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# NON-WOOD PRODUCTS

Contents


## Energy from Wood

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### Introduction

In most developing countries wood and charcoal are the predominant fuels for preparation of food to maintain the quality of life that encompasses the majority of citizens. In many developing countries wood fuels are also important for small and medium-size industries.

Moreover, energy from wood continues to be important in industrial countries. In the USA biomass including waste wood and alcohol from corn provided about 3.3% of total energy consumption in 2000. This was more than was provided by conventional hydroelectric power and more than other forms of renewable energy. Wood energy is consumed in a variety of forms that include fireplace lengths, chunkwood, chips, sawdust and shavings, black liquor from pulp manufacture, pellets, fireplace logs, briquettes, charcoal, gasified wood fuel, and liquefied wood fuel. Wood provides warmth and comfort to homes through burning in fireplaces and automated heating systems. And even in industrial countries wood is used for cooking where it is burned in specially designed stoves for convenience or on grilles to bring out special flavors.

Wood fuel is important to commercial wood manufacturing facilities where waste wood can be disposed and used profitably for energy at the same time. In areas where wood from logging and manufacturing is abundant, other industries such as brickmaking and cement manufacture also benefit from sales of wood fuel. In some South American countries wood charcoal provides the fuel for smelters in manufacturing steel.

Some major considerations in using wood for fuel are environmental impact, economics, convenience, reliability, and simplicity. On balance, wood is an environmentally benign fuel. It tends to be more economic than some other fuels, but may be less convenient.

### How Wood Is Used for Energy

#### Solid Wood

**Fireplace lengths** The most common way of using wood for fuel is to burn pieces about 40–50 cm long that are split from logs. We burn much of such wood in our fireplaces today, and, formerly, such firewood provided the main fuel source for home heating, domestic hot water, and food preparation. Wood is still used for heating some homes in industrial countries. Usually heat is not produced efficiently in fireplaces, but some fireplaces are designed to use blowers to be more effective. Stoves and furnaces burn firewood more efficiently. However, for many applications, wood is converted to other forms of fuel that are more convenient, waste less energy, and are less prone to emit undesirable particulates and other pollutants to the air.

**Chunkwood** A few manufacturers make machines that can produce fairly uniform particles about the size of an average fist. Such fuel is called chunkwood. Chunkwood can be readily dried since there are openings for air to circulate when it is piled for storage. Drying green wood to lower moisture contents makes it easier to burn with less smoldering and smoking and gives the wood a higher heating value. Transfer of creosote residues to chimneys is of lesser impact. Chunkwood is rarely used now, but it will probably become more popular in the future.

**Chips and sawdust** Chips and sawdust are more common types of particulate wood fuel. There are some special combustors that can burn green (unseasoned) sawdust, but it is usually necessary that chips and sawdust be fairly dry. Chips are dried in special dryers that may use wood or fossil fuels to generate heat. Sometimes dry sawdust and chips are available at secondary wood manufacturing plants such as furniture plants. Dry sawdust can be a very desirable fuel for use in special combustors that burn particles in suspension. In such cases grates are not necessary. Chips are advantageous for handling and storing. They can be used effectively in automated stoker applications.

**Shavings** Shavings are produced when lumber is planed or molded or spun off from logs that are peeled. Since shavings are usually produced in the processing of dry lumber they make good fuel. Green shavings from applications such as rounding logs for log home construction may be further processed by chipping and drying.

### Pellets

Wood pellets are becoming increasingly popular. They are made by compression milling small wood particles such as sawdust. When pellets are made from clean wood with little bark, the ash content is low. Pellets are sold at retail outlets in 18 kg (40 pound) sacks. They handle and store easily. They should be kept dry to prevent disintegration, and to avoid risk of mold and decay. Sometimes pellets for cooking are made from woods with special flavors that can be used in barbecuing, directly or with charcoal or gas, for conveying this flavoring to meat or poultry.

However, the most common use of pellet fuel is for heating with modern and convenient pellet stoves. Some of these stoves burn pellets with 85% efficiency and have automatic ignition, feed, and control systems.

### Manufactured Fireplace Logs and Briquettes

Manufactured fireplace logs (firelogs) are made from waste wood to provide open-hearth warmth and ambience with clean fuel. Wood briquettes are similar products of smaller length that are used as barbecue fuel or industrial stoker fuel.

There are two types of firelogs or fuel logs; one type is made with the addition of around 50% wax. The other type is all wood. In the USA wax-type logs are more popular, but the all-wood type is more popular throughout the rest of the world. Wax-type logs burn with fewer gaseous emissions to the air, but they do emit carbon compounds from nonrenewable fuel that lead to an increased greenhouse effect. All-wood logs do not emit nonrecyclable carbon.

All-wood logs are made in machines that apply pressure with screws or pistons. The heat developed in the process is sufficient to cause the lignin in the wood to flow and act as a binder for the particulate wood waste. Many machines to make fireplace logs are designed to take advantage of the heat generated by high pressure and do not use supplementary heat. Other machines have extrusion cylinders that are externally heated to temperatures between 180°C and 300°C. Electrical resistance coils provide heating, and after the manufacturing process starts a temperature control setting permits operation at an optimum temperature level. The heating process slightly carbonizes the surfaces of the logs or briquettes and gives them a dark brown color. Heating may also contribute to better particle adhesion and less friction in the extrusion process.

Briquettes are made in the same ways as all-wood logs, but the log lengths from the machines are cut into thin disks. In developing countries brickmaking presses have been adapted for briquetteing. In these cases pressures are lower and inexpensive adhesives are used as binders.

The wax-sawdust firelog manufacturing process is not used for producing briquettes, only for fireplace logs. Wax-sawdust logs are composed of about 40–60% wax with the remaining portion being sawdust. The heat content of wax-sawdust logs is higher than all-wood logs. Compared to wood, which has a high heating value of about 20 MJ $kg^{-1}$ (8500 Btu $lb^{-1}$), wax-sawdust logs have a heat content of 36.4 MJ $kg^{-1}$ (15 700 Btu $lb^{-1}$).

### Charcoal

In industrialized countries wood charcoal is often used as a cooking fuel, particularly in barbecuing or grilling. But consumption for such use is minor. In developing countries charcoal is much more commonly used as a fuel. This is an advance from use of solid wood fuel for use in domestic or light institutional or industrial (e.g., baking) applications. Charcoal is more easily stored and transported than wood, and it is more durable in the presence of moisture.

In developing countries primitive earth or pit kilns are still used in charcoal manufacture. In industrialized countries, various types of improved kilns are used. They may be of brick, concrete or cinder block, or steel construction. Kilns are designed to char the wood without burning it. This is accomplished, after the charge of wood has been ignited and preliminarily heated, by regulating the amount of air entering the kiln so that only 'glowing' and not combustion takes place.

### Gaseous Fuel

Charcoal is only one of several different forms of advanced products that may be obtained through pyrolyzing wood in the presence of insufficient oxygen to cause complete combustion. Depending on pyrolysis temperature there may be different proportions of char, tar, liquids, and gases. With high temperatures and proportionately low oxygenation, mostly gas is formed. Wood gasification results in gaseous products composed of mainly hydrogen and carbon monoxide and some hydrocarbons that include methane.

Wood gasifiers are of different types that include updraft, downdraft, side draft, and fluidized bed. Most experience in using wood gasifiers has been with the downdraft type. Downdraft gasifiers produce cleaner gases that have less tar. These gases may be filtered further so that they are clean enough to use as fuel in internal combustion engines without causing severe carbon deposits in the pistons and heads of the engines in short periods of time. The gasifiers and engines are most often used in combination with electrical power generators or transmission drive mechanisms for powering automobiles or other modes of transportation. Such combinations are known as gasogens. Wood gas may also be combusted directly. However, unless it is refined it has much lower heating value than natural gas.

Gasogens were used in many countries to power automotive transportation during World War II, but were abandoned after the war because of higher maintenance costs. Today there are better filters for removing tars from the gases before they enter the internal combustion engines so maintenance costs are less. Today gasogens are becoming increasingly popular for power generation, especially in locations where electrical demand is low and power from the electrical grid distribution network is not readily available.

There are also efforts to use gases generated through pyrolysis of wood with insufficient oxygen for complete combustion in turbine generators, but for use with turbines gases must be even cleaner than for use with internal combustion engines. Combustion gases have also been tried in turbines, but in this case corrosive ash that might get through to the turbine is a greater problem.

### Liquid Fuels

**Alcohols** Previously wood distillation through heating in a retort without introducing oxygen was popular in the USA, and the process is still applied in some countries of the world today. This process can produce methanol for fuel along with other chemicals and charcoal.

However, for producing methanol from wood it is more efficient to use a synthesis process similar to that used for making methanol from natural gas. In the synthesis process wood is first gasified. Then it is compressed for removal of carbon dioxide, nitrogen, and hydrocarbons. This is followed by a shift reaction to obtain a gas with two parts hydrogen and one part carbon monoxide. This gas is subjected to high pressure and conversion to methanol results.

There is much more effort to produce ethyl alcohol or ethanol for fuel. In the process for making ethanol wood is first separated into its main constituents of cellulose (about 50%), hemicellulose (about 25%), and lignin (about 25%). The cellulose is then hydrolyzed to glucose and the glucose is fermented to ethanol. Previously this was the extent of the process. But, more recently, ways have been found to ferment xylose. Now xylose can be liberated from hemicellulose and fermented to ethanol.

Little alcohol fuel is made from wood today, but the promise for the future, with continuous development of cost-lowering technology, appears better.

**Black liquor** The kraft paper manufacturing process is popular throughout the world. It can produce high-quality paper with less pollution than with the sulfite process. In the kraft process recovery of papermaking chemicals is important. These chemicals are contained in the large amounts of liquid waste known as 'black liquor' from the process. Therefore the overall process includes a large recovery boiler that produces much energy in using the black liquor as fuel. In 1992 in the USA 32.5 million tonnes or 26.5% of the energy obtained from wood came from black liquor (**Figure 1**).

## Where Wood Is Used for Energy

### Home Heating

Throughout industrialized countries wood for home heating is a minor, though increasingly important, application. In developing countries wood is a major source of fuel, but there is little need for domestic heat, because of warm tropical temperatures.

Nonetheless flaming wood is appreciated as a source of warmth and center for socializing. In industrialized countries, also, wood for home heating is often used in fireplaces for the warmth and ambience of the hearth, although fireplaces are relatively inefficient means of producing heat.

But, there are also efficient ways of using wood for home heating. One traditionally effective and efficient example is the masonry stove commonly used in Europe. These unique heaters are sometimes known as Russian stoves, German tiled stoves, Finnish masonry stoves, or Finnish contraflow fireplaces. Such stoves may be constructed in place by masons, but there are also fully fabricated wood-fired masonry heaters that may be purchased for simpler installation.

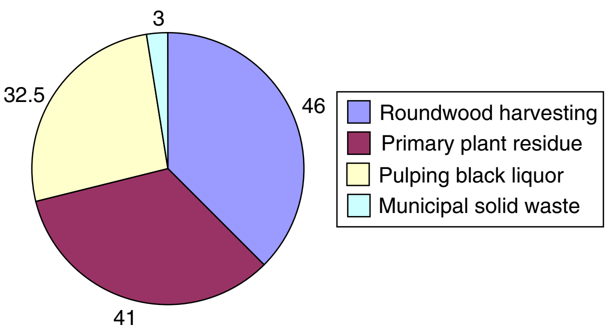


**Figure 1** Source of fuels derived from wood in the USA in 1992 (in million tonnes).

Other improved stoves and furnaces for handling wood or wood-derived fuels supplement traditional firewood stoves and furnaces. The more recent technologically advanced stoves and combustors operate with wood chips and pellets.

In the USA wood was an important fuel from the beginning of European settlement. First wood was used mainly for domestic heating, but charcoal fired furnaces for making iron became important during the eighteenth century, and by 1870 when consumption of wood fuel reached a maximum, use in steam engines such as in locomotives and for riverboat propulsion was significant (**Figure 2**).

## Industrial Plants

Industrial use of wood fuels today is a typical practice in primary and secondary forest products manufacturing plants. Unseasoned wood and bark fuel is typically used in sawmills and plywood and particleboard manufacturing plants. Pulp and paper mills burn green manufacturing waste, and, sometimes, forest harvesting waste. The black liquor that pulp mills use is a high percentage of total overall wood fuel usage. Furniture plants often have premium dry wood fuels available.

Outside the forest industry, wood fuels are often used in brickmaking, lime kilns, and cement manufacture throughout the world. In countries including Brazil and Argentina wood charcoal is used extensively in the manufacture of steel.

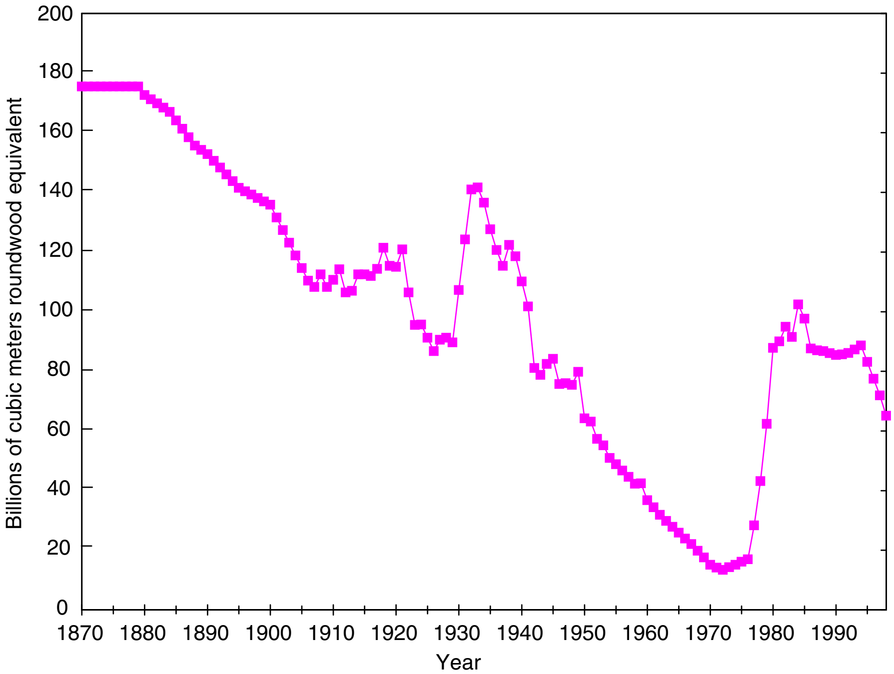


**Figure 2** Trend line for wood fuel consumption in the USA from 1870 to 1998.

### Institutional Wood Fuel Usage

In the US Midwest and New England and in Canada wood fuel is an important base for providing heat for schools during moderately severe winters. On several campuses district heating is employed. Many other schools have individual heating units in separate buildings. Other wood fuel applications provide heat for hospitals, prisons, government administrative offices, and small businesses. In another application wood is used to provide fuel for both heating and air conditioning in a large Midwest US conference center.

### Power Plants

Electricity generation in wood-fueled power plants in the USA became significant with the passage, in 1978, of legislation favorable to small producers who would generate less than 80 MW of electricity. More recently competition for smaller generating plants has become more critical, and some plants have shut down. However, besides the stand-alone generating plants, the majority of the existing capacity is operated in combined heat and power (CHP) facilities in the industrial sector, primarily in pulp and paper mills and paperboard plants. Other countries that have wood-fueled generating plants include Sweden, Finland, and Brazil.

In addition to larger power plants to provide electricity to a distribution grid, there are opportunities to generate electricity at smaller capacities at locations away from grid supply, or at locations where electricity from the grid is very high cost. Often such locations are dependent on diesel engine generators for electricity. Wood gas fueled generators may be competitive in these cases. Examples are a coconut plantation in the Philippines and an Indian reservation in the USA.

### Importance of Wood Fuel in Developing Countries

Energy use in developing countries is much more dependent on wood than in industrial countries. As a typical example in 1992 nearly 70% of the final energy consumption in the Southern African Development community countries was derived from wood biomass. In the household sector, wood fuel accounted for 97% of the energy consumed. This consumes significant amounts of wood from developing country forests, but use of wood in more refined form, mainly charcoal, causes an even greater demand.

In many cities in developing countries charcoal is the major cooking fuel. For example, in Abidjan, Côte d'Ivoire, to satisfy the household supply of charcoal the annual demand is about 300 000 tonnes, produced from 5 million tonnes of wood.

Besides household use the demand of wood fuel and charcoal for industry use is also great. Fuelwood is the dominant source of energy for many rural industries in Malaysia. In 2000 almost 85% of the energy source for numerous medium-scale industries such as smoking of rubbersheets, curing of tobacco leaves, firing of bricks, and the drying of foodstuffs came from fuelwood.

**Figures 3** and **4** show charts of the sharp difference between the developing world and the industrialized world in relative use of wood for fuel and for roundwood. In the developing world the relative use of wood for fuel is much higher.

### Vehicles

Since automotive vehicles consume such a large portion of the world petroleum resources, they present a market opportunity for wood-derived fuels. Today small quantities of ethanol derived from wood are used, but the potential for greater future use of wood converted to liquid fuel is good.

## Co-Firing Wood with Other Fuels

### Coal

Wood fuel is fired together with coal in some power plants where the primary coal fuel has high sulfur content. Wood is low in sulfur so that the mixture of coal and wood facilitates meeting sulfur emission requirements.

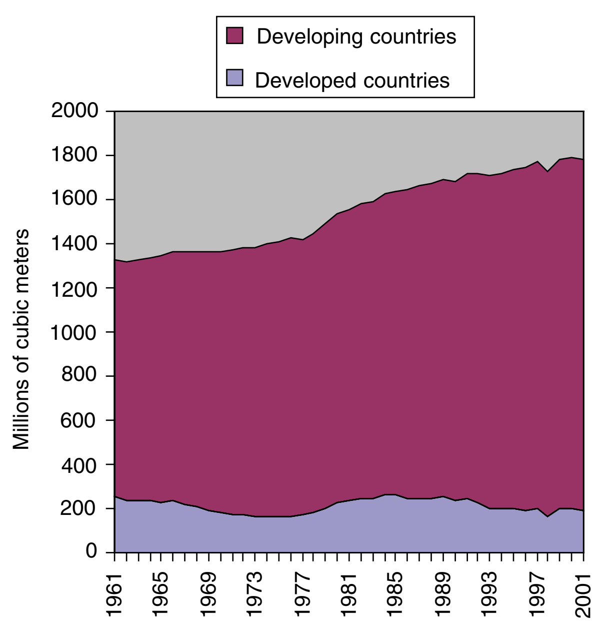


**Figure 3** Annual fuelwood consumption in millions of cubic meters for developing and developed countries. Estimated data from Food and Agriculture Organization.

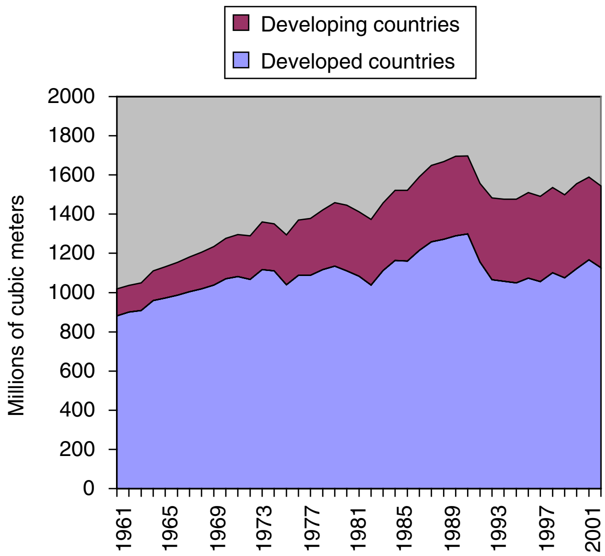


**Figure 4** Annual roundwood production in millions of cubic meters for developing and developed countries. Data from Food and Agriculture Organization.

### Gas

Gas is co-fired with wood to overcome difficulties when wood is at a higher moisture content than that at which it can readily be combusted. With co-firing gas it is fired through one or more burners mounted above wood fuel feeders. The gas burners can also be fired to maintain up to 100% of the heat delivery load for start-up and as a back-up during fuel supply shortages.

## Wood Energy and the Environment

### Carbon Dioxide

The increasing accumulation of carbon dioxide and other greenhouse gases in the atmosphere is generally considered to be a threat to future stability of the earth's climate, and, though there are disagreements, climate change could be unsettling to our modus operandi and quality of life. There can be no doubt that our vast use of fossil fuels is the major contributor to increased atmospheric carbon. The renewability of wood and other biomass fuels makes them a desirable alternative to fossil fuels to prevent or retard increasing retention of carbon dioxide emissions. In wood fuels when new trees are grown to replace the wood that was the source of the fuel, carbon is constantly used and regenerated in the growth cycle. The carbon that is emitted to the atmosphere is absorbed by photosynthesis in new growth.

### Sulfur

Sulfur emissions to the atmosphere are undesirable because they can precipitate and cause harmful acidic conditions in soil and water. Wood contains little sulfur, but some coal and some oil contain substantially more. Therefore sulfur emissions from wood are more easily controlled than those from their fossil fuel counterparts.

### Oxides of Nitrogen

Oxides of nitrogen emissions tend to be lower with wood fuel than with fossil fuels. On the other hand, a major source of nitrous oxide, a greenhouse gas, in the atmosphere is forest fires. Higher oxides of nitrogen emissions usually accompany combustions at higher temperatures. New technology stoves designed to be more efficient have higher oxides of nitrogen emissions than conventional stoves.

### Particulates

Emission of particulates is the most common cause for concern in meeting environmental requirements with the burning of wood fuel. In the USA in some municipalities and under some atmospheric conditions, particularly air inversions, there are periods when wood burning in fireplaces and stoves is not permitted. Catalytic stoves can help in attaining lower emission rates.

*See also*: **Non-wood Products**: Chemicals from Wood.

## Further Reading

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# Chemicals from Wood

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## Introduction

A wide array of both commodity and specialty chemicals can be derived from wood, either as a primary product or by-product of another process. The technologies in which chemicals are the primary products include thermal degradation, hydrolysis/fermentation, direct collection, and extraction methods. Chemicals collected as by-products generally come from fiber-producing processes, including pulp and paper and steam explosion. While cellulose, lignin, and derivatives thereof could be classified as chemicals derived from wood, the current review will be limited to low-molecular-weight chemicals from wood. The synthesis and utilization of various chemicals from renewable resources have received considerable recent attention through research efforts in green chemistry.

## Extractives

Perhaps the oldest of the chemicals produced from wood are those derived from the extractives. The term 'naval stores' provides a clue to the waterproofing applications for which these chemicals were originally used. The extractives can broadly be divided into terpenes, resin acids, and fatty acids.

### Terpenes

Terpenes are relatively volatile hydrocarbons based on isoprene (2-methyl-butadiene) units, and are the major components of turpentine. Turpentine was once produced largely by tapping trees and collecting the exudates, which after processing are called 'wood naval stores.' Currently, most turpentine comes from the sulfate pulping process, in which the volatile materials are removed by the action of heat and pressure in the digestion step. The volatiles consist mainly of the monoterpenes, α-pinene, β-pinene, and $\Delta^3$-carene, depending on the wood species (**Figure 1**). While turpentine was once used extensively as an industrial solvent, the monoterpenes are now modified into much more valuable products, used in perfumery, flavorings, and to some extent insecticides and disinfectants. Although most terpenes are now produced as a by-product of the pulping industry, the exception to this generalization is natural rubber production. Natural rubber (*cis*-1,4-polyisoprene) comes from *Hevea brasiliensis*, and is still collected by tapping living trees and collecting the latex sap.

### Resin Acids

The resin acids, the main components of rosin, are diterpenoids such as abietic acid, neoabietic acid, palustric acid, pimaric acid, and isopimaric acid (**Figure 2**). Rosins can be isolated from directly collected oleoresins, but are now more commonly separated from tall oil as a by-product of the kraft, black liquor recovery process. Metallic salts and esters of resin acids are used as additives to printing inks to improve gloss, mechanical stability and resistance to chemicals. Rosins are also extensively used in paper sizing and in rubber manufacture as emulsifiers and tackifiers.

### Fatty Acids

In addition to the resin acids, tall oil also contains fatty acids. Given the acidic character of both of these components and the very high pH in kraft black liquor, during the recovery process, the acids are converted to insoluble salts, referred to as soaps, that are skimmed from the concentrated black liquor. The skimmings are acidified to release the acids resulting in crude tall oil (CTO). Resin acids, fatty acids, and any unsaponifiable neutral compounds are separated by vacuum distillation. Among the fatty acids are oleic and linoleic acid. The fatty acids find applications in ore separation, metal working, rubber, as detergents, and as drying agents in finishes.

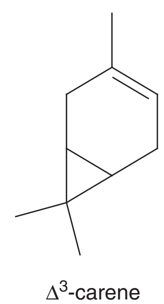


**Figure 1** Monoterpenes.