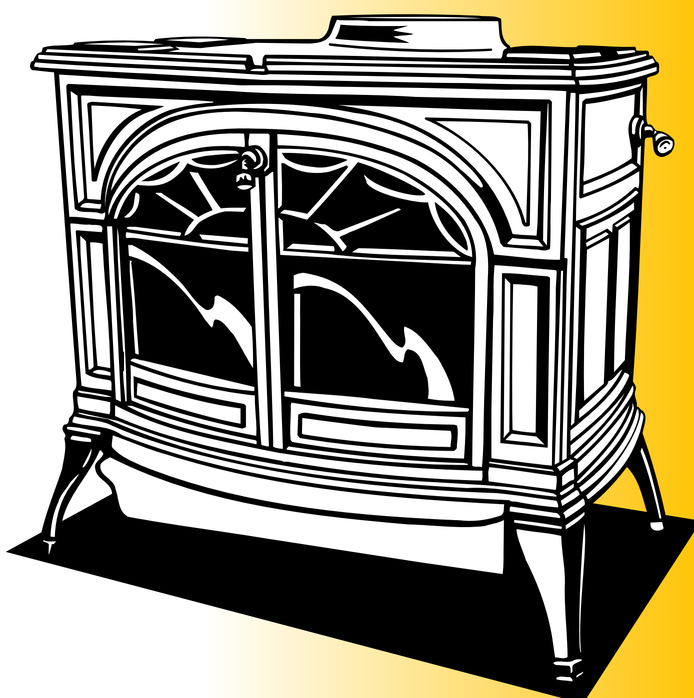
Solid-Fuel Heating Appliances

June 2003

Table of Contents



Engineering Extension

Introduction

Heating with solid fuels was the norm for thousands of years. Wood and coal were common fuels but in areas devoid of these resources, peat, agricultural residue, and dried animal dung were also used. The advent of modern, safe, and automatic gas- or liquid-fueled heating appliances has replaced most solid-fuel heating appliances. Tending the fire in a solid-fuel heating appliance requires at a minimum, adding fuel and removing ash or clinker. We have grown accustomed to simply adjusting the thermostat if we are uncomfortable

> "… old wood burns brightest."
> *John Webster*

In spite of the inconvenience, heating with wood or other solid fuels has continued. Burning wood for fuel can be a cost-effective way to heat. Hardwood at $100 per cord, burned in a modern wood stove, is roughly equivalent to natural gas at $4.25 per MCF or propane at $.30 per gallon. During times of increasing fuels prices, use of wood undergoes a renaissance. In 1960, the Energy Information Administration estimated Kansans burned 157,000 cords of wood. That amount steadily declined until 1974, the time of the initial energy crisis. By the 1980s, wood consumption was over half a million cords in Kansas and stayed at that level until nearly 1990. Wood use again declined and in 1999, about 200,000 cords were consumed. While cord wood use has declined, other solid fuels are gaining popularity. Corn, pellets made from wood, and coal use as heating fuels has grown in recent years.

> Wood burns in several phases.
>
> First, the wood must reach ignition temperature. Usually some moisture will be driven off at this stage.
>
> Wood begins to break down chemically at about 500°F. Volatile compounds are released and burn at 1,100°F. This high temperature must be maintained or some of the volatile gasses will not burn.
>
> Finally, the remaining charcoal burns slowly at temperatures exceeding 1,100°F.
>
> Emissions are higher from smoldering fires, when flames impinge on cool surfaces, and when unseasoned high-moisture wood is burned.

The decision to heat with wood is not just an economic one. Cutting wood for heat provides the individual a sense of control and self reliance. And when the power goes out, many who heat with a sold fuel will continue to have warm houses.

Most solid fuels, with the exception of coal, are considered renewable fuels. Using them for heat rather than fossil fuels reduces depletion of finite resources. Using renewable fuels also reduces release of carbon dioxide, which has been linked to global warming. However, using inefficient solid-fuel heating equipment releases large quantities of smoke and unburned particles into the air and reduces air quality. In some areas of the country, air-quality problems limit the resale of inefficient and polluting stoves, prohibit use of certain types of wood-burning appliances during times of poor air quality, or otherwise restrict use of certain appliances. Check with local officials before purchasing or installing any solid-fuel device.

Heating with wood

Wood is the most popular of the solid fuels for home heating. Wood is burned in conventional fireplaces, improved fireplaces including inserts, wood stoves, masonry heaters, and central furnaces and boilers. The relative efficiency and emission characteristics of each of these appliances are detailed in Table 1, Efficiency and particulate emission[i]. These values represent average values; actual ratings will vary.

Table 1. Efficiency and particulate emission.

Appliance	Efficiency	Emission (Pounds per MBtu Heat Delivered)
Stoves		
Conventional (Pre EPA rule)	54	3.89
Non-catalytic EPA certified	68	1.14
Catalytic EPA certified	72	1.02
Pellet	78	0.31
Masonry heater	58	0.59
Fireplaces		
Conventional open radiant	7	19.9
Double-shell convection, natural draft	13	10.7
Convection tubes, C-shaped with glass door	15	9.3
Double-shell convection with blower and glass doors	32	4.4
Non-catalytic insert, EPA certified	66	1.15
Catalytic insert, EPA certified	70	1.04
Pellet stove insert	76	0.30
Gas-fired insert	75	Negligible
Gas-fired fireplace	50	Negligible
Catalytic fireplace-like wood stoves, EPA certified	70	1.04
Central Boilers and Furnaces	50	Uncertain

Wood stoves

Wood stoves are some of the most popular and efficient solid-fuel home-heating appliances. Earlier wood stove technology increased the heating efficiency and burn-time of a wood charge by throttling the amount of combustion air allowed to the fire. While this extended the time between charges of wood and increased efficiency over open fireplaces, the slow-smoldering burning process emitted large amounts of carbon monoxide and particulate materials. Some areas of the country suffered significantly from the pollution from early "air-tight" wood stoves.

Improvements in stove technology during the 1980s have increased stove performance to around 70 percent, with emissions three to five times lower than early air-tight stoves. New wood stoves must meet federal emission standards before they can be sold. This helps assure they are both efficient and non-polluting. Both non-catalytic and catalytic wood stoves are available.

Non-catalytic stoves are most common. They have air controls and baffles to route combustible gasses released from the wood into high-temperature areas to assure complete combustion, high efficiency, and low emissions. Primary combustion air is preheated to promote complete burning. Metal baffles keep combustion gasses in the primary combustion zone as long as possible. Combustion of the charcoal portion of the fuel occurs in the primary combustion zone. Unburned combustible gases then enter a high-temperature secondary combustion zone where preheated secondary air is introduced to finish the combustion process.

Non-catalytic stoves often have small fire boxes which are usually insulated or have fire brick to maintain high temperatures, and air inlets that are adjustable but cannot close completely.

Catalytic stoves use a specially treated ceramic combustor, similar to the catalytic converter on your car, to assure complete combustion. Fires are built with the combustion gasses initially bypassing the catalyst. When temperatures reach 350-600^{o}F, the gasses are routed through the catalyst. Preheated combustion air is usually admitted near the catalyst to assure complete combustion. Proper operation is critical to assure low emissions and long catalyst life. Only untreated wood should be burned and temperatures above 1,600^{o}F must be avoided to prevent harming the catalyst. Catalytic stoves cost more and many require maintenance of the catalytic combustor.

Table 2. Price of delivered heat for typical EPA-certified wood stoves.

Price per Cord	$80	$100	$120	$140
Species	Price per Delivered Million Btu for Typical EPA-Certified Wood Stove			
Cottonwood	$7.23	$9.04	$10.85	$12.66
Elm, American	$5.71	$7.14	$8.57	$10.00
Hackberry	$5.39	$6.74	$8.09	$9.43
Honeylocust	$4.28	$5.35	$6.42	$7.49
Maple, Silver	$6.02	$7.52	$9.02	$10.53
Oak, Red	$4.65	$5.81	$6.97	$8.13
Osage Orange	$3.47	$4.34	$5.21	$6.08

Stoves can be equipped with glass fronts to allow for viewing the fire. Early glass-door systems did not stay clean. Newer designs employ an air curtain across the glass surface to keep the glass clean and soot free.

Fireplaces

Conventional, open-radiant fireplaces provide a wonderful ambiance but provide only a small amount of heat to the home. Industry experts agree open fireplaces may only deliver 10 percent of the heat in the wood to the home. Adding glass doors and outside combustion air will help, but site-built fireplaces are not efficient heating devices.

One source of the problem is the large amount of combustion air required for roaring fires. Conditioned air is drawn from the house and exhausted up the chimney by the strong draft created. In the cold of winter, open fireplaces may actually lose more heat up the flue than they deliver to the home. Adding glass doors will reduce air flow up the chimney and improve efficiency, but the efficiency improvement will be small.

Because an open fireplace may require 200-600 cubic feet per minute of air, it may be a serious problem if installed in tight, well-sealed housing. Spillage from the fireplace can occur, especially during start-up and as the fire dies out. Use of outside combustion air directly into the firebox of an open fireplace does not reduce spillage. However, use of glass doors in combination with outdoor air supply has been shown to mitigate spillage. Care is needed to prevent any hot gas or ash entry into the fresh air supply, because it is not usually designed for high temperatures.[ii]

Table 3. Price of delivered heat for typical open fireplaces.

Price per Cord	$80	$100	$120	$140
Species	Price per Delivered Million Btu for Typical Open Fireplace			
Cottonwood	$50.63	$63.29	$75.95	$88.61
Elm, American	$40.00	$50.00	$60.00	$70.00
Hackberry	$37.74	$47.17	$56.60	$66.04
Honeylocust	$29.96	$37.45	$44.94	$52.43
Maple, Silver	$42.11	$52.63	$63.16	$73.68
Oak, Red	$32.52	$40.65	$48.78	$56.91
Osage Orange	$24.32	$30.40	$36.47	$42.55

Factory-built fireplaces can generally provide higher efficiencies than open masonry fireplaces. They often have glass doors, heat exchangers, and blower-driven heat delivery systems to extract more heat from the fire and provide more uniform heat delivery to the home. Table 1 lists typical efficiencies and emission rates for several fireplace, fireplace insert, and wood stove configurations.

Fireplace inserts

To gain more heat from a fireplace, consider a fireplace insert rather than a site- or factory-built fireplace. Fireplace inserts are built to the same standards as wood stoves and are EPA certified for higher efficiency and low emissions. Inserts have tight-fitting doors that limit combustion air to the levels needed.

Table 4. Price of delivered heat for typical EPA-certified fireplace inserts.

Price per Cord	$80	$100	$120	$140
Species	Price per Delivered Million Btu for Typical EPA-Certified Fireplace Insert			
Cottonwood	$7.23	$9.04	$10.85	$12.66
Elm, American	$5.71	$7.14	$8.57	$10.00
Hackberry	$5.39	$6.74	$8.09	$9.43
Honeylocust	$4.28	$5.35	$6.42	$7.49
Maple, Silver	$6.02	$7.52	$9.02	$10.53
Oak, Red	$4.65	$5.81	$6.97	$8.13
Osage Orange	$3.47	$4.34	$5.21	$6.08

Some inserts set into an existing fireplace opening, while others protrude beyond the hearth. While those that are flush take less room than those that protrude, the latter expose the sides and maybe the back of the insert to the room for heat delivery. Many inserts are equipped with fans or blowers to circulate air and increase heat delivery. Fans can be manual or thermostatically controlled.

Early inserts were often installed without a ducted connection between the insert flue outlet and the chimney. This often created problems with creosote buildup between the insert and the chimney. The National Fire Protection Association and many building codes now require a flue-vent connection between the outlet of the appliance (insert) and the chimney.

Outside air may be required by local codes. If it is connected directly to the combustion chamber, they are effective in reducing air drawn from the home and reduce spillage from the fireplace.

Masonry heaters

Masonry heaters need to be distinguished from masonry fireplaces. The Masonry Heaters Association (MHA) of North America defines a masonry heater as "a site-built or site-assembled, solid-fueled heating device constructed mainly of masonry materials in which the heat from intermittent fires burned rapidly in its firebox is stored in its massive structure for slow release to the building. It has an interior construction consisting of a firebox and heat-exchange channels built from refractory components." A charge of wood is burned in a hot fire. In mild weather, a small firewood charge is burned. In colder weather, a larger charge is burned.

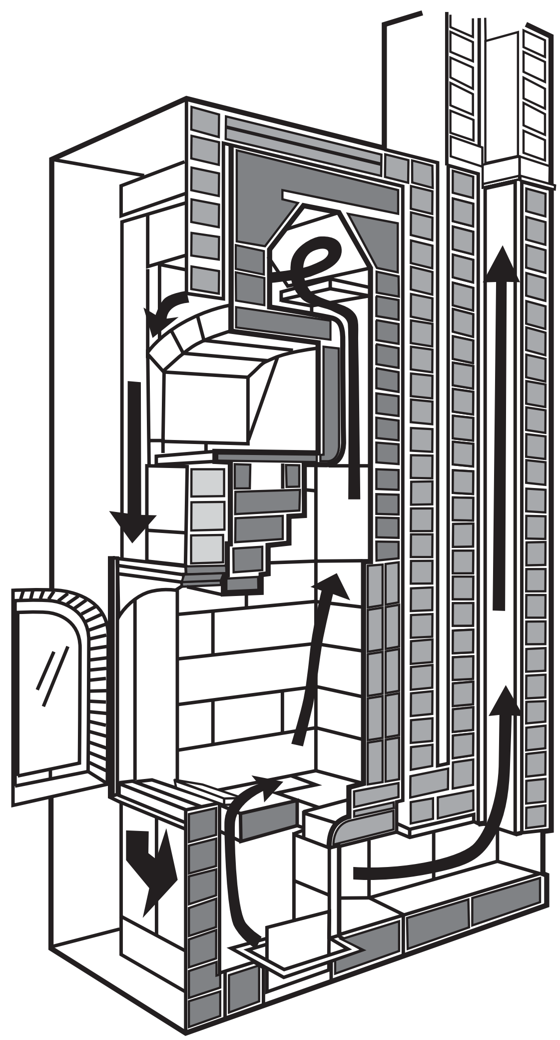


Figure 1. Hot gas flow in a masonry heater (courtesy Masonry Heater Association of North America).

Because most carbon monoxide and particulate emissions are created during the starting phase of a fire and the slow-smoldering phase at the end, this short-burning hot fire has low emissions. In fact, estimates for emissions from masonry heaters are about half of those for EPA-certified wood stoves. See Table 1 for estimated efficiencies and emissions.

Table 5. Price of delivered heat for typical masonry heaters.

Price per Cord	$80	$100	$120	$140
Species	Price per Delivered Million Btu for Typical Masonry Heater			
Cottonwood	$8.73	$10.91	$13.09	$15.28
Elm, American	$6.90	$8.62	$10.34	$12.07
Hackberry	$6.51	$8.13	$9.76	$11.39
Honeylocust	$5.17	$6.46	$7.75	$9.04
Maple, Silver	$7.26	$9.07	$10.89	$12.70
Oak, Red	$5.61	$7.01	$8.41	$9.81
Osage Orange	$4.19	$5.24	$6.29	$7.34

Masonry heaters can also be fitted with bake ovens and heat exchangers for providing domestic hot water. Because they are site-built and require special designs that go beyond those used for standard fireplaces and chimneys, seek out a designer, supplier, and mason familiar with the system. A good place to start is the MHA Web site, *mha-net.org/*.

Central wood fired heating systems

Approximately 80 percent of homes in America have some form of central-heating systems. These include predominately warm-air furnaces, steam or hot water boilers, or heat pumps. Central systems tend to provide even heat throughout the house, have high levels of automation, and in many cases support the addition of space cooling. Wood-fired boilers and furnaces are available that provide nearly all these benefits.

Wood-fired boilers

Residential-scale wood boilers are offered by several manufacturers. Wood-fired boilers can be installed inside but are commonly located outside, often 50 to 100 feet from the residence. Locating the boiler outdoors removes the fuel, ash, and possible air quality problems from the home. Boilers heat water that is pumped through underground pipes to the home or shop where it is used for either space heat or sometimes to heat domestic hot water. Space heat is provided either by a water-to-air heat-exchanger located in air ducts, by circulating hot water through conventional baseboard heaters, or through in-floor radiant heating systems. Because of the high capacity of some boilers, it may be possible to heat several buildings.

These units are not regulated by the Environmental Protection Agency, so there are no restrictions on efficiencies or emissions. There is considerable debate regarding actual efficiencies and emissions, and no standardized testing method has been adopted in the United States or Canada. Some preliminary testing done by EPA indicates average emissions are higher but in the same range as older wood stoves. Efficiencies of about 50 percent were also reported.[iii] Some wood-fired boilers use a wood gasification process that reduces emissions and improves overall efficiency. While not tested to EPA standards, manufacturers' claims indicate emissions below those set for EPA-certified wood stove.

Low efficiency and high emissions reported by some owners stem from several sources.[iv]

- Few boilers are refractory-lined. Flames impinging on low-temperature water-cooled surfaces quench the flame, causing smoke and creosote.
- Boilers are over-sized, especially in mild weather. Combustion air dampers or blowers restrict combustion air when the boiler reaches the desired temperature. A smoldering fire results. After the boiler cools and there is a call for heat, the dampers open or combustion fans start. Several minutes of very smoky operation result until the fire is fully re-established.
- Low quality, green, or wet wood is used. Poor quality fuel always results in higher levels of emissions.

Adding a large hot water storage tank (thermal storage) helps to reduce emissions allowing the boiler to operate at high load a larger portion of the time. Water in the boiler and water in the storage tank is all heated to the desired set point, keeping the boiler on high-fire for a long time. Heat is then drawn from storage for space or domestic water heating. Gasification, coupled with thermal storage, can greatly improve the performance.

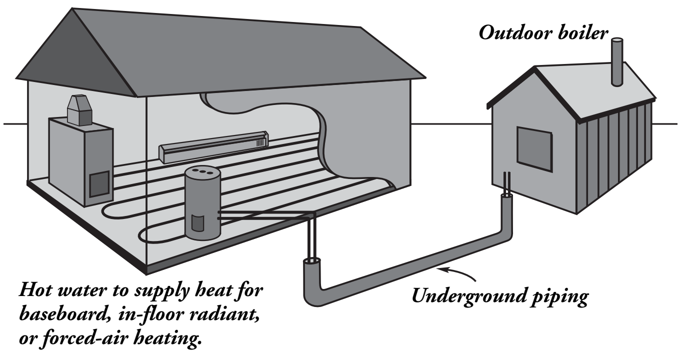


Figure 2. Wood-fired boiler heating option.

Multi-fuel boilers are also available that burn either wood or coal solid fuels, and either oil or natural gas. These offer flexibility and redundancy.

Wood-burning furnaces

Wood furnaces heat air directly. Ductwork is connected to the furnace. When the thermostat calls for heat, combustion air dampers or fans admit air to the combustion chamber, allowing the fire to rebuild, producing heat. Circulating fans are also started. When the home thermostat is satisfied, combustion air is restricted to the minimum needed to keep the fire burning. Some furnaces are designed to be dual-fuel combining wood, coal, and conventional fuels including gas, propane, or oil. Because of the dual-fuel nature of these devices, they are exempt from federal minimum efficiency standards applicable to most gas, fuel oil, and propane furnaces.

There are no standards for determining efficiency or emissions. As a result, claims made by manufacturers should be considered carefully, with significant effort made to find and discuss products with current users.

Some factory-built fireplaces have heat-exchangers and warm-air distribution systems that allow more uniform whole-house heating. These fireplaces generally do not have controls to limit the heat-release rate of the fireplace.

> "… that age appears to be best in four things—old wood best to burn, old wine to drink, old friends to trust, and old authors to read."
>
> *Francis Bacon, Apothegms. No. 97*

Wood

Heating with wood requires a supply of fuel, either purchased or gathered from private or public land. In many area of the Midwest, cordwood can be purchased at reasonable prices. For those with the industry and time, cutting their own wood greatly reduces the cost of heating. For those without their own wood lots, firewood is often available for cutting at state and federal lakes, military reservations, and other public lands. A permit may be required.

Wood species, preparation, storage, and moisture content all affect performance and emissions from wood-burning appliances. Wood that is less than 20 percent moisture, split to less than six inches across, and cut to the length required by the combustion chamber will be best. Burning green or wet wood will reduce available heat and increase smoke and other emissions. You will also notice smoke stains on glass doors, and the chimney will require more frequent cleaning because of creosote buildup.

Table 6 shows the heat content from a cord of several common species. All wood has about the same Btu content per pound, but some woods are denser than others. In the middle of the winter when you need more heat and longer burn times, use hard dense woods with higher Btu content. Use softer woods in the spring and fall when you need less heat. The softer woods grow faster and replenish quicker.

Wood is sold by the cord. A cord is a stack of wood that is four feet tall, four feet wide, and eight feet long. That is a total of 128 cubic feet. If you have your wood cut to 16-inch lengths, then there should be three stacks four feet tall and eight feet long. The quantity of wood that is in a "truck load" will vary greatly, depending on the size of the truck and the care in loading. Once delivered, stack the wood and determine the actual volume to determine if the seller is providing a fair value.

If you cut or purchase green wood, stack the wood to encourage drying. If possible, cut and split wood should be stacked with access to the sun and air for drying. The time required to dry wood to 20 percent moisture will depend on exposure, temperature, and wind. In general, wood split to not more than six inches across will dry in four or five months, provided it gets enough air and sun. Stack the wood on pallets or scrap poles to get it off the ground and reduce drying time. Pallets are often available for the asking at many local stores, but remember to ask.

Table 6. Heat content of several wood species in million Btus per cord.

Species	Million Btus per Cord
Ash, Green	20.0
Ash, White	24.2
Cottonwood	15.8
Elm, American	20.0
Elm, Red	21.6
Hackberry	21.2
Hickory, Shagbark	27.5
Honeylocust	26.7
Locust, Black	27.9
Maple, Silver	19.0
Maple, Other	25.5
Mulberry	25.8
Oak, Red	24.6
Oak, White	29.1
Osage Orange	32.9

A wood shed or other covered area is a real convenience during the winter heating season. The cover keeps the snow and rain off the wood so it stays dry and as clean as possible for entry to the home. If you live in areas where termite activity is likely, periodically inspect your wood pile and areas around wood storage for signs of termites. Plans for inexpensive wood sheds are available on-line at *www.woodheat.org/firewood/woodshed.htm.*

Wit is brushwood; judgment timber; the one gives the greatest flame, and the other yields the most durable heat; and both meeting make the best fire.

Wood appliance installation

Wood-burning appliances should be installed in accordance with the manufacturer's recommendations and in conformance with local building codes. In general, these guidelines include clearance from combustible materials; size and type of flue and chimney pipe; details of chimney penetration of walls, ceilings, or roofs; and exterior chimney details including height, spark arrestors, and chimney caps.

Clearance between solid-fuel appliances and combustible materials is often specified by the manufacturer. This includes clearance in front, behind, and above the appliance.

Where clearance information is not available from the manufacturer, there should be a minimum of 36 inches between the stove and combustible materials like wood paneling, sheet rock, or trim. This clearance can be reduced to 12 inches by installing a heat shield of non-combustible material spaced one inch from the wall and two inches off the floor. The shield must protect all combustible materials within 36 inches of the stove of pipe. Stove pipe must be three times its diameter from combustibles. Using double-wall stove pipe will allow reduced clearance, usually six inches to walls and eight to ceilings.

Provided the appliance has legs that elevate its base at least six inches, the stove can sit on solid masonry bricks not less than two inches in thickness and covered with 24-gauge or thicker sheet metal. The floor protection should extend 18 inches beyond the front and 12 inches from the side edges of the appliance.

You cannot pass the stove pipe through combustible materials like walls or ceilings. It is best to use a pre-fabricated, UL-approved thimble. You can also build a masonry insert into the combustible wall that provides 18 inches clearance to combustibles.

Because the chimney is an integral part of a masonry heater operation and heat delivery system, special flue paths are involved. Design and construction should only be attempted by qualified and experienced installers.

Conventional open masonry fireplaces can be vented into lined masonry chimneys or factory-built metal chimneys. Wood-burning appliances of any kind should not be vented into an unlined chimney. Have a qualified chimney sweep inspect existing flues

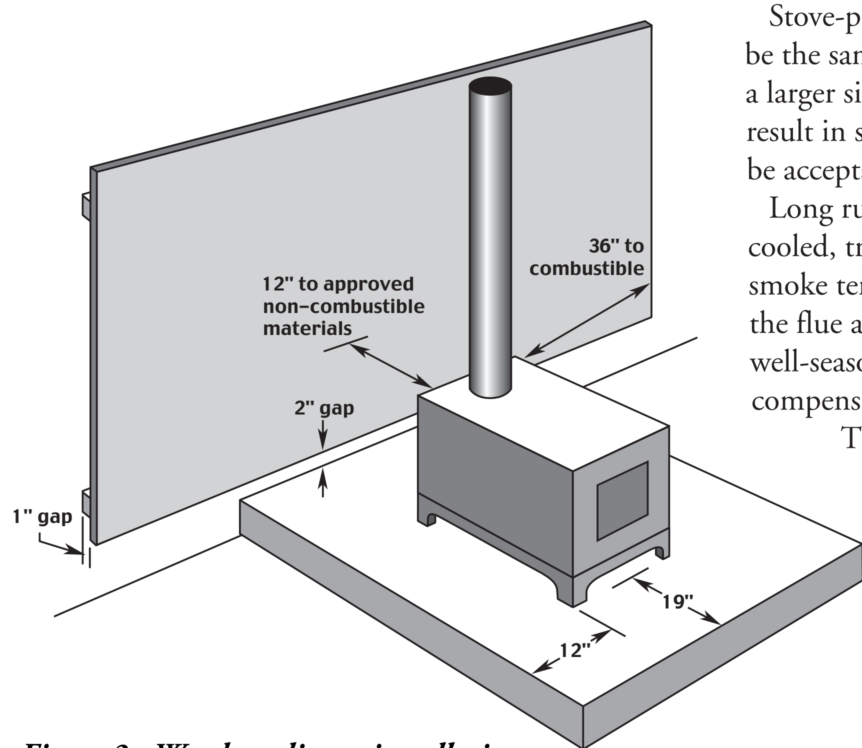


Figure 3. Wood appliance installation

to insure safety. If clay linings are chipped or broken, they can be lined using a stainless or cast-in-place masonry liner. These should be rated for the type of appliance being used. Stainless steel liners are most popular in the Midwest.

Pre-fabricated chimneys are commonly used for wood stoves and factory-built fireplaces. In general, use a Class A-rated chimney.

Chimney pipes are also described as either double- or triple-wall pipe. Double-wall chimney pipe is most common and has an inner pipe of stainless steel, insulation in the annular space, and an outer pipe typically of stainless steel. It can withstand high temperatures and provides good protection to combustibles. However, there is still a clearance requirement.

Triple-wall chimneys are less common today. There are two types of triple-wall chimney pipe. Air-cooled triple-wall chimneys draw air through the outer annular space, and then back up in inner annular space. While this provides a cool outer surface, it can over-cool the flue gasses, reducing draft and increasing creosote problems. This is generally not recommended for wood stoves. A second type of triple-wall is similar to double-wall in that it has insulation between the inner and second metal layers, but a third air-insulted wall encases all.

Stove-pipe and chimney-pipe size should generally be the same size as the collar on the appliance. Using a larger size will generally reduce draft and may result in smoke problems. Using a smaller size may be acceptable, but may not always work well.

Long runs of single-wall stove pipe or use of air-cooled, triple-wall chimney pipe may reduce the smoke temperature and increase creosote buildup in the flue and chimney. Burning hot, short fires with well-seasoned wood will help but may not be able to compensate for overcooling the flue products.

The chimney should extend two feet above any portion of the building within ten feet, but shall not be less than three feet above where the chimney passes through the roof. A chimney cap is also important to keep rain, insects, and animals out.

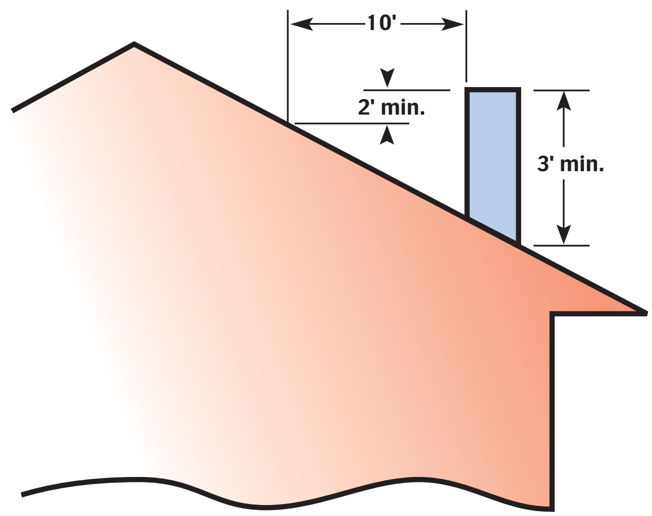


Figure 4. Chimney installation.

Pellet-burning appliances

Pellet stoves, boilers, and central furnaces are some of the cleanest and most efficient solid-fuel heating appliances and depending on the cost of pellets, can be cost-effective when compared with many other fuels. Pellet fuel consists of ground biomass materials commonly from plants and trees that have been compressed into pellets that are about 1/4-inch in diameter and 1 to 1-1/2 inches long. Some stoves are listed by the manufacturer to burn fuels other than pellets including corn, fruit pits, and nut shells. Locally available fuel may cost less than traditional pellets.

Features to consider when purchasing a pellet appliance include efficiency, hopper capacity, feed location, heat capacity, heat-rate and combustion-air adjustment, heat-exchanger cleaning methods, routine maintenance requirements, appearance, and startup characteristics.

Pellet appliances automate the fuel-delivery system so the owner only needs to add fuel about once a day on average. A hopper, ranging in size from about 40- to over 100-pound capacity, serves as the in-house fuel storage. Fuel is metered from the hopper to the combustion chamber, typically in response to the heating needs of the home. In many stoves, the amount of air delivered for combustion is automatically adjusted to meet combustion requirements.

In Kansas, a home built to current practices might need about 30 Btu per hour per square foot. A 1,500-square-foot home would need a stove with a capacity of 45,000 Btu per hour. An energy-efficient home in that same climate might only need about 21 Btu per hour per square foot, or a stove capacity of about 31,500 Btu per hour.

Pellets are fed to the stove, in response to a thermostat. If the room needs more heat, pellets are added to the stove and additional combustion air is admitted. Flue gasses are extracted from the stove and exhausted outside. Most stoves have a fan to circulate room air through a heat exchanger and out into the room. A few stoves rely on radiant and convective heat delivery. Pellet central furnaces have a large circulation fan delivering heat to the house through a duct system.

Fuel-feed systems generally either feed the pellets to the top of the stove or the bottom. Feeding pellets at the bottom forces ash and clinker (fused ash) out of the combustion area. This helps keep air openings clear and reduces the burn pot cleaning frequency. Top-feed stoves meter fuel at the top where they drop into the combustion zone. Top-feed stoves may have a minor advantage in efficiency since the pellets stay in the burn zone until exhausted, and the products of combustion move through the furnace more slowly giving off more heat.[v] Some top-feed stoves use movable grates or drop-through designs to keep the air inlets open and minimize maintenance. Many modern stoves will burn and handle the ash from a wide variety of fuels, but it is wise to verify those features if you plan to burn other than premium pellets.

The heating capacity required to heat your home will depend on size, level of insulation, and air-tightness of your home. Some manufacturers offer assistance in selecting the proper stove capacity and Web-based resources are also available. Manufacturers rate both total heat output and efficiency of the stove. Some provide both a minimum and maximum rating.

Table 7. Price of delivered heat for typical pellet-burning appliance.

Price per 40-Pound Bag	$2.50	$3.00	$3.50	$4.00
Price per Ton	$125	$150	$175	$200
	Price per Delivered Million Btu for Typical Pellet Appliance			
	$9.77	$11.73	$13.68	$15.63

Pellet stoves typically have a heat exchanger to improve heat delivery to the room. A fan blows air across one side of the heat exchanger and delivers warm air to the space. The inside of the heat exchanger exposed to the fire will require periodic cleaning. This may be as simple as moving an external rod back and forth or may be considerably more involved.

Ask the dealer to identify the location of all ash bins and demonstrate the procedure to remove ash from the stove and for cleaning. Some stoves require the stove be shut down, while others can be cleaned during operation.

The pellet-feed system, supply-air fan, and exhaust fan all require electricity for operation. Stoves equipped with backup power supply can continue to operate during periods of power failure. A 12-volt battery with an inverter can provide limited backup. Larger engine-driven standby power systems must be installed in a fashion acceptable to the local utility to prevent danger to utility workers.

Automatic startup offers quick, reliable stove starting. Stoves equipped with auto-start cycle the stove on and off based on the demand for heat. Manually started stoves throttle the fire to low when heat output is not needed and increase the firing rate when heat is needed.

Pellets and similar fuels

Pellets are commonly made from wood residue resulting from furniture, other wood-product manufacturing, or as a by-product of the lumber industry. They are made by extruding wood through a die, much like dog food is produced. Pellets range in fuel content from about 8,000 to 9,000 Btu per pound.

The Pellet Fuel Institute (PFI) identifies two grades of pellets—standard and premium. The only measurable difference in their standards is the amount of ash. Standard-grade pellets can produce up to three percent ash. Higher percentages of bark and agricultural residues used in producing standard pellets are the cause of higher ash levels. Standard pellets should only be used in stoves rated for standard pellets.

Premium pellets are limited to one percent ash. Ash content and the resulting fuel grade play a major role in determining the frequency of maintenance for the stove. High ash content will require more frequent removal of ash from the ash bin and possibly the venting system. However, ash-bin size, combustion technology, fuel-feed and grate design, and venting systems all play a role in the maintenance level and frequency.

There are a several differences among pellets that cannot be accounted for in the PFI grading system. Heat content can vary, as can the tendency to form clinker when burned. Clinker is clumped ash that is fused when the fuel burns. The trace content of some minerals in the raw materials can increase the tendency to form clinker. These tendencies can vary some within pellet suppliers, as well as among varying suppliers.

Pellets are typically sold in 40-pound bags for ease of handling. Prices will vary with quality of the pellet and distance from the wood resource and point of sale. Table 7 provides an estimate on the cost of delivering one million Btus of heat from typical pellet appliances. The cost of operating fans and augers is not included. European pellet manufacturers have developed bulk pellet-delivery systems that reduce cost. The Pellet Fuels Institute is conducting tests on bulk pellet-delivery in the U.S.

Pellets can be made from other agricultural products or residues too. Straws can be pelletized and burned. In addition, warm-season grasses like switchgrass can be pelletized and may enter the market as a renewable fuel.

In addition to pellets, some pellet stoves can burn unprocessed fruit pits and shell corn. Check with the manufacturer for details.

Pellet appliance installation

Pellet appliances should have specific instructions for installation from the manufacturer. Installation and venting recommendations should be followed carefully. Clearance between the stove or vents and combustible materials is generally less than for wood stoves. Because the flue is operating at a positive pressure, you cannot use type-B double-wall vent products. You must use products specifically designed for pellet stove operation that have seals between stove pipe sections. For most applications, this is Type-PL vent pipe tested to UL 641.

Pellet fireplace inserts are often vented into existing masonry or factory-built chimneys. These chimneys should be inspected prior to use for venting pellet stoves. Some stove manufacturers will require relining existing chimneys with an approved metal liner, pipe, or PL vent pipe.

Corn-burning appliances

Corn has become an economic alternative for home heating in some areas. Some pellet stoves are rated to burn corn, but there are also stoves specifically designed to burn corn. The cost of corn and corn-burning equipment must be compared to alternative fuels and equipment costs. Stoves, furnaces, and boilers configured to burn unprocessed shelled corn resemble pellet appliances. They generally consist of a hopper for holding a supply of fuel, an auger-feed system, a separate combustion chamber, a combustion air-delivery system, and an exhaust system. Hoppers can hold enough fuel for over 24 hours, depending on the manufacturer. Most corn stoves require electricity to operate the auger, combustion air blower, and for some, a heat-exchanger blower. Unless backup power is available, they won't operate in a power outage. However, there are a few non-powered corn stoves.

Table 8. Price of delivered heat for typical corn-burning appliance.

Price Bushel	$1.50	$2.50	$3.50	$4.50
	Price per Delivered Million Btu for Typical Corn Burning Appliance			
	$5.05	$8.42	$11.78	$15.15

Corn-fed systems can either operate from the top or bottom. This may affect how often the clinker needs to be removed from the stove. Combustion-air and exhaust systems must be installed according to manufacturers' directions. Depending on stove design, vent pipes may be stove pipe similar to that used on wood stoves, through-the-wall systems that preheat combustion air as it exhausts the products of combustion, or pipe used for pellet stoves.

Shelled corn is readily available in some areas of the country. Prices fluctuate based on markets and have seen a high of nearly $4.50 per bushel and a low of $1.50 per bushel in the mid to late 1990s[vi]. The higher heating value of corn is about 8,000 to 8,500 Btu of dry weight. Corn at about 15 percent moisture only has about 6,800 Btus available. The rest must be used to evaporate the moisture in the corn. Table 8 provides the cost per million Btus when burning corn in a common appliance. These values do not include the cost of electricity to operate the blowers.

Coal-burning appliances

Coal-burning appliances have been around for centuries and are experiencing a renaissance in some areas. Free-standing stoves, furnaces, and boilers are all available. Most are designed to use anthracite coal. Anthracite is a hard coal with a high heat content, around 15,000 Btu per pound, and low sulfur content. Coal is generally sold by the ton and in some areas, in 40-60 pound bags. At the time of this writing, coal is not readily available in Kansas.

Stoves can be fed by gravity from a hopper or with an auger. The heat-release rate of hopper-type stoves is controlled by regulating the amount of fuel that is allowed into the grate area. A non-electric thermostatic control moves a baffle to regulate fuel flow. On auger-fed stoves, a thermostat controls the amount of fuel an auger moves into the combustion zone. Auger systems have been used for years and are similar in some respects to pellet stove systems.

Some stoves are fitted with blowers to increase heat release. Both blowers and augers require electric power; they will not operate without a standby source of power if there is a power outage. Many stove retailers offer small back-up power supplies for stove operation. Stoves and furnaces designed to burn coal or duel-fuel wood/coal appliances are not regulated by the EPA.

Straw burners

Denmark has pioneered the burning of straw in medium-sized combined heat and power or district heating systems. Plant sizes range from about two to 10 megaWatts. A centrally located boiler provides heat for a whole town. These industrial-scale systems generally chop the straw and inject it into the boiler on a continuous basis. They achieve high overall efficiencies.

Smaller scale straw-fired boilers and furnaces are being used in some areas where straw is plentiful and fuel prices are high. Research on the current status (1995) of straw heating systems identified 14 North American manufacturers of straw-burning equipment, with all but one in Manitoba, Canada[vii]. However, some wood-fired boilers may be suitable for use with square bales with little or no modification. Check with the manufacturer.

Many of the straw-bale burners are atmospheric boilers. The firebox is surrounded by a water jacket. Heat from the burning bales is used to heat water which is then pumped to a home or other farm buildings. Homes with existing hot-water, radiant-heating systems can use the water directly. Buildings with air-delivery heating systems have a heat exchanger installed in the duct work and heat the air with the hot water. Water temperature is controlled by starting and stopping a fan delivering combustion air to the fire box.

Table 9. Price of delivered heat for typical straw-bale burner.

Price per Ton	$20	$40	$60	$80
	Price per Delivered Million Btu for Typical Straw-Bale Burner			
	$4.84	$9.69	$14.53	$19.37

Heaters are available that burn both square and round bales. Square bales are easier to load by hand but have a much shorter burn time. The boiler may need stoked several times a day. Round-bale burners generally cannot be loaded by hand. Often round bales are made slightly smaller than normal to make feeding into the combustion chamber easier.

System efficiency is generally low for this class of combustion equipment, in the range of 30–40 percent. However, if the straw is inexpensive, it can still be cost-effective. While there is some variation between the heat content of different types of straw, most will have about 7,600 Btu per pound.

Environmental benefits

Several arguments support use of solid fuels from an environmental perspective. With the exception of coal, solid fuels are renewable, they reduce the release of green house gasses, they save valuable liquid and gaseous fuels for better uses, and they reduce our dependence on foreign oil and the cost of securing it. But there are also problems. Harvesting timber may reduce habitat and contribute to erosion. Burning any sold fuel releases a host of chemicals and small particles that may pose health risks.

Renewable means that the resources will be replaced rather than used up. But all things renewable are not equal. Hardwoods take a long time to grow. It is better to use softer, quick-growing woods when possible, rather than slow-growing woods.

> Burn sustainably harvested, properly processed, and seasoned fuel in an advanced combustion stove or fireplace that is vented through a chimney that runs straight up through the building.
>
> –*Woodheat.org*

Pellets are generally made from wood that would otherwise be disposed of. Finding another use for wood residue keeps it out of landfills. While not currently available, pellets can also be produced from straw and switchgrass. Warm-season grasses like switchgrass renew annually. Straw-derived pellets use a resource that may be field-burned.

Using a renewable resource does not add greenhouse gasses to the atmosphere. While the carbon stored in the trees, grasses, or straw is released when burned, the new plants grown to replace the resource extract carbon from the atmosphere in equal share. Burning fossil fuels releases carbon that has been stored for millennia.

How you burn solid fuels also affects the environment. Combustion of solid fuels releases not only carbon dioxide, but also a few hundred other chemical and very fine particles. Using older, dirty combustion equipment significantly increases the release of these pollutants. EPA-certified stoves release about one fourth of the emissions as pre-EPA stoves.

For a comparison of heating costs between the solid-fuel heating options discussed above and conventional fuels, see *Fuel Cost Comparisons*, a fact sheet available from Engineering Extension at Kansas State University.

Resource organizations

Wood heating

- Hearth Education Foundation
  (703) 524-8030; Fax: (703) 522-0548
  Email: info@hearthed.com
  www.hearthed.com
  The Hearth Educational Foundation is a not-for-profit organization dedicated to educating the public and professionals about safe installation and efficient use of wood-heating appliances.
- Masonry Heaters Association of North America
  (802) 728-5896; Fax: (802) 728-6004
  Email: bmarois@sovernet.com
  mha-net.org/
  The Masonry Heaters Association of North America promotes the construction and use of masonry heaters as an efficient and non-polluting heating source.
- Environmental Protection Agency
  (202) 564-5950
  Email: Dupree.john@epa.gov
  www.epa.gov/Compliance/monitoring/programs/woodstoves/index.html
  The Wood Heater Program (WHP) promotes compliance with federal requirements on emission levels from regulated wood stoves.
- Wood Heat Organization Inc.
  www.woodheat.org/
  Wood Heat is a nonprofit, nongovernmental agency dedicated to responsible use of wood as a home heating fuel.

Pellet stoves and fuels

- BC Pellet Fuel Manufacturers Association, a Canadian regional trade association.
  (250) 963-7220 or (250) 563-7909
  Email: mail@pellet.org
  www.pellet.org/
- Pellet Fuels Institute
  (703) 522-6778; Fax: (703) 522-0548
  Email: pfimail@pelletheat.org
  www.pelletheat.org/
  The North American pellet trade association represents fuel preparation and clean-burning technology of renewable bio-mass energy resources.
- Combustion Net
  Email: combustion@combustion-net.com
  www.combustion-net.com/pellet_fuels/

Chimney

- Chimney Safety Institute of America
  (800) 536-0118; Fax: (317) 837-5365
  Email: office@csia.org
  www.csia.org/
  The Chimney Safety Institute of America certifies chimney sweeps and maintains a Web site on chimneys and combustion venting systems.

Footnotes

i Residential Wood Combustion Technology Review, Volume 1, Technical Review, EPA-600/R-98-174a, December, 1998

ii The Effects of Glass Doors on Masonry Fireplace Spillage and Surface Temperatures, Canada Housing and Mortgage Association, 1995

iii Valenti, Joseph C., and Clayton, Russell K., Emissions from Wood-Burning Residential Outdoor Furnaces, EPA-600/R-98-017, 1998

iv Gulland, John, *Outdoor Boilers—Today's Most Controversial Wood Heating Technology, www.woodheat.org/*, November 2002

v Pellet Fuels Institute, What Types of Pellet Stoves Are Available, *www.pelletheat.org/stoves/stoves.html*, January 2003

vi U.S. Farm Network.com, Prices Received by Farmers, Corn, U.S., *usfarmnetwork.com/cornprices.html*. March 2003

vii Using Straw as a Farm Heating Fuel, Prairie Agricultural Machinery Institute (PAMI), ISSN 1188-4770, July 1995

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