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# SELECTING A WOOD-BURNING STOVE

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Texans are searching for home heating alternatives because of increasing fossil fuel costs. Wood is becoming an increasingly economical alternative, but many Texans know little about selecting and operating a wood-burning stove. And, few people know the real facts about wood energy efficiency.

Before purchasing a wood-burning stove, investigate the economics of burning wood. Wood-burning stoves and accessories are not cheap, and one should expect enough fuel savings to pay back the investment in 7 years or less. To determine if wood is the most economical home heating alternative, refer to the Extension Service publication L-1807, *When Does It Pay to Burn Wood*. Then, the following information on wood combustion and stove design, size, type, efficiency, capacity and heating capability will help you select a wood-burning stove.

## WOOD COMBUSTION

### Wood Structure Versus Energy

Wood is primarily water and various cell structures. The cell walls are mostly cellulose and hemicellulose bonded together by lignin. The cells have void centers that contain various amounts of air and water. This is why wood has a relatively low energy density when compared to fossil fuels.

In wood, carbon is the principal energy source, but wood has less carbon and more oxygen than fossil fuels, yielding less energy per unit weight.

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### Three Stages of Wood Combustion

Wood combustion takes place in three stages. First, wood moisture must evaporate before ignition takes place. Water evaporation, which takes place at about 212° F., requires energy, reducing the amount available for heat. The moisture content determines the energy and time required to complete this stage. If the moisture content is above 67 percent, the wood will not ignite because the evaporating water consumes enough energy to prevent the wood temperature from reaching the ignition point.

The second stage of combustion takes place at temperatures from 300° F. to 1,000° F. The complex polymeric wood compounds begin to break down into gases that burn outside the wood when they combine with oxygen, creating flames. Around 60 to 80 percent of the wood's dry weight evolves as flaming gases, accounting for much of the total energy released.

The final combustion stage is the oxidation of the remaining carbon after the gases are completely burned. As in burning charcoal, this glowing combustion stage creates no flame and takes place at temperatures above 1,000° F.

These three combustion stages account for wood's usable heating value. The total heating value of oven dry wood is around 8,600 BTU's per pound. However, since air drying fuelwood in Texas still leaves a final wood moisture content of around 20 percent, wood burned in wood-burning stoves is never oven dry. The heat energy required to vaporize and superheat moisture in the wood — approximately 1,200 BTU's per pound of water — is lost as a source of home heating energy. The heat available after water

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evaporation energy losses is called *the net heating value,* which is around 6,400 BTU's per wood pound at 20 percent moisture content. This is the energy available to heat the home. Depending on stove efficiency, a certain percent of this net heating value is lost through the chimney. Stove efficiency determines the percentage loss of net heating value, which determines how much wood is needed.

## WOOD-BURNING STOVE CHARACTERISTICS

### Stove Efficiency

Fuelwood burned in a stove combines chemically with oxygen in the air, releasing chemical energy as heat. Useful heat enters the room via transfer through the stove walls, stovepipe and chimney. The remaining released energy escapes through the chimney to the atmosphere.

Maximum energy efficiency is gained when fuelwood combustion and useful energy transfer are complete. Complete wood combustion occurs if all the wood carbon, hydrogen and oxygen atoms are converted to carbon dioxide ($CO_2$) and water ($H_2O$), releasing all possible wood energy. Complete useful heat transfer is achieved if the flue gases have cooled to room temperature before leaving the house. A wood-burning stove that could achieve complete fuelwood combustion and useful heat transfer would have an efficiency of nearly 100 percent.

However, complete useful heat transfer is not desirable because room-temperature flue gases would create inadequate stove draft, causing the stove to smoke while reducing complete wood combustion because of less available oxygen. Also, considerable water condensation would occur inside the cool stovepipe and chimney. Because in practice complete wood combustion does not occur, this condensation would contain tar, acids and other ingredients which collectively are termed "creosote." Creosote is untidy, creates fire hazards and corrodes the chimney.

Design problems in maximizing heat efficiency and minimizing creosote deposits partially explain why wood-burning stoves do not achieve 100 percent efficiency. The other basic problem is maintaining high combustion chamber temperatures (1,100° F.) for complete burning. This requires insulating firebricks or metal liners, which reduce useful heat transfer from the stove walls to the house. Because of this reduced heat transfer, a stove designed to achieve almost complete wood combustion still may not have high energy efficiency. These stove-design conflicts explain why wood-burning stove efficiencies range from only 40 to 60 percent.

Airtight stoves have the highest repeatable energy efficiency of around 55 percent. Non-airtight stoves can achieve up to 40 percent and conventional fireplaces only 15 percent. The higher a stove's energy efficiency, the less fuelwood required to heat one's home. Thus, select airtight stoves if fuelwood is to economically compete with fossil fuels.

### Catalytic Converters

Catalytic combustion systems similar to those found in automobiles, self-cleaning ovens and industrial incinerators increase stove heating efficiency 30 percent. The process basically reduces flammable woodgas ignition temperatures from around 1,100° F. to 500° F. The woodgas passes through a ceramic honeycomb coated with a thin film of precious metal catalyst, which causes a catalytic reaction, reducing the woodgas ignition temperature. Since the firebox temperature usually is about 500° F., the woodgas ignites and burns. When the woodgas does not pass through a catalytic converter and its ignition temperature remains around 1,100° F., the firebox temperature is too low for ignition, and the unburned woodgas passes out of the firebox into the chimney flue.

Catalytic converter stoves also reduce air pollution and cut creosote formation by 90 percent. They burn up two-thirds of the particulate emissions and allow primarily only carbon dioxide ($CO_2$) and water ($H_2O$) to enter the chimney. Thus, most of the smoke particles that collect on the chimney walls as creosote burn instead.

### Stove Design Versus Efficiency

Three design features, openness, air leakage and smoke chambers, significantly affect stove efficiency.

Open stoves have the lowest energy efficiencies. If the doors do not seal well, closing them with the flue damper open does not help. However, when the doors are closed, considerable damping is possible. Closing the built-in flue gas damper or stovepipe damper just to where the stove does not smoke improves stove efficiency.

Stoves with large air leaks have low efficiencies compared to airtight stoves. Flue gas dampers help, but large air leaks still reduce efficiency below that of an airtight stove. Some stoves have tightly fitting doors and use an air inlet damper to control air flow. Such stoves can be as efficient as an airtight stove; however, airtightness alone does not guarantee high efficiency.

Smoke chambers (figure 1) improve heat transfer and increase efficiency 5 to 10 percent, reducing fuelwood consumption 10 to 20 percent. Increasing exposed stovepipe length or using an interior, exposed, uninsulated chimney (uninsulated pipe is not allowed by fire safety standards when going through a ceiling or roof) also increases the system's net energy efficiency. However, the cooling effect of the stovepipe and exposed, uninsulated chimney increases creosote accumulation.

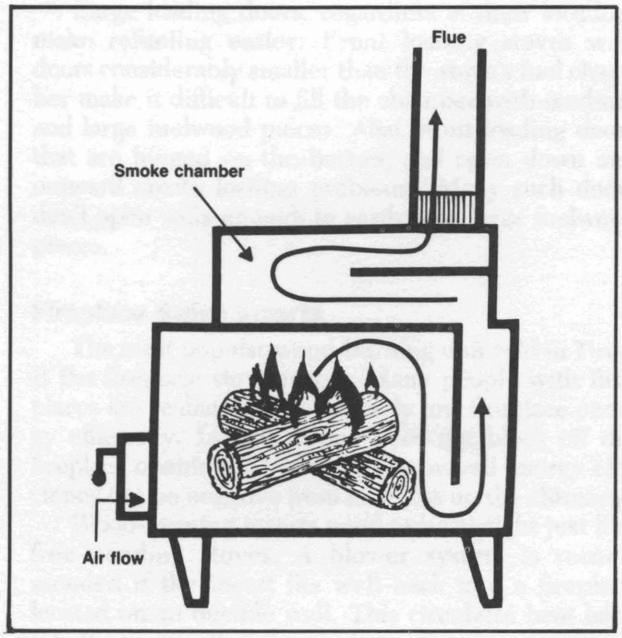


*Figure 1. Smoke chambers result in more complete heat transfer, improving energy efficiency.*

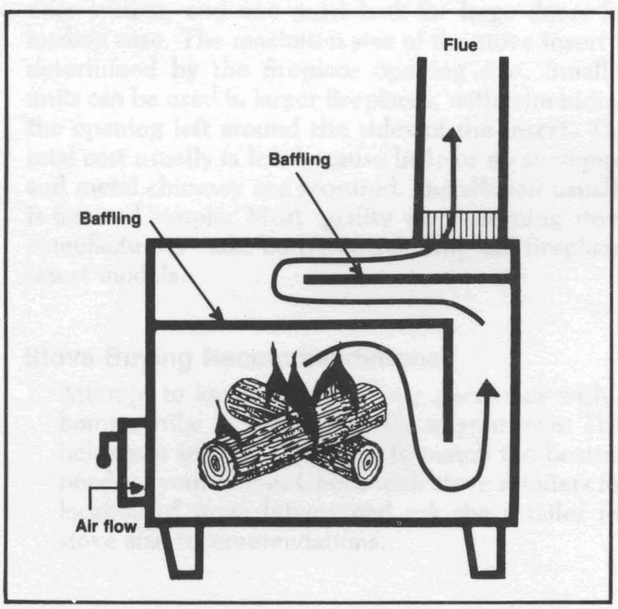


*Figure 2. Internal baffling creates a smoke chamber effect and insures good contact of hot flue gases with the stove's outer layer, increasing heat transfer efficiency.*

Internal fixed baffling (figure 2) also increases heat transfer. This baffling insures hot flue gas contact with the stove's outer layer, instead of quick exit out the flue. The longer the hot flue gas contact period, the more heat transfer from the stove to the home, thereby increasing energy efficiency. Most U.S.-made airtight stoves use some form of baffling rather than a separate smoke chamber as shown in figure 1.

## Stove Heating Capability

To determine which stove will best serve the intended purpose, you need to know the stove's heating capability, or "power," and its ability to generate steady heat for an extended period (8 to 12 hours) without frequent refueling.

Selecting stove size for adequate heating capability is probably the most difficult task for the homeowner. Many stoves are rated by the number of cubic feet they can heat. This is inappropriate because the required heat depends on many variables other than room or house size, such as insulation, number of windows and doors and outdoor temperature.

Most stoves can generate a wide range of heat outputs by controlling fuel size, fuel species, wood moisture content, air flow and installation details such as exposed stovepipe length. These controls, particularly air flow, wood species, moisture content and size, are important because they allow one to adjust heat requirements for the different seasons and weather changes. For example, an undersized stove may be inadequate only on the coldest days. However, one may have to operate it near its peak power capability most of the time, requiring more frequent refueling. An oversized stove probably will be operated at its low power level, but still may generate too much heat at certain times of the year. The most common stove-size complaint comes from owners of oversized stoves that put out too much heat, even at their lowest power level.

The lack of reliable stove-performance data (particularly expected BTU's per hour at maximum and minimum power levels) and the difficulty of accurately calculating wood-burning stove heating needs for the home make it difficult to select stove size. Seek advice from people with experience. Wood-burning stove owners usually are eager to share their experiences and usually can offer advice on stove sizing.

## Radiant Versus Circulating Stoves

Wood-burning stoves are radiant or circulating types, depending on their dominant energy-transfer method. Radiant-type stoves transfer 60 to 70 percent of their energy output as infrared radiation. A circulating stove is basically a radiant stove surrounded by an outer jacket with openings at the bottom and top so that air circulates between the stove and jacket (figure 3). The cool air entering at the bottom rises as it warms and enters the room through the stove stop. Small blowers often are used to speed air flow. As a result, more of the stove's energy output is in the form of hot air. However, some radiated heat still is emitted from the jacket.

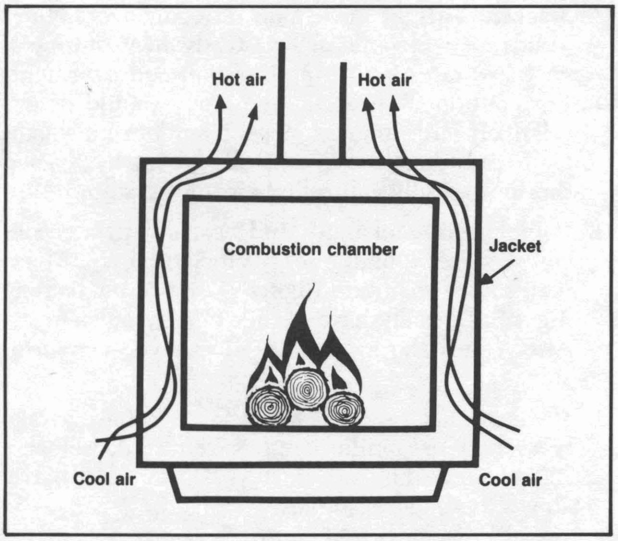


*Figure 3. Circulating type of wood-burning stove.*

A circulating stove's exposed surfaces are cooler than radiant stoves because of the air space between the combustion chamber and jacket. This makes them safer, particularly for small children; also, people, furniture and walls can be closer to the stove. This is important, since the distance stoves must be from combustible materials to meet fire safety standards often creates furniture arrangement problems in small homes and mobile homes.

Radiant heat is emitted outward from a stove much like light beams. Objects can block radiated heat, preventing it from reaching parts of the room. It also heats a person's side facing the stove more than his opposite side. On the other hand, circulating stoves emit hot air which is more uniformly distributed but which can cause more thermal and breathing discomfort.

There is no evidence that energy efficiency is higher for either a radiant or circulating stove.

## Steel Versus Cast Iron

Most wood-burning stoves are made of steel (plate or sheet) or cast iron. Cast iron is harder and stiffer, making it less susceptible to warping. Thus, it is excellent for doors and door frames because even small distortions in these areas can create excess air leakage. However, cast iron's stiffness makes it susceptible to cracking when exposed to extreme heat. Steel is softer than cast iron, and if stressed by high temperatures, it may distort but doesn't crack. Thus, most U.S. manufacturers use steel for the stove walls and cast iron for doors and door frames. Many European manufacturers use all cast iron and, because of craftsmanship and higher grade iron, produce quality stoves. Cast iron stoves imported from the Orient apparently are not high quality because many of them crack, eliminating the stove's airtightness.

Steel and cast iron stoves are susceptible to corrosion. Stove wall oxidation (rusting) occurs because of the burning wood (fire). The rate of oxidation increases with increased temperature. Thin-walled stoves, when operated at consistently high temperatures, can burn out in one season. Firebrick or metal liners, placed in the stove's combustion area, reduce the chances of cast iron cracking, steel warping and corrosion. They keep the main stove's body at temperatures below the critical stage and are replaced easily.

Thick stove walls are less likely to distort, crack or corrode. They have less intense hot spots because the heat is more evenly distributed laterally within the wall. This keeps the stove's wall temperature more uniform, reducing thermal stress.

Cast iron and steel stoves of identical design (including wall thickness) are almost identical in their ability to store heat for distribution into the home. Cast iron stoves have a reputation for better heat-holding capability, but this is because they usually have thicker walls. Basically, both steel and cast iron are suitable materials for stoves. Cast iron probably is a better choice for doors and door frames because of less chance of warping and resultant air leaks.

## Fuelwood Loading

Many stoves are loaded through a side opening located near the bottom of the combustion chamber. This usually eliminates smoke coming back into the home during refueling, but can create loading problems. Large pieces of wood sometimes are difficult to load into bottom side doors because of weight and leverage problems and danger of burning one's hand. The difficulty is intensified if the stove is long and narrow. One can use smaller pieces of wood, but this requires splitting and cutting, which reduces the longer burning times achieved with larger wood.

Top loading doors are more likely to let smoke out during fuelwood loading. This can be corrected by fully opening the air inlets before opening the door. The increased air flow ignites smoking fuelwood; if only a small amount of smoking fuelwood is left, it clears the air in the stove. Ignition of the smoking fuelwood warms the fuel gases, increasing the chimney's draft. This increases the pull away from the loading door to the chimney, keeping the combustion gases and smoke from escaping when the door is opened.

Top loading doors eliminate much of the difficulty of handling large fuelwood pieces because they can be dropped gently into the stove. Also, it is usually easier to completely fill the fuel chamber through a top loading door.

Large loading doors, regardless of their location, make refueling easier. Front loading stoves with doors considerably smaller than the stove's fuel chamber make it difficult to fill the chamber with medium and large fuelwood pieces. Also, front loading doors that are hinged on the bottom and open down and outward create loading problems. Many such doors don't open wide enough to easily load large fuelwood pieces.

### Fireplace Stove Inserts

The most popular wood-burning unit sold in Texas is the fireplace stove insert. Many people with fireplaces are realizing the extremely low fireplace energy efficiency. In fact, if one does not block off the fireplace opening at bedtime, the overall energy efficiency can be negative from heat loss up the chimney.

Wood-burning inserts need to be airtight just like free-standing stoves. A blower system is recommended if the insert fits well back into a fireplace located on an outside wall. This circulates heat back into the room rather than losing radiated heat through the outside chimney wall. Other efficiency measures are similar to those already mentioned for free-standing stoves. The loading is always through a front door system, and one must look for large doors for loading ease. The maximum size of the stove insert is determined by the fireplace opening size. Smaller units can be used in larger fireplaces, with trim hiding the opening left around the sides of the insert. The total cost usually is less because little or no stovepipe and metal chimney are required. Installation usually is fast and simple. Most quality wood-burning stove manufacturers make both free-standing and fireplace-insert models.

### Stove Buying Recommendations

1. Attempt to locate a wood stove purchaser with a home similar in size and design to your own. This helps you select a stove size to match the heating needs of your home. Check with stove retailers for location of stove buyers and ask the retailer for stove size recommendations.
2. Select an airtight stove, thus reducing overall fuelwood use and obtaining a steady heat output at very low rates for springtime, fall and overnight. For continuous heating, the stove should hold a relatively large amount of wood and burn it steadily. Steady heating is controlled best by a good thermostatically controlled air inlet system.
3. If fuelwood availability and cost are prime concerns, select a high energy-efficient stove. Those with smoke chambers (figure 1) or internal baffling (figure 2) usually have higher energy efficiencies. Also, check the availability of catalytic converter stoves.
4. If occasional quick heating for a cabin, garage workshop or similar area is required, select a lightweight, thin-walled stove. Drum and barrel stoves are good examples.
5. Because of space limitations, small circulating stoves are best for heating small homes and mobile homes. Direct feeding of outside air to the stove for combustion is best for mobile homes due to small natural air infiltration rates. Stoves designed for mobile homes are available.
6. Steel and cast iron both are suitable materials for stoves. Many U.S.-made stoves have steel sides and cast iron doors. Both cast iron and steel can rust (burn out). The thicker the material, the longer it lasts.
7. Look for stoves with firebrick or metal liners placed in the fuelwood combustion chamber. They reduce cast iron cracking, steel warping and corrosion by keeping the main stove body at temperatures below the critical stage, and they are replaced easily.

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