should be the only binding agent.

f. Density of pellets. Wood pellets should be highly compressed. The looser the wood pellets, the higher the amount of fines.

Quality wood pellets have minimal ash content, which means they burn clean and leave very little residue (ash). This makes for long intervals between cleaning out the ash pan. Two “grades” for pellets are available today, “Standard” and “Premium”. While they have the same energy content per pound, “Premium” pellets must have an ash content of <1%.

Care has to be taken when storing wood pellets. Their low initial moisture content makes them hygroscopic (water loving), and storing them in an environment with increased humidity will allow them absorb moisture over time.

Source: Canada Mortgage and Housing Corporation (CMHC). A Guide to Residential Wood Heating , 2008 (About your House: Combustion Gases in Your Home, 2006; About your House: Efficient and Convenient Wood Heating, 2009).

Notes

E³A: Economics of Heating with Wood

STEP 5

Steps in the Wood Heat Series

E3A-WH.5
Printed April 2014

Heating with wood can reduce home heating costs – but accurately forecasting the cost reduction is a challenge. The major share of the lifecycle cost of a wood heating unit is the cost of a new unit, supplementary materials/tools, and installation. Potential cost savings arise when an inexpensive source of suitable wood fuel is available. However, there are factors that complicate the discussion of the economic benefits of wood heat installation. The following are a few of those complicating factors.

Local Regulations

Local ordinances influence the economics of wood heat in three ways. First, local emission standards may dictate the type of the unit allowed and the installation cost. Second, local ordinances may dictate when the unit can operate. This is especially true for new wood heating units (homes that had wood heat as a primary heating source prior to the ordinance may be exempt.) For example, an area prone to inversions may restrict burning for many days during the cold season, thus the economic discussion of wood heat must consider both the inability to use the unit during peak cold times and the cost of having a redundant fuel source (natural gas, electricity or propane) operating for that period. Third, local regulations in building codes may affect the cost of installation.

Fuel Cost

Wood is a renewable resource, though there are costs for obtaining wood fuel. Determining the actual cost of wood can vary based upon type of wood source, condition and storage. Here are some variables that influence the cost of the fuel:

Wood Availability

Wood can be gathered by the homeowner or a third party can deliver the wood. Third party delivery prices will vary based on distance to the wood resource, type of wood, costs of transportation, and the condition of the wood (split or round). In some areas, local saw mills will sell truckloads of "ends and pieces" or logs that are not saleable for the mill, but work well for burning in the home. These loads may cost less than cut and stacked wood that is gathered from the forest, but also may require additional processing such as cutting, splitting and stacking.

The cost of cutting your own firewood will depend on the homeowner. Someone who already possesses a saw and safety equipment, has the skill and physical ability to cut down trees, and has the ability to transport wood may find wood heat a reasonable option. Alternatively, buying equipment and learning how to use it safely may add thousands of dollars to the expense of using wood for heat.

Time and Physical Ability

The opportunity cost (you could be doing something else with your time) is also important to include in accurate assessments of economic viability. Gathering, splitting, and stacking firewood is a time consuming process. If you consider preparing your supply of wood as recreation, your opportunity cost may be quite low. If you would rather be fishing (or working overtime at your regular job), then it may be high. Your ability to conduct this type of hard physical labor may also change as you get older.

Some homeowners opt to pay a premium for delivered firewood to reduce the amount of physical labor required to burn wood. The cost per cord will increase if the wood is cut, split, and stacked.

While it is difficult to provide accurate average costs or return on investment information for wood, understanding the number of heating days and the amount of heating demand in the home can help in understanding the potential savings or cost.

Heating Degree-Days

Fuel demand for space heating varies according to the temperature outdoors. "Degree-day units" help in estimating the heat requirements and fuel costs for a building. Heating degree-days are a way to estimate heating costs. A heating degree-day is the demand for energy needed to heat a building for one day. When the outside air is above the base temperature of 65° F, no heat is required. To determine heating degree-days, the average daily temperature is subtracted from 65° F. Each degree accounts for one degree-day.

> Example: if a day's High temperature is 50° F and the Low is 30° F, the average daily temperature is 40° F. Subtracting 40° F from 65° F results in 25 degree-days for that day.

Heating demand is directly proportional to the number of degree-days in a year.

Example:

Here are some averages for Heating Degree Days from across Montana:

Heating Degree Days (Base 65)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Billings, MT	1,308	1,008	915	582	316	119	12	42	242	498	897	1,225	7,164
Glasgow, MT	1,686	1,330	1,104	621	322	121	19	71	267	586	1,074	1,544	8,745
Great Falls, MT	1,358	1,053	983	642	372	156	37	91	299	543	933	1,274	7,741
Havre, MT	1,546	1,201	999	613	324	113	33	49	270	622	1,067	1,410	8,247
Helena, MT	1,407	1,081	973	648	388	137	34	65	321	617	1,002	1,358	8,031
Kalispell, MT	1,380	1,075	970	654	425	235	97	128	367	716	1,020	1,311	8,378
Missoula, MT	1,311	1,002	905	624	409	179	65	81	303	645	978	1,290	7,792

Similar numbers for Wyoming include:

Heating Degree Days (Base 65)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Casper, WY	1,189	1,038	898	632	346	32	-	-	194	586	929	1,205	7,049
Cheyenne, WY	1,094	983	893	653	368	76	-	-	211	569	891	1,122	6,860
Jackson, WY	1,495	1,326	1,166	842	569	335	112	167	443	798	1,172	1,495	9,920
Rock Springs, WY	1,334	1,154	977	691	413	108	-	-	259	631	1,037	1,339	7,943
Sheridan, WY	1,250	1,048	904	589	324	43	-	-	189	591	972	1,256	7,166
Worland, WY	1,451	1,174	854	497	229	-	-	-	173	580	1,015	1,462	7,435

Wood Heat's Role in the Home

Economic discussions are further complicated based on the role that wood heat will play in the home. Some of the factors that make it difficult to provide an "average" economic benefit include: The floor plan of the home and where the stove will be located (i.e. – if the home has a basement, but the stove will be on the ground level, the heat may not be able to easily circulate to the lower level). In addition, consider if wood heat is a supplemental or primary source of heat, and the additional time required to use wood heat, as fuel needs to be constantly refilled and there is a "start-up" delay from when you start your unit and when it actually starts to heat the house.

Averages can be provided based on fuel substitutions. In North America, heat value (energy content) of fuels is commonly measured in BTU (British Thermal Units), which is roughly defined as the amount of energy needed to raise the temperature of 1 pound of water by 1°F, or in "therms", where 1 therm equals 100,000 BTU's. A Fuel Value Calculator, published in cooperation with the USDA Forest Service, Forest Products Laboratory, and the Pellet Fuels Institute in Arlington, Virginia, is a tool that can be used to compare typical unit costs of various fuels and is available online at http://goo.gl/wP8kR.

The following is an example for a Fuel Heating Cost Comparison for October 2013 in Montana, provided by NorthWestern Energy, a major utility. A similar cost structure and combustion efficiencies can be assumed for Wyoming.

Fuel Type	Heat Value (Therms/Unit)	Unit Cost	Unit Cost/Therm	Applicance Type	Appliance Efficiency (%, COP, or AFUE)		Cost/Therm
Wood	200/Cord	$150/Cord	$ 0.75	Fireplace	38%		$ 1.97
Wood	200/Cord	$150/Cord	$ 0.75	Stove	72%		$ 1.04
Electric	0.03413/kWh	$0.106/kWh	$ 3.11	Baseboard	100%		$ 3.11
Electric	0.0529/kWh	$0.106/kWh	$ 2.00	Air-Air Heat Pump	1.55	COP	$ 2.00
Electric	0.1024/kWh	$0.106/kWh	$ 1.04	Ground-Air Heat Pump	3	COP	$ 1.04
Propane	0.915/Gal	$2.05/Gal	$ 2.24	Furnace	80%	AFUE	$ 2.80
Propane	0.915/Gal	$2.05/Gal	$ 2.24	Furnace	90%	AFUE	$ 2.49
#2 Oil	1.39/Gal	$3.39/Gal	$ 2.44	Furnace	72%	AFUE	$ 3.39
Pellets	150/Ton	$240/Ton	$ 1.60	Stove	80%	AFUE	$ 2.00
Natural Gas	1/Therm	$0.739/Therm	$ 0.74	Furnace	64%	AFUE	$ 1.15
Natural Gas	1/Therm	$0.739/Therm	$ 0.74	Furnace	80%	AFUE	$ 0.92
Natural Gas	1/Therm	$0.739/Therm	$ 0.74	Furnace	90%	AFUE	$ 0.82

Cost per 100,000 Btus delivered as useable heat.	1,000 Btu	=	1 cubic foot
British Thermal Unit (Btu) is the amount of energy needed to raise the temperature of 1 pound of water 1° F.	100,000 Btu	=	1 therm
Based on altitude and atmospheric pressure in Helena, MT	1,000,000 Btu	=	1 dekatherm

The fuel comparisons shown are based on NorthWestern Energy's rates for electricity and natural gas and are subject to change. Monthly meter charges and/or tank rental charges are not included in the comparisons and need to be included if calculating a change in fuel sources. If you are comparing costs to other fuels or other energy providers, please adjust for fuel or rate cost difference applicable to your market area.

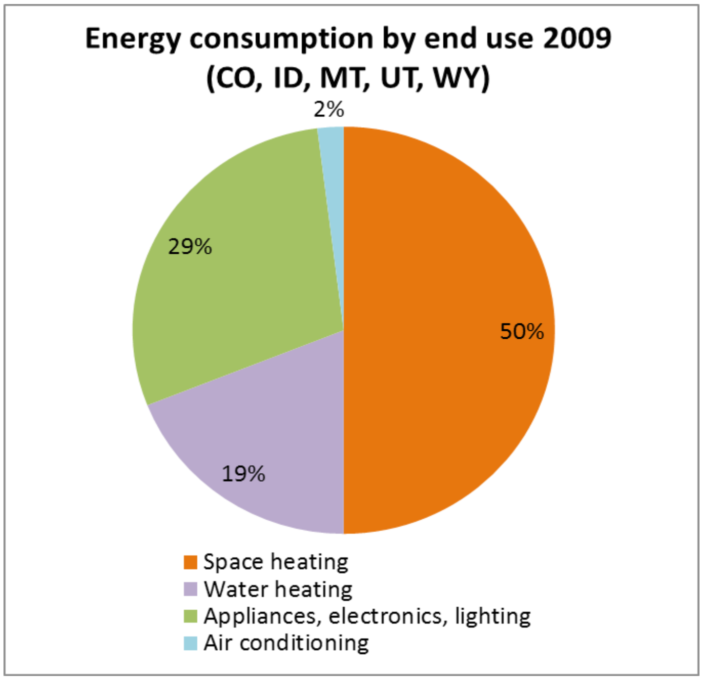


Figure 1: Adapted from EIA's 2009 Residential Energy Consumption Survey

Using some of the above numbers and assuming 50 Million BTU's/500 therms for annual home heating demand, a household in Montana or Wyoming would pay approximately $1,560 for fuel oil #2, or $480 for natural gas, or $1,550 for electric heat, or $1,320 for propane, or $640 for purchasing cordwood, or $1,000 for buying wood pellets. An online comparison calculator is available here: http://goo.gl/lhNmqC.

Space Heating Energy Consumption

An important step in evaluating the economic impact of a wood-fired heating system is the current space heating demand. The following steps will help you with this process (An online calculator is available as well: http://goo.gl/9PU0Q0.)

1. Obtain a 12-month fuel usage history. This information will come from different sources depending on the existing heating system. For example, if the home is currently heated with a propane-based forced air heating system, the information will be available from the propane supplier. Conversely, contact the electrical utility if the home is currently heated with electric baseboard.

My Heat Consumption

Month	Energy units	Cost ($)	$/unit of fuel	"Base Load" Units	Space Heating Units (Approx)	Cost for Space Heating
Example	96 therms	$80.02	$80.02/96=$0.83	8	96-8=88	88*$0.83=$73.04
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						
Total						

**The cost of fuel (per unit of fuel) is generally expressed as: $/gallon for heating oil, $/therm (or ccf) for natural gas, $/kWh for electricity, $/gallon for propane, $/ton for coal.*

Some utilities provide this history online or in monthly statements. The utility should be able to provide estimates based on energy usage for similar homes in the area if new construction is planned. Enter the amount used per month (this may require some division if the home is not billed monthly) in the table above.

2. Find the cost per energy unit. Use the table above to calculate the amount of energy used and the average cost per energy unit for the 12-month period.

3. Estimate the amount of the fuel used for space heating. Often, homes use one fuel for multiple purposes. For example, a home heated with propane may use the fuel in a cooking range, for domestic hot water heating, and for hot water-base board heating. To determine your space heating energy consumption, you need to approximate what percent of your total fuel is dedicated to space heating.

Things to consider:

a. If your home is all-electric, i.e. space heating is provided with electricity, assume that on average about 50% of the energy consumed in a Montana or Wyoming home annually is for space heating. So about half of your annual bill would be the demand and cost allocated to space heating.

b. Because most people don't meter their space heating separately from other end uses, a more involved calculation is necessary for a more accurate estimate. Assuming natural gas is used for heating, find a month (or the average of two) with the lowest natural gas consumption on the utility bill. This should be a summer month, when no or very little energy is required for space heating, and establishes a "base load" from water heating, cooking, etc. After subtracting this amount from the natural gas consumption of any other month the balance should provide a fairly good estimate of the amount consumed for space heating.

c. A general rule of thumb for annual consumption could be to assume 20% of natural gas consumption for domestic hot water heating.

Multiply both the total usage by month and the cost per month by the percentage used for space heating (see the example at left).

Once you understand your space heating costs and have discussed realistic estimates for the percentage of space heating demand you can offset with wood with a qualified installer, you can begin to assess both the total costs of the system and some simple return on investment calculations.

Incentives

A federal biomass heating tax incentive is available, which provides a tax credit up to $300 for the purchase of a biomass burning appliance, including pellet stoves, with a thermal efficiency rating of at least 75%. The Residential Energy Efficiency Tax Credit is for purchases/installations made in 2012, and 2013 (http://goo.gl/1x1s).

The State of Montana currently offers state incentives:

- Residential Alternative Energy System Tax Credit (personal tax credit), including for low-emission wood stoves, and biomass. Maximum Incentive is $500 per individual taxpayer or up to $1,000 per household.
- Renewable Energy Systems Exemption (property tax incentive), including low-emission wood or biomass combustion systems. May be claimed for 10 years after installation of the property; up to $20,000 (single-family residential)/$100,000 (multi-family residential dwellings or non-residential structures.)
- Alternative Energy Revolving Loan Program (state loan program). Maximum Incentive: $40,000, up to 10 years; 3.25% interest rate (for 2014). (Note: interest rate subject to change.)

The State of Wyoming does not offer any incentives for the use of wood for residential or commercial heating systems.

More and current information at DSIRE™ - http://dsireusa.org/

E³A: Installation and Maintenance

STEP 6

Steps in the Wood Heat Series

E3A-WH.6
Printed April 2014

Proper installation of a wood-fired heating system is necessary for clean and efficient operation and for safety. Improperly installed wood burners and chimneys are a major cause of house fires. Most states have statewide fire code standards for stove installation, usually overseen by local building code officials. **Always follow manufacturer's instructions as well as state and local building codes**. Pay particular attention to clearance from combustible surfaces. It is advisable to have professional help in choosing and installing a wood-fired heating system; however, the following information is provided as a general guide. This information is not exhaustive. Check your owner's manual and local building codes for detailed information. When in doubt, seek out a professional wood stove installer.

Location

Your stove should be located in a frequently used, central area, such as the living room or family room. When you have decided on a location, inspect the structural support under the floor on which the stove will be placed to make sure it is adequate. The most efficient heating place for a stove is in the center of the room, where it can radiate heat in all directions, however you should also consider the use of the room. The least efficient place to put a stove is in a closet or alcove, so consider where you can install the unit so it will be safe (both in distance from combustible surfaces as well as out of the way of the homes flow or traffic movement).

Installation requires proper clearances between stove system surfaces and their surroundings to keep your home safe from fire. Remember: heat transfer from the walls of the stovepipe and chimney, as well as from the stove itself, must be considered.

Clearances from combustible materials

A noncombustible material is defined as one that will not ignite or burn when subjected to flame or intense heat for extended periods of time. Steel, iron, brick, tile, concrete, slate, and glass are noncombustible. All walls containing wood framing are combustible - including plaster and sheetrock walls on wood lath or on wood studs. Nearly every wall and ceiling in residential buildings contains wood. Constant exposure to heat lowers the temperature at which a combustible material will begin to burn. A joist or rafter too close to the chimney walls, or a wall stud too close to the stove and its stovepipe, will overheat and ignite over time. Therefore, it is essential that the stove be installed with adequate clearance from combustible materials. If you are unsure about the construction of your home, assume that the wall or ceiling is combustible and maintain proper clearance.

A floor is considered noncombustible if it is concrete, slab-on-grade design, or solid concrete with steel or concrete—but not wood—supports. An existing masonry hearth extension is noncombustible if no wood forms have been left in place below it, and if stove placement allows at least 18 inches of hearth extension in front of the loading door. All wood floors, carpets and synthetic materials are considered combustible and must be protected in an approved manner. Other combustible materials include furniture, draperies, books and clothing.

All stoves and stovepipes require a minimum clearance to unprotected combustibles on top and on all sides of the wood stove. Clearances are specified by building codes to prevent overheating of combustible materials by keeping them at a safe distance from the stove and its components. Required clearances for stoves and stove parts from all combustible materials like walls and furniture can be found on the certification label for safety test standards or in the manufacturer's installation instructions. If performance is unknown such as on uncertified stoves, minimum required clearances to combustible materials are very large: 48 inches for radiant stoves and 36 inches for stoves surrounded by jackets behind which convection air can flow. If you install a stove for which there are no instructions, you should observe state building codes. The clearances listed in this guide may also be useful.

Manufacturers of EPA-certified stoves are required to specify minimum clearances. These clearances vary, depending on the construction of the stove. If there is no label, the stove is not EPA-certified. Some insurance companies will only accept EPA-certified appliances. Also, be aware that failure to properly install your stove may nullify your insurance policy in the event of a house fire.

No clearance is needed for stoves or stovepipes to noncombustible walls (i.e., concrete walls or dirt floors). It is a good practice, however, to allow six inches or more for good air circulation and heat dissipation.

Clearances for Wood Stoves and Stovepipes

State and local building codes and clearances listed in this section should be observed when manufacturer's installation instructions are not available. When manufacturer's instructions are available, compare the recommended clearances with state and local building codes and those listed here. Always adhere to the building codes and manufacturer's specifications as a minimum; using a larger clearance will provide a margin of safety, but never go smaller than what they recommend.

Unprotected floors, walls and ceilings.

All stoves require a minimum 36-inch clearance to unprotected combustibles above and on all sides of the stove. A single wall stovepipe must have a clearance to combustible walls and ceilings, measured at right angles to the pipe of at least 18 inches. No clearance is needed to noncombustible walls (i.e., concrete). It is good practice, however, to allow six inches or more for good air circulation and dissipation of heat.

The only base on which a stove can be installed without special protection is a noncombustible floor or properly built hearth extension. Such a base should extend at least 18 inches on all sides of the stove.

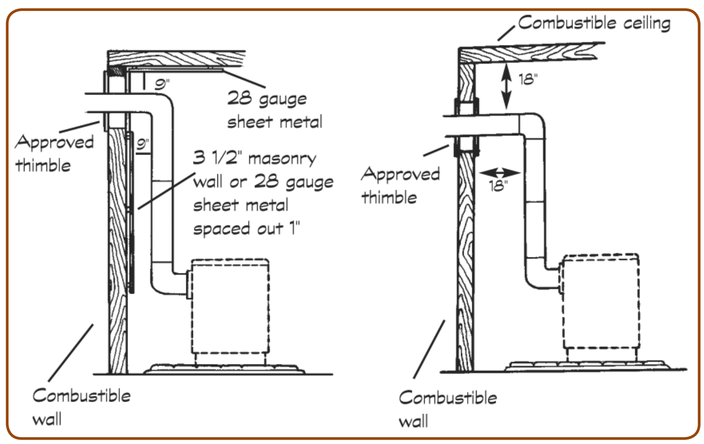
Protected walls and ceilings.

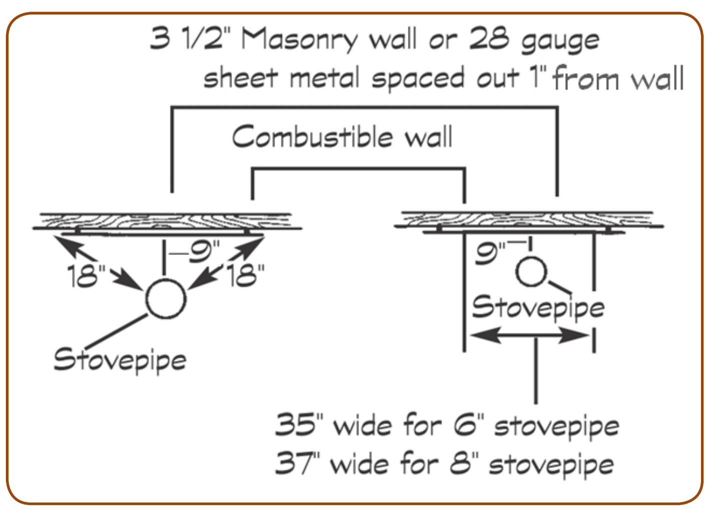
A wood stove and stovepipe may be placed closer than 18 inches to a combustible material if the material is protected in an approved manner with either a home-built or prefabricated clearance-reduction system.

The two most common types of home-built clearance-reduction systems use 24-gauge sheet metal (galvanized steel, aluminum, or copper) or 3-1/2-inch-thick (4-inch nominal) masonry wall. Either of these materials must be spaced out one inch from the combustible surface; that is, they must be anchored to the combustible surface so that there is an air space between the sheet metal or masonry and the combustible material of at least one inch. With sheet metal, noncombustible spacers are used to maintain the one-inch air space. With a masonry wall, metal wall ties and furring strips, if needed, are used to anchor the brick to the wall.

Do not place the spacers or wall ties directly behind the stove or stovepipe. The one-inch air space must be maintained around the entire perimeter of the clearance-reduction system so that air flows freely and removes heat. This prevents the combustible surface from catching fire.

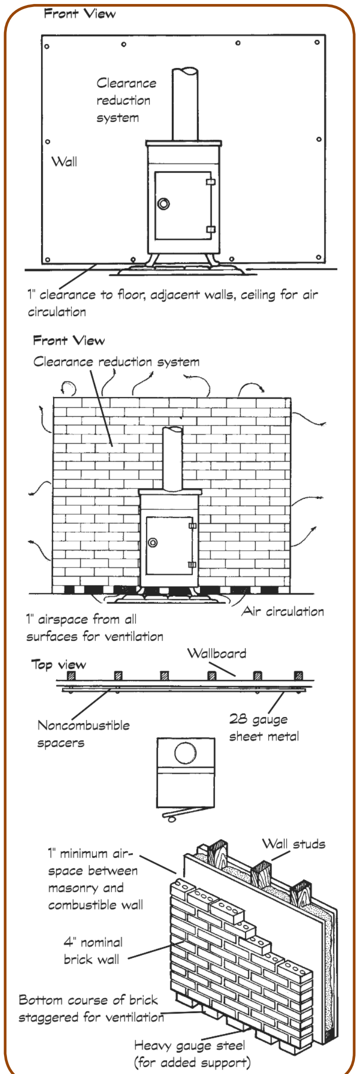
Sheet metal or masonry attached to the wall without this air space offers no protection and cannot be considered a clearance-reduction system.



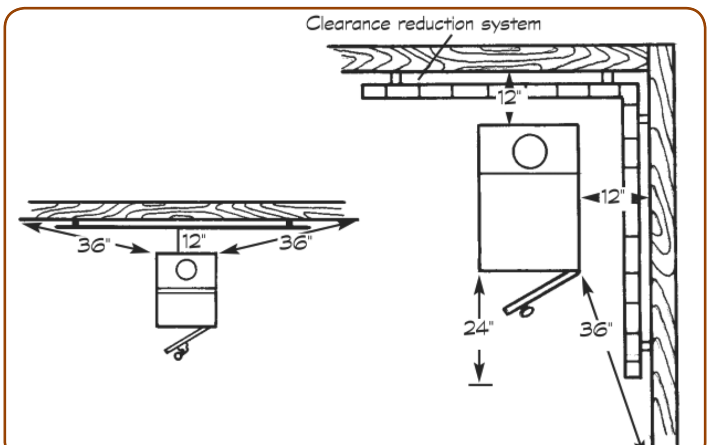


Protective or clearance-reduction systems

A clearance-reduction system provides a ventilated airspace between a heat source and combustible material, spaced out one inch from the combustible surface. Installing a clearance-reduction system will reduce heat transferred to the combustible surface, allowing specific clearances to be lowered. A variety of prefabricated clearance-reduction systems are available through wood stove and fireplace dealers. Always look for the safety listing and make sure the system is designed to be used with a wood stove. The manufacturers of these tested and listed accessories provide specific installation instructions that must be followed.



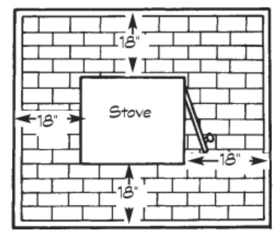
The clearance-reduction system must be centered behind or above the stove and stovepipe to protect the wall or ceiling, respectively. The system should extend at least 36 inches past the stove in height and width, measured diagonally. If the stove is placed farther from the wall than the minimum distance required, the width and height of the clearance system can be determined by measuring from the side and top edge of the stove to the unprotected wall. This distance should be no less than 36 inches. The larger the distance between the stove or stovepipe and the wall, the smaller the clearance-reduction system needs to be.

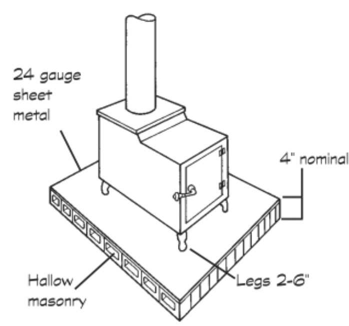


Some manufacturers may specify greater clearances. For a complete listing of clearances using clearance-reduction systems, contact your local fire marshal's office.

Floor protection

All combustible floors must be protected. The only base on which a stove can be installed without special protection is a noncombustible floor or properly built hearth extension. Manufacturers of listed stoves usually specify the type of material required for floor protection. If the manufacturer does not specify a material, you may purchase one or more of the safety-tested and listed prefabricated stove boards on the market.





Floor protection should extend at least 18 inches in front of the loading door to prevent damage to the floor from sparks, embers, ash or radiant heat. It should also extend 18 inches or more on the remaining sides of listed stoves, unless the manufacturer specifies a greater amount. An unlisted stove requires at least 18 inches of floor protection on all sides, including the loading and ash doors.

If more than one safety-listed prefabricated stove board is needed to meet the clearance requirements, the junction between the stove boards should be made using either a safety tested and listed stove board adapter or a strip of 24-gauge sheet metal four to six inches wide.

The type of floor protection recommended depends on stove leg length. Stoves with legs less than two inches in height must rest only on floor protection as specified by the manufacturer, safety tested and listed prefabricated stove boards, or a noncombustible floor.

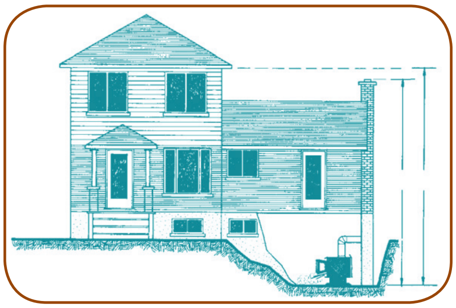
If your stove has legs two inches or greater in height, you are also allowed to use a combination of sheet metal and masonry. The arrangement of sheet metal and masonry for floor protection depends upon the length of the stove legs:

- Stoves with legs two inches to six inches: Floor protection can consist of four-inch (nominal) hollow masonry laid to provide air circulation through the layer and covered with 24-gauge sheet metal. Another layer of masonry may be laid over the sheet metal for aesthetic appeal.

- Stoves with legs higher than six inches: Floor protection can consist of closely spaced masonry units of brick, concrete or stone that provide a thickness of not less than two inches. Such masonry must be covered by or placed over 24-gauge sheet metal.

If you use a combination of sheet metal and masonry for floor protection, be sure that each stove leg has a firm, solid footing.

Chimneys and stovepipes.



The Stack Effect. Source: Residential Heating with Wood. Canada Mortgage and Housing Corporation (CMHC)[1]

The chimney is the engine that drives the wood-fired heating system. The chimney works with the stove or fireplace in a feedback loop. Heat in the chimney creates draft, which pulls in more combustion air, which makes the fire burn hotter, which delivers more heat to the chimney, which creates more draft, and so on. An insulated chimney creates more draft with less heat. Chimneys used with wood stoves must meet "all fuel" standards, also called "Class A."

Chimneys should adhere to the following design guidelines as much as possible:

a) Inside the warm building environment (the conditioned/ heated space), rather than on an outside wall

b) Taller than the building

c) Penetrate the building envelope at or near its highest point

d) Straight up, no elbows or offsets

e) Insulation around the flue liner

f) Flue sized to match stove

Chimney height is critical to creating proper draft and meeting fire codes. The chimney should extend at least three feet above the point where it exits the roof, and should be a minimum of two feet higher than any part of the roof within ten feet. (See "The 3-2-10 Rule", below.)

Stack effect, or the "cold hearth syndrome" - At standby with no fire in the stove, a house that is taller than the chimney can act like a better chimney than the chimney itself. This so-called stack effect is created by (rising) warm air in the house creating a slight negative pressure down where the stove is, and because the chimney is shorter than the house, it cannot compete. Hence, the flow direction in the chimney is reversed, flowing backwards and pulling cold air, and potentially exhaust, into the house.

The 3-2-10 Rule

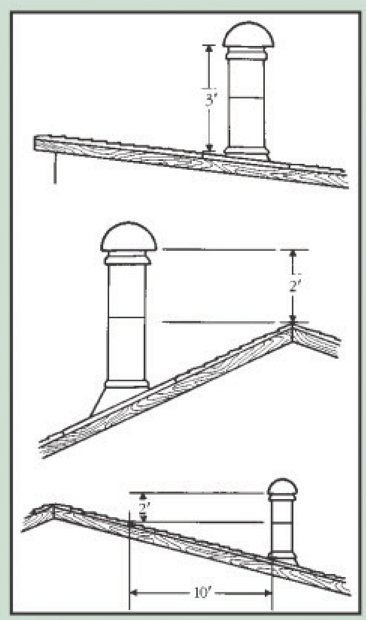
Chimney height is critical to creating proper draft. The chimney must extend at least three feet up from the roof and be at least two feet higher than any part of the roof within ten feet, measured horizontally. Measurements are made from the high side of the roof to the top of the chimney wall.

If your chimney is 10 feet or more from the roof ridge, you may use the chart below directly. If the ridge is closer than ten

Table 1

Minimum Chimney Heights

Roof slope*	Height above the roof ridge 10 feet or more from chimney
Flat	3'
1/12	3'
2/12	3'8"
3/12	4'6"
4/12	5'4"
5/12	6"2"
6/12	7'
7/12	7'10"
8/12	8'8"
10/12	10'4"
12/12	12'



** Roof slopes are given in feet of rise per 12 feet of run. A 6/12 slope rises 6 feet per 12 feet of horizontal run.*

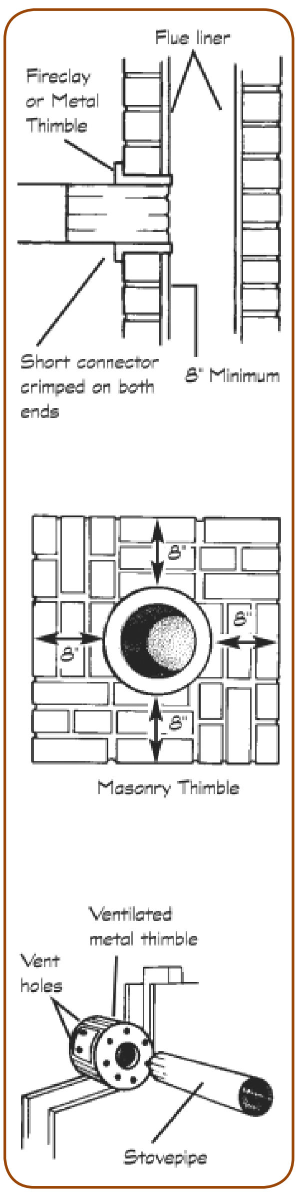
[1] Source: Canada Mortgage and Housing Corporation (CMHC). A Guide to Residential Wood Heating , 2008 (About your House: Combustion Gases in Your Home, 2006; About your House: Efficient and Convenient Wood Heating, 2009). All rights reserved. Reproduced with the consent of CMHC. All other uses and reproductions of this material are expressly prohibited.

feet, calculate the proper height by using the numbers from the chart above in the following formula: (roof slope x distance to ridge) + 2 feet = required height above the roof.

For example, a chimney on a 5/12-slope roof located 6 feet from the ridge requires: (5/12 x 6 ft.) + 2 feet = 4 feet, 6 inches above roof.

The **chimney connector** or vent connector is commonly known as the stovepipe. It connects the stove to the chimney. A stovepipe may have a single or double metal wall-construction. Double wall offers better protection and many home insurers require this feature. It may not pass through a wall, ceiling, attic, closet, or any concealed area.

Studies show that most house fires related to wood-fired heaters often originate around the chimney or stovepipe. According to the U.S. Consumer Product Safety Commission, house fires involving chimneys are caused primarily by creosote buildup in the chimney (creosote is soot and tar produced as a by-product of wood burning), metal chimneys too close to combustibles, chimney failure, improper construction or deterioration of a masonry chimney, and improper installation of a chimney connector (stovepipe). Before building or installing a chimney and stovepipe, it is very important to contact the fire marshal's office and the local building code officials for information on making your system safe (in many areas, the installation will have to be inspected by the local building codes official).



For safety reasons, the stovepipe should be as short as possible, but installations with five feet or so of pipe are acceptable. Keep in mind that the most trouble-free system will have few, if any, horizontal pipe sections and elbows. A vertical stovepipe gives the best possible draft and allows creosote and soot to fall back into the stove to be burned. Long runs of stovepipe and elbows should be avoided because they inevitably fill up with soot, ash, and creosote.

Thimbles

Use a metal or fire clay thimble when passing a stovepipe through noncombustible walls. The thimble should be permanently cemented into the masonry chimney and extend through the chimney wall to the inner face or liner, but not beyond. Push the short section of stovepipe, crimped on both ends, into the thimble and secure it with high-temperature sealant. The stovepipe should extend as far as possible into the thimble, but should not stick out into the chimney.

If you must vent through a combustible interior or exterior wall, contact the fire marshal for instructions. A stovepipe may never pass through a ceiling, closet, or concealed area. For these situations a "Class A" chimney is required. Once the stovepipe connects to the chimney, it must remain a chimney from that point on. No further use of stovepipe is allowed.

Masonry or metal chimney

Whether to have a metal or masonry chimney depends on a number of factors. Both types have advantages and disadvantages.

Metal chimneys are often less expensive than masonry chimneys and are more adaptable to installation in existing houses. (Some insurance companies, however, will not approve coverage for homes with a metal chimney; be sure to check with your insurance company before installing a metal chimney.) Most masonry chimneys require the work of an experienced mason and are usually built at the same time as the house.

Masonry chimneys require a cleanout opening, which provides a convenient way to remove creosote after a cleaning. The opening should be more than two feet below the stovepipe entry port, should be made of ferrous metal frame, and must have a door designed to remain airtight when the stove is in use.

A chimney cap is often added to keep out rain. On masonry chimneys, a flat plate of steel or concrete is most often used, but more stylish ceramic and metal caps are available. Caps for safety-tested and listed manufactured chimneys are also available.

Masonry chimneys are very durable, and some homeowners consider them more attractive than prefabricated chimneys. In addition, massive interior masonry chimneys will store heat longer and continue to release this heat to the room long after the wood fire has subsided.

Masonry chimneys also have disadvantages. They are expensive to build and more difficult to inspect and maintain than prefabricated chimneys. Masonry chimneys that are built on exterior walls reduce heating efficiency. This exposure to cold outdoor temperatures leads to greater heat loss and higher accumulations of creosote deposits.

Whether you have a masonry chimney built or plan to use an existing one, safety should be your prime consideration. A masonry chimney is a very heavy structure that must be able to withstand many years of use, including occasional chimney fires in which temperatures may reach 2,700°F.

Safety do's and don'ts when connecting a wood stove to a masonry chimney:

- Make sure the stove will have enough air for combustion and proper draft for that size chimney.
- Check the general condition of an existing chimney. Look for loose bricks and cracks in the mortar that might allow creosote to leak out or sparks to escape and ignite creosote or dry structural wood. Have a competent mason do any needed repairs or add a chimney liner.
- Many older homes have chimneys that are in good structural shape but do not meet "all fuel" or "Class A" requirements. A typical example is a chimney constructed of four-inch brick without a fire clay liner. These chimneys can be made safe by lining them with safety-listed liners.
- Each wood-burning appliance must have its own flue (a fireplace is considered an appliance). If you have more than one fireplace, check the chimney to make sure that a flue exists for each appliance.
- Frequently in older homes, an existing masonry chimney may have served more than one appliance in various rooms. It is critical to locate and seal these unused entry ports or *breachings*. Unused breachings are often covered with a thin metal "pie plate" cover. They may be hidden by paneling or plaster, especially if the house has been remodeled. Unused breachings should be sealed using masonry and fire clay mortar to make the former entry port as sound as the rest of the chimney.

Chimney inspection and cleaning

All chimneys require regular inspection for deterioration and creosote buildup. Even a correctly built chimney can settle and require repair within time – a poorly built chimney is dangerous from the start. The chimney should be inspected and cleaned at least once a year, and as often as biweekly if you use your wood stove daily. Also, disassemble the stovepipe and inspect it.

Creosote should never be allowed to deposit more than one-quarter-inch thick on the chimney or stovepipe. Inspect the flue at both the stove end and chimney top. Remember that cooler surfaces will have the thickest creosote deposits (these are usually near the top).

You can have a professional clean your chimney or you may choose to clean it yourself. If you do it yourself, wear a protective mask and goggles and gloves and use a quality steel-bristle brush. You'll also need to clean the inside of the stove and stovepipe. If you suspect leaks or cracks in your stove system, call in a professional to perform a leak test. If any leaks are found, have them repaired immediately. If a chimney passes through an attic area it is essential this is inspected every year for cracks.

Combustion air

Depending on the state you live in, state and/or local building codes may require an outdoor air inlet to ensure adequate air for combustion. The size, design and location of the inlet required depend on a number of variables, such as type and height of the chimney and heating size of the stove. Check with your building code officials. Without an outdoor air supply, your stove will take combustion air from the room, creating the potential for dangerous back drafting of noxious gases and smoke into the house. With inadequate combustion air, your central furnace or water heater can also backdraft toxic gases, even if the fireplace or stove appears to work properly.

Some wood stoves draw outdoor air directly into the stove, ensuring an adequate combustion air supply and reducing unwanted infiltration. For a new home built to meet energy codes, an air inlet is absolutely necessary. Without proper design and consideration combustion air inlets can become problematic as well. For example if the intake happens to be on the downwind side of the house during severe weather there is a potential that air can get sucked out through it resulting in back drafting..

Notes

Notes

E3A: Agricultural Wood-Burning Applications

STEP 7

Steps in the Wood Heat Series

E3A-WH.7
Printed April 2014

Many common stove types and styles for the home are available in scaled-up versions for farm, shop and ranch applications. With increased size efficiency improvements are possible, both in terms of operation and utilization of the energy stored in the wood. In addition to larger stoves, agricultural and commercial applications may be better able to take advantage of hydronic heaters, which utilize wood to heat water.

Agricultural and commercial applications that demand both space heat and domestic hot water in close proximity can more readily use large amounts of water to store and transport heat. They can take advantage of the fact that wood fires burn most efficiently and cleanly at higher temperatures, and store heat that is not immediately used (excess heat) in storage tanks.

The most commonly available form of hydronic systems today are outdoor wood boilers that burn cordwood. The best use of outdoor boiler technology is for "mini district heating," where multiple buildings are heated from a centrally located boiler. An example could be a farming operation where there is a need to heat outbuildings or machine shops near the house. Hydronic systems use water or antifreeze to transport heat from the wood boiler to the point of use. In the house, the heat typically circulates around the house as baseboard hot water or radiant floor heat. The boiler heat can also feed into a heat exchanger that blows air through fins for a forced-air system, which is more common in the farm buildings.

Outdoor wood boilers have gained a bad reputation for inefficiency and creating air pollution, particularly during start-up. While most of these problems are inherent in their design (primarily due to the use of a water-jacket around the burn chamber, which is good for heat transfer, but keeps the temperature too low for complete and efficient combustion), new advanced technology boilers promise some relief. Other developments include a cordwood boiler with a hopper that automatically loads the firewood, http://goo.gl/3xYzL.

EPA's Hydronic Heater program Phase 2 units have a white tag and are about 90 percent cleaner than unqualified units. EPA's Phase 1 models are no longer considered "qualified" under the program. Wood-burning appliances that are "qualified" under the EPA's Voluntary Hydronic Heater and Fireplace Program are NOT "certified" per EPA's New Source Performance Standard for New Residential Wood Heaters.

Other systems applicable to agricultural operations include hog fuel/wood chip as well as pellet boilers. The former are more commonly found in commercial and industrial-scale applications, like sawmills and district heating plants, but they are also used in school and hospital settings.

While smaller installations of woodchip boilers are possible as well, pellets might be a more suitable option. The physical characteristics of wood pellets, like size, shape and density, resemble those of grains more than any other fuel source, which makes their handling very similar as well. They can be transported in bulk on trucks and trailers, augured and blown, as well as delivered and stored in grain bin-like containers. The most compact units come as a turn-key kit readily assembled in a container, complete with controls, combustion unit, air handlers, pumps and conveyers. On-site set-up is reduced to connecting the pellet storage bin, power and waterlines.

If considering heating multiple, clustered buildings, like on a farm, ranch, small community, or resort, consult a knowledgeable installer. Wood may provide a renewable and relatively price stable heating fuel that integrates well with your current operations and utilizes locally available labor and resources.

Notes