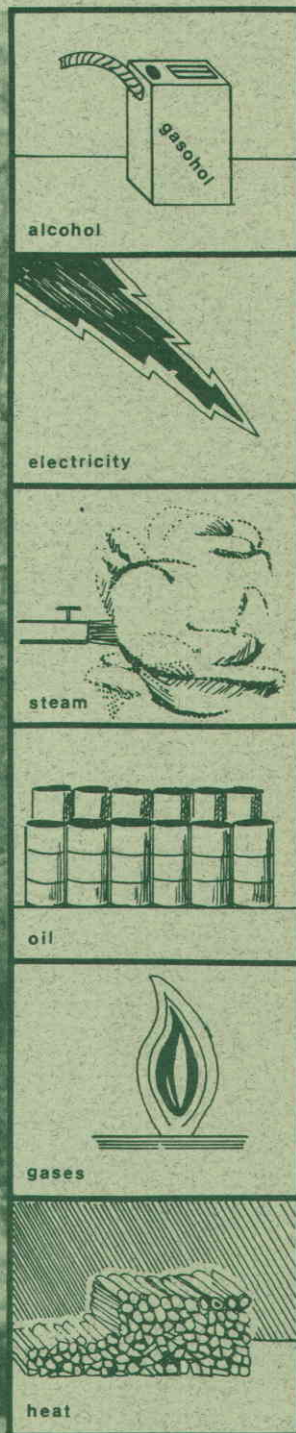


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# Wood for Energy in the Pacific Northwest: An Overview

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## ABSTRACT

This report presents an overview of the technology of converting wood to energy and the availability of wood.

The first section describes fuel values and significant processes used to generate various energy products from wood. Physical, technical, and economic availability of the wood resource is discussed in the second section. The paper concludes with an outline of some critical problems in handling wood and some socioeconomic factors that impact the production of energy from wood.

An extensive bibliography covers topics discussed in the paper.

KEYWORDS: Energy, biomass,  
wood utilization,  
Pacific Northwest.

## Introduction

Recent shortages of energy and rapidly escalating prices for natural gas and petroleum products have generated much interest in development of alternative sources of fuel. Wood, one of our most abundant renewable resources, has been the focal point for a great deal of this activity.<sup>1/</sup>

The objectives of this report are to present a summary of the state of the art of the technology of converting wood to energy and to discuss the wood resource base from which energy might be produced.<sup>2/</sup> The information is aimed at a wide audience at planning and management levels in both the private and public sector of the United States.

This report focuses on wood biomass, either from standing trees or the material left after harvesting and manufacturing operations. Other forms of biomass, such as agricultural and municipal wastes, will only be considered as they interface with wood in situations favoring use of multiple feedstocks for production of energy.

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<sup>1/</sup> "Wood," as used in this report, includes bark, unless otherwise specified.

<sup>2/</sup> "Energy" refers to a wide range of products, including electricity, steam, gases, oil, alcohols, and various chemicals.

Most of the data were drawn from sources for the State of Oregon. Less emphasis on the other Pacific Coast States does not imply that similar opportunities do not exist. In almost all cases, conclusions inferred from the Oregon data apply directly to Washington and California. The conclusions, however, may not apply to Alaska because of the special physical and socioeconomic circumstances prevailing in that State.

## Wood as a Fuel

Wood has long been used as a fuel for producing energy. The history of wood use for energy is well documented and need not be presented here. The issue is not one of new products, although there are a few, but rather one of advancing the technology of using wood for energy and of insuring adequate supplies for large-scale applications. In addition, the possibility of removing the total biomass from a given area has raised questions about future productivity of sites and stability of soil and water.

The forest products industry is the largest user of wood for energy in the Pacific Northwest. In 1976, about 4.3 million tons (dry weight) of mill residues were used for fuel, mostly by the industry itself (33). The primary use was to fuel boilers for steam or direct heat, and, in a few cases, for electricity (21, 37). Although not produced in large quantities locally, charcoal and various chemicals are also produced from wood. The forests of this region supply a great deal of fuelwood for residential consumption. Use of fuelwood has increased

considerably the past few years. Although data on consumption of fuelwood from all lands are not available, the USDA Forest Service reported that about 378,000 dry tons were removed from Oregon and Washington National Forests in fiscal year 1978. The trend in residential use would appear to be upward in light of recent increases in sales of wood stoves for heating homes.

The energy value of wood is usually measured in terms of its heat value, expressed as British thermal units (Btu) per oven-dry pound. Resin has a higher heat value than wood, about 17,000 Btu per pound (11). Thus, resinous softwoods have a higher heat value than hardwoods on a weight basis; however, hardwoods produce more Btu's on a volume basis because of their greater density. Energy values in this report are expressed on an *oven-dry* basis.

Actual heat values of wood do not vary significantly between species. Since moisture content has a greater impact on available heat than species, average values are used in most analyses. Various studies indicate the heat value of most softwoods to be between 8,300 and 9,000 Btu per pound (4, 11, 34, 50). The wood of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is estimated at 8,600 to 9,200 Btu per pound; the bark at 9,400 to 10,100. Bark values are generally higher because of greater concentrations of resin, less cellulose, and a higher proportion of lignin. Heat values for hardwoods range from 8,000 to 8,800 Btu. Red alder (*Alnus rubra* Bong.) is estimated at 8,000 Btu.

Little information is available on which to base estimates of heat values resulting from utilization of the whole tree. A higher proportion of bark in the upper stem portion would generally lead to higher heat values. In addition, the resinous nature of softwood needles would raise the heat values somewhat.

Material commonly used for fuel in the forest products industry is generally referred to as hogged fuel or "hog fuel." This fuel usually has a high proportion of bark with an average heat value of 8,500 to 9,000 Btu per pound. Although hog fuel from hardwoods is not marketed extensively in the Pacific Northwest, heat values should range from 8,000 to 8,500 Btu per pound.

Wood is a clean burning fuel and offers some advantages over conventional fuels, such as coal. The ash content of wood is very low, less than 3 percent by weight. Bark has a slightly higher level. The ash content of coal on the other hand is 3 to 5 times higher. Thus, disposal problems are fewer when wood is used as a fuel. Sulfurous compounds are a special problem encountered when coal or oil is burned. Wood, however, has a negligible sulfur content, making it easier to meet air pollution standards. A crucial problem in using wood as a fuel is meeting standards for smoke and particulate matter, which may require expensive equipment to comply with standards for visible emissions. Advances in the technology of combustion, such as fluidized bed burners, should aid in decreasing costs of meeting environmental standards in the future.

In certain situations, wood may be used in conjunction with other fuels to produce energy. The use of two or more feedstocks for energy production is referred to as cofiring. Cofiring may involve conventional fuels, such as coal and oil, or municipal and agricultural wastes in conjunction with wood. In general, the various feedstocks are not processed simultaneously, although this may be possible with certain technologies.

A new coal-fired electric facility, owned by Portland General Electric Company (PGE), is being constructed to accept wood for as much as 20 percent of its fuel, although such use is not now planned on a production basis. A Georgia Pacific pulpmill in Toledo, Oregon, uses hammer-milled tires as a partial source of fuel to produce steam. Wood and municipal waste are being considered as fuel sources for some pyrolytic processes elsewhere in this country.

A major advantage of cofiring is the use of a resource that does not exist in sufficient quantities to fully fuel an energy facility. This will be the case in many areas where municipal or agricultural wastes are being considered as fuels. Using wood waste as a backup source of fuel has been given consideration in studies of grass straw utilization. The wood can be used as fuel when seasonally produced fuels or supplies of other fuels are not available.

Certain problems are encountered when more than one feedstock is used for energy. Preparation and handling requirements of different fuels may necessitate additional equipment and thereby increase capital costs. Generally, materials have to be prepared so that physical properties are similar. Equipment for controlling pollution may have to be more flexible, again increasing costs. Finally, operation costs may be higher because of the need for increased monitoring of controls as feedstocks change.

## Conversion Technologies

Energy in various forms can be produced by combustion or by thermochemical or aqueous processing of wood. Figure 1 shows the common products that can be produced by each of these processes. The following discussion will describe each process and the resulting products.

### Direct Combustion

Direct combustion of wood is the oldest form of energy known, other than sunlight. In its simplest form, radiant heat is utilized from open burning in an enclosure, such as a fireplace or pit. Commonly used in homes, this process is inefficient; its main appeal is esthetic. Use of airtight wood stoves increases overall efficiency of burning fuel and thus offers some incentive to residents where fuelwood costs are reasonable. Although not very efficient overall, home heating does produce energy from wood that would not be utilized otherwise.



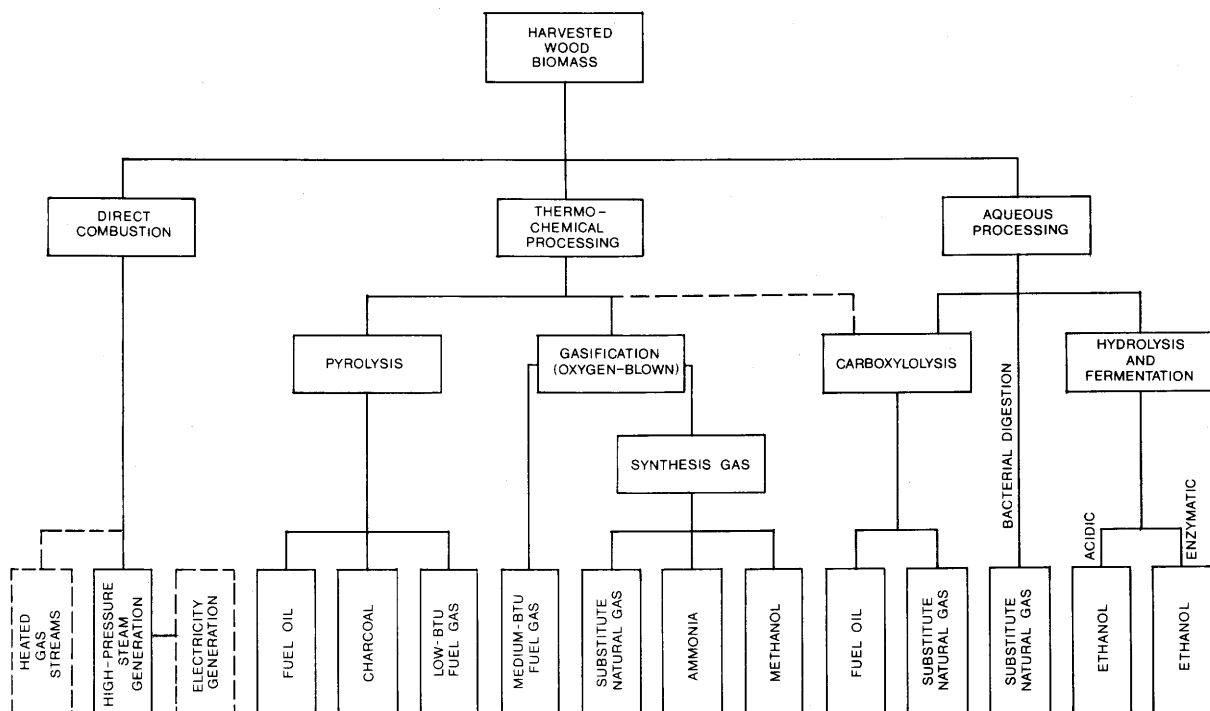


Figure 1.--Alternative conversion routes for producing energy-related products from wood (Source: Mitre Corp., Silvicultural Biomass Farms (50)).

Wood has been used as a fuel by industry for some time (2). Interest in hog fuel has increased considerably in recent years after a continuous decline from levels of the late 1800's. Regionally, the forest products industry is the major user of hog fuel. Many mills utilize boilers to produce steam for operating equipment, drying products, and, in some cases, generating electricity. The largest non-forest industry user of wood for energy in Oregon is Eugene Water and Electric Board. This local utility consumes about 240,000 tons annually, producing both electricity and steam for local businesses (7).

Several combustion systems are available which can utilize hog fuel. The most common burners in use are the fixed-

and moving-bed variety. Prior to 1940, most burners were two-stage furnaces referred to as "Dutch ovens"; in these systems, fuel is fed into a firebox where moisture evaporates and partial gasification occurs. The hot gases are then vented into the boiler where combustion is completed and steam produced. A more recent version of the Dutch oven, the fuel cell burner, is highly automated and uses a water-cooled grate. This unit is commonly used to heat kilns at sawmills.

Newer burners utilize inclined, pinhole, or moving grates. For the most part, these burners do not require gas or oil for overfiring, as do many older types. Fuel is introduced into the furnace via mechanical or pneumatic stokers, and combustion occurs in suspension and on the grates. Moving or dump grates have the added advantage of making removal of ash easier.

For suspension burners, often used for combustion of coal, the fuel must be reduced to fine particles. In this type of burner, the fuel burns in a large fireball above the grate. Burners of this type using wood have been employed to overfire existing boilers. A disadvantage of this type of burner is the added effort and cost required to reduce wood to the necessary size. An exception is sander dust which burns well in suspension.

A newer type of suspension burner is the cyclonic variety (19). This system uses forced air to hold fuel in suspension until combustion is complete. These burners are small modular units with broad application for drying chips or solid wood products and generating steam (10, 13, 36). In one case, installation of wood-fired cyclone burners for drying veneer resulted in annual savings in fuel costs of \$450,000 (21, 69). It should be noted that these savings were based on mill residues having zero value, which is not the case for most mills.

Much interest has recently been generated concerning the combustion of wood in fluidized-bed burners. This concept involves passing a gas stream, such as air, upwardly through a bed of inert particles (5, 19, 41, 44, 52, 54). This agitated, fluidlike bed results in high heat and high mass transfer rates. Lower bed temperatures reduce sintering and agglomeration of ash and thus facilitate removal. A special advantage of this type of burner is the ability to burn

fuels of various sizes and moisture contents. One such burner being tested in Washington operates on a mixture of millyard waste, wet sawdust, old chips, and sawmill end trim. A burner such as this can play an important part in overall management of mill residues and waste. Another advantage of the fluidized bed is the ease of handling noncombustibles, such as metal or rocks. Results from early tests also indicate very low levels of particulate emissions (44).

As will be discussed later, fluidized-bed reactors are being tested for the gasification of wood. This system, using coal or municipal wastes, has been used extensively in Europe for many years (31, 47).

The preceding discussion focused mainly on the production of steam or process heat for industrial use. Generation of electricity--an alternative that has captured much interest lately (17, 18, 26)--at a central power facility appears to be economically questionable at this time. Several factors act as impediments to generation of central power. Economies of scale favor large thermal powerplants. Current technology, however, limits the size of wood-fired boilers so that generation of electricity in excess of 100-150 megawatts (MW) is not practical. Most existing or planned wood-based facilities are 50 MW or less. A second problem associated with size is that of fuel supply. For example, a 100 MW plant operating at 75-percent capacity would consume about 600,000 dry tons annually. A long-term supply of

this quantity of wood cannot be assured (46). In addition, there are special problems in handling and storing this mass of material.

Several studies have shown the price of wood-fueled power to be competitive with new conventionally fueled plants (7, 38, 50). Although the data base for these conclusions is not especially strong, a more pressing concern is the existing pricing structure for electricity. Many people consider the low-cost electric power in the Northwest to be a major deterrent to small scale, nonutility generation of electricity from wood. In general, most consumers of industrial power consider it cheaper and less troublesome to continue purchasing electric power than to install equipment to generate their own power.

The general environment surrounding power generation is constantly changing and varies throughout the country (24, 30). More costly power and less certainty about future supplies spurred the city of Burlington, Vermont, to pass a bond issue for a 50-MW wood-fired powerplant (30).

A concept currently receiving much attention is cogeneration. This is defined as the concurrent production of process steam and electricity from a boiler system. This has most frequently been done at pulpmills utilizing kraft black liquor as the fuel source. Faced with rising prices for power and the potential for interrupted supplies, the forest product industry has been giving this concept much attention lately.

There are many options for equipment to produce steam and electricity, depending on a mill's needs. The choice of turbines ranges from fully condensing turbines to extractive turbines which allow removal of steam at various pressures. Back pressure turbines, of which extractives are a variety, vent steam at relatively low pressures for industrial use. The proper choice of equipment depends on steam requirements and quantity of electricity needed. In some situations a plant may sell both steam and electricity to outside users and thus enhance the economics of the operation.

A major deterrent to extensive application of cogeneration is the existing marketing structure for electricity. It is difficult to find outlets for privately generated electricity. Local utilities will frequently pay only a portion of the cost of the power. Thus, nonutility producers must look elsewhere for purchasers. By working with Bonneville Power Administration (BPA), ~~U.S. Department of the Interior~~, through its power management position, customers outside the region may be found. If a contract is secured, power can be wheeled throughout a complex trading system.

A major breakthrough in power generation could occur if BPA was able to purchase power under a roll-in pricing scheme. Under this framework, higher cost new power is averaged in with existing cheaper power. The result would be slightly higher prices and larger supplies for all users. Given the authority, BPA might also trade power with the small producer. A



possible drawback is that BPA might need power at the same time as the producer.

Aside from the problems mentioned above, cogeneration is the most likely candidate for short-term increases in power supplies (16). Even with no changes in the marketing structure, the threat of a power cutoff might result in installation of steam-driven turbines (56). Some larger mills in the region currently sell or trade electricity, and a number of mills are closely scrutinizing this option.

### Pyrolytic Conversion

Pyrolytic conversion of wood into energy-related products is not a new process. Charcoal has long been made by this process. What is new is the diversity of products being considered and the advancing technology on use of reactors. Although fairly common in Europe, the use of pyrolytic techniques to produce gases and oil is just emerging in this country. Most applications to date have used coal or municipal waste as feedstock (31).

A dichotomy in terminology exists in describing this process. When the feedstock is heated to temperatures below 600°C, the process is usually referred to as *pyrolysis*. Products at this level of thermal degradation are gases, oils, and a considerable amount of char. At temperatures above 600°C the process is called *gasification*, resulting primarily in vaporous products with much less carbonaceous residue (6, 14, 28, 67). Both pyrolysis and gasification involve thermal degradation of organic matter in an oxygen deficient atmosphere.

The gas produced by this process is referred to as low Btu gas. The gas has a heat value of 150-300 Btu per cubic foot and is composed of hydrogen, carbon monoxide, methane with smaller amounts of nitrogen, and carbon dioxide (6, 19, 28, 44). Because it is laden with tars and oils and has a low Btu value (natural gas is about 1,000 Btu per cubic foot) low Btu gas must be consumed close to the production point. Low Btu gas can be converted to pipeline gas or substitute natural gas by a process called methanation. The result is greater transportability, but at a higher cost.

Currently, no significant market exists for low Btu gas. This situation could change radically, however, if legislation restricting consumption of industrial natural gas was enacted. In this event, segments of industry might start producing their own gas rather than converting to other energy sources, such as electricity.

Another product of gasification receiving attention recently is methanol (22). Methanol is produced by further refining low Btu gas by catalytic conversion of methane. Methane is currently made from natural gas and has a wide variety of uses, the most significant being conversion to formaldehyde (40).

The interest in methanol focuses on its use as a fuel for internal combustion engines. As an additive to gasoline (usually 10-20 percent), forming a product called gasohol, methanol increases power and burns cleaner. Disadvantages of its use are fewer miles per gallon, vaporization, phase separation due

to water contamination, and effects of corrosion on existing fuel systems (1). There are indications that use of pure methanol rather than blends would better utilize its unique properties (1). For existing cars this would require modification of the fuel-feeding system and an increase in the capacity of the tank.

The greatest drawback to the use of methanol or ethanol as a fuel for cars is cost. Most studies indicate that methanol from wood will currently cost from two to three times as much as gasoline at the plant gate (1, 51, 63). Cost aside, recent legislative activities indicate that the use of methanol as a gasoline additive may be decided by public policy at the national level.

One further concern in the production of methanol is the net balance of energy. As much as 62 percent of the energy value of the feedstock is required in the production phase (38).

Other products, such as ammonia and furfural, can be derived from pyrolytic processes. Conventional sources are now readily available and cheaper to use. Thus, unless taken as a credit during multiproduct processing, large-scale generation of these products is unlikely within the existing economic environment.

Another product of pyrolytic conversion of wood is substitute fuel oil. These oils can also be produced by a process known as carboxylolysis. This term describes a process by which wood fiber is catalytically converted to oil in the

presence of carbon monoxide and water at temperatures of 250°-400°C and pressures of 2,000-4,000 psi (47, 50). A pilot plant utilizing this technology is operating in Albany, Oregon. Oil from pyrolysis or carboxylolysis is similar to Number 6 residual oil now being used by industries and for generation of electricity. The wood-based oil is more viscous than Number 6 oil, has a lower sulfur content, and is somewhat more corrosive. Blending of Number 6 oil with the wood-based oil has been considered to take advantage of the better qualities of each (47). Currently, the economics of wood-based oils are not favorable; however, rising petroleum prices and a generally increasing demand for fuel oils indicates potential for the future.

## Hydrolysis and Fermentation

This process utilizes hydrolytic agents, such as sulfuric or hydrochloric acids or enzymes, to depolymerize cellulose into sugars. Ethanol can then be produced by fermentation of the sugar. Some interest in sugars is generated where conventional sources are not available. Such is the case in the Soviet Union (50). In this country, the interest is in ethanol for industrial feedstock or as a gasoline additive. A pilot study now underway in Nebraska is testing the use of a 10-percent mixture of ethanol; this "gasohol" sells for about 6 cents per gallon more than pure gasoline. Studies to date indicate that ethanol produced by this process is not competitive in cost and has a very low net energy balance (1, 40, 50).

## Bacterial Digestion

Production of a gas containing methane and carbon dioxide by bacterial digestion of wood has received some attention. The process is aerobic (oxygen using) or anaerobic (oxygen deficient) and uses the digestive capabilities of various microorganisms (50). The process is slow and requires constant monitoring of temperature. There is some indication that the lignin in wood may be toxic to the bacteria.

Bacterial digestion is not now considered a significant fact or in producing energy from wood; animal and municipal wastes are more favored sources.

## The Resource Base

The intent of this section is to describe the characteristics and availability of various sources of wood that may be used for energy. Quantities of wood from the various sources will be discussed where data permit. The general thrust is to bring into focus the physical and economic factors affecting the availability of the resource for production of energy. Analyses of case studies of the availability of wood for a specific energy facility are site specific and thus beyond the scope of this report. The discussion that follows points out the potentials and shortcomings of existing resource data as they pertain to energy. The availability of wood for fuel is to a great degree a function of the dynamic economic environment and competition from conventional products.

## Mill Residues

Mill residues are generally viewed as a first-line source of wood feedstock for energy and are used as such by the forest products industry. The advantages offered by mill residues are apparent. They are in a convenient form, are readily accessible, are generated in fairly large quantities, and are the cheapest form of wood fiber. The total quantities generated tend to be misleading. In 1976 about 15.4 million tons, dry weight, of wood and bark residues were created by the forest products industry in Oregon (33). Of this total, however, only 510,000 tons were reported as unused. This lesser volume represents the most likely source for new products, such as energy. As is indicated by figure 2, no significant concentration of unused residues exists in the State.<sup>3/</sup> The situation in the northeast part of the State has changed since 1976. A large, wood-fired boiler has been installed at a pulpmill at Wallula, Washington. Contracts for hog fuel have no doubt greatly reduced the unused volume in the surrounding area.

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<sup>3/</sup> This map and the one shown in figure 3 indicate the quantity of mill residues, by volume class, tributary to various locations within the 50-mile-radius supply zones noted. The volumes are not additive, however, since the supply zones overlap. Thus, care must be taken in assessing the number of opportunities for generating energy in the State.



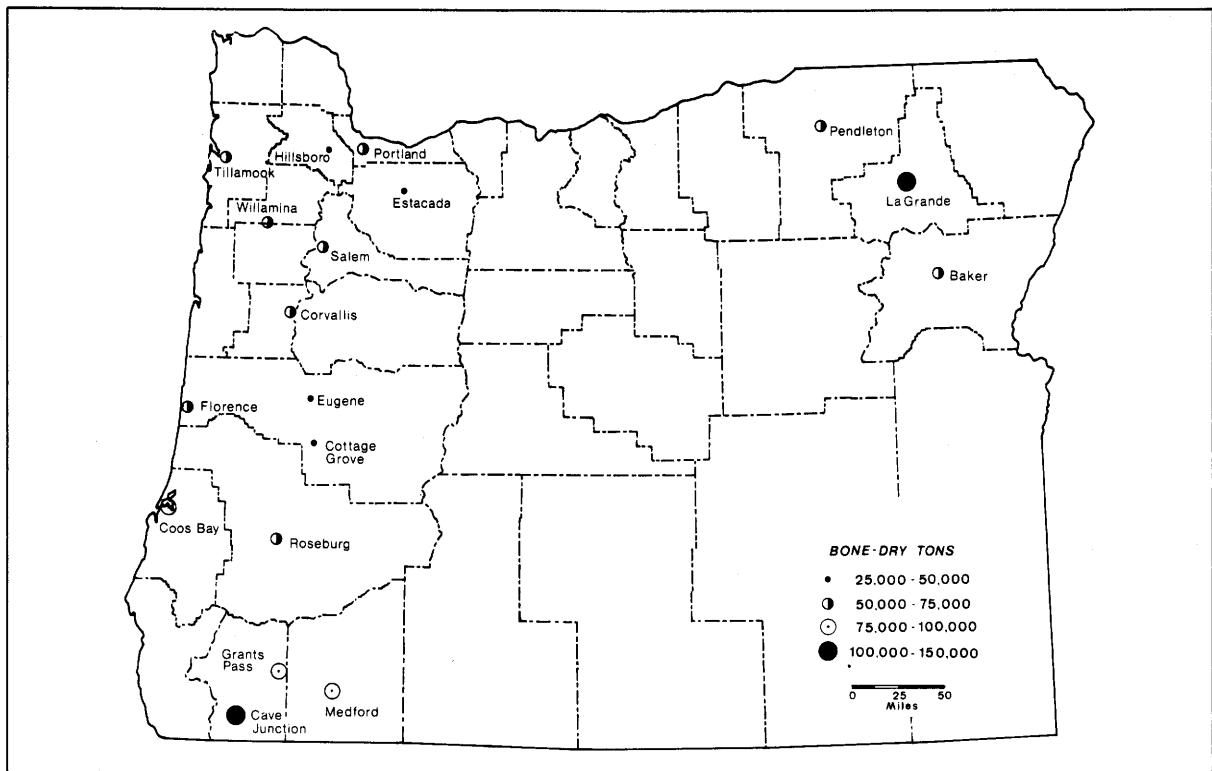


Figure 2.--Quantity of unused mill residues within 50-mile supply zones of selected cities.

To put these quantities in perspective, a 50-MW powerplant would require about 250,000 bone-dry tons of hog fuel annually (operating at 75 percent of capacity). As figure 2 shows, no location in Oregon has this quantity in its supply zone. The 50-mile supply zone was the consensus from various studies as a reasonable distance for wood residues to be transported to a central energy facility. In practice, residues are transported farther than 50 miles; the end value of the final product is the determining factor.

As the value of energy products increases it is likely that residues now used for low-value products, such as mulch and decorative bark, may be used for energy. Although all residues now used for miscellaneous purposes, as defined by the 1976 Oregon industry survey (33), may not be available for energy, some will be bid away from other uses. Figure 3 indicates the volume of "unused" plus "miscellaneous use" residues for a 50-mile supply zone. These volumes represent physical existence only. Competing uses and the difficulty of securing long-term contracts will considerably reduce the volume available for energy in today's economic environment.

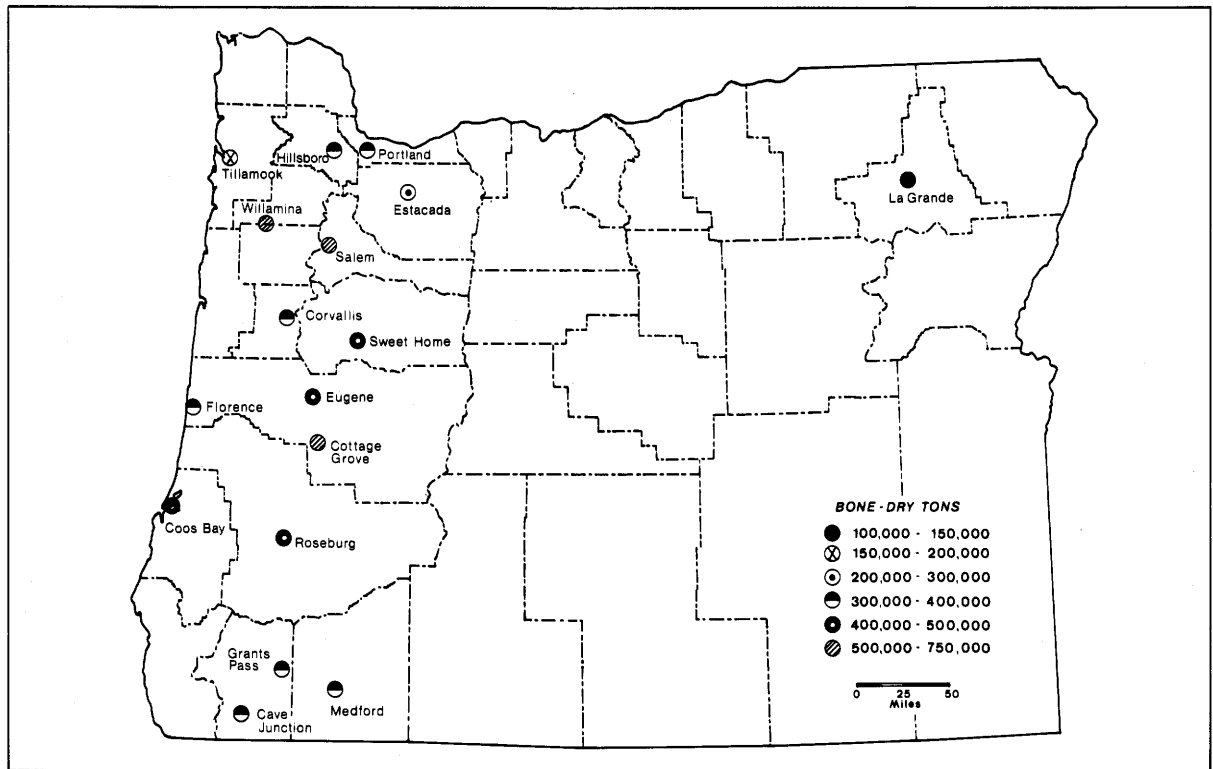


Figure 3.--Quantity of unused and miscellaneous use mill residues within 50-mile supply zones of selected cities.

Cogeneration within the forest products industry in the Pacific Northwest is a likely candidate for immediate additions to the area's supplies of electricity. Within the forest products industry, large volumes of residue are used as boiler fuel, about 4.3 million tons in 1976 (33).<sup>4/</sup> In plants where steam is now produced, generation of electricity would require less additional input than at a central powerplant. Thus,

<sup>4/</sup> Although a portion of the total volume of residues used for fuel was consumed outside the industry or for general heating, by far the majority was used for boiler fuel.

significant opportunities exist to generate electricity--coupling residues presently used for boiler fuel with those now unused or used for low-value miscellaneous purposes. Although cogeneration may not be feasible for each mill, it may provide a physical or economic alternative for clusters of mills close to each other.

Cogeneration will probably increase in importance in this region. Difficulty in securing adequate supplies of residues may restrict expansion for some mills. In addition, competition from conventional products and other types of energy will impact the level of electrical output in the future.

## Logging Residues

The volume of logging residues throughout the Pacific Coast is very high and represents significant potential for production of energy (8, 27). The main concerns are not about total volume, however, but of cost and future availability. The latter is a factor of increased utilization of residues for conventional products and a shift from old-growth to young-growth forests.

Three characteristics distinguish logging residues from mill residues as a resource base for energy. First, they are not in a readily usable form. At the minimum, chipping would be required. Second, they may have to be yarded to a loading point before they are prepared or transported—a relatively high cost to be borne by low-value products, such as energy. Finally, they are usually located some distance from processing facilities and thus incur higher costs for transportation. The fact that residues are not used for higher value conventional products says much about the economics of their use for energy.

Most studies of the energy potential of residues are using out-of-date information. The major point, however, is still valid; large quantities of logging residue exist if the means can be found to utilize them in an economically viable manner.

Data for the 1980 national timber assessment indicate a total of 181 million cubic feet of logging residues are generated annually in western Oregon (32, 64). For eastern

Oregon the total is 26 million cubic feet. Converted to weight on the basis of 25 pounds per cubic foot (dry basis), the total for Oregon is over 2.6 million tons; this figure refers only to the growing-stock portion of logging residues. The non-growing-stock<sup>5/</sup> portion is roughly equal to the growing-stock portion. Thus, the total volume for Oregon expands to about 5 million oven-dry tons annually.

Also not taken into consideration is the material less than 4 inches in diameter. Little definitive work has been done on measurement of total biomass of logging residues. Data from a recent study give a hint of the possible magnitude<sup>(50)</sup>; from information compiled from various sources, the main-stem portion of logging residues is estimated to be slightly less than 50 percent of total biomass. By this standard, total biomass of logging residues in Oregon would be approximately 10 million dry tons. Maintenance of site productivity, however, requires leaving some material on the ground. Suffice it to say there is a considerable volume of material that could be converted to energy or related products. The 10 million tons quoted above could fuel forty 50-MW plants for a year.

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<sup>5/</sup> Volume from previously dead, cull, or noncommercial trees on harvested areas.



Estimates of costs of removing logging residues range from \$20 to \$40 per ton, depending on various physiographic and technological factors. This is equivalent to 16-40 mills per kilowatt hour (38, 50). Add to this the costs of transporting, preparing, and processing the residues and it becomes apparent that production of electricity from logging residues is at a disadvantage in today's market, where it must compete with prices that include large quantities of cheap hydropower. Even if the above costs are conservative, electric power--or almost any energy product--cannot compete with the average cost of conventional sources. A change in the existing pricing system for electricity would make the situation more favorable. But even this would prompt use of more readily accessible sources, such as mill residues. Sharing the costs of removing residues, up to the benefits to land management, will be discussed later.

The situation surrounding logging residues is dynamic and presents problems in projecting future volumes. Increased demand from conventional products, more efficient techniques and equipment for harvesting timber, and a shift toward young growth will act to reduce future volume and concentration of residual materials. This uncertainty about future supplies presents special problems for central power facilities for capital investments with long payoff periods. Investors are reluctant to finance construction when long-term supplies of raw material are in doubt.

## Mortality

It is doubtful that naturally occurring mortality, because of generally low concentrations per acre, will be a major factor in this region's energy picture. If a significant market for energy existed, there might be greater utilization of lower quality logs.

Catastrophic mortality, on the other hand, may make significant contributions to future needs for energy. In the case of major fires, salvage for conventional products may account for most of the volume. There may be, however, greater volumes of residue created by milling of these trees.

Epidemics of insects or disease, such as the tussock moth and mountain pine beetle outbreaks in northeast Oregon, offer substantial opportunity for production of energy. Studies by Oregon State University indicate that insects have killed approximately 1.3 billion board feet of timber in the Blue Mountain area over the past few years (12, 70). Much of this volume has value for solid products and pulp chips. Some of the material is not suitable for these products but has much value for energy products. This proportion will increase as the trees deteriorate in quality over time. A multi-product operation, including energy, would be a most likely approach to utilizing this fairly large volume of timber. Such a facility, however, must be predicated on assurance of obtaining adequate supplies of dead timber for many years.

It has been estimated that timber killed by insects in northeast Oregon will be physically available for energy for 20 years. Thus, an energy-producing facility could be established with an adequate supply of material for a period long enough to write off the investment. This alternative, along with proposals for overcoming institutional constraints to long-term contracts, is being considered in a study by Oregon State University funded in part by the U.S. Department of Energy.

### Hardwoods

Hardwoods, particularly on the west side of the Cascades, currently represent a little used resource. Many forest managers consider hardwoods an impediment to management of more desirable softwoods. Although some mills process hardwoods, mainly red alder, the timber inventory is enormous when compared with harvest. A recent survey of the forest industry (33) shows that only 65.5 million board feet (about 13 million cubic feet) of hardwoods were utilized in 1976. Recent inventories of western Oregon (3, 35, 49) show a roundwood volume of 4.8 billion cubic feet. As can be seen, the harvest is less than one-third of 1 percent of inventory volume.

The inventory figure stated above does not represent the total biomass of hardwoods, nor does it include volume on noncommercial land. From the little solid data existing, the total biomass of hardwoods is estimated at roughly one-and-two-thirds times the reported inventory volume. By this rough rule of thumb, the total volume of

hardwoods suitable for energy is over 8 billion cubic feet. All of this volume, of course, is not available for energy-or other products, for that matter. Many private owners may not offer timber for sale at any price, much less at prices low enough to make energy products economically competitive. Some of the better quality timber will be used for higher value products, such as furniture. In addition, scattered pockets of hardwoods may not be economically retrievable. Even one-half of the available volume, however, could support five 50-MW electric plants for 30 years.

Hardwood stands are presently being converted to softwood in some areas. This is a costly practice but deemed necessary by those land managers desiring to return these productive lands to softwood types. The availability of energy markets for the bulk of this material might provide an impetus for increased stand conversion. Preliminary estimates supplied by the Industrial Forestry Association indicate that 6,000 acres of hardwood were converted to softwood in 1977. This figure is considered somewhat conservative and includes only lands owned by forest industry. There are about 2,700,000 acres of hardwood type in western Oregon. Obviously, all areas will not be converted to softwoods. Yet, a large portion of the area will yield greater volumes in the long run if hardwoods are converted to coniferous species and produce fuel for energy in the process.

It is obvious from these figures that significant potential exists to augment regional supplies of energy through increased use of the hardwood resource.

### **Silvicultural Materials**

Residues generated during silvicultural operations (thinning, stand release, or site preparation) may serve as a source of raw material for production of energy. Some estimates are available for acres treated by these practices, but little is known about volume removed. Even less is known about the total biomass treated.

Advances in technology aimed at utilization of the whole tree may increase the quantity of material available for energy. The opportunities lie with greater recovery of fiber content through removal of the entire tree. Relogging of treated areas is generally not feasible because of potential damage to residual trees. For treatments such as site preparation, reentry may be impractical unless done before the new stand is established. In general, additions to raw material supplies for energy will be from tops and branches of trees and from trees currently below commercial size. A new market for this type of material, such as for energy, could provide the impetus for increased silvicultural activities. A major question, however, is how much material could be removed without deleterious effects on levels of soil nutrients(42, 43).

### **Brush Species**

A large quantity of brush exists on forest lands throughout the Pacific Coast States. Many of these areas require treatment to return the site to full productivity. It is doubtful, however, if much of this type of material will be converted to energy in the near future. Little is known about the cost of removing and handling brush or the equipment necessary to accomplish the task. Another unknown is the factor brush plays in maintaining nutrient levels of the soil. Many questions would have to be answered and the economics improved before brush could be considered as a source of supply for energy in this area.

### **Biomass Farms**

The use of short-rotation tree farms to provide wood for energy has gained much attention in the past few years (9, 20, 50, 57, 60, 61, 71). The concept entails intensive short rotation (usually 2-15 years) management of closely spaced, fast-growing trees. Hardwoods are most frequently considered because of their ability to propagate by coppicing.

Results of studies of species indigenous to the Northwest indicate yields from 4 to 33 tons (dry weight) per acre (15, 23, 29, 45, 50, 60). Yields of 10 to 20 tons per acre were frequently recorded. A shortcoming of most of these studies is the relatively small sample plots--some were only one-thousandth of an acre. There is some doubt whether these levels can be sustained on larger areas (20).



A number of issues remain unanswered concerning the concept of plantations for energy. The costs of large-scale plantations have yet to be established. Unknowns include the requirements and costs of fertilizing, irrigating, and harvesting. There is some uncertainty as to the success of repeated coppicing. Planting a new crop would increase costs significantly. Another factor relevant to the broad issue of alternative sources of wood for energy is the net energy balance of plantations. A major concern here is the potential dependence on petroleum-based fertilizers.

Technically, energy plantations are feasible. Their application centers around economics and development of necessary equipment. Possibly a more crucial question is that of availability of land. The data below provide a reasonably good estimate of land requirements for a 150-MW powerplant (20).

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Sustained-yield productivity and land needs for a 150-MW power unit

<u>Ovendry tons per acre per year</u>	<u>Acreage required</u>
1	620,000
5	120,000
10	62,000
15	41,000
20	31,000

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As can be seen, even with high, sustainable yields acreage requirements are high. Smaller facilities would obviously require less acreage. The problem of land availability comes into focus when specific locations are considered. Gentle terrain with adequate water supplies are paramount for success. In the Northwest most areas fitting this description are currently

producing other crops or are within urban zones. Many areas in eastern Oregon, although having moderate slopes, suffer from restricted water supplies (50); where available, warm water from industrial processing, such as from pulpmills or thermal powerplants, could be used for irrigation of plantations.

A study in Washington should provide data for answering some of the above questions (59). This study was conducted in powerline rights-of-way. Utilizing the productive potential of these nonproducing lands could add valuable acreage to the region's declining commercial forest land base. The study was designed to produce cost and yield data for a number of management regimes on 1/4-acre plots, somewhat larger than in most studies.

Biomass farms offer advantages over other forms of fiber production through increased efficiency of harvesting, short waiting periods for cash flows, and lower regeneration costs via coppicing. Chief disadvantages are higher costs per acre for establishment and management, restrictions on available land, genetic problems associated with monoculture, and the impact of devastation by fire or wind or outbreaks of insects or disease.

Few studies indicate short-term application of large-scale energy plantations in the Northwest. Major determinants are cost and availability of underutilized sources, such as logging residues. The opportunity may be best for an independent energy facility desiring a guaranteed supply of raw materials.

# Materials Handling

## Preparation

Most systems for converting wood to energy have strict requirements concerning the size, form, and moisture content of wood or bark fuels. Most sources of wood, mill residues being the usual exception, must be modified to some degree to meet these requirements(39). Roundwood is usually hogged or chipped to produce what is called hog fuel. This is not a common practice, however, as mill residues currently meet most of the demand for energy. Wetter types of hog fuel are usually passed through a drying phase to attain the desired moisture content. Hog fuel from mill residues are frequently dry enough to avoid this phase; however, water absorption during storage may present problems. Drying of large quantities of hog fuel is a problem in terms of cost and time. Some integrated systems use the fines (sawdust, for example) to fire drying furnaces or modular units, such as the cyclone burners previously discussed. Some fluid-bed reactors do not require all material to be dried if a proper mix of high- and low-moisture content feedstock is maintained.

Drying of fuels is a critical factor in determining efficiency of the overall process. Corder (11) indicates heat loss of 13 percent for wood fuel at 100-percent moisture content (dry basis),

and 26 percent at 200-percent.<sup>6/</sup> In addition to causing a loss of realized heat, excess moisture acts to retard combustion. Difficulty in maintaining combustion occurs when the moisture content exceeds 200 percent.

Suspension burners, such as will be used by PGE's Boardman coal plant now under construction, require that the feedstock be reduced to fine particles. This is usually accomplished by hammermilling and screening. The added costs, however, reduce the competitiveness of wood compared with more easily pulverized fuels, such as coal--sawdust and sander dust being exceptions.

Densification of wood fiber by pelletizing has recently received much attention. In this process, wood--usually hog fuel--is dried and compressed into cylindrical pellets. Based on early findings, major advantages of this procedure are uniformity in size and moisture content, reduced storage requirements, and clean burning. Pelletizing is not required for some conversion systems and represents an unnecessary cost. On the other hand, the pellets are ideally suited to the needs of small installations, such as those in schools or hospitals for direct heating or steam production.

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<sup>6/</sup> All moisture contents are stated in terms of dry basis; that is, the weight of water relative to the weight of the wood portion. These moisture contents can be converted to wet basis by the following formula:

$$MC(wet) = \frac{100 [MC(dry)]}{100 + MC(dry)}.$$

There is some evidence that the resins in bark provide some of the adhesive agents that assist in preventing physical deterioration of pellets. Thus, it may be necessary to mix bark with wood residues from some manufacturing operations. Normally, hog fuel contains more than an adequate proportion of bark. Bark also increases the value of pellets because of its higher heat value compared with wood.

Analysis of the long-term potential of pelletizing is hampered by lack of available operational data and costs. Figures quoted at a recent hearing in Eugene indicate the cost of pellets to be about \$20 to \$24 per dry ton, f.o.b. mill--about three to five times higher than hog fuel, at \$5 to \$7 per dry ton. It does compare favorably with Wyoming coal at \$20 per ton, which has approximately the same heating value per pound.

### **Transportation**

Unless a source of fuel, such as onsite mill residues, is adequate for all energy needs, transportation of materials is a major factor in determining economic feasibility of energy production. Four modes of transportation are usually given consideration for movement of wood: trucks, railroads, pipelines, or conveyor systems. Barges have been considered but are limited to facilities on or near a navigable river.

Trucking usually costs least and is most adaptable for transporting wood fuels. Trucks are flexible enough to reach remote locations and handle small quantities of fuels. The extensive road network favors the use of

trucks over other transportation with more restricted avenues of movement. In the case of in-woods chipping, trucks offer the only reasonable alternative. Trucks are also better able to meet the fuel needs of an immediate increase in energy production. Trucking costs are somewhat site specific, depending on type of roads, discounts, tax structure, contract specifications, and equipment. Average costs used in various studies range from 10 to 17 cents per ton-mile. One component of this cost being given careful consideration is the weight-mile tax currently levied against all hauling of commodities. This tax tends to favor high-value products over low-value products, such as hog fuel. Various political bodies are examining this tax in terms of its impact on use of wood for energy. A reduction in the tax would obviously reduce costs and thereby increase the competitiveness of wood as a fuel.

A study in Vermont (30) considered the merits of trucks versus railroads for hauling chips to a central power facility. Complete use of rail systems and trucking to dispersed railheads were examined. Trucking was concluded to be the cheaper of either rail-oriented option. Much of the cost differential was attributed to the additional handling of the chips between trucks and railcars.

Hauling of hog fuel by rail is currently practiced, primarily to move mill residues. This is a viable alternative where processing facilities lie on an existing rail network. Building of spur lines would be prohibitive for most energy-related operations.



Use of rail delivery for energy production might be favored at large-scale central facilities but not for widely scattered, small-scale ones. The general push, at least politically, is for decentralized production of energy. Thus, the use of railroads to haul fuels would be less advantageous. The key here is the cost associated with delivery and handling of materials from woods or concentration yard to rail-head. Smaller facilities could best be served by trucks loaded in the woods where reloading into railcars would not be necessary. Larger facilities, requiring a greater volume of fuel, could reach farther and thus amortize the reloading costs over greater distances. This would enable them to use a rail system if one was close.

Conveyor belts are frequently used for onsite movement of residues within the forest products industry. Conveyor systems in excess of 1 mile in length are used to move chips between adjacent processing centers. The major disadvantages to the use of conveyors are cost and inflexibility. Costs of installation are high, especially when rights-of-way must be secured. Although these systems can be moved, time and cost are a major consideration. Figures from a recent study of energy plantations (50) place the cost of installing a conveyor system at \$250 per foot. At this rate, the installation cost of 1 mile of belt would exceed \$1.3 million.

Pipelines are also expensive and are stationary. Some consideration was given to construction of a pipeline for transporting Wyoming coal to eastern Oregon. Actions were deterred by relatively high costs of construction and difficulty in obtaining permission for access along the proposed route. An additional problem associated with pipelines is the requirement for large quantities of water. For example, movement of 1,400 tons of chips would require about 2 million gallons of water (66).

### Storage

Problems in storage of wood generally relate to the scale of operation and rotation of inventory to avoid deterioration. Fewest difficulties are encountered when materials are used at the same location and time as they are created. This obviously eliminates the need for storage areas, except as a safeguard against shutdown of the residue-producing facility. Therein lies the advantage of the forest products industry as generator of energy from mill residues.

Deterioration of wood fuels depends mainly on length of time in storage and degree of protection from the elements. Potential problems can be mitigated by proper rotation of the inventory. Other problems encountered in storage are fires, freezing of materials in colder climates, and increased moisture content from precipitation. Where materials are constantly being created, such as in the forest products industry, these problems or their impacts are not as significant.

## Institutional Factors of Energy Production

Many institutional factors affect new sources of energy. Some are local, and others are national with political origins. Some of the significant problems are summarized below.

Marketing of both energy and fuel supplies are an area of major concern. The current pricing structure of electricity, for example, does not favor generation by nonutility companies. Few new sources of energy can compete with the existing prices which are average prices from existing sources, including low-cost hydropower. Private utilities will purchase some power but at prices as low as one-tenth of its market value. Marketing of power through the BPA grid is possible where customers can be found, usually in California. This entails a marketing fee of about 3 mills/kWh which further reduces the competitiveness of new sources. A generally more positive approach to marketing of small-scale power and the use of roll-in pricing would open the door to greater production of electricity by nonutility companies, especially the forest products industry. BPA is currently giving some attention to this situation. Enactment of statutes giving BPA power to purchase energy is being considered.

On the other side of the coin is the supply issue. Securing an adequate supply of wood is a problem voiced by most potential producers of energy. Development of a contractual procedure by which public landowners could insure a long-term supply of underutilized material would be a major breakthrough. The prospects for this do not look bright. There is no legal framework for this type of action, and competition from other uses of wood is a complicating factor. A similar environment exists in the industrial sector. A recent study of the Eugene area (46) indicated a general reluctance on the part of millowners to enter into any type of long-term contract to supply residues for energy production. At best, some of the suppliers would agree to a year-to-year basis, leaving the price negotiable. This situation does not favor construction of an energy facility with a writeoff period of 15 to 30 years.

Existing tax structures also affect the energy situation to a great degree. Placing privately financed energy facilities on the property tax rolls increases costs of production. The question raised here is whether these facilities are in fact pollution control efforts which enables them to be placed in a tax exempt status (66). A policy favoring the use of biomass for energy might require a major overhaul in property tax laws. Changes in State and Federal tax laws governing depreciation of capital investments could have positive effects on production of energy by nonutility companies.

Incentive programs have been and will continue to be an important means for stimulating research and development of various forms of energy. Much of the effort in this area has been focused on high technology solar energy, which has little impact on the use of biomass. Increasingly, however, efforts have been stepped up by the U.S. Department of Energy and other agencies to stimulate research into the use of wood for energy. Although incentive programs are valuable tools, economics is the overriding factor in terms of adaptation of technology. The message is that the product must be competitive and profitable. These criteria, for example, apparently are not met by methanol production from wood at this time.

A topic being discussed is sharing the cost of removal of raw material to the extent of benefits to the land or landowner. A case in point is logging residues on National Forest lands. It appears that the cost of removing these residuals for energy uses is currently too high to be supported by prices for energy. In many cases this material must be treated, frequently at rather high costs, to prepare the land for the next crop of trees. Investigations have been made into development of a cost-sharing program to allow for payment for removal of these materials, at least to the level of current costs of treatment. Whether or not this would make the price of wood-based energy competitive is unknown. The main concern again might be guarantee of supply.

## Summary

Insuring an adequate supply of energy for the future is a concern that affects almost everyone. The national and worldwide environment of nonrenewable sources dictates impending changes in our patterns of producing and consuming energy. Greater diversity in sources of energy is paramount to progress toward meeting this country's enormous appetite for energy. Solar, nuclear, and fusion technologies hold much promise for the long term; coal plays a potentially important role in the short-term future. The use of this region's abundant biomass, however, may be prominent in the interim before these high-technology alternatives make significant contributions.

Utilization of biomass for energy may occur in two forms. Most obvious is the direct generation of energy from various sources of biomass. An indirect approach would be the substitution of wood for more energy-intensive materials, such as iron or aluminum. The impact of these actions is largely unknown; the direction taken will be, to a great extent, a matter of national policies and economics. Regionally, the use of wood for generation of electricity appears to be the most likely alternative. Cogeneration by the forest products industry will be the probable vehicle for this output. The production of low Btu gas may become a factor if national legislation restricts industrial use of natural gas. Analysis of the energy potential of wood is not just a matter of electricity generation but which of a wide

variety of energy products offers the greatest advantage to the Nation and the region.

The opportunities for producing energy are predicated on the vast quantities of biomass in the Pacific Coast States. Some of this material has received special attention because of its current status of underutilization. Such is the case with logging residues and insect-killed trees in eastern Oregon. No single source of wood fiber, however, has to supply all the needs of an energy conversion facility. In the broadest sense, there is an abundance of wood fiber having potential for producing energy. Physical availability is not the real issue--rather the question is one of economic availability and marketing. Other restrictive factors are competition from the use of wood for conventional products and the relative cost of other sources of energy. Technology will, of course, affect the rate at which wood sources will augment future supplies of energy.

An additional means of affecting future supplies of energy is through conservation. Effective conservation in the use of energy might temporarily dampen efforts to produce energy from woody biomass. On the other side of the issue, substitution of wood for more energy intensive products would increase demand on a dwindling resource. This potential shift in emphasis toward solid products would probably decrease the quantity of wood now considered a source for production of energy(25). The extent to which conservation will be effective is, to a large degree, a policy issue and a matter of educating the public. There is one certainty: Demand for energy will continue to grow. With attention being given to use of renewable resources, the forests of the Pacific Northwest will be expected to supply energy and greater quantities of all wood-based products.

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#### METRIC EQUIVALENTS

1 cubic foot = 0.283 cubic meter  
1 pound = 0.454 kilogram  
1 ton = 0.907 metric ton

1 mile = 1.609 kilometer

1 acre = 2.47 hectares

1 British  
thermal  
unit (Btu) = 1 055.87 joules

1 kilowatt  
hour (kWh) =  $3.6 \times 10^6$  joules

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The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

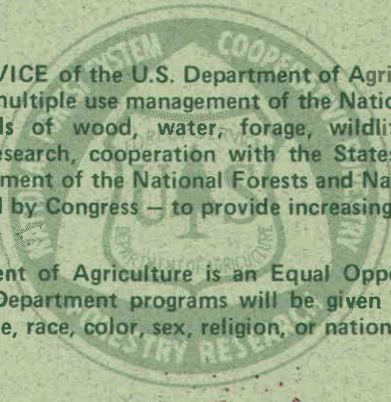
The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

Anchorage, Alaska  
Fairbanks, Alaska  
Juneau, Alaska  
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Experiment Station  
809 N.E. 6th Ave.  
Portland, Oregon 97232*





The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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