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Biomass Estimates for Five Western States

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Forward

The purpose of this report is to describe the woody biomass resource within U.S. Department of Energy's Pacific Northwest and Alaska Regional Biomass Program, comprised of southeast Alaska, Idaho, Montana, Oregon, and Washington. In addition to the regional forest biomass assessment, information will be presented for logging residue, which represents current energy conversion opportunities.

The information presented in the report is based on data and relationships already published. Regionally applicable biomass equations are generally not available for species occurring in the west. Because of this, a number of assumptions were made to develop whole-tree biomass tables. These assumptions are required to link algorithms from biomass studies to regional timber inventory data published by the Forest Inventory and Analysis Research Units (FIA), of the Pacific Northwest and Intermountain Research Stations, U.S. Forest Service. These sources and assumptions will be identified later in this report. Tabular biomass data will be presented for 11 resource areas, identified in the FS inventory publications. These areas are shown below:

State	Resource Areas	Inventory Date	References
SE Alaska	Entire area	1970-1976	(23), (24), (33-37)
Idaho	Entire State	1981	(6)
Montana	Entire State	1980	(15)
Oregon	Northwest	1977	(13)
	West Central	1975	(13)
	Southwest	1975	(13)
	Eastern	1977	(11)
Washington	Olympic Peninsula	1980	(3)
	Puget Sound	1979	(7)
	Southwest	1978	(2)
	Eastern	1981	(5)

Figure 1: Map of study area showing resource areas

This report does not include information for the vast area encompassing interior Alaska. Comparable inventory data are not available for this area thus biomass tables could not be developed. In addition, much of the interior area is inaccessible to conventional harvesting operations or is in areas considered to be sensitive to these operations. Thus it is doubtful if the biomass resource of this area could generate significant outputs under these circumstances.

Total tree biomass as defined in the report refers to the above ground weight of a tree above a 1.0 foot stump, and exclusive of foliage. A glossary is included that defines specific terms as used in the report. Inventory terminology is derived from forest inventory reports from Forest Inventory and Analysis units at the Intermountain and Pacific Northwest Research Stations.

Significant highlights and relationships of the regional resource will be shown in a series of graphs and charts.

Introduction

The five western States representing the Pacific Northwest and Alaska Regional Biomass Program of the U.S. Department of Energy, cover about 256 million acres of land and contain approximately one-third of the Nation's timber resource (U.S. Department of Agriculture 1981b). This vast resource is concentrated on approximately 30 percent of the total area, referred to as timberland; land supporting timber that is generally considered to be available for continuing production of woody fiber (see figure 2 for general forest zones). This resource supports a large forest products industry, accounting for a significant share of the wood products consumed in United States. This resource also represents a source of supply for a potentially significant wood using industry—energy. Energy production based on woody biomass¹ grew considerably following the fuel shortages of the mid-seventies. This growth occurred primarily within the forest products industry and residential sectors of the economy. New legislation, advancing technology, and the renewable nature of wood provide the basis for greater reliance on biomass as a contributor to the region's energy needs in the future.

Figure 2: Generalized forest zones within 5-State area

¹ See Glossary for terms used in this report.

The current surplus of energy in the region, while dwindling, has temporarily slowed the rate of growth of consumption of wood for energy. An examination of the wood energy situation in California, however, gives a good indication of changes that might be expected in the near future in this five-State region.

Based on different economic and energy supply and demand relationships, the use of woody biomass for energy in California has expanded rapidly in the last five years. Information from energy producers in that State indicate that total demand for wood by all existing and planned facilities equals almost 10 million tons annually. This expansion has resulted in some energy producers looking to other areas for potential sources of wood supply. Where and how this growth in the use of wood for energy will occur is an important question. A better understanding of the region's vast timber resource is a prerequisite for addressing this question. Adequate information exists to evaluate the supply needed by conventional wood product industries. What is needed, however, is more information on the entire woody biomass resource. This report brings together the best data available on the woody biomass resource of the 5-State area, as input to energy and other wood products industries and decisionmakers considering the above question. This report does not add to the depth and precision of biomass data, a major issue faced by all woody biomass users and managers in the West. This need must be met before the region's biomass resource can be effectively managed.

The primary purpose of this report is to identify significant sources of woody biomass that may have potential for supplying current or future energy conversion facilities. No attempt is made to define amounts that might be available to a specific location. This is a large task, needing information on a complex set of criteria that affect the physical and economic feasibility of using woody biomass for energy. Because of this complexity, and additional constraints related to forest management objectives, estimates of the total amount of biomass that might be available on an annual basis were not made. An exception to this are the logging residue data, which are based on annual harvest levels.

Area figures were taken directly from the FIA inventory reports noted above. Total land area represents all land within the State boundaries, except bodies of water so designated by the Bureau of Census. Timberland is that area considered to be suitable for producing continuing crops of trees, and not withdrawn from timber production for various reasons. Trees do occur on other lands, but are not considered for future timber production because of statute, low productivity, or other special use designations.

Inventory volumes (cubic feet) were accumulated for each State or resource area from the latest FIA report. These volumes were then converted to weight using average weight values. These average values were computed by taking wood density information by species, weighted by the proportion of total inventory volume by that species. This information is displayed in the appendix of this report, for green and dry weights. Following calculation of inventory weight, bark was added to the bole by applying bark factors, also shown in the appendix. This value, wood and bark, is reported as total bole weight.

The next step was to add the top to the bole. Top factors were derived from tariff table used by FIA at the PNW Station. Evaluation of the relationship of top to main portion of the bole showed very little variation by species. Therefore, average values for all species were applied to the bole weight figures. These values are shown in the appendix.

Weight of all branches was then added to the total weight of the entire bole. This was accomplished by applying branch factors from published sources to the bole weight figures. Many sources were used to develop the branch factors. Where different sources gave widely different values for branches an average value was chosen. This, of course, was the norm rather than the exception. A summary of branch factors is shown in the appendix.

Methods

Area Determination

Growing Stock Trees

Small Trees

Cull Trees

The general formula for this process is shown below:

$$\text{total tree weight} = (\text{inventory bole vol.}) \times (\text{ave. wood density}/2000 \text{ lbs.}) \\ \times (1.0 + \text{bark factor}) \times (1.0 + \text{top factor}) \times (1.0 + \text{branch factor})$$

These calculations were completed by species and diameter class in order to generate the desired tables shown in this report. Proportions from FIA inventory reports were used when other distributions of biomass were required, such as for ownership.

Total biomass for small trees (1.0 to 4.9 inches, dbh) was developed by applying average tree weights to total number of trees from FIA reports. For some areas the number of small trees was not identified in the FIA reports. For these areas total weight taken from a 1980 biomass assessment (U.S. Department of Agriculture 1981a). The date of inventory for these cases was similar, thus the expected number and weight of small trees should be approximately the same for the two time periods. Average weight of small trees, by diameter class and species, is shown in the appendix. Dry weights were computed using dry/green weight ratios from the density values also shown in the appendix.

Volume of cull trees (net) was taken from the respective FIA inventory report for each area. The bole weight of these trees was computed in the same manner as for growing stock trees. The proportion of other biomass, top and branches, was computed using the proportions developed for the 1980 compilation (U.S. Department of Agriculture 1981a). An assumption was made that the proportion of crown weight to bole weight has not changed since the 1980 figures were computed.

Weight of salvable dead trees was computed by converting FIA inventory volume to dry or green weight using the average density values noted above. Only bole weight is shown for salvable dead trees. An assumption was made that bark and branch material does not exist. This is of course not entirely true, but no data exists to determine the amount of the material that is present. Because of this, figures given in this report underestimate the actual weight of salvable dead trees by an unknown amount.

Logging residue information in this report includes only pieces that are at least 3.0 inches in diameter and 1.0 foot long. Other material, primarily crowns of trees harvested, has not been estimated on a regional basis. The volume of additional residue in the smaller sizes could be in excess of 20 dry tons per acre (Maxwell and Ward 1976). Estimates of logging residue volume and weight were derived from published data for each area (Howard 1981a, 1981b; Howard and Fiedler 1984; Howard and Setzer 1989). Information in Tables 18, 19, 21, 22, and 23 was taken directly from these reports. Weight information in Table 20 was derived by applying dry weight values to cubic foot logging residue volumes. Total residue weight for each area (Table 12) was computed by multiplying the average weight of residue per 1,000 board feet of timber harvest by the total board foot volume of timber harvest. This was done for each ownership/harvest method represented in each area. Total weight for the area was the sum of these computations.

Energy values, Btu's, were computed for portions of the forest biomass of the 5-State area that were considered to be the most likely conversion opportunities. This includes crowns of growing stock trees, small trees, cull trees, and logging residue. No information is given on the amount of these sources that might actually be available for energy conversion, nor is the assumption made that all of this material should in fact be used for that purpose. Energy values, expressed in Btu's per pound, vary considerably by species and type of

Salvable Dead Trees

Logging Residue

Energy Values

material (wood and bark). No attempt was made to determine the actual energy value of each source of biomass; weighing specie values by proportion of wood and bark. Rather, an average value of 8500 Btu's per bone dry pound was used to compute energy values. This amounts to 17 million Btu's per bone dry ton.

This figure represents an estimate of the higher heating value of each biomass source. Actual recoverable energy values depend on moisture content and efficiencies of conversion equipment. The information given in this report is intended to provide relative energy values for each area. Actual opportunities for converting woody biomass to energy must be made on a site specific basis, utilizing detailed information for the area and sources considered as supply for the facility under study. National energy consumption is frequently shown in terms of quads (1×10^{15} Btu's). This measure is used to judge the relative significance a particular source of energy contributes, or might contribute, to National or regional supplies.

Assessment of the Resource

Area Analysis

As noted earlier this area of the United States contains a large share of the Nation's timber resource. This resource occurs on a land area of nearly 80 million acres; about 30 percent of the total land area of the five states. The area of timberland by resource area is shown in table 1. As this data shows the proportion of timberland varies considerably between the 11 resource areas. The proportion ranges from 16 percent in Montana, to 80 percent in southwest Washington (see figure 3). In general the area west of the Cascade mountain range has a much higher proportion of timberland than the areas to the east. Just over 40 percent of the Southeast Alaska area is covered by timberland.

Table 1. Total land area by State, resource area, and land class

State and resource area	----- Forest land -----			Non-forest land	Total land area
	Timberland	Other	Total		
----- Thousand acres -----					
SOUTHEAST ALASKA	6,317	4,364	10,681	4,820	15,501
IDAHO	17,661	4,280	21,941	30,950	52,891
MONTANA ^{1/}	13,571	6,655	20,226	63,453	83,679
OREGON:					
Northwest	3,548	213	3,761	1,824	5,585
West Central	3,978	337	4,315	1,117	5,432
Southwest	6,143	891	7,034	1,116	8,150
Eastern	<u>10,126</u>	<u>4,238</u>	<u>14,364</u>	<u>27,865</u>	<u>42,229</u>
Total	23,795	5,679	29,474	31,922	61,396
WASHINGTON:					
Olympic Peninsula	3,092	863	3,955	612	4,567
Puget Sound	3,462	1,017	4,479	2,074	6,553
Southwest	3,652	218	3,870	689	4,559
Eastern	<u>7,144</u>	<u>2,073</u>	<u>9,218</u>	<u>17,751</u>	<u>26,968</u>
Total	17,350	4,171	21,521	21,126	42,647

^{1/}Does not include 8.1 million acres of land for which no data was available.
(see Green, O'Brien, and Schaefer 1985)

Figure 3: Total land area by classification by resource area

A considerable amount of timber exists on Other Forest Land throughout the 5-state area. The proportion of this land classification ranges from 4-28 percent of the total land base. Timber on this land is not readily available for harvest, either by being withdrawn from production by statute, or by nature of its quality, species, or remoteness. A certain amount of wood from these lands might enter the energy market in the future. No effort has been made to estimate these quantities in this report. Future biomass assessment, however, may incorporate this information.

Of the 80 million acres of timberland, roughly two-thirds is in public ownership (table 2). National Forests account for about 55 percent of the total, with Bureau of Land Management and State lands being the next largest owner groups. As shown in figure 4, the highest proportion of public ownership is in southeast Alaska (93 percent) and the lowest in southwest Washington (41 percent). Western Washington has the highest percentage of land in private ownership of all the areas, an average of about 58 percent, over 60 percent of which is owned by forest industries. Other Private holdings are highest in Montana and the Puget Sound area of Washington. Ranches and farms are a major component of this ownership in Montana, while miscellaneous private owners predominate the Puget Sound area.

Table 2. Area of timberland by State, resource area, and ownership

State and resource area	National Forest	Other public	Forest industry	Other private	All ownerships
----- Thousand acres -----					
SOUTHEAST ALASKA	5,649	200	--	468	6,317
IDAHO	12,808	1,635	1,178	2,040	17,661
MONTANA	8,162	759	1,601	3,049	13,571
OREGON:					
Northwest	936	802	1,042	768	3,548
West Central	1,630	551	1,097	700	3,978
Southwest	2,019	1,509	1,641	974	6,143
Eastern	<u>7,046</u>	<u>606</u>	<u>1,567</u>	<u>907</u>	<u>10,126</u>
Total	11,631	3,468	5,347	3,349	23,795
WASHINGTON:					
Olympic Peninsula	538	758	1,215	581	3,092
Puget Sound	835	629	998	1,000	3,462
Southwest	1,081	427	1,495	649	3,652
Eastern	<u>2,907</u>	<u>1,977</u>	<u>880</u>	<u>1,380</u>	<u>7,144</u>
Total	5,361	3,791	4,588	3,610	17,350

Figure 4: Percent of timberland by ownership class by resource area

The data in table 3 show that timberland with sawtimber size trees are by far the most highly represented in each of the resource areas. Sawtimber stands cover from 54 to 95 percent of total timberland. As shown in figure 5, most of the resource areas average about 55-65 percent of timberland in stands of this size. Poletimber and seedling/sapling stands range from 5 to 43 percent of the timberland base. A later discussion will show that the resource area with the highest percent of poletimber and seedling/sapling stands, Olympic Peninsula in Washington, also has the highest per acre growth rate. As will be discussed later these stands have the potential of making significant contributions to the Nation's supply of energy.

Table 3—Area of timberland by State, resource area, and stand-size class.

State and resource area	-----Sawtimber stands ^{1/} -----		Total	Poletimber stands	Sapling and seedling stands	Nonstocked areas	All classes
	Large sawtimber	Small sawtimber					
----- Thousand acres -----							
SOUTHEAST ALASKA	2/	2/	5,993	54	270	--3/	6,317
IDAHO	2/	2/	9,408	2,157	1,669	773	14,006 ^{4/}
MONTANA	2/	2/	8,280	3,111	1,962	218	13,571
OREGON:							
Northwest	646	1,509	2,155	508	679	206	3,548
West Central	1,313	1,196	2,509	395	841	233	3,978
Southwest	2,424	1,453	3,877	513	1,404	349	6,143
Eastern	164	6,589	6,753	2,238	838	297	10,126
Total	4,547	10,747	15,294	3,654	3,762	1,085	23,795
WASHINGTON:							
Olympic Peninsula	377	1,279	1,656	601	748	87	3,092
Puget Sound	493	1,569	2,062	641	659	100	3,462
Southwest	819	1,221	2,040	592	851	169	3,652
Eastern	728	3,559	4,287	1,234	1,368	255	7,144
Total	2,417	7,628	10,045	3,068	3,626	611	17,350

^{1/}On National Forests, large sawtimber includes stands 100 years or older and small sawtimber less than 100 years old. On other ownerships, large sawtimber includes trees 21.0-inch d.b.h. and larger. On other ownerships, small sawtimber includes softwood trees 9.0- to 20.9-inch d.b.h. and hardwood trees 11.0- to 20.9-inch d.b.h.

^{2/}Breakdown by size-class not available from existing inventory reports.

^{3/}Included with seedling and sapling stands.

^{4/}Does not include 3,654,000 acres of low productivity land not classified by stand size-class.

Figure 5: Percent of timberland by stand-size class by resource area

Douglas-fir is the predominate forest type in the 5-State area (see table 13, in appendix). Only in southeast Alaska (hemlock/spruce), and Montana and eastern Oregon (pines) do other species cover a higher proportion of the timberland. The proportion of major forest types is depicted in figure 6. Stands of red alder cover occur in many of the resource areas. Table 13 shows red alder to be well represented in 6 of the resource areas, ranging from 6-20 percent of the timberland base. Through the years red alder has been underutilized, in comparison to its inventory. While there has been a recent upswing in interest in red alder, this type represents a potential major contributor of wood energy. It should be noted that forest type classification depicts the predominate species in a stand. Other species do occur in many of these stands, and are often not used to the same extent as the major species. A good example of this is small hemlock in Douglas-fir stands, and lodgepole pine in ponderosa pine type. A viable energy market might encourage better utilization of these trees.

Figure 6: Percent of timberland by forest type by resource area

Table 14 (in the appendix) shows area of timberland by cubic-foot site class. This classification is an attempt to define the basic growth capability of a stand. Stands with the highest potential can produce in excess of 225 cubic feet per acre per year. Those with the lowest potential produce less than 49 cubic feet per acre per year. Stands capable of producing 120 cubic feet or more per year are considered as sites with good growth potential. The data in table 14 show that almost 30 percent of the timberland is capable of producing 120 cubic feet per acre per year. These stands are not uniformly distributed. Roughly 72 percent of stands with this growth potential are located in the western parts of Oregon and Washington. Data on site class are not available for southeast Alaska, thus the above figures do not include the Alaska acreage.

Stands with a relatively high level of productivity, are also the stands that produce high quantities of total biomass. On the other hand, stands with lower

The Biomass Resource

productivity, like lodgepole pine, often represent a good potential for wood energy due to the smaller size and lower quality tree that occurs on the site. Trees with these characteristics are frequently not highly demanded for conventional products. Thus, the proportion of biomass in these stands available for energy is relatively high, in some cases nearly 100 percent. These data are useful for determining the relative growth potential of stands. As the examples above indicate, however, growth potential is not directly correlated with wood energy supplies.

The estimated total quantity of woody biomass for the 5-State area is 4.425 billion bone dry tons (table 4). As noted earlier total tree biomass refers to the above ground weight of a tree above a 1.0 foot stump, and exclusive of foliage; included are small trees, those from 1.0 - 4.9 inches in diameter; cull trees; and salvable dead trees. The equivalent green weight (containing water, in natural conditions) of the woody biomass is just under 9.3 billion green tons (table 5). Current figures for the U.S. are not available, but the total green weight of the 5-State area roughly compares to 13.9 billion green tons for a 13 state area in southeastern U.S. (Waldrop and Brooks 1984). About 44 percent of the 4.425 billion dry tons occurs in western Oregon and western Washington. The remainder is divided fairly evenly among the other five areas (southeast Alaska has the next highest total, 14 percent).

**Table 4. Total dry weight of above ground biomass on timberland
by State, resource area, and class of timber.**

State and resource area	Sawtimber trees	Poletimber trees	All growing stock	Small trees	Cull trees	Salvable dead trees	All timber
----- Million bone dry tons -----							
SOUTHEAST ALASKA	520.86	56.47	577.33	10.80	28.06	8.66	624.85
IDAHO	351.97	163.99	515.96	18.40	10.20	24.26	568.82
MONTANA	300.66	168.11	468.77	32.60	9.29	36.00	546.66
OREGON:							
Northwest	217.56	30.34	247.90	23.50	6.70	2.02	280.12
West Central	306.21	24.18	330.39	18.50	9.05	4.41	362.35
Southwest	365.70	38.85	404.55	34.80	28.09	6.43	473.87
Eastern	<u>278.86</u>	<u>80.17</u>	<u>359.03</u>	<u>19.30</u>	<u>10.08</u>	<u>3.70</u>	<u>392.11</u>
Total	1,168.33	173.54	1,341.87	96.10	53.92	16.56	1,508.45
WASHINGTON:							
Olympic Peninsula	222.87	28.87	251.74	8.40	2.71	3.91	266.76
Puget Sound	234.14	33.17	267.31	10.20	4.85	4.30	286.66
Southwest	247.86	26.33	274.19	9.10	8.16	4.14	295.59
Eastern	<u>245.06</u>	<u>55.97</u>	<u>301.03</u>	<u>20.50</u>	<u>2.95</u>	<u>3.45</u>	<u>327.93</u>
Total	949.93	144.34	1,094.27	48.20	18.67	15.80	1,176.94

Table 5. Total green weight of above ground biomass on timberland by State, resource area, and class of timber

State and resource area	Sawtimber trees	Poletimber trees	All growing stock	Small trees	Cull trees	Salvable dead trees	All timber
----- Million green tons -----							
SOUTHEAST ALASKA	1,176.10	127.50	1,303.60	24.39	63.36	19.56	1,410.91
IDAHO	738.43	344.05	1,082.48	38.60	21.40	50.90	1,193.38
MONTANA	615.45	344.12	959.57	66.73	19.02	73.69	1,119.01
OREGON:							
Northwest	455.14	63.47	518.61	49.16	14.02	4.23	586.02
West Central	634.77	50.12	684.89	38.35	18.76	9.14	751.14
Southwest	748.59	79.53	828.12	71.24	57.50	13.16	970.02
Eastern	<u>574.17</u>	<u>165.07</u>	<u>739.24</u>	<u>39.74</u>	<u>20.75</u>	<u>7.62</u>	<u>807.35</u>
Total	2,412.67	358.19	2,770.86	198.49	111.03	34.15	3,114.53
WASHINGTON:							
Olympic Peninsula	451.76	58.52	510.28	17.03	5.49	7.93	540.73
Puget Sound	496.14	70.29	566.43	21.61	10.28	9.11	607.43
Southwest	521.74	55.42	577.16	19.16	17.18	8.71	622.21
Eastern	<u>507.52</u>	<u>115.91</u>	<u>623.43</u>	<u>42.46</u>	<u>6.11</u>	<u>7.14</u>	<u>679.14</u>
Total	1,977.16	300.14	2,277.30	100.26	39.06	32.89	2,449.51

Both dry and green weights are provided. Dry weight is used to calculate comparative energy values, as it remains relatively constant for a given species and is the basis for most reported levels of energy values. Green weight on the other hand is commonly used to determine the weight of biomass that has to be handled by harvesting equipment or transported to conversion facilities.

Biomass is distributed somewhat differently than acreage of timberland among the 11 resource areas covered by this report. Figure 7 below shows a comparison of proportion of acres of timberland to proportion of total biomass for each area. Noticeable is the difference in these proportions between the wetter and drier areas. Idaho, Montana, eastern Oregon, and eastern Washington have higher percents of timberland than biomass, while the other, wetter, areas exhibit

the opposite situation. Greater quantities of biomass may represent greater opportunities for energy conversion, although this is not always the case.

Figure 7: Proportion of total timberland compared to proportion of total biomass by area

As might be expected the largest portion of the total is represented by sawtimber trees, those greater than 11.0 inches in diameter. Figure 8 shows the distribution of total biomass by class of timber. While sawtimber trees account for the largest share of the total, the distribution by class of timber is not uniform when comparing the different areas. Montana, for example differs considerably from the other areas. The sawtimber portion in Montana is the lowest among the areas, at 55 percent, while poletimber trees account for 31 percent, highest among the 11 areas. Also notable is the relatively high proportion of biomass in salvable dead trees. This is most likely attributable to the high incidence of beetle killed lodgepole pine trees. Southeast Alaska on the other hand has 83 percent of its biomass in sawtimber trees and only 9 and 2 percent respectively in poletimber and seedling/sapling trees.

Figure 8: Percent of total biomass by stand-size class by resource area

Generally speaking these proportions give a clue to the sources of woody biomass that may be available for energy. Sawtimber stands are the source of most of the wood harvested in the 5-State area. Thus, it is these stands that offer opportunities to increase utilization during regular harvest operations. Poletimber and some of the larger seedling/sapling stands offer different opportunities. Specifically, many land managers would like to enter these stands at an earlier age to accomplish silvicultural objectives. Thinning to increase growth on remaining trees is an example. Costs of doing this work are high, and frequently there is no income to offset these costs. Having a market for this material, possibly for energy, would offer the incentive needed to increase the level of these activities. A very active energy market might attract a significant amount of biomass from these stands, beyond that left to protect other resource values.

The proportion of total biomass in small, cull, and salvable dead trees is relatively small in all areas, ranging from 5-15 percent. These classes of timber do offer some opportunity for energy conversion, usually in conjunction with regular or salvage harvest operations. Cull and dead trees are usually scattered throughout the forests, the exception being trees killed by fire or insects and diseases. Small trees are found both as components of stands with larger trees and as entire stands, particularly following harvesting. In most situations they offer limited conversion opportunities, at least until they reach the size where thinning becomes a management alternative.

Public lands account for about three quarters of the 4 billion dry tons of woody biomass from growing stock trees (table 15, in appendix). National Forests contribute nearly 60 percent, while other public owners account for just over 16 percent. The National Forest figure is only an estimate since a breakdown by ownership is not available for southeast Alaska (at the date of the inventories used as a basis for this report). In terms of acres of timberland, National Forests in southeast Alaska account for almost 90 percent of the total. This proportion was used to develop the National Forest estimate noted above.

With some exceptions National Forest lands also have the highest per acre amounts of biomass, ranging from 28.52 tons per acre, dry weight, in Idaho to 123.63 tons per acre, dry weight, in West Central Oregon (table 6). Averages for all owners range from 29.21 tons per acre, dry weight, in Idaho to 81.42 tons per acre, dry weight, in the Olympic Peninsula area of Washington. Ownership breakdown is was not available for southeast Alaska when data for this report were compiled. Thus, the range of biomass weights may differ when the Alaska data are known.

Table 6. Dry weight per acre of above ground biomass of growing stock trees¹ on timberland by State, resource area, and ownership.

State and resource area	National Forest	Other public	Forest industry	Other private	All ownerships
----- Bone dry tons per acre -----					
SOUTHEAST ALASKA	2/	2/	2/	2/	91.39
IDAHO	28.52	34.72	32.72	27.13	29.22
MONTANA	39.80	29.91	31.73	23.09	34.54
OREGON:					
Northwest	118.88	57.32	53.31	45.72	69.87
West Central	123.63	86.08	48.24	40.76	83.04
Southwest	91.16	76.58	46.88	28.75	65.86
Eastern	39.38	42.39	24.56	19.17	35.45
WASHINGTON:					
Olympic Peninsula	95.32	89.96	83.48	53.08	81.42
Puget Sound	105.86	81.10	63.57	64.47	77.20
Southwest	109.41	74.61	59.13	54.95	75.08
Eastern	42.65	46.69	46.89	31.51	42.14

^{1/}Includes trees 5.0-inch d.b.h. and larger.

^{2/}Breakdown by ownership class not available for Southeast Alaska.

Table 7 gives the total amount of woody biomass by tree component; bole and crown (excluding foliage). It should be noted that weights for boles include bark, which is different from most reported inventory volumes that show wood only. Bark is included with the bole because most of it is attached to the bole when harvested and transported to the conversion facility. An unknown quantity of bark is knocked off trees during harvest. When evaluating the additional quantity of biomass that may be available during harvest, bark should not be considered. Much of the bark is subsequently converted to energy or other products at the receiving facility.

Table 7. Total dry weight of above ground biomass of growing stock trees¹ on timberland by State, resource area, softwoods and hardwoods, and by bole and crown.

State and resource area	----- Softwoods -----			----- Hardwoods -----			----- All species -----		
	Bole	Crown	Total	Bole	Crown	Total	Bole	Crown	Total
----- Million bone dry tons -----									
SOUTHEAST ALASKA	484.72	88.26	572.98	3.28	1.07	4.35	488.00	89.33	577.33
IDAHO	421.35	89.31	510.66	4.34	0.96	5.30	425.69	90.27	515.96
MONTANA	361.61	100.60	462.21	5.04	1.52	6.56	366.65	102.12	468.77
OREGON:									
Northwest	184.60	33.42	218.02	24.92	4.96	29.88	209.52	38.38	247.90
West Central	269.49	39.19	308.68	18.51	3.20	21.71	288.00	42.39	330.39
Southwest	315.85	46.76	362.61	35.82	6.12	41.94	351.67	52.88	404.55
Eastern	<u>295.83</u>	<u>62.59</u>	<u>358.42</u>	<u>0.50</u>	<u>0.11</u>	<u>0.61</u>	<u>296.33</u>	<u>62.70</u>	<u>359.03</u>
Total	1,065.77	181.96	1,247.73	79.75	14.39	94.14	1,145.52	196.35	1,341.87
WASHINGTON:									
Olympic Peninsula	184.92	34.68	219.60	26.79	5.35	32.14	211.71	40.03	251.74
Puget Sound	187.69	35.19	222.88	36.95	7.48	44.43	224.64	42.67	267.31
Southwest	207.90	36.39	244.29	25.05	4.85	29.90	232.95	41.24	274.19
Eastern	<u>247.29</u>	<u>49.44</u>	<u>296.73</u>	<u>3.52</u>	<u>0.78</u>	<u>4.30</u>	<u>250.81</u>	<u>50.22</u>	<u>301.03</u>
Total	827.80	155.70	983.50	92.31	18.46	110.77	920.11	174.16	1,094.27

^{1/}Includes trees 5.0-inch d.b.h. and larger.

The proportion of crown to total tree biomass does not differ much between areas. At first thought this might not be expected. Particularly since the proportion does vary by species. From table 7 the amount of crown in softwood trees varies from 12.7 to 21.8 percent of total biomass. The higher figure is in Montana. The next highest proportion of crown material is in Idaho, at 17.5 percent, and is closer to that of the other areas. The reason for the relatively high proportion in Montana is not known. The proportion of hardwood crown material exhibits roughly the same pattern between the areas. There is also little difference in the proportion of crown to total biomass between softwoods and hardwoods. For all areas and species crown biomass averages 16.3 percent.

Table 8 gives the per acre values for bole and crown biomass. These are included to give some idea of concentrations of potentially available biomass. Generally speaking higher concentrations tend to be more economically attractive to potential users. This is particularly true for situations where only crown materials are currently not utilized for other products. In some cases, small diameter lodgepole pine stands for example, additional biomass in the boles may be available for energy products. In these situations the amount of crown biomass underestimates the overall potential.

Table 8. Dry weight per acre of above ground biomass of growing stock trees on timberland by State, resource area, softwoods and hardwoods, and by bole and crown.

State and resource area	---- Softwoods ----			---- Hardwoods ----			---- All species ----		
	Bole	Crown	Total	Bole	Crown	Total	Bole	Crown	Total
----- Bone dry tons per acre -----									
SOUTHEAST ALASKA	76.73	13.97	90.70	0.52	0.17	0.69	77.25	14.14	91.39
IDAHO	23.86	5.06	28.92	0.25	0.05	0.30	24.11	5.11	29.22
MONTANA	26.65	7.41	34.06	0.37	0.11	0.48	27.02	7.52	34.54
OREGON:									
Northwest	52.03	9.42	61.45	7.02	1.40	8.42	59.05	10.82	69.87
West Central	67.74	9.85	77.59	4.65	0.80	5.45	72.39	10.65	83.04
Southwest	51.42	7.61	59.03	5.83	1.00	6.83	57.25	8.61	65.86
Eastern	29.21	6.18	35.39	0.05	0.01	0.06	29.26	6.19	35.45
WASHINGTON:									
Olympic Peninsula	59.81	11.22	71.03	8.66	1.73	10.39	68.47	12.95	81.42
Puget Sound	54.21	10.16	64.37	10.67	2.16	12.83	64.88	12.32	77.20
Southwest	56.93	9.96	66.89	6.86	1.33	8.19	63.79	11.29	75.08
Eastern	34.62	6.92	41.54	0.49	0.11	0.60	35.11	7.03	42.14

The total dry weight of biomass by species is given in table 16 (in appendix). For the most part the distribution of biomass follows the same pattern as for acreage of timberland by forest type noted earlier (see figure 6). The distribution by major species or species group is shown below.

Species	Total biomass, million BD tons	Percent of total biomass
Douglas-fir	1,413	35.3
Hemlock/spruce	1,070	26.8
Pines	621	15.5
True firs	399	10.0
Red alder	119	3.0
Other species	376	9.4
Total	3,998	100.0

Distribution of the biomass by species is not uniform among the resource areas. Pines are generally found in the drier interior forests, while Douglas-fir and hemlock are found in the coastal regions. Nearly half of the hemlock/spruce type occurs in southeast Alaska, however, none of the Douglas-fir is located there. Red alder is also geographically specific. Of the 119 million dry tons, 98 percent grows in western Oregon and western Washington. As noted earlier in this report, acreage of lodgepole pine exceeds that of ponderosa pine. The same situation exists for biomass, where lodgepole accounts for 296 million dry tons and ponderosa just over 281 million dry tons.

Table 9. Total dry weight of above ground mass of live trees on timberland by State, resource area, and diameter class.

State and resource area	Diameter class											All classes
	1.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-28.9	29.0 & larger	
----- Million bone dry tons -----												
SOUTHEAST ALASKA	10.80	1/	1/	56.47	2/	2/	2/	2/	188.68	183.87 ^{2/}	148.31	588.13
IDAHO	18.40	44.29	62.36	57.34	53.93	51.16	43.13	37.83	31.27	82.62	52.03	534.36
MONTANA	32.60	74.33	93.78	73.92	58.43	43.02	32.44	24.44	18.33	36.92	13.16	501.37
OREGON:												
Northwest	23.50	12.99	17.35	19.26	21.56	20.34	19.33	18.97	15.76	47.29	55.05	271.40
West Central	18.50	10.26	13.92	14.94	16.95	17.98	17.63	18.97	17.57	61.05	141.12	348.89
Southwest	34.80	19.16	19.69	18.41	19.93	19.68	19.56	20.29	19.05	68.97	179.81	439.35
Eastern	<u>19.30</u>	<u>44.97</u>	<u>35.20</u>	<u>33.10</u>	<u>30.54</u>	<u>25.77</u>	<u>23.43</u>	<u>21.54</u>	<u>19.53</u>	<u>66.89</u>	<u>58.06</u>	<u>378.33</u>
Total	96.10	87.38	86.16	85.71	80.98	83.77	79.95	79.77	71.91	244.20	434.04	1,437.97
WASHINGTON:												
Olympic Peninsula	8.40	10.95	17.92	21.79	21.73	21.99	20.62	20.12	17.38	47.20	52.04	260.14
Puget Sound	10.20	13.11	20.06	24.95	25.34	26.00	23.22	19.78	16.92	44.45	53.48	277.51
Southwest	9.10	10.82	15.51	19.41	22.22	22.66	23.33	21.64	18.27	55.11	65.22	283.29
Eastern	<u>20.50</u>	<u>22.35</u>	<u>33.62</u>	<u>30.27</u>	<u>32.27</u>	<u>30.35</u>	<u>27.50</u>	<u>23.59</u>	<u>18.99</u>	<u>49.16</u>	<u>32.93</u>	<u>321.53</u>
Total	48.20	57.23	87.11	96.42	101.56	101.00	94.67	85.13	71.56	195.92	203.67	1,142.47

^{1/}Weight of trees from 5.0- 8.9 inches in diameter are included in 9.0- 10.9 inch diameter class.

^{2/}Weight of trees from 11.0- 18.9 inches in diameter are included in 19.0- 20.0 inch diameter class.

^{3/}Weight of trees from 28.9- 30.9 inches in diameter are included in the 21.0- 28.9 inch diameter class.

Size is the biggest factor in amount of biomass per tree. The proportion of bole and crown materials is also related to tree size. As noted above harvest usually occurs in stands of larger trees, while silvicultural activities are directed at stands in earlier stages of development. While different, both situations offer opportunities for the use of woody biomass for energy. Table 9 shows the distribution of total biomass by diameter class. This data differs from that in prior tables in that trees less than 5.0 inches in diameter are included.

The distribution of biomass by diameter class differs considerably between the resource areas. This distribution is depicted in figure 9. As can be seen there are some interesting differences in the size class distributions. For example, in Montana 55 percent of total biomass is in trees less than 11.0 inches in diameter. This compares to a 5-State average of only 28 percent in this same size range. There are a number of factors that lead to this size distribution, one of which is that nearly 30 percent of biomass in Montana is accounted for by lodgepole pine, usually occurring as stands of relatively small diameter trees. Just the opposite occurs in southeast Alaska where trees less than 11.0 inches account for only 11 percent of total biomass in the area. Another unique situation occurs in western Oregon. Two resource areas, Southwest and West Central, account for 38 percent of biomass in trees greater than 29.0 inches. The other area with a high proportion of biomass in this size class of tree is southeast Alaska, having about 17 percent of the 5-State total. As figure 9 shows the interior areas tend to have a higher proportion of biomass in trees less than 11.0 inches than do the coastal areas.

Figure 9: Biomass distribution (percent) by diameter class by resource area

Table 10. Total dry weight of net annual growth of growing stock trees on timberland by State, resource area, and ownership.

State and resource area	National Forest	Other public	Forest industry	Other private	All ownerships
----- Million bone dry tons -----					
SOUTHEAST ALASKA	<u>1/</u>	<u>1/</u>	<u>1/</u>	<u>1/</u>	0.24
IDAHO	4.65	1.02	0.86	1.35	7.88
MONTANA	4.01	0.33	0.64	1.12	6.10
OREGON:					
Northwest	0.67	1.17	1.85	1.04	4.73
West Central	0.89	0.71	1.40	0.82	3.82
Southwest	1.01	0.83	1.02	0.75	3.61
Eastern	<u>2.83</u>	<u>0.28</u>	<u>0.65</u>	<u>0.37</u>	<u>4.13</u>
Total	5.40	2.99	4.92	2.98	16.29
WASHINGTON:					
Olympic Peninsula	0.19	1.83	2.84	0.85	5.71
Puget Sound	0.16	1.31	1.84	1.89	5.20
Southwest	0.71	0.96	2.85	1.10	5.62
Eastern	<u>1.22</u>	<u>1.54</u>	<u>0.76</u>	<u>1.19</u>	<u>4.71</u>
Total	2.28	5.64	8.29	5.03	21.24

^{1/} Breakdown by ownership not available for Southeast Alaska.

Table 10 gives the dry weight of net annual growth for each of the 11 resource areas. These figures represent growth on only the bole portion of trees. Increments of crown biomass have not been estimated for this report. The total net annual growth of all 11 areas is approximately 52 million dry tons. A comparison to annual removals (harvest plus logging residue and other types of removals) is not readily available. For the most part removals are reported in units other than weight. The latest National assessment (U.S. Department of Agriculture 1981b) gives removals in cubic feet. Using average dry density factors calculated for this report, the above reported removals equals approximately 51 million dry tons. Even with the differences in data bases and inventory dates the two estimates indicate that growth and removals are roughly in balance. Table 17 in the appendix gives per acre figures for net annual growth for each resource area.

Biomass left in the woods following logging operations has been the focus of many feasibility studies since the energy crises of the mid-1970's. Aside from by-products from the forest products industries, this potential source of wood is usually considered to be the most likely to be converted to energy. Most often economics have played a key role in determining the rate at which this biomass is actually recovered for energy uses. The highest degree of recovery is currently occurring in California, spurred by construction of numerous wood fired power plants over the past 10 years. While recovery of logging residue has not been very high, lower amounts are being left now than in the past. In the future we can expect higher levels of utilization during harvest, which means less logging residue. Until that time rather large total quantities of residue will be available for potential conversion to energy. It should be noted that not all logging residue is available for energy or any off-site product. Other resource considerations, such as site productivity and wildlife habitat, will require that some amount of biomass needs to remain on site. The amount associated with these needs is not well defined at this time.

Table 11 shows the total gross and net weight of logging residue by resource area. No breakdown is given for resource areas within western Oregon and western Washington. The total net weight, 17.2 million dry tons, is about 62 percent of the total gross weight, 27.8 million dry tons. This means that the average usable content of the residue is 62 tons per every 100 tons. Many factors affect the economic and physical feasibility of using residual materials for energy. The relation of net to gross weight by area is shown in figure 10.

Logging Residue

Table 11. Total gross and net weight (wood and bark) of logging residue by area, ownership, and harvest method.

Area and ownership	Clearcut		Partial cut		All methods ^{1/}		Total	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net
----- Thousand bone dry tons -----								
SOUTHEAST ALASKA								
Public	580	393	--	--	--	--	580	393
Private	<u>732</u>	<u>535</u>	--	--	--	--	<u>732</u>	<u>535</u>
Total	1,312	928	--	--	--	--	1,312	928
IDAHO:								
National Forest	616	375	975	643	--	--	1,591	1,018
Other public	--	--	--	--	576	370	576	370
Private	--	--	--	--	<u>1,465</u>	<u>956</u>	<u>1,465</u>	<u>956</u>
Total	<u>616</u>	<u>375</u>	<u>975</u>	<u>643</u>	2,041	1,326	3,632	2,344
MONTANA:								
Public	480	321	585	348	--	--	1,065	669
Private	--	--	--	--	1,418	879	1,418	879
Lodgepole pine ^{2/}	--	--	--	--	<u>686</u>	<u>453</u>	<u>686</u>	<u>453</u>
Total	<u>480</u>	<u>321</u>	<u>585</u>	<u>348</u>	2,104	1,332	3,169	2,001
WESTERN OREGON:								
National Forest	1,877	1,146	592	371	--	--	2,469	1,517
Other public	1,098	715	696	320	--	--	1,794	1,035
Private	<u>2,126</u>	<u>1,308</u>	<u>1,736</u>	<u>1,077</u>	--	--	<u>3,862</u>	<u>2,385</u>
Total	5,101	3,169	3,024	1,768	--	--	8,125	4,937
EASTERN OREGON:								
Public	--	--	--	--	2,571	1,416	2,571	1,416
Private	--	--	--	--	<u>756</u>	<u>473</u>	<u>756</u>	<u>473</u>
Total	--	--	--	--	3,327	1,889	3,327	1,889
WESTERN WASHINGTON:								
National Forest	809	481	276	173	--	--	1,085	654
Other public	835	533	231	135	--	--	1,066	668
Private	<u>2,760</u>	<u>1,621</u>	<u>1,086</u>	<u>676</u>	--	--	<u>3,846</u>	<u>2,297</u>
Total	4,404	2,635	1,593	984	--	--	5,997	3,619
EASTERN WASHINGTON:								
Public	--	--	--	--	1,488	965	1,488	965
Private	--	--	--	--	<u>758</u>	<u>488</u>	<u>758</u>	<u>488</u>
Total	--	--	--	--	2,246	1,453	2,246	1,453

NOTE: -- means no data are available.

^{1/}Samples were selected from all harvest methods; most samples were from partial cut areas.

^{2/}Data for pure lodgepole pine harvest areas; samples were selected from all harvest methods and ownership classes.

Figure 10: Gross and net weight of logging residue by area

Size, recoverable volume, location, and policies of land owners are examples of such factors. Some information needed to make feasibility assessments is provided in tables in the appendix of this report. Data given in tables 21–23 in the appendix can be used to determine the allocation of these weights by diameter and length classes, whether the material was live or dead or cull at the time of harvest, and provides information on the number of pieces per acre. Also included in the appendix are factors (tables 18–20) that can be used to estimate gross and net volumes of logging residue by owner class. These factors were the basis for the weight estimates shown in table 11. As table 11 shows about 7.4 million dry tons of residue comes from clearcut harvesting. This is 43 percent of the 17.2 million ton total. Some clearcutting does occur in the areas

Energy Potential

where residue is shown under the "all methods". Thus, the total weight of residue from clearcutting is a little higher than indicated above. Also notable is the distribution of residue by geographic area. Almost one-half, 8.6 million dry tons, of the total amount of residue exists in western Oregon and western Washington. The total weight in the other areas reflects either lower total harvest volumes, or lower per acre harvest volumes. These figures do not include residue less than 3.0 inches in diameter, essentially the biomass in tree crowns. Region-wide estimates for this smaller material are not available, but the total weight is considerable. In terms of energy potential the opportunities are much less, since smaller size pieces tend to be much more costly to recover. Additionally, this source of residue is usually viewed as an important source of nutrients for future trees. The relative amount needed for this purpose is not well defined.

It should be noted that the logging residue weights provided in this report are not additive to the total weight of the biomass inventory (table 4). The inventory figure includes the biomass of all trees, above a 1.0 foot stump (excluding foliage). The logging residue figure includes parts of trees that remain on site following a logging operation. As such, residue biomass has been included in the inventory estimate. The term logging residue only defines the disposition of some biomass at the time of harvest.

Energy potential as expressed here is defined as the maximum amount of energy that would be available if the stated source was fully converted at the highest level of efficiency. This of course is not feasible nor necessarily desirable in the real world. The value of figures reported here is for identification of those areas or sources with the greatest potential for energy production. Table 12 shows the energy potential by source of biomass for each geographic area. The total amount of energy represented by these sources, nearly 19 quads, is equivalent to 25 percent of current US consumption.

**Table 12. Energy values¹ of potentially available woody biomass
by State, resource area, and source.**

State and resource area	Annual logging residue	Cull/dead trees	Crowns of growing stock trees	Small trees	All sources
----- Quads ^{2/} -----					
SOUTHEAST ALASKA	0.02	0.62	1.54	0.18	2.36
IDAHO	0.04	0.59	1.53	0.31	2.47
MONTANA	0.03	0.77	1.74	0.55	3.09
OREGON:					
Northwest	0.02	0.15	0.65	0.40	1.22
West Central	0.03	0.23	0.72	0.31	1.29
Southwest	0.03	0.59	0.90	0.59	2.11
Eastern	<u>0.03</u>	<u>0.23</u>	<u>1.07</u>	<u>0.33</u>	<u>1.66</u>
Total	0.11	1.20	3.34	1.63	6.28
WASHINGTON:					
Olympic Peninsula	0.02	0.11	0.68	0.14	0.95
Puget Sound	0.02	0.16	0.73	0.17	1.08
Southwest	0.02	0.21	0.70	0.15	1.08
Eastern	<u>0.02</u>	<u>0.11</u>	<u>0.85</u>	<u>0.35</u>	<u>1.33</u>
Total	0.08	0.59	2.96	0.81	4.44

^{1/}Derived by converting bone dry tons to maximum heating value using an average of 17,000,000 Btu's per ton.

^{2/}A quad equals 1×10^{15} Btu's.

The logging residue figure is based on estimated annual quantities of residue created as a result of current levels of timber harvesting. The other biomass energy sources are based on standing inventory data, and as such would be available for conversion to energy over a considerable time period. No attempt has been made to estimate the time period over which this material might enter the energy market. As will be discussed below there are other sources of woody

biomass that might provide additional opportunities for energy conversion. The relative contribution of each source of woody biomass is shown in figures 11 and 12. Since logging residue is an annual estimate it is proportionally less than the other sources. Realistically speaking, the other sources of biomass are the resource from which logging residue is created during harvest. Thus, in the current energy market, logging residue represents the main portion of the other sources that might be considered available on an annual basis. Even this amount is significant if converted into energy. The total value for logging residue is about 0.3 quad, almost 10 times the energy output of the Trojan nuclear plant operating at 80 percent of capacity.

Figure 11: Proportion of total energy potential for each source

Figure 12: Distribution of total biomass inventory by source by resource Area

Each source of biomass has unique characteristics and opportunities for energy production. These unique aspects are briefly described below.

Logging residue—As noted earlier, the figure for logging residue does not include materials less than 3.0 inches in diameter. This would be primarily tree crowns. Thus, the energy value noted above is only part of the absolute total quantity that exists. It is questionable whether this smaller material would be converted to energy in today's technological and energy environment. This material is also considered to be valuable for maintaining site productivity and habitat for many animal species, although the amount and distribution for these purposes is not well defined. With these existing constraints it would seem unreasonable to expect much of a contribution from this small diameter material.

Changing harvest technology, coupled with growing demand for all wood products, may result in a different utilization rate for these smaller tree components in the future. As we look into the future we will be paying less attention to what we now call logging residue and more to total biomass management. Eventually the term logging residue will become obsolete.

Figure 13: Small size residue (less than 3.0 inches) such as this may be available for energy.

The amount of logging residue that might enter the energy market under current circumstances is a function of cost of recovery, transportation distance, and energy values. All of these are in relation to location of the conversion facility. What may be feasible in western Washington, may not be economically possible in the more sparsely timbered areas in Idaho and Montana. Thus, site specific analyses are needed to determine the amount of residue that may be converted into energy. A recent report to the U. S. Department of Energy (Envirosphere 1986 a,b) provides supply curves for logging residue for the five state area encompassing Region X of DOE. This information may be useful in making the economic assessments needed to determine the feasibility of converting residue to energy for a specific location in the 5-State area.

Cull/Dead trees—Energy potential from this source is fairly significant, nearly 4 quads. A key question for these sources, however, is availability. For the most part cull and dead trees are scattered throughout the forests of the 5-State area, an exception being concentrations of dead trees caused by incidents such as insect epidemics. Trees in this classification tend to be associated with older stands, with areas like southeast Alaska and southwest Oregon, where large acreages of older stands exist, having higher concentrations of biomass in cull and dead trees. Absolute quantities, and therefore opportunities for recovery of this material for energy, are higher for these areas than for areas where younger forests predominate.

Figure 14: Cull trees, which contain logs like this, and dead trees are a significant but widely scattered resource.

The scattered nature of cull and dead trees inhibits their recovery for energy because of higher harvesting costs. As a result, biomass from these sources is generally associated with normal harvesting operations, or salvage sales. Even the salvage sales tend to produce a high proportion of product recovery for other uses. In areas with flatter terrain, characteristic of the ponderosa pine type east of the Cascades, there are greater opportunities for recovery of cull and dead trees. This is due largely to lower harvesting costs and the partial cut practices that are common to these areas. For most areas it is likely that good energy markets might spur recovery of additional amounts of cull and dead biomass.

Tree crowns—Crowns of live trees comprises the single largest source of biomass in the 5-State area, over 11 quads. As defined earlier this does not include foliage, which would add considerably to this total. Obviously crowns should not be considered as a source for energy conversion independent of the entire tree. Nor should the total amount of potential energy be considered as being available for energy production. The forest resource will be managed and harvested in conjunction with a complex set of societal and owners objectives. As trees are deemed ready for harvest the crown portion then comes into the energy equation. As is the case for logging residues, some quantity of crown material may be left on site to enhance or protect other environmental considerations or for future site productivity. How much of this material needs to be left on site is under investigation and will probably vary considerably from one area to another.

The opportunity to utilize crown biomass for energy, or other products for that matter, is much greater for younger stands. Average diameters of these stands is considerably less than for the old growth stands that have constituted most of the harvest for this decade. Smaller trees are more likely to be harvested by mechanical means, or if done by hand are less apt to breakup during the felling process. Harvesting whole trees or longer sections with crowns intact will provide economic incentives for greater utilization of crown materials. In general the amount of crown biomass entering the energy market will be closely tied to harvest levels and criteria that determine the proportion that must remain on site. The opportunity to extend harvest to trees of marginal value will be greater if a larger portion of the tree can be marketed. Thus, expanding energy markets might actually result in greater amounts of these materials being available for utilization. A key to greater utilization of crown biomass will be efficient handling and processing technology. Lower valued products usually require a higher degree of efficiency to ensure economic feasibility of recovery. New technologies may help bridge this gap.

Small trees—Trees less than 5.0 inches in diameter account for a significant energy opportunity in total, about 3.5 quads, but are extremely variable in terms of real opportunity. These trees, along with seedlings less than 1.0 inch in diameter, represent our future forests. As such they would not be considered as a current source of raw material for energy or any other product. For the most part small trees occur as components in stands with larger trees, or as the single component, such as following clearcutting, or fires and other natural catastrophes. In the first case they may be an integral part of the stand structure, representing one of several age classes. In the latter case they are from natural or planted origins and of varying stocking densities. In either case overstocking of small trees may present an opportunity for energy conversion.

Figure 15: Recovery of biomass from thinning small trees may be an important source of wood for energy in the future.

Reducing the density of overstocked stands is usually accomplished by thinning operations. In many operations, called pre-commercial thinnings, unwanted trees are cut and left to decay, providing greater growing space for remaining desirable trees. These procedures are expensive and usually do not result in removal of products until the trees are larger; the operations are then called commercial thinnings. The smaller trees have rarely had much product value, off site that is. This has contributed to a lower than desirable level of thinning operations for most land owners. A viable market for small trees might change the situation considerably. First, additional biomass might be recovered from current or planned operations. Secondly, the ability to generate some income from these operations might create opportunities for additional thinnings that would otherwise be passed over. While thinnings do take place, there are thousands of acres of forests in the 5-State area that could benefit from thinning, but are being delayed because of high treatment costs. It is these stands, along with some having slightly larger trees, that represent a significant opportunity to recover energy wood. The extent and feasibility of these opportunities are unique to each location. Availability to energy markets may be a key to more intensive forest management in the future.

In addition to woody biomass currently being converted to energy, primarily in the forest industries and for residential heating, the forests of the Pacific Northwest and Alaska represent a significant opportunity to help meet future energy needs. The extent to which these forests contribute is a function of a complex set of criteria, and varies considerably from one geographic area to another. Expanding the use of woody biomass for energy holds promise not only for meeting growing demands, but may provide an economic incentive for intensifying management of the region's forests. Obviously only a small portion of the nearly 19 quads of energy from the sources in this report will be physically available in any given year. Even less may find its way to markets because of critical economic factors. But, the amount that does reach conversion facilities can make a significant and lasting contribution to the region's energy requirements. Unlike other sources of energy, woody biomass is a renewable resource.

There are other sources of forest biomass not addressed by this report. The largest such source is biomass occurring on what are frequently referred to as non-commercial forests. Juniper stands in eastern Oregon and Washington are examples of this type of forest. Data in table 1 showed a total of just over 25 million acres of "other forest land" in the 5-State area. Much of this land is covered with trees that are not generally considered to be of commercial value. Eastern Oregon alone has over 3.6 million acres of other forest land, most of which is occupied by non-commercial species (Farrenkopf 1982). The very definition of these stands indicates that few products are removed from trees growing on these sites. In some cases products such as posts, poles, and firewood are taken from these forests. Large scale removal of biomass from these forests may not be reasonable for a number of reasons. They do, however, represent a potentially large source of biomass, particularly for products that do not require high quality wood—such as energy.

Reliability of data for most of the sources of biomass presented in this report is difficult to assess. Each of the Forest Service reports from which inventory

Conclusion

volumes were derived, gives information on sampling errors for land area and volume. These sampling errors, however, do not apply to the total biomass estimates in this report, which were constructed by applying factors to the basic inventory estimates. Thus, sampling errors for total tree biomass estimates by resource area were not determined. The main stem of a tree accounts for the largest proportion of total tree biomass, and the sampling errors associated with this portion are relatively low as indicated in the Forest Service reports. Therefore, the combined error associated with total tree biomass in almost all cases will be lower than that for the non-stem portion of a tree. For example, a standard error of 5 percent for the main stem and 25 percent for the other biomass components, could result in a combined error as low as 10 percent for total tree biomass, because the biomass of the main stem accounts for such a large proportion of the total biomass of the tree. The data presented here provides information on the relative size and distribution of biomass for the resources areas. Site specific needs should be met by deriving estimates from the local data base. Standard errors for logging residue estimates are available in the referenced reports. Since total residue estimates rely on actual harvest figures, errors associated with the totals should be the same as those associated with the estimators themselves.

Whether augmenting regional supplies or facilitating forest management, the use of woody biomass for energy has the potential to impact both people and forests of the region. Energy markets in the 5-State area are currently not conducive to rapid growth in the use of woody biomass. Likewise, there are many gaps in harvesting and processing technologies needed to support this growth. Finally, we do not fully understand the role of woody biomass in the enhancement and protection of the forest environment. Time, however, will see changes in all three elements: markets, technology, management. It is anticipated that woody biomass will play a larger role in future energy production. The extent and rapidity with which this may occur is unknown. Another unknown, and a potentially major consideration, is the effect of international energy demands and politics on utilization of the region's forest biomass. While not widely discussed,

the potential exists for forests within the 5-State area to become significant sources of wood for the many nations in the world that are facing serious shortages of fuel for cooking and heating. It would not be unreasonable to expect these countries to look toward the U.S. for assistance with this critical issue. Following the example of other commodities, we could easily see a flow of woody biomass to some of these countries within a matter of years.

How much and when are the main questions concerning the use of woody biomass for energy. Possibly *where* should be added to that list. The resource available to support this use is large and spread throughout the 5-State area of the Pacific Northwest and Alaska. A great deal of research, development, and innovation will occur as we move toward the year 2000. All three will be necessary to ensure efficient and effective management of this important resource.

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Basal area — The area in square feet (square meters) of the cross section at breast height of a single tree or of all trees in a stand, usually expressed as square feet (square meters) of basal area per acre (hectare).

Class of timber — A classification of trees as growing stock, cull, and salvable dead. Growing stock trees are subdivided into seedling, sapling, poletimber, and sawtimber trees.

Cull trees — Live trees of noncommercial species, or live trees of commercial species that are more than 75-percent defective or with defect caused primarily by poor form or roughness, and are unlikely to become growing stock.

Diameter class — A classification of trees based on diameter outside bark measured at breast height, 4-1/2 feet (1.37 m) above the ground. D.B.H. is the common abbreviation for "diameter at breast height".

Forest industry lands — Lands owned by companies or individuals owning or operating wood-using plants.

Forest land — Land at least 10 percent (16.7 percent in southeast Alaska) stocked with live trees or land formerly having such tree cover and not currently developed for nonforest use.

Forest types — Stands with 50 percent or more stocking in live conifer trees are classified as softwood types. Stands with a majority of stocking in live hardwood trees are classified as hardwood types. Within these two groups, the individual forest type is determined by plurality of stocking by species of live softwood or hardwood trees.

Growing stock trees — All live trees with the exception of cull trees.

Growing stock volume — Net volume in cubic feet of live sawtimber and poletimber growing stock trees from stump to a minimum 4-inch (10 cm) top (of central stem) outside bark. Net volume equals gross volume less deduction for rot and missing bole sections.

Hardwoods — Trees that are angiosperms, usually broad-leaved and deciduous.

Land area — Area as reported as land by the Bureau of Census. Total land area includes dry land and land temporarily or partially covered by water such as marshes, swamps, and river flood plains; streams, sloughs, and canals less than 1/8-mile (200 m) wide; and lakes, reservoirs, and ponds less than 40 acres (16 ha) in area.

Glossary

A. Forest Inventory Terms

Mean annual increment — A measure of the productivity of forest land in terms of the average increase in cubic-foot volume per acre per year. For a given species and site index the average is based on the number of years needed for the mean annual increment to culminate in fully stocked stands.

Mortality — Volume of sound wood in trees dying from natural causes during a specified period, such as between inventories.

National Forest lands — Federal lands which have been designated by Executive order or statute as National Forest or purchase units and other lands under the administration of the Forest Service, including experimental areas and Bankhead-Jones Title III lands.

Net annual growth — The net increase in volume of trees during a specified year. Components of net annual growth of trees: (a) the increment in net volume of trees alive at the beginning of the specified year and surviving to the year's end, plus (b) the net volume of trees reaching sawtimber or poletimber size during the year, minus (c) the net volume of trees that died during the year, minus (d) the net loss to tree decay during the year.

Noncommercial species — A tree species not suitable for industrial wood products.

Nonforest land — Land that has never supported forests or was formerly forested and is currently developed for nonforest uses. Included are lands used for agricultural crops, Christmas tree farms, improved pasture, residential areas, city parks, improved roads, operating railroads and their right-of-way clearings, powerline and pipeline clearings, streams over 30 feet (10 m) wide, and 1- to 40-acre (0.4- to 16- ha) areas of water classified by the Bureau of Census as land. If intermingled in forest areas, unimproved roads and other nonforest strips must be more than 120 feet (35 m) wide, and clearings or other areas must be 1 acre (0.4 ha) or larger in size to qualify as nonforest land.

Nonstocked areas — Timberland less than 10 percent (16.7 percent in southeast Alaska) stocked with growing stock trees.

Other forest land — Forest land incapable of producing 20 cubic feet per acre per year of industrial wood because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness; or public land withdrawn from timber utilization through statute, ordinance, or administrative order but which otherwise qualifies as timberland; or National Forest timberland temporarily withdrawn from timber utilization and under study for possible inclusion in the wilderness system.

Other private lands — All privately owned lands except those classed as forest industry lands.

Other public lands — Lands administered by public agencies other than the Forest Service.

Poletimber stands — Stands of timberland with a mean diameter (weighted by basal area) from 5.0-9.0 inches (12.5-22.5 cm) if softwood and from 5.0-11.0 (12.5-27.5 cm) if hardwood.

Poletimber trees — Live trees of commercial species at least 5.0 inches (12.5 cm) in d.b.h. but smaller than sawtimber size, and of good form and vigor.

Salvable dead trees — Standing or down trees of commercial species, at least 9.0 inches (22.5 cm) in d.b.h. for softwoods and at least 11.0 inches (27.5 cm) in d.b.h. for hardwoods, containing 25 percent or more sound wood volume and at least one merchantable 12-foot (3.8-m) log if softwood or one merchantable 8-foot (2.5-m) log if hardwood.

Sapling and seedling stands — Stands of timberland with a mean diameter (weighted by number of trees) less than 5.0 inches (12.5 cm).

Sapling and seedling trees — Live trees of commercial species less than 5 inches (12.5 cm) in d.b.h. with no disease, defects, or deformities likely to prevent their becoming poletimber trees.

Sawtimber stands — Stands of timberland with a mean diameter (weighted by basal area) larger than 9.0 inches (22.5 cm) if softwood (11.0 inches [27.5 cm] in southeast Alaska) and larger than 11.0 inches (27.5 cm) if hardwood.

Sawtimber trees — Live softwood trees of commercial species at least 9.0 inches (22.5 cm) in d.b.h. (11.0 inches [27.5 cm] in southeast Alaska) and hardwood trees of commercial species at least 11.0 inches (27.5 cm) in d.b.h. At least 25 percent of the board-foot volume in a sawtimber tree must be free from defect. Softwood trees must contain at least one 12-foot (3.8-m) saw log with a top diameter of not less than 6 inches (15 cm) inside bark; hardwood trees must contain at least one 8-foot (2.5-m) saw log with a top diameter of not less than 8 inches (20 cm) inside bark.

Site class — A classification of the potential productivity of forest land, defined by capacity for cubic-foot annual growth per acre at culmination of mean annual growth in fully stocked natural stands.

B. Logging Residue Terms

Softwoods — Coniferous trees, usually evergreen.

Stocking — A measure of the area occupied by trees of specified classes. FIA forest inventories consider three categories of stocking: all live trees, growing stock trees, and desirable trees. Stocking of all live trees is used to delineate forest land and forest types. Stocking of growing stock trees is used in classifications of stand size and stand age. Stocking of desirable trees is used to delineate area condition classes.

Timber harvest — Volume of roundwood removed from forest land for products.

Timberland — Forest land capable of producing 20 cubic feet per acre (1.4 cubic meter per ha) per year of industrial wood, and not withdrawn from timber utilization.

Volume of growing stock — Volume of sound wood in the bole of live growing stock sawtimber and poletimber trees from stump to a minimum 4.0-inch (10-cm) top outside the bark or to the point where the central stem breaks into limbs.

Clearcut — A harvest operation in which all, or nearly all, trees in a stand are cut in one operation.

Cutover area — Synonymous with sample unit or sample area; the area encompassing a single harvest operation; a clearcut for example.

Harvest volume — Net scaled volume of timber removed, or estimated to be removed, from a cutover area during harvesting; expressed in thousand board feet (log scale, as reported by land owners) per acre (MBF/AC).

Logging residue:

General — All down and dead woody material existing on a cutover area after harvesting is completed; excluding standing trees or portions thereof.

Specific — All logging residue (as defined above) 3.01 inches (7.5 cm) and larger in diameter inside bark (d.i.b.) and 1.0 foot (30.5 cm) and longer in length; includes limbs, slabs, and splinters.

MBF — One thousand board feet of logs; a measure of the volume of timber harvested.

Owner class:

Private — Lands owned by private individuals, forest industries, and Native and other corporations.

Public — Lands owned by the public or managed by a public agency.

Partial cut — A harvest method in which portions of a stand of timber are cut during a number of entries over time; precommercial thinnings are not included.

Residue volume:

Chippability — Condition of residue sound enough to be physically handled and capable of producing usable chips; includes residue exhibiting early stages of wet or dry rot.

Cull — Residue from trees that were cull (less than 25 percent sound) at the time of harvest.

Dead — Residue from trees or portions of trees that were dead before harvest; includes material on the ground at the time of harvest.

Gross — Volume of a piece of residue measured only by its external dimensions; includes rot, cracks, and missing parts.

Live — Residue from trees or portions of trees that were alive before they were cut or knocked down during harvest.

Net — The usable portion of a piece of residue; for this report, usability is based on physical chippability of the material and does not imply solid product potential.

Small-end-diameter — measured inside bark at the smallest end of a piece of residue, to a 3.01-inch (7.5-cm) minimum.

Stratum — A category of timber harvest area defined for this study by land ownership.

Supply zone — A uniquely defined area containing timber or logging residue that is considered to be potentially available for a processing facility.

YUM (or PUM) — Terms used by the USDA Forest Service for large piles of residue yarded or bulldozed to a common location. If the residue has been piled with some degree of uniformity it is referred to as PUM (piled unmerchantable material); otherwise, the term YUM (yarded unmerchantable material) is used.

C. Biomass Terms

Biomass inventory — The dry or green weight of wood and bark of trees, above a 1.0 foot (30.5 cm) stump, excluding foliage, that are at least 1.0 inch (2.54 cm) in diameter at d.b.h., and located on timberland.

Bole — All wood and bark of a tree above a 1.0 foot (0.4 m) stump and below the point where either the diameter of the central stem is less than 4.0 inches (10 cm) or the central stem breaks into limbs.

Bone dry ton — One dry ton, 2000 pounds (907.2 kg), of wood or bark.

Branches — Weight of wood and bark of trees from point where main stem breaks into limbs to a minimum of 1/4-inch (0.6 cm) in diameter; excluding foliage.

Crown — Synonymous with branches for this report.

Dry weight — Weight of wood or bark containing no water.

Green weight — Weight of wood or bark in its natural or growing condition; varies by season and location in tree; green weight is equal to dry weight times (1 + moisture content, oven dry basis).

Wood density — Weight of wood expressed in pounds per cubic foot, green or dry; affected by specific gravity and moisture content; where dry density is calculated by multiplying specific gravity of wood times the density of water (62.4 pounds per cubic foot).

Quad — Quadrillion (1×10^{15}) Btu's.

Top — Portion of the main stem or forks of a tree above 4.0 inches (10 cm) to the tip of the main stem or fork.

Appendix

Tables 13 — 23 Biomass Information Metric Equivalents

Table 13. Area of timberland by State, resource area, and forest type

State and resource area	Douglas-fir	Hemlock	True fir	Lodgepole pine	Incense cedar	Western redcedar	Sitka spruce	Sugar pine	Western white pine	Ponderosa pine
Thousand acres										
SOUTHEAST ALASKA	--	4,772	7	--	--	794	642	--	--	--
IDAHO	5,846	542	1,767	3,020	--	616	--	--	239	1,906
MONTANA	4,780	94	1,448	3,827	--	122	--	--	38	1,597
OREGON:										
Northwest	2,007	250	180	38	--	60	160	--	--	6
West Central	2,588	383	129	12	14	43	16	--	--	3
Southwest	3,383	169	450	83	111	51	26	25	17	116
Eastern	1,260	146	2,041	1,786	40	--	--	9	24	4,317
Total	9,238	948	2,800	1,919	165	154	202	34	41	4,442
WASHINGTON:										
Olympic Peninsula	1,022	1,108	110	32	--	155	21	--	--	--
Puget Sound	1,202	768	468	--	--	118	--	--	--	--
Southwest	1,701	767	278	25	--	22	11	--	7	4
Eastern	2,590	130	1,026	714	--	141	--	--	4	1,486
Total	6,515	2,773	1,882	771	--	436	32	--	11	1,490

State and resource area	Englemann spruce	Western larch	Other softwood	Red alder	Aspen/cottonwood	Oak	Other hardwood	Nonstocked ^{1/}	All types
Thousand acres									
SOUTHEAST ALASKA	--	--	2	16	84	--	--	--	6,317
IDAHO	2,499	657	--	--	569	--	--	--	17,661
MONTANA	312	663	179	--	282	--	11	218	13,571
OREGON:									
Northwest	2	--	2	554	9	53	110	117	3,548
West Central	5	--	20	389	--	70	162	144	3,978
Southwest	1	--	101	351	--	367	657	235	6,143
Eastern	95	92	5	--	7	--	7	297	10,126
Total	103	92	128	1,294	16	490	936	793	23,795
WASHINGTON:									
Olympic Peninsula	--	--	2	487	14	--	54	87	3,092
Puget Sound	--	--	2	686	22	--	96	100	3,462
Southwest	4	--	--	550	26	2	86	169	3,652
Eastern	191	511	9	5	47	25	10	255	7,144
Total	195	511	13	1,728	109	27	246	611	17,350

^{1/} Nonstocked type is less than 10 percent stocked with live trees.

Table 14. Area of timberland by State, resource area, and cubic-foot site class

State and resource area	Site class ^{1/}						All classes
	225 or more	165 to 224	120 to 164	85 to 119	50 to 84	49 or less	
----- Thousand acres -----							
SOUTHEAST ALASKA	<u>2/</u>	<u>2/</u>	<u>2/</u>	<u>2/</u>	<u>2/</u>	<u>2/</u>	6,317
IDAHO	--	543	2,005	3,640	4,078	3,740	14,006 ^{3/}
MONTANA	--	53	1,426	4,032	4,702	3,358	13,571
OREGON:							
Northwest	180	456	1,846	599	454	13	3,548
West Central	77	670	1,904	829	447	51	3,978
Southwest	58	606	1,971	1,518	1,495	495	6,143
Eastern	<u>1</u>	<u>69</u>	<u>302</u>	<u>1,771</u>	<u>4,918</u>	<u>3,065</u>	<u>10,126</u>
Total	316	1,801	6,023	4,717	7,314	3,624	23,795
WASHINGTON:							
Olympic Peninsula	543	987	774	511	204	73	3,092
Puget Sound	185	848	1,156	845	337	91	3,462
Southwest	404	997	946	559	661	85	3,652
Eastern	<u>--</u>	<u>212</u>	<u>988</u>	<u>1,736</u>	<u>2,513</u>	<u>1,695</u>	<u>7,144</u>
Total	1,132	3,044	3,864	3,651	3,715	1,944	17,350

^{1/}Relative measure of stand productivity defined by capacity for cubic-foot annual growth per acre at culmination of mean annual growth in fully stocked natural stands.

^{2/}Breakdown by cubic-foot site class not available for Southeast Alaska.

^{3/}Does not include 3,654,000 acres of low productivity land not classified by site class.

Table 15. Total dry weight of above ground biomass of growing stock¹ trees on timberland by State, resource area, and ownership

State and resource area	National Forest	Other public	Forest industry	Other private	All ownerships
----- Million bone dry tons -----					
SOUTHEAST ALASKA	<u>2/</u>	<u>2/</u>	<u>2/</u>	<u>2/</u>	577.33
IDAHO	365.29	56.77	38.55	55.35	515.96
MONTANA	324.86	22.70	50.80	70.41	468.77
OREGON:					
Northwest	111.27	45.97	55.55	35.11	247.90
West Central	201.51	47.43	52.92	28.53	330.39
Southwest	184.06	115.56	76.93	28.00	404.55
Eastern	<u>277.47</u>	<u>25.69</u>	<u>38.48</u>	<u>17.39</u>	<u>359.03</u>
Total	774.31	234.65	223.88	109.03	1,341.87
WASHINGTON:					
Olympic Peninsula	51.28	68.19	101.43	30.84	251.74
Puget Sound	88.39	51.01	63.44	64.47	267.31
Southwest	118.27	31.86	88.40	35.66	274.19
Eastern	<u>123.99</u>	<u>92.30</u>	<u>41.26</u>	<u>43.48</u>	<u>301.03</u>
Total	381.93	243.36	294.53	174.45	1,094.27

^{1/} Includes trees 5.0-inch d.b.h. and larger.

^{2/} Breakdown by ownership class not available for Southeast Alaska.

Table 16. Total dry weight of above ground biomass of growing stock trees on timberland by State, resource area, and species

State and resource area	Douglas-fir	Hemlock	True fir	Lodgepole pine	Incense cedar	Western redcedar	Sitka spruce	Sugar pine	Western white pine	Ponderosa pine
----- Million bone dry tons -----										
SOUTHEAST ALASKA	--	399.48	2.29	0.61	--	17.59	128.45	--	--	--
IDAHO	159.45	25.84	100.47	68.49	--	25.58	--	--	19.46	47.95
MONTANA	148.26	6.11	35.40	137.55	--	3.90	--	--	3.51	39.08
OREGON:										
Northwest	133.65	56.01	15.68	1.16	0.01	4.85	4.46	--	0.55	0.43
West Central	234.02	48.26	13.40	0.53	0.87	5.80	2.54	0.72	1.60	0.26
Southwest	268.03	24.87	31.54	1.87	5.48	4.47	--	8.81	2.40	9.17
Eastern	58.21	10.28	71.95	58.81	1.14	0.15	--	0.86	1.39	130.34
Total	693.91	139.42	132.57	62.37	7.50	15.27	7.00	10.39	5.94	140.20
WASHINGTON:										
Olympic Peninsula	76.74	111.07	12.52	1.50	--	10.18	7.14	--	0.21	--
Puget Sound	91.14	75.77	39.09	0.17	--	14.63	0.82	--	0.14	--
Southwest	131.78	69.23	31.85	0.71	--	6.70	1.82	--	0.88	0.56
Eastern	111.45	10.99	44.99	24.96	--	5.84	--	--	2.85	53.66
Total	411.11	267.06	128.45	27.34	--	37.35	9.78	--	4.08	54.22

State and resource area	Engelmann spruce	Western larch	Other softwood	Red alder	Aspen/ cottonwood	Oak	Other hardwood	All types
----- Million bone dry tons -----								
SOUTHEAST ALASKA	--	--	24.56	1.74	2.61	--	--	577.33
IDAHO	32.74	28.56	2.12	--	5.30	--	--	515.96
MONTANA	32.29	44.80	11.31	--	5.30	--	1.26	468.77
OREGON:								
Northwest	0.35	0.64	0.23	18.04	0.61	3.34	7.89	247.90
West Central	0.59	--	0.09	11.97	0.10	2.64	7.00	330.39
Southwest	--	--	5.97	10.89	--	--	31.05	404.55
Eastern	8.25	16.87	0.17	0.03	0.26	0.26	0.06	359.03
Total	9.19	17.51	6.46	40.93	0.97	6.24	46.00	1,341.87
WASHINGTON:								
Olympic Peninsula	--	--	0.24	26.28	0.58	0.03	5.25	251.74
Puget Sound	0.04	--	1.08	28.31	2.52	--	13.60	267.31
Southwest	0.42	0.20	0.14	21.43	0.90	0.03	7.54	274.19
Eastern	12.25	28.92	0.75	0.17	1.85	0.16	1.92	301.03
Total	12.71	29.19	2.21	76.19	5.85	0.42	28.31	1,094.27

Table 17. Dry weight per acre of net annual growth of growing stock trees on timberland by State, resource area, and ownership

State and resource area	National Forest	Other public	Forest industry	Other private	All ownerships
----- Bone dry tons per acre -----					
SOUTHEAST ALASKA	1/	1/	1/	1/	0.04
IDAHO	0.36	0.62	0.73	0.66	0.45
MONTANA	0.49	0.43	0.40	0.37	0.45
OREGON:					
Northwest	0.72	1.46	1.76	1.35	1.33
West Central	0.55	1.29	1.28	1.17	0.96
Southwest	0.50	0.55	0.62	0.77	0.59
Eastern	0.40	0.46	0.41	0.41	0.41
WASHINGTON:					
Olympic Peninsula	0.35	2.41	2.34	1.46	1.85
Puget Sound	0.19	2.08	1.84	1.89	1.50
Southwest	0.66	2.25	1.91	1.69	1.54
Eastern	0.42	0.78	0.86	0.86	0.66

1/ Breakdown by ownership not available for Southeast Alaska.

Table 18. Average gross volume (wood and bark) of logging residue by area, ownership, and harvest method

Area and ownership	Cubic feet per 1,000 BF harvested			Cubic feet per acre		
	Clearcut	Partial cut	All harvest methods ^{1/}	Clearcut	Partial cut	All harvest methods ^{1/}
SOUTHEAST ALASKA						
Public	143	--	--	4,602	--	--
Private	182	--	--	6,176	--	--
IDAHO:						
National forest	143	185	--	3,564	2,585	--
Other public	--	--	221	--	--	1,833
Private	--	--	167	--	--	1,264
MONTANA:						
Public	142	173	--	2,369	1,846	--
Private	--	--	221	--	--	1,602
Lodgepole pine ^{2/}	--	--	162	--	--	2,009
WESTERN OREGON:						
National forest	77	217	--	3,982	2,375	--
Other public	80	143	--	4,037	1,820	--
Private	65	477	--	3,306	2,478	--
EASTERN OREGON:						
Public	--	--	138	--	--	1,008
Private	--	--	128	--	--	860
WESTERN WASHINGTON:						
National forest	74	217	--	4,173	2,375	--
Other public	80	202	--	3,310	1,533	--
Private	63	225	--	2,273	1,596	--
EASTERN WASHINGTON:						
Public	--	--	148	--	--	1,026
Private	--	--	112	--	--	607

NOTE: -- means no data are available.

^{1/} Samples were selected from all harvest methods; most samples were from partial cut areas.

^{2/} Data for pure lodgepole pine harvest areas; samples were selected from all harvest methods and ownerships.

Table 19. Average net volume (wood and bark) of logging residue by area, ownership, and harvest method

Area and ownership	Cubic feet per 1,000 BF harvested			Cubic feet per acre		
	Clearcut	Partial cut	All harvest methods ^{1/}	Clearcut	Partial cut	All harvest methods ^{1/}
SOUTHEAST ALASKA						
Public	97	--	--	3,130	--	--
Private	133	--	--	4,502	--	--
IDAHO:						
National Forest	67	122	--	2,182	1,701	--
Other public	--	--	142	--	--	1,182
Private	--	--	109	--	--	824
MONTANA:						
Public	95	103	--	1,594	1,100	--
Private	--	--	137	--	--	994
Lodgepole pine ^{2/}	--	--	107	--	--	1,321
WESTERN OREGON:						
National Forest	47	136	--	2,471	1,488	--
Other public	52	93	--	2,642	1,184	--
Private	40	296	--	2,070	1,537	--
EASTERN OREGON:						
Public	--	--	76	--	--	553
Private	--	--	80	--	--	534
WESTERN WASHINGTON:						
National Forest	44	136	--	2,497	1,488	--
Other public	51	118	--	2,110	895	--
Private	37	140	--	1,351	992	--
EASTERN WASHINGTON:						
Public	--	--	96	--	--	670
Private	--	--	72	--	--	394

NOTE: -- means no data are available.

^{1/}Samples were selected from all harvest methods; most samples were from partial cut areas.

^{2/}Data for pure lodgepole pine harvest areas; samples were selected from all harvest methods and ownerships.

Table 20. Average net dry weight (wood and bark) of logging residue by area, ownership, and harvest method

Area and ownership	Bone dry tons per 1,000 Bf harvested ¹			Bone dry tons per acre		
	Clearcut	Partial cut	All harvest methods ²	Clearcut	Partial cut	All harvest methods ²
SOUTHEAST ALASKA						
Public	1.18	--	--	38.03	--	--
Private	1.62	--	--	54.92	--	--
IDAHO:						
National Forest	1.06	1.49	--	26.62	20.75	--
Other public	--	--	1.73	--	--	14.42
Private	--	--	1.33	--	--	10.05
MONTANA:						
Public	1.19	1.29	--	19.92	13.75	--
Private	--	--	1.71	--	--	12.42
Lodgepole pine?	--	--	1.34	--	--	16.51
WESTERN OREGON:						
National Forest	0.62	1.80	--	32.62	19.64	--
Other public	0.69	1.23	--	34.87	15.63	--
Private	0.53	3.91	--	27.32	20.29	--
EASTERN OREGON:						
Public	--	--	0.93	--	--	6.75
Private	--	--	0.98	--	--	6.51
WESTERN WASHINGTON:						
National Forest	0.56	1.73	--	31.71	18.90	--
Other public	0.65	1.50	--	26.80	11.37	--
Private	0.47	1.78	--	16.90	12.60	--
EASTERN WASHINGTON:						
Public	--	--	1.21	--	--	8.44
Private	--	--	0.91	--	--	4.96

NOTE: -- means no data are available.

¹Samples were selected from all harvest methods; most samples were from partial cut areas.

²Data for pure lodgepole pine harvest areas; samples were selected from all harvest methods and ownerships.

Table 21. Average gross volume (wood only) of logging residue by area, ownership, harvest method, and live or dead/cull material

Area and ownership	---- Clearcut ----		--- Partial cut ¹	
	Live	Dead/cull	Live	Dead/cull
----- Cubic feet per acre -----				
SOUTHEAST ALASKA				
Public	1,737	2,274	--	--
Private	2,847	2,530	--	--
IDAHO:				
National Forest	1,394	1,704	642	1,573
Other public	--	--	412	1,174
Private	--	--	407	694
MONTANA:				
Public	930	1,091	489	1,089
Private	--	--	498	847
Lodgepole pine	--	--	636	1,180
WESTERN OREGON:				
National Forest	1,485	1,890	646	1,374
Other public	1,293	2,109	555	987
Private	1,179	1,627	649	1,443
EASTERN OREGON:				
Public	--	--	184	654
Private	--	--	230	490
WESTERN WASHINGTON:				
National Forest	1,475	2,123	646	1,374
Other public	1,314	1,542	312	989
Private	894	1,050	406	949
EASTERN WASHINGTON:				
Public	--	--	280	570
Private	--	--	183	325

¹Includes clearcuts for ownerships where the predominate method for harvesting is by partial cutting.

Table 22. Average gross volume (wood only) of logging residue ¹ per acre, by area, ownership, harvest method, and small-end diameter and length class

Area, ownership, and harvest method	Small-end diameter	Length (feet)				Total
		1.0- 7.9	8.0- 15.9	16.0- 31.9	32.0+	
----- Cubic feet per acre -----						
Inches						
SOUTHEAST ALASKA						
Public	3.1- 7.9	275	315	278	54	922
	8.0-15.9	250	491	355	63	1,159
	16.0-27.9	174	433	513	194	1,314
	28.0+	<u>45</u>	<u>119</u>	<u>208</u>	<u>43</u>	<u>415</u>
Total		744	1,358	1,354	354	3,810
Private	3.1- 7.9	214	223	318	177	932
	8.0-15.9	164	396	471	230	1,261
	16.0-27.9	225	347	746	277	1,595
	28.0+	<u>209</u>	<u>350</u>	<u>462</u>	<u>196</u>	<u>1,417</u>
Total		812	1,316	1,997	1,080	5,205
IDAHO						
National Forest: Clearcut	3.1- 7.9	50	112	231	397	790
	8.0-15.9	30	102	279	310	721
	16.0-27.9	9	42	309	401	761
	28.0+	<u>15</u>	<u>--</u>	<u>57</u>	<u>174</u>	<u>246</u>
Total		104	256	876	1,282	2,518
Partial cut	3.1- 7.9	30	112	237	367	746
	8.0-15.9	32	114	288	441	875
	16.0-27.9	10	50	68	357	485
	28.0+	<u>10</u>	<u>--</u>	<u>40</u>	<u>--</u>	<u>50</u>
Total		82	276	633	1,165	2,156
Other public	3.1- 7.9	17	54	130	226	427
	8.0-15.9	17	86	194	417	714
	16.0-27.9	8	29	75	264	376
	28.0+	<u>2</u>	<u>7</u>	<u>31</u>	<u>17</u>	<u>57</u>
Total		44	176	430	924	1,574
Private	3.1- 7.9	24	83	171	219	497
	8.0-15.9	19	65	139	153	376
	16.0-27.9	7	29	80	52	168
	28.0+	<u>--</u>	<u>--</u>	<u>--</u>	<u>42</u>	<u>42</u>
Total		50	177	390	466	1,083
MONTANA ^{2/}						
National Forest: Clearcut	3.1- 7.9	234	246	276	155	911
	8.0-15.9	131	117	110	79	437
	16.0-19.9	21	43	37	19	120
	20.0+	<u>21</u>	<u>18</u>	<u>51</u>	<u>15</u>	<u>105</u>
Total		407	424	474	268	1,573
Partial cut	3.1- 7.9	137	182	219	213	751
	8.0-15.9	87	109	128	102	426
	16.0-19.9	10	24	29	47	110
	20.0+	<u>19</u>	<u>31</u>	<u>32</u>	<u>20</u>	<u>102</u>
Total		253	346	408	382	1,389

Table 22. Average gross volume (wood only) of logging residue¹ per acre, by area, ownership, harvest method, and small-end diameter and length class (continued)

Area, ownership, and harvest method	Small-end diameter	Length (feet)				Total
		1.0- 7.9	8.0- 15.9	16.0- 31.9	32.0+	
		Inches	----- Cubic feet per acre -----			
MONTANA ¹ (Continued)						
Other public	3.1- 7.9	125	153	152	73	503
	8.0-15.9	90	86	78	50	304
	16.0-19.9	19	13	32	8	72
	20.0+	55	14	12	12	133
Total		289	266	294	163	1,012
Lodgepole pine	3.1- 7.9	237	226	309	177	949
	8.0-15.9	86	71	80	35	272
	16.0-19.9	7	21	16	3	47
	20.0+	0	15	--	15	30
Total		330	333	405	230	1,298
WESTERN OREGON						
National Forest: Clearcut	3.1- 7.9	60	122	235	130	547
	8.0-15.9	157	312	244	265	978
	16.0-27.9	105	269	592	250	1,216
	28.0+	42	46	226	174	488
Total		364	749	1,297	819	3,229
Partial cut	3.1- 7.9	18	49	91	74	232
	8.0-15.9	34	90	164	197	485
	16.0-27.9	16	90	275	452	833
	28.0+	6	40	116	223	405
Total		74	269	666	946	1,955
Other public: Clearcut	3.1- 7.9	41	154	275	243	713
	8.0-15.9	77	210	395	433	1,115
	16.0-27.9	29	172	239	356	796
	28.0+	6	97	390	210	703
Total		153	633	1,299	1,242	3,327
Partial cut	3.1- 7.9	15	53	115	135	318
	8.0-15.9	25	56	112	186	379
	16.0-27.9	13	61	136	316	526
	28.0+	4	15	65	201	285
Total		57	185	428	838	1,508
Private:						
Clearcut	3.1- 7.9	31	77	161	151	420
	8.0-15.9	55	137	229	187	608
	16.0-27.9	40	213	422	351	1,026
	28.0+	30	47	406	239	722
Total		156	474	1,218	928	2,776
Partial cut	3.1- 7.9	20	57	114	93	284
	8.0-15.9	22	77	157	204	460
	16.0-27.9	18	94	236	426	774
	28.0+	4	55	140	370	569
Total		64	283	647	1,093	2,087
EASTERN OREGON						
Public	3.1- 7.9	11	30	48	115	204
	8.0-15.9	12	35	71	214	332
	16.0-27.9	6	24	71	110	211
	28.0+	1	11	40	39	91
Total		30	100	230	478	838
Private	3.1- 7.9	17	54	72	104	247
	8.0-15.9	11	25	48	130	214
	16.0-27.9	4	20	53	117	194
	28.0+	1	3	--	59	61
Total		33	102	173	410	718

Table 22. Average gross volume (wood only) of logging residue¹ per acre, by area, ownership, harvest method, and small-end diameter and length class (continued)

Area, ownership, and harvest method	Small-end diameter	Length (feet)				Total
		1.0- 7.9	8.0- 15.9	16.0- 31.9	32.0+	
<hr/>						
	Inches	Cubic feet per acre				
<hr/>						
WESTERN WASHINGTON						
National Forest:						
Clearcut	3.1- 7.9	58	174	236	54	522
	8.0-15.9	136	368	260	169	933
	16.0-27.9	120	363	761	376	1,620
	28.0+	32	119	163	--	314
Total		346	1,024	1,420	599	3,389
Partial cut	3.1- 7.9	18	49	91	74	232
	8.0-15.9	34	90	164	197	485
	16.0-27.9	16	90	275	452	833
	28.0+	6	40	136	223	405
Total		74	269	666	946	1,955
Other public:						
Clearcut	3.1- 7.9	46	125	221	105	497
	8.0-15.9	67	178	208	88	541
	16.0-27.9	59	263	359	274	955
	28.0+	20	164	366	262	819
Total		192	730	1,154	736	2,812
Partial cut	3.1- 7.9	22	67	170	147	406
	8.0-15.9	22	34	115	45	216
	16.0-27.9	2	36	59	214	311
	28.0+	--	97	183	88	368
Total		46	234	527	494	1,301
Private:						
Clearcut	3.1- 7.9	47	142	238	60	487
	8.0-15.9	69	178	217	139	603
	16.0-27.9	36	92	159	150	437
	28.0+	7	67	196	111	381
Total		159	479	810	460	1,908
Partial cut	3.1- 7.9	26	89	203	271	589
	8.0-15.9	18	117	117	51	303
	16.0-27.9	14	40	148	70	272
	28.0+	--	--	130	59	189
Total		58	246	598	451	1,353
<hr/>						
EASTERN WASHINGTON						
Public	3.1- 7.9	16	48	66	106	236
	8.0-15.9	14	41	102	154	311
	16.0-27.9	5	15	68	130	218
	28.0+	1	8	22	28	59
Total		36	112	258	418	824
Private	3.1- 7.9	11	36	85	70	202
	8.0-15.9	11	23	47	58	139
	16.0-27.9	5	13	52	56	126
	28.0+	2	6	9	8	25
Total		29	78	193	192	492

¹ Does not include residue in large piles.

² Sampling by diameter classes was different in Montana than that in the other States.

Table 23. Average number of pieces of logging residue¹ per acre, by area, ownership, harvest method, and small-end diameter and length class

Area, ownership, and harvest method	Small-end diameter	Length (feet)				Total
		1.0- 7.9	8.0- 15.9	16.0- 31.9	32.0+	
		Inches	----- Number of pieces per acre -----			
SOUTHEAST ALASKA						
Public	3.1- 7.9	150.8	144.4	97.2	12.6	405.0
	8.0-15.9	29.5	52.6	30.0	4.2	116.3
	16.0-27.9	7.1	14.6	16.3	3.9	41.9
	28.0+	0.8	2.0	2.9	0.7	6.4
Total		188.2	213.6	146.4	21.4	569.6
Private	3.1- 7.9	129.4	94.2	87.4	38.6	349.6
	8.0-15.9	23.2	42.3	42.1	13.0	120.6
	16.0-27.9	9.0	12.1	22.2	7.3	50.6
	28.0+	2.4	4.2	6.2	3.7	16.5
Total		164.0	152.8	157.9	62.6	537.3
IDAHO						
National Forest: Clearcut	3.1- 7.9	71.6	71.0	59.7	26.6	228.9
	8.0-15.9	11.3	12.8	14.2	7.0	45.3
	16.0-27.9	1.0	1.6	4.7	2.0	9.3
	28.0+	0.4	--	0.1	0.6	1.1
Total		84.3	85.4	79.0	36.2	284.9
Partial cut	3.1- 7.9	56.7	67.1	60.0	22.2	206.0
	8.0-15.9	13.3	15.3	16.0	9.6	54.2
	16.0-27.9	1.2	2.3	1.4	3.1	8.0
	28.0+	0.2	--	0.4	--	0.6
Total		71.4	84.7	77.8	34.9	268.8
Other public	3.1- 7.9	31.2	34.3	31.3	15.5	112.3
	8.0-15.9	6.0	10.9	10.9	8.0	35.8
	16.0-27.9	1.3	1.4	1.5	2.1	6.3
	28.0+	0.2	0.2	0.3	0.2	0.9
Total		38.7	46.8	44.0	25.8	155.3
Private	3.1- 7.9	41.9	52.5	46.6	18.3	159.3
	8.0-15.9	6.9	9.1	8.0	3.0	27.0
	16.0-27.9	1.1	1.3	1.8	0.4	4.6
	28.0+	--	--	--	0.3	0.3
Total		49.9	62.9	56.4	22.0	191.2
MONTANA ¹						
National Forest: Clearcut	3.1- 7.9	182.7	166.2	168.5	66.7	584.1
	8.0-15.9	19.1	14.9	12.8	6.7	53.5
	16.0-27.9	1.2	2.2	1.5	0.9	5.8
	28.0+	0.6	0.5	1.4	0.5	3.0
Total		203.6	183.8	184.2	74.8	646.4
Partial cut	3.1- 7.9	103.6	117.8	117.5	73.7	412.6
	8.0-15.9	12.6	13.3	16.3	9.2	51.4
	16.0-27.9	0.6	1.3	1.4	1.7	5.0
	28.0+	0.5	1.0	0.7	0.4	2.6
Total		117.3	133.4	135.9	85.0	471.6

Table 23. Average number of pieces of logging residue¹ per acre, by area, ownership, harvest method, and small-end diameter and length class (continued)

Area ownership, and harvest method	Small-end diameter	Length (feet)				Total
		1.0- 7.9	8.0- 15.9	16.0- 31.9	32.0+	
Inches		Number of pieces per acre				
MONTANA ^{2/} (Continued)						
Other public	3.1- 7.9	100.1	93.6	87.2	29.7	310.6
	8.0-15.9	12.0	11.0	8.7	4.8	36.5
	16.0-27.9	0.9	0.7	1.3	0.4	3.3
	28.0+	<u>1.1</u>	<u>0.4</u>	<u>0.8</u>	<u>0.6</u>	<u>3.1</u>
	Total	114.3	105.7	98.0	35.5	353.5
Lodgepole pine	3.1- 7.9	190.4	159.4	181.5	74.9	606.2
	8.0-15.9	14.5	9.8	10.5	3.8	38.6
	16.0-27.9	0.5	0.7	0.8	0.2	2.2
	28.0+	<u>--</u>	<u>0.3</u>	<u>--</u>	<u>0.5</u>	<u>0.8</u>
	Total	205.4	170.2	192.8	79.4	647.8
WESTERN OREGON						
National Forest: Clearcut	3.1- 7.9	97.7	72.0	58.7	18.3	246.7
	8.0-15.9	50.3	37.2	15.4	4.0	106.9
	16.0-27.9	11.2	10.5	9.6	2.8	34.1
	28.0+	<u>1.8</u>	<u>0.7</u>	<u>1.4</u>	<u>0.7</u>	<u>4.6</u>
	Total	161.0	120.4	85.1	25.8	392.3
Partial cut	3.1- 7.9	28.6	27.5	21.4	5.3	82.8
	8.0-15.9	11.6	10.3	8.7	3.4	34.0
	16.0-27.9	2.2	3.7	4.6	3.5	14.0
	28.0+	<u>0.3</u>	<u>0.5</u>	<u>1.0</u>	<u>0.6</u>	<u>2.4</u>
	Total	42.7	42.0	35.7	12.8	133.2
Other public: Clearcut	3.1- 7.9	74.8	97.4	69.6	23.0	264.8
	8.0-15.9	27.3	27.2	20.8	7.2	82.5
	16.0-27.9	3.3	6.9	4.7	2.7	17.6
	28.0+	<u>0.4</u>	<u>1.7</u>	<u>2.1</u>	<u>0.8</u>	<u>5.0</u>
	Total	105.8	133.2	97.2	33.7	369.9
Partial cut	3.1- 7.9	29.0	36.3	30.8	9.8	105.9
	8.0-15.9	9.7	8.1	6.3	3.8	27.9
	16.0-27.9	1.3	2.4	2.7	2.3	8.7
	28.0+	<u>0.2</u>	<u>0.2</u>	<u>0.4</u>	<u>0.7</u>	<u>1.5</u>
	Total	40.2	47.0	40.2	16.6	144.0
Private:						
Clearcut	3.1- 7.9	48.0	47.4	40.2	12.4	148.0
	8.0-15.9	18.8	19.1	13.2	3.8	54.9
	16.0-27.9	4.3	8.2	7.3	3.0	22.8
	28.0+	<u>0.9</u>	<u>0.8</u>	<u>2.3</u>	<u>0.7</u>	<u>4.7</u>
	Total	72.0	75.5	63.0	19.9	230.4
Partial cut	3.1- 7.9	36.6	40.2	32.1	9.5	118.4
	8.0-15.9	7.5	9.3	9.0	2.9	28.7
	16.0-27.9	2.2	3.8	3.8	3.4	13.2
	28.0+	<u>0.2</u>	<u>1.0</u>	<u>1.2</u>	<u>1.1</u>	<u>3.5</u>
	Total	46.5	54.3	46.1	16.9	163.8
EASTERN OREGON						
Public	3.1- 7.9	19.9	17.2	9.8	4.7	51.6
	8.0-15.9	3.3	4.0	3.0	2.2	12.5
	16.0-27.9	0.8	0.9	1.2	0.8	3.7
	28.0+	<u>0.1</u>	<u>0.3</u>	<u>0.3</u>	<u>0.1</u>	<u>0.8</u>
	Total	24.1	22.4	14.3	7.8	68.6
Private	3.1- 7.9	31.4	31.0	17.7	5.3	85.4
	8.0-15.9	4.2	3.0	2.6	1.6	11.4
	16.0-27.9	0.5	0.7	1.0	0.5	2.7
	28.0+	<u>0.1</u>	<u>0.1</u>	<u>--</u>	<u>0.2</u>	<u>0.4</u>
	Total	36.2	34.8	21.3	7.6	99.9

Table 23. Average number of pieces of logging residue¹ per acre, by area, ownership, harvest method, and small-end diameter and length class (continued)

Area, ownership, and harvest method	Small-end diameter	Length (feet)				Total
		1.0- 7.9	8.0- 15.9	16.0- 31.9	32.0+	
Inches		Number of pieces per acre				
WESTERN WASHINGTON						
National Forest:						
Clearcut	3.1- 7.9	88.9	86.9	54.4	5.3	235.5
	8.0-15.9	46.3	44.0	14.8	3.3	108.4
	16.0-27.9	11.5	15.4	12.9	3.7	43.5
	28.0+	<u>1.4</u>	<u>2.1</u>	<u>1.1</u>	<u>--</u>	<u>4.6</u>
Total		148.1	148.4	83.2	12.3	392.0
Partial cut	3.1- 7.9	28.6	27.5	21.4	5.3	82.8
	8.0-15.9	11.6	10.3	8.7	3.4	34.0
	16.0-27.9	2.2	3.7	4.6	3.5	14.0
	28.0+	<u>0.3</u>	<u>0.5</u>	<u>1.0</u>	<u>0.6</u>	<u>2.4</u>
Total		42.7	42.0	35.7	12.8	133.2
Other public:						
Clearcut	3.1- 7.9	82.9	81.1	62.4	14.3	240.7
	8.0-15.9	24.8	25.5	14.4	2.2	66.9
	16.0-27.9	7.1	10.0	6.0	2.1	25.2
	28.0+	<u>0.7</u>	<u>2.1</u>	<u>2.2</u>	<u>0.8</u>	<u>5.8</u>
Total		115.5	118.7	85.0	19.4	338.6
Partial cut	3.1- 7.9	50.0	55.2	55.6	18.1	178.9
	8.0-15.9	5.7	4.2	6.9	1.2	18.0
	16.0-27.9	0.4	1.2	1.2	1.6	4.4
	28.0+	<u>--</u>	<u>1.2</u>	<u>0.8</u>	<u>0.4</u>	<u>2.4</u>
Total		56.1	61.8	64.5	21.3	203.7
Private:						
Clearcut	3.1- 7.9	77.7	80.1	62.7	7.2	227.7
	8.0-15.9	24.8	24.4	13.7	3.6	66.5
	16.0-27.9	3.5	3.2	3.5	1.4	11.6
	28.0+	<u>0.2</u>	<u>0.6</u>	<u>1.0</u>	<u>0.2</u>	<u>2.0</u>
Total		106.2	108.3	80.9	12.4	307.8
Partial cut	3.1- 7.9	49.5	68.6	68.6	27.6	214.3
	8.0-15.9	7.3	7.8	7.3	1.4	23.8
	16.0-27.9	1.5	1.8	3.3	0.8	7.4
	28.0+	<u>--</u>	<u>--</u>	<u>0.6</u>	<u>0.2</u>	<u>0.8</u>
Total		58.3	78.2	79.8	30.0	246.3
EASTERN WASHINGTON						
Public	3.1- 7.9	27.2	26.7	16.3	6.4	76.6
	8.0-15.9	5.3	5.4	5.1	3.2	19.0
	16.0-27.9	0.6	0.5	1.5	1.1	3.7
	28.0+	<u>0.1</u>	<u>0.2</u>	<u>0.2</u>	<u>0.2</u>	<u>0.7</u>
Total		33.2	32.8	23.1	10.9	100.0
Private	3.1- 7.9	19.2	22.3	16.8	4.7	63.0
	8.0-15.9	3.2	3.1	2.8	1.4	10.5
	16.0-27.9	0.7	0.6	1.2	0.7	3.2
	28.0+	<u>0.2</u>	<u>0.1</u>	<u>0.1</u>	<u>0.1</u>	<u>0.5</u>
Total		23.3	26.1	20.9	6.9	77.2

¹Does not include residue in large piles.

²Sampling by diameter classes was different in Montana than that in the other States.

Biomass Relationships

A. Wood Densities

Wood Density Values ¹

State and Resource area	Wood densities	
	Dry weight	Green weight
	<i>(Pounds per cubic foot)</i>	
Southeast Alaska	24.3	54.87
Idaho	24.3	50.97
Montana	24.9	50.96
Oregon:		
Northwest	26.0	54.39
West Central	26.4	54.73
Southwest	26.3	53.83
Eastern	24.4	50.25
Washington:		
Olympic Pen.	25.3	51.29
Puget Sound	25.2	53.40
Southwest	25.7	54.10
Eastern	25.2	52.18

¹ Average density values derived by weighting individual specie values by the proportion of inventory volume for that particular species. Density information from Wood Handbook.

B. Bark Factors

Bark Weight Ratios by Species (oven dry basis)

Species	Ratio of bark to wood
Douglas-fir	0.15
True firs	0.18
W. Hemlock	0.13
W. redcedar	0.10
Spruces	0.10
Ponderosa pine	0.19
W. white pine	0.16
Lodgepole pine	0.08
Larch	0.10
Incense cedar	0.26
Other conifers	0.15
Red alder	0.18
Other hardwoods	0.16

C. Top of Tree

Top of Tree as a Percent of Total Stem¹

Diameter	Percent of top
5.0	0.510
7.0	0.190
9.0	0.100
11.0	0.060
19.0	0.035
29.0	0.033
39.0	0.030

¹ Average values for top of tree from 4.0" top to tip of stem. No apparent differences exist between species, so one set of factors was used. Relationships are from tariff tables used in FIA inventory volume computations.

Branches as a Percent of Total Stem ¹

Species	Diameter Class (Inches)			
	5.0 - 8.9	9.0 - 18.9	19.0 - 28.9	29.0+
	(Percent)			
Douglas-fir	20.0	12.0	9.0	5.0
Ponderosa pine	18.0	10.0	8.0	6.0
True firs	20.0	12.0	7.0	5.0
Spruces	38.0	15.0	10.0	6.0
Larch/redwood	20.0	7.0	5.0	4.0
Hemlocks	25.0	15.0	10.0	8.0
W. White pine	15.0	8.0	6.0	4.0
Cedars	25.0	15.0	8.0	6.0
Lodgepole pine	15.0	12.0	10.0	8.0
Other softwoods	20.0	12.0	8.0	5.0
Cottonwood/aspen	25.0	12.0	9.0	7.0
Red alder	25.0	15.0	11.0	8.0
Oaks	35.0	20.0	15.0	12.0
Other hardwoods	25.0	12.0	10.0	8.0

¹ Average of values from various sources of biomass information. Does not include foliage.

D. Branch Factors

E. Small Tree Information

Average Small Tree Weight¹ by Diameter Class

Species	Diameter Class (Inches)	
	1.0 - 2.9	3.0 - 4.9
	<i>green pounds</i>	
Douglas-fir	8.20	69.00
Ponderosa/sugar pine	6.05	37.90
True firs	6.15	47.10
Spruces	15.50	85.00
Larch/redwood	15.50	92.50
Hemlocks	15.80	91.85
W. white pine	6.25	37.50
W. redcedar	15.65	82.55
Other cedars	15.50	80.00
Lodgepole pine	7.50	46.60
Other softwoods	10.00	75.00
Cottonwood/aspen	8.50	80.00
Red alder	8.50	79.75
Oaks	15.00	97.50
Other hardwoods	11.75	85.00

¹ Dry weight computed using ratio of dry to green weight by species, from density values shown in tabulation A, above

Metric Equivalents

1 inch = 2.54 centimeters

1 foot = 30.48 centimeters

1 mile = 1.609 kilometers

1 acre = 0.405 hectare

1 square foot = 0.0929 square meter

1 cubic foot = 0.0283 cubic meter

1 cubic foot per acre = 0.07 cubic meter per hectare

1 pound = 0.454 kilogram

1 ton = 0.907 metric ton

1 British thermal unit (Btu) = 1,055.87 joules

END

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