Direct burning is the most familiar way of producing energy from wood. Forest products industries are the main users of wood as fuel on a large scale, because they have much woody debris left over from milling and harvesting.

The basic strategy is to reduce leftover wood to walnut-size or smaller particles. This size reduction is usually done by a "hog." Large pieces enter the top of the hog and are forced down by rotating hammers. The small pieces fall through spaced bars, which control their size. This particulate fuel is then stored in piles at the mill, and from there reclaimed to fire boilers that produce steam for heat and power.

The largest wood-fired boilers commonly used in pulp and paper plants or in small utility plants produce enough steam to generate 35 to 50 megawatts of electrical power. This is enough electricity to drive machines demanding 35,000 to 50,000 horsepower—or to heat, cool, and light 10,000 to 14,000 households in the South. Such a boiler consumes about 500,000 tons of green wood fuel annually, or about three 20-ton truckloads an hour, 24 hours a day, 365 days a year.

Wood has a lower heating value than coal or oil per unit of weight. In other words, it takes more pounds of wood than of coal or oil to produce a given amount of energy. Wood has its advantages, however. For example, wood has a much lower ash content than coal and, unlike coal, contains little or no pollution-producing sulfur.

Chief drawbacks of wood are high moisture content and bulkiness. Most freshly cut wood is approximately half water by weight. Such green wood gives off only about half as much heat as dried wood. If wood is burned when green, furnace efficiency is lowered because heat energy is required to vaporize the moisture in the wood and much of this heat is lost up the stack. If fired with dry fuel instead of

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green, a furnace can burn about twice as much wood per hour.

Boiler tests have shown that drying hogged fuel both increases the efficiency of steam generation and reduces waste emissions. Most furnaces designed for wet wood operate best if weight of water does not exceed that of wood, that is, if moisture content is 50 percent or less on a wet basis. At moisture contents over 60 percent, most furnaces operate poorly, if at all.

It is not yet clear whether the benefits of drying wood for boiler fuel in a separate operation offset the costs. Many combustion engineers feel that the cheapest procedure is to admit green fuel to the furnace and dry it in the firebox before combustion.

If wood fuel must be dried, it can be dried in several ways. Mechanical pressing (visualize squeezing a sponge) removes water with simple equipment that requires no heat. Moisture content can be reduced to 50-55 percent of wet weight by this method.

Air-drying in thinly spread piles is laborious and takes many days, but can reduce the moisture content to about 20 percent if the climate is suitable. Today, however, fuel is most commonly dried with hot gases. The most common type of hot-gas dryer is the rotary drum.

In a typical rotary drum dryer system, wood to be dried is first screened to remove large pieces that must be “rehogged.” This wood and hot gases obtained by burning gas or dry wood enter one end of the rotating drum or cylinder and are brought into contact with each other by forced flow of the gas. A fan draws the hot gases through the dryer, and these gases push the dried fuel toward the outlet end of the dryer.

Two- to four-inch pieces can be dried in 20 minutes or less. At the dryer outlet, fuel is separated into different sizes. Very small pieces that are airborne go to the cyclone separator with the gas flow.

Rotary drum dryers can handle large quantities of wet fuel. Inlet temperature can be as high as 1,600° F if there is enough moisture in the fuel to absorb the heat without scorching the wood. However, one must be careful to prevent formation of blue haze, a form of air pollution caused by distillation of some components of the wood. Douglas-fir dried above 750° F creates blue haze. The best drying conditions for hardwoods are unknown.

It is likely that large-scale industrial users of wood for fuel will continue to burn it green and
in particulate form—that is, as “hogged” fuel. Some smaller-scale users, however, may need fuel not only dried but reduced in bulkiness. The problem of bulkiness of wood fuel can be solved, at some cost by compressing it and thereby densifying it.

There are several ways to densify wood for fuel. Compression baling can reduce wood residue volume to one-fifth its loose bulk while squeezing out 12 to 15 percent of its moisture.

**Elasticity**

**Breakdown**

Most of the densified products can be formed by compressing the residue in a die under heat and pressure. Apparently the key to success is to break down elasticity of the wood or bark. If the elasticity is not destroyed, the densified form will not last.

Some of the compounds in wood and bark act as natural binding agents or glues when subjected to heat and pressure. Fire logs for home use may employ a wax or other binder to hold the densified dry wood particles together.

The technology for densifying particulate wood and bark has been around for over 50 years. The famous “pres-to-logs” used for hand-firing fireplaces and stoves were first made about 1933. In the 1950’s, machines were developed to extrude dense wood residue rods suitable for fueling coal stoker furnaces. Generally, the rods are about 1 inch in diameter and can be cut to desired lengths.

In 1959 a company in Tennessee first pelletized bark for fuel. These oak bark pellets were used with coal to fire a steam boiler, and reportedly gave burning rates equivalent to soft coal.

Pelletization can be accomplished with standard agricultural pellet mills. The product is generally 3/16- to 1/2-inch in diameter and 1/2-inch long. The compression ratio in pelletizing is usually about 3 to 1. Because of their uniform density, fuel pellets are easier than hogged fuel to meter into a furnace and can be burned at more closely controlled rates.

Wet fuel cannot be pelletized unless it is first dried, however, and part of the fuel must be used to dry the material to be pelletized. Because of this, those industries such as furniture and cabinet manufacturers that have dry wood wastes may find pelletizing most economically attractive.

A company in Alabama pelletes sawdust and bark after pre-drying it in a rotary dryer fired by some of the pelletized product. The pellets are sold to a power plant. Estimated total investment is about a half million dollars including land. The pellete sells for around $32,000.
A company in Oregon markets pelletized Douglas-fir bark. Reportedly, the product sells for about half the price of the amount of coal needed to produce the same amount of energy. Plant operations use the equivalent of 12 percent of the energy contained in the pelletized product.

Combustion is the rapid chemical combination of oxygen with the elements of a fuel that will burn. It results in release of heat energy. The major combustible elements in wood are carbon and hydrogen.

Burning of wood can be divided into three stages. In the first stage, the moisture is evaporated to dry the wood. In the second, temperature of the fuel rises to the point where some gases are driven off and burned. In the third, remaining carbon is burned as fast as oxygen from the air can be brought into contact with it. About 75 percent of the average wood will burn in the second stage, and about 25 percent in the third.

Ash and incompletely burned carbon are the solid residues from burning wood. In boiler furnaces, where high burning temperatures are achieved, slag and clinkers are formed from the melting and fusion of ash.

Wood ash generally has not been considered chemically active, but this may not be entirely true. In at least one case, wood ash has been shown to be an effective catalyst in gasification of wood.

Increased use of wood for fuel might make ash disposal a problem. Perhaps ash could be used as a soil conditioner, and the alkalinity of ash could help raise the pH of acid soil. Ash also has the potential to be used as a fertilizer. It is a good source of potash but contains no nitrogen. One mill in central Louisiana uses clinkers for roadbed surfaces around the plant.

Wood gives off both gases and small solid particles when burned. Carbon dioxide and water vapor combined with nitrogen and oxygen from the combustion air comprise 98 to 99 percent of the total material emitted from an efficient combustion process.

### Air Pollution Concerns

In terms of potential air pollution, the Environmental Protection Agency (EPA) is concerned with the amounts of particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and other unburned gases (hydrocarbons) that enter the atmosphere. In wood combustion, sulfur dioxide emission is negligible, and carbon monoxide and hydrocarbon emissions usually present no problems. The situation with nitrogen oxides is less certain.
When combustion is poor, hydrocarbon emissions are increased. In extreme cases, these emissions may be 55 to 85 pounds per ton of fuel.

High hydrocarbon emissions could present a twofold pollution problem. First, some compounds produced through the incomplete combustion of solid fuels such as coal are suspected of being cancer-causing agents. The second problem is production of other compounds that react with sunlight to form smog. However, neither of these kinds of compounds is likely to form in wood burning if combustion is efficient.

Nitrogen oxides are instrumental in smog formation. Fortunately, the ambient concentration of nitrogen oxides is low enough in most areas that emission control for them from wood burning should not be required.

Particulate emissions can be controlled by any of four basic devices. These are cyclone separators, scrubbers, baghouse filters, and electrostatic precipitators. Most wood-fueled boilers are equipped with cyclone separators that spin the gases to centrifugally separate them from particles, or scrubbers that wash particles free of the gases.

Basically, there are two classes of wood-burning furnaces—grate burners and suspension burners. Dutch ovens and spreader stokers burn the fuel on a grate, either in a pile or spread into a thin bed.
Historically, Dutch ovens provided steam for many industries in this country. While thousands are probably still in use, they are now considered obsolete for new installations because they are expensive to maintain and respond poorly to load changes.

Fuel cell burners are an adaptation of the Dutch oven design. Fuel chips are fed into the primary furnace, which is a vertical cylinder with a water-cooled grate. The cylinder is lined with firebrick which protects it from the intense heat. Fuel is partially burned in the primary furnace and gases given off pass into the upper chamber where burning is completed.

Boilers of this type are common in the western United States, where they are used to kiln-dry lumber. They generally produce 10,000 to 30,000 pounds of steam per hour. Dryers are needed when fuel moisture content is above 50 percent of green weight.

The spreader stoker is probably the most commonly used wood and bark burning furnace. With little difficulty, these furnaces can burn wood and bark alone or in combination with coal, oil, or gas.

In spreader stokers, fuel in the form of chips is spread into an even, thin bed across the grates. When the fuel is added above the grate, smaller particles and gases burn in suspension while the large pieces of fuel fall to the grate and burn in the fuel bed. Flames from the particles suspended above the grate radiate heat that aids in combustion of the fuel bed.

Furnace walls are normally lined with heat exchange tubes (water walled). Because there is no refractory to reflect heat back to the fuel, combustion air is sometimes preheated. Spreader stokers are used with boilers that generate from 25,000 to 600,000 pounds of steam per hour.

Suspension burning of wood and bark in large boiler furnaces is similar to the burning of pulverized coal. Usually bark hogged to a small size and blown into the furnace is the fuel. If injection is high enough in the furnace and the fuel particles are small enough, then the fuel will be completely burned before it falls out of the combustion zone.

In one system, turbulence is provided by preheated air injected from the sides of the furnace at various heights. The airflows create spinning air masses or fire circles that hold the fuel particles in suspension while they burn.

With suspension burners, a small dump grate at the bottom of the furnace catches and burns larger fuel particles that fall. Suspension-fired
boilers are often large units, some capable of generating over 500,000 pounds of steam per hour.

**Cyclonic Burners**

Cyclonic furnaces also burn wood in suspension, but it must be dry (15 percent moisture content, wet basis) and sized (1/8-inch or less).

In the horizontally mounted cyclonic burner, a drumlike combustion chamber is closed at one end. Hot combustion gases are let out from the opening in the other end called the choke. Combustion air is forced by a blower through the air manifold into tuyeres, which admit the air.

The airflow pattern created is a double cyclonic action. Fuel is injected into the burner from the side with a stream of high velocity air. Fuel and air are mixed around the sides of the burner as they move toward the choke. Both the high turbulence of the cyclonic airflow and time in the burner contribute to complete combustion as long as proper temperatures are maintained.
This type of burner can be used for direct firing—that is, heating with combustion gases instead of steam—lumber kilns, rotary and veneer dryers, and boilers.

Much wood available for burning is of low quality, that is, dirty, mixed with rock or metal, wet, and variable in size. Such wood can be burned effectively in a fluidized bed burner: within a bed of hot sand through which hot gases are passed.

The Jasper-Koch burner takes a new approach to suspension burning. The unit can burn wet wood or bark efficiently in a small furnace that costs less than grate-type furnaces of comparable capacity.

As already stated, bark or sawdust that is half water by weight burns very poorly and must be partially dried before it is burned. This drying can take place in a separate dryer before wood enters the burner, in a pile on the floor of the furnace combustion chamber, or in an integral dryer that passes through the burning zone. The Jasper-Koch burner works on the latter principle.

In the Jasper-Koch design, the combustion chamber is a doughnut-shaped space between two concentric vertical cylinders; particulate fuel burns in suspension in this chamber. In the commercial prototype, a stainless steel inner cylinder 29 inches in diameter with walls 1/4-inch thick houses a huge screw that forces fuel down into the bottom of the chamber. The outer stainless steel cylinder through which the upward-moving combustion gases travel is 49 inches in diameter and has walls 1/4-inch thick. The fuel is partially dried (nearly oven-dried) in its 15-minute trip from the fuel hopper to the combustion zone.

Surrounding the outer cylinder, along the entire 7-foot-high burning zone, is a heat exchanger that preheats air to about 500°F and forces it into the bottom of the burner. This air carries fuel particles upward into the combustion zone, where the temperature is about 1,600°F. A 30 horsepower blower is required for the preheated air to assure proper airflow and velocity.

The burner has neither grate nor fuel bed. Combustion occurs throughout a zone in which particles are suspended in the airstream. The outer cylinder is flared at the top of the combustion zone. Since the inner cylinder has constant diameter, the flare increases flow area for upward-moving combustion gases, slowing their velocity. This causes particulate matter (other than fine ash) to fall back into the burning zone so it continually recirculates until completely burned.
Because combustion temperatures do not exceed 1,800°F, neither the laboratory model nor the commercial prototype has formed slag. Ash formed during combustion is discharged upwards along with the hot combustion gases for later separation. The burner is equipped with a gas jet of one million Btu per hour capacity to facilitate startup.

**Prospects for Future**

Several driving forces will strongly influence the use of wood as industrial fuel. Currently built central utility plants that burn coal, gas, or oil generate about 800 megawatts, whereas the largest current wood-burning boilers are sized for about 50 megawatts. Even a 50 megawatt wood-fired boiler requires a substantial fuel procurement program. Thus it seems unlikely that wood will compete with coal in firing large-scale central utility plants in the future.

The forest products industry is the fourth largest consumer of purchased energy in the Nation (the petroleum, chemical, and primary metals industries are the three largest users), and purchases about 2 percent of the Nation's total energy use.

Although the forest products industry is only about 50 percent self-sufficient in energy, it is in a good position to achieve greater self-sufficiency by burning more wood and bark residues to replace or supplement purchased fossil fuels. Such action would free oil, natural gas, and coal for use elsewhere as a fuel or chemical feedstock. The forest products industry has experience in handling bulky wood materials and its mills are close to wood sources.

In past years, cull wood from the forest has not been harvested for use in mill power plants because harvest costs were high and gas, oil, and purchased electricity were cheap. Now that fuel oil costs about $1 a gallon, green fuel wood has a theoretical fuel value close to $40 per ton. The high cost of building and operating wood-fired boilers compared to gas- or oil-fired boilers prevents this theoretically equivalent price from being offered in the market place.

It seems likely, however, that a price of $20 per ton for green fuel wood delivered to a mill's fuel pile will be widely offered before the end of the 1980's. At this price, it will be profitable to harvest cull wood and logging slash from many forested sites for use as industrial fuel.