The Use of Wood for Fuel.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 753

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. March 10, 1919

THE USE OF WOOD FOR FUEL

Compiled by the Office of Forest Investigations

CONTENTS

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INTRODUCTION.

Wood has always been of considerable importance as fuel in this country, and the present emergency has greatly increased its comparative value for this purpose. Wood is now being cut for fuel in places where for many years it had practically gone out of use. On farms where coal had become the ordinary fuel and was brought in from great distances while wood suitable for fuel went to waste in the neighborhood, wood is now coming into its own again. It is being more used in churches, schools, and homes, and even in factories. The use of wood for fuel saves transportation, it utilizes wood that would otherwise go to waste, and it releases coal for ships and railroads and munitions plants. Heretofore wood has supplied between 10 and 15 per cent of the total amount of fuel used in the United States. The wide distribution of wood fuel supplies, and the fact that they are so located as to save transportation should, under present conditions, lead to a considerable increase in the proportion of wood in our fuel consumption.

The purpose of this bulletin [1] is to aid in the conservation of the Nation's coal supply and in the full and proper use of our wood

[1] As is readily apparent, the material used in this bulletin is largely compiled from many sources. Credit has been given as far as it has seemed practical, but in many instances the data are so adapted and changed that a specific reference would be misleading. Information has been obtained from State wood-fuel and Forest Service publications mainly, but miscellaneous data and tables have been drawn from everywhere. This general statement is made in order to acknowledge help from sources not specifically mentioned.

resources to prevent the recurrence of such a fuel shortage as occurred during the winter of 1917–18, by indicating the best and most economical methods of cutting, distributing, and using wood for fuel. Uneconomical methods of handling the wood increase the cost and waste the product, careless methods of cutting the trees may endanger the future supply, and the reckless use of shade or ornamental trees for fuel is an unjustifiable extravagance.

In the utilization of the forests of the country, including farm woodlands, a great deal of wood material is produced which can not find a use other than as fuel wood. While some of it is used for acid wood, charcoal, etc., most of it is left for fuel or wasted.

Since many of the trees in our forests are fit only for fuel, they will not be cut unless there is a demand for fuel wood. Improvement cuttings, which take the small, diseased, or defective trees, can not be profitably made in many cases unless there is such a demand. Thinnings can frequently be made to pay for themselves if the material is used for fuel. Sometimes products of thinnings can be used for other purposes than fuel, but more often they can not. As proper thinnings and improvement cuttings are a great stimulus to increased production and at the same time improve the quality of the timber, a fuel wood demand opens up a great opportunity for forest improvement and, if widespread and continued, will produce a vast total effect for the better in the character and quality of our forest resources.

Wood waste occurs at every stage of the manufacture of wood products, from the lumber operations through the milling process and in the special processes necessary to shape the article into its final form. A wide use of wood fuel affords a market for this waste, which would otherwise be lost.

Preparing wood for fuel involves slightly more labor than is required to produce coal. It is, however, usually widely scattered labor which is used in wood cutting and hauling, and no increased demand on labor is really made. On most farms there is plenty of time during the winter for both men and teams to work at getting out wood.

WOOD INSTEAD OF COAL FOR FUEL.

USE OF WOOD SHOULD BE LARGELY INCREASED IN RURAL DISTRICTS.

Who can with the least hardship restrict his consumption of coal? Certain classes of consumers require concentrated fuel, such as coal or crude oil; others can use other fuels, but at a considerable disadvantage. Most manufacturers are unable to substitute wood for coal to any great extent because of the character of their heating and power plants and because of their location, which involves railroad haul for wood. For similar reasons domestic consumers in the cities can not well use wood to any great extent. Wholesale rail transportation of fuel wood is not desirable because of its bulk as compared with coal of the same heating value. The substitution can best be made in places where team-hauled wood will take the place of rail-hauled coal. Farmers who own woodlands and villagers who can buy wood from near-by farms can reduce their consumption of coal with least inconvenience to themselves and with the greatest benefit to the public interest.

Because of the large proportion of wood normally used in the South and the long hauls involved in the West it is not likely that the use of wood for fuel can be greatly increased in those regions. In New England, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Iowa, Missouri, and the Lake States it ought to be entirely practicable in many cases to replace coal with wood. In these 17 States is a rural population of about 20,000,000, which is estimated to use annually 18,000,000 tons of coal. If by substituting wood one-quarter less coal could be burned on farms and one-tenth less in villages, the total saving would amount to nearly 3,000,000 tons, or between 65,000 and 70,000 carloads.

For many uses, and particularly for summer-time use, wood is a more convenient and cheaper fuel than coal. Churches, halls, summer cottages, and other buildings where heat is wanted only occasionally, and then on short notice, find wood more satisfactory for this purpose.

PRESENT USE OF WOOD FUEL.

Up to the present time practically no systematic attempt has been made to take a census of the wood fuel cut or on hand each year. Wood seems to be the only form of fuel on which annual statistics of production are not available.

In 1916 and 1917 the Bureau of Crop Estimates in the Department of Agriculture secured estimates of the number of cords used on the farms but not the total amount cut. It is understood that in 1918 the amount sold from the farm annually will be obtained also, thus showing the total cut.

According to figures collected by the Bureau of Crop Estimates (see Table 1) about 83,000,000 cords of wood fuel were used in 1917 on the farms of the United States. Similar estimates made in December, 1916, indicated that about 82,000,000 cords were used. It is likely that the total amount consumed on farms and in villages and cities is upwards of 100,000,000 cords annually. In these estimates, and in all other references to "cord" in this bulletin, unless otherwise stated, a cord is reckoned as 128 stacked cubic feet—i. e., a pile 8 by 4 by 4 feet.

The value of wood advanced more than 24 per cent from December, 1916, to December, 1917. On the basis of 1917 prices reported, the value of firewood used on farms of the United States is about $283,000,000, or $43.13 per farm.

TABLE 1.—*Wood fuel used on farms.*

	Number of farms 1917 (estimated).	Cords per farm.	Number of cords per State.	Value per cord.		Value of wood used on basis of December, 1917, values.	
				December, 1917.	December, 1916.	Value per farm.	Total value.
Maine	60,000	13	780,000	$6.40	$4.50	$83.20	$4,992,000
New Hampshire	27,000	12	324,000	6.40	4.60	76.80	2,074,000
Vermont	33,000	15	495,000	6.00	4.35	90.00	2,970,000
Massachusetts	37,000	10	370,000	6.35	4.70	63.50	2,350,000
Rhode Island	5,000	10	50,000	5.80	4.00	58.00	290,000
Connecticut	27,000	13	351,000	6.00	4.50	78.00	2,106,000
New York	215,000	14	3,010,000	4.60	4.00	64.40	13,846,000
New Jersey	33,000	8	264,000	5.10	4.00	40.80	1,346,000
Pennsylvania	218,000	9	1,962,000	3.50	2.60	31.50	6,867,000
Delaware	11,000	13	143,000	4.20	3.10	54.60	601,000
Maryland	50,000	13	650,000	4.15	3.20	53.95	2,698,000
Virginia	190,000	18	3,420,000	3.20	2.40	57.60	10,944,000
West Virginia	99,000	16	1,584,000	2.90	2.30	46.40	4,594,000
North Carolina	259,000	17	4,403,000	2.75	2.10	46.75	12,108,000
South Carolina	185,000	14	2,590,000	3.00	2.10	42.00	7,770,000
Georgia	300,000	16	4,800,000	2.50	2.00	40.00	12,000,000
Florida	55,000	11	605,000	3.10	2.60	34.10	1,876,000
Ohio	271,000	13	3,523,000	3.60	3.00	46.80	12,683,000
Indiana	215,000	12	2,580,000	3.70	3.30	44.40	9,546,000
Illinois	250,000	9	2,250,000	4.60	3.40	41.40	10,350,000
Michigan	209,000	13	2,717,000	5.25	4.00	68.25	14,264,000
Wisconsin	180,000	13	2,340,000	5.50	4.20	71.50	12,870,000
Minnesota	157,000	11	1,727,000	5.40	4.30	59.40	9,326,000
Iowa	215,000	5	1,075,000	4.70	4.20	23.50	5,052,000
Missouri	275,000	13	3,575,000	3.20	2.60	41.60	11,440,000
North Dakota	90,000	3	270,000	7.50	6.40	22.50	2,025,000
South Dakota	90,000	3	270,000	6.20	6.00	18.60	1,674,000
Nebraska	135,000	3	405,000	4.25	3.90	12.75	1,721,000
Kansas	180,000	6	1,080,000	4.25	3.30	25.50	4,590,000
Kentucky	265,000	18	4,770,000	2.20	1.70	39.60	10,494,000
Tennessee	250,000	19	4,750,000	2.20	1.75	41.80	10,450,000
Alabama	270,000	18	4,860,000	2.00	1.80	36.00	9,720,000
Mississippi	285,000	16	4,560,000	2.30	1.90	36.80	10,488,000
Louisiana	122,000	15	1,830,000	2.50	2.25	37.50	4,575,000
Texas	430,000	9	3,870,000	3.40	2.80	30.60	13,158,000
Oklahoma	210,000	10	2,100,000	3.10	2.75	31.00	6,510,000
Arkansas	225,000	19	4,275,000	2.35	2.00	44.65	10,046,000
Montana	35,000	10	350,000	4.80	4.50	48.00	1,680,000
Wyoming	15,000	10	150,000	4.50	3.80	45.00	675,000
Colorado	55,000	6	330,000	4.50	3.70	27.00	1,485,000
New Mexico	45,000	9	405,000	4.20	4.00	37.80	1,701,000
Arizona	12,000	9	108,000	5.75	5.40	51.75	621,000
Utah	23,000	8	184,000	5.00	4.00	40.00	920,000
Nevada	3,000	11	33,000	7.00	6.00	77.00	231,000
Idaho	36,000	9	324,000	5.00	4.60	45.00	1,620,000
Washington	65,000	11	715,000	5.20	4.50	57.20	3,718,000
Oregon	50,000	12	600,000	4.70	3.90	56.40	2,820,000
California	95,000	10	950,000	7.40	5.80	74.00	7,030,000
United States	6,562,000	12.6	82,777,000	3.42	2.75	43.13	282,915,000

F-36656-A

FIG. 1.—SAWING EMERGENCY WOOD TO RELIEVE COAL SHORTAGE, GREENVILLE, TENN., JANUARY 18, 1918.

F-43247

FIG. 2.—A LOAD OF STOVE WOOD IN NORTHERN MICHIGAN (ONTONAGON COUNTY).

A detailed survey of the use of wood and coal in selected localities in a number of States gave the following comparative data:

TABLE 2.—*Average annual consumption of coal and wood per family on farms in eight States.*[1]

State and county.	Coal, per family.		Wood, per family.	
	Tons.	Value.	Cords.	Value.
Vermont (Lamoille)	0.1	$1.01	14.3	$65.40
New York (Otsego)	2.5	16.00	12.2	54.80
Pennsylvania (Bucks)	4.9	26.90	6.2	19.00
Ohio (Champaign)	5.7	23.70	12.0	32.50
Wisconsin (Jefferson)	3.0	20.70	7.5	38.80
Iowa (Montgomery)	3.9	29.57	4.8	22.40
North Carolina (Gaston)	....	....	14.0	43.58
Georgia (Troup)	....	....	17.8	51.60
Average	2.5	14.74	11.1	41.01

[1] From Farmers' Bulletin 635, "What the Farm Contributes Directly to the Farmer's Living," by W. C. Funk. See also Department of Agriculture Bulletin 410, "Value to Farm Families of Food, Fuel, and Use of House," by W. C. Funk.

TABLE 3.—*Average annual consumption of wood per person in eight States, showing the per cent of wood bought and the per cent furnished by the farm.*

State and county.	Per person.		Per cent.	
	Cords.	Value.	Bought.	Furnished by farm.
Vermont (Lamoille)	3.0	$13.62	3.0	97.0
New York (Otsego)	3.1	13.70	1.8	98.2
Pennsylvania (Bucks)	1.2	3.65	5.8	94.2
Ohio (Champaign)	2.9	7.93	6.2	93.8
Wisconsin (Jefferson)	1.1	5.34	7.7	92.3
Iowa (Montgomery)	1.7	8.82	....	100.0
North Carolina (Gaston)	3.1	9.68	3.9	96.1
Georgia (Troup)	3.3	9.56	....	100.0
Average	2.4	9.04	3.55	96.45

INDUSTRIAL USE OF WOOD FUEL.

The use of wood fuel by factories reached its greatest development in New England during the acute coal shortage of the winter of 1917–18, because this section was practically shut off for a time from all supplies of bituminous coal, which is the factory fuel. Complete information is not available on the quantity of wood used by the factories or how extensive its use was throughout New England, but it is known that a great many factories were forced to use wood to keep in operation. One dealer reported that he had shipped 5,500 cords of wood to the factories in eastern Massachusetts.

Such use of wood will come about only through necessity, as it costs at least three times as much as soft coal. The only reason for using it, therefore, is to keep the factories running. This points to the fact that in wood fuel the country has a reserve or substitute fuel which can be drawn upon in an emergency, not only to supply domestic consumption but to keep the factories running, although it may not be so efficient in the latter case as coal. Instead of waiting for emergency conditions to arrive, it would be well for both domestic and industrial users of fuel to plan on wood reserves in case the main reliance, coal, is not forthcoming.

It has been reported that cotton mills in South Carolina and elsewhere throughout the South are laying in wood to supply the mills in case of shortage, in addition to their usual supplies of wood for the operatives.

It is, of course, not desirable to use railroad transportation for wood fuel to factories unless there is no coal to haul. Then wood may be moved by rail to avoid shutting down. Many factories are so located at points away from large centers that wood can be used without shipping, and as in the aggregate they consume a large amount of fuel, a change to wood would be an appreciable help.

WHAT TO USE FOR WOOD FUEL.

THINNINGS AND IMPROVEMENT CUTTINGS.

The great bulk of the wood-fuel supply in farming regions should come from thinnings and improvement cuttings on farm woodlands. Except under stress of emergency, trees which will produce lumber or other material of higher value than cordwood should not be cut for fuel.

Trees which are better suited for fuel than for any other purpose, and whose removal will be of benefit to the remaining stand, are:

1. Sound standing and down dead trees.
2. Trees diseased or seriously injured by insect attacks, or those extremely liable to such injury, such as chestnut in the region subject to blight, or birch in the gypsy-moth area; badly fire-scarred trees.
3. Crooked trees and large-crowned short-boled trees which will not make good lumber and which are crowding or overtopping others.
4. Trees which have been overtopped by others and their growth stunted.
5. Trees of the less valuable species where they are crowding more valuable ones, as beech, block oak, birch, hard maple, white oak, or white pine.
6. Slow-growing trees which are crowding fast-growing species of equal value.

TREES ON OLD PASTURES.

On many farms former pastures have become overgrown with red cedar, gray birch, aspen, pine, or other trees. The trees came in slowly and through neglect were allowed to steal much of the pasture. If fuel is to be cut somewhere on the farm, such land as this should be drawn upon first of all and redeemed by removing all the trees and restoring the land to grass. Also, uncleared corners of fields or patches of agricultural land within the border of the wood lot may be cut clean, the wood used for fuel, and the land eventually farmed. The expense of clearing is thus largely or entirely met by the value of the fuel produced.

TOPS AND LOPS.

Thousands of cords of wood from the tops and limbs of trees felled in lumbering operations rot annually or furnish fuel for forest fires. Ordinarily this waste can not be avoided, because lumbering is most important in the less thinly populated parts of the country, and long hauls to cordwood markets are too costly. Sometimes, however, farmers overlook near-by woods operations as sources of fuel. The material is already down and can be worked up easily into cordwood. Owners of cut-over land usually are glad to have such material removed.

MILL WASTE.

Mill waste is very widely used as fuel in the neighborhood of sawmills and woodworking plants. Much of this refuse is burned to supply power for the mills themselves, but considerable is used as fuel by individuals and in some regions by other manufacturers. In many instances there are still large amounts of this material going to waste which could be made available for fuel.

SAWDUST BRIQUETS.

There are now at least three firms on the Pacific coast engaged in the manufacture of sawdust briquetting machinery, and at least three plants for the manufacture of this fuel have been established there.

The main market for briquets will probably be for domestic use where the cleanliness and easy kindling qualities of the briquet are a fine asset. For this use the briquet might be able to compete with coal at only $8.50 a ton, the housewife being willing to pay a little more for the same heat value on account of these desirable properties. The almost total absence of ash, the absolute absence of clinker, and the lack of smoke are great advantages of briquets over coal.

In competing with cordwood the briquet has certain advantages, such as requiring less labor in preparing for the fire, containing less moisture and more wood per pound, and obviating the need for kindling wood.

The best chance for the success of the wood or sawdust briquet is in those regions where sawdust is abundant and coal is expensive. The region best fulfilling these conditions in this country is the Pacific coast, and it is a significant fact that the companies now establishing the industry in America are all, as far as the author knows, on the Pacific coast.

CHARCOAL.

In England it is said that the war has caused a revival of the dying charcoal industry. A great deal has been done with this fuel and there is a possibility of a like interest being aroused in this country as fuel conditions become acute. There are doubtless many places in the wooded districts of the East, especially near large cities, where charoal can be made to advantage in the next few years. Charcoal has a larger heating power per cubic foot than wood, a ton yielding about 2,000 horsepower, and it is cheaper to transport on account of its light weight.[1]

Table 4 gives the production of charcoal in the United States in 1909. It is reported that Michigan and Wisconsin now lead in charcoal production.

TABLE 4.—*Charcoal production in 1909.*[1]

State.	Quantity.	Value.
	Bushels.	
Michigan	13,514,106	$868,003
New York	5,147,160	287,103
Pennsylvania	16,357,598	936,357
All other States	3,998,383	260,181
Total	39,017,247	2,351,644

[1] Thirteenth Census, U. S. 1910, vol. 10, p. 622.

SUPPLY OF FUEL WOOD.

With the increased use of wood fuel which is likely to continue for several years, it is important to know how much fuel wood there is in the country and its local distribution and availability. An estimate of the total amount of firewood has never been made. Tentative figures show the following cords per farm in certain selected regions:

Region.	No. of cords per farm.
Northern Vermont	952
Southeastern Pennsylvania	218
Southern Indiana	474
Central Indiana	167
Northern Indiana	344
Northern Wisconsin	317
Southern Minnesota	256
Eastern Iowa	243
Southeastern Nebraska	141
Central North Carolina	1,231
Northeastern South Carolina	1,978
Central Tennessee	192
Northern Alabama	1,660
Northern Louisiana	2,315
Southern Missouri	601
Average	739

[1] "Logging and Lumbering," by C. A. Schenck.

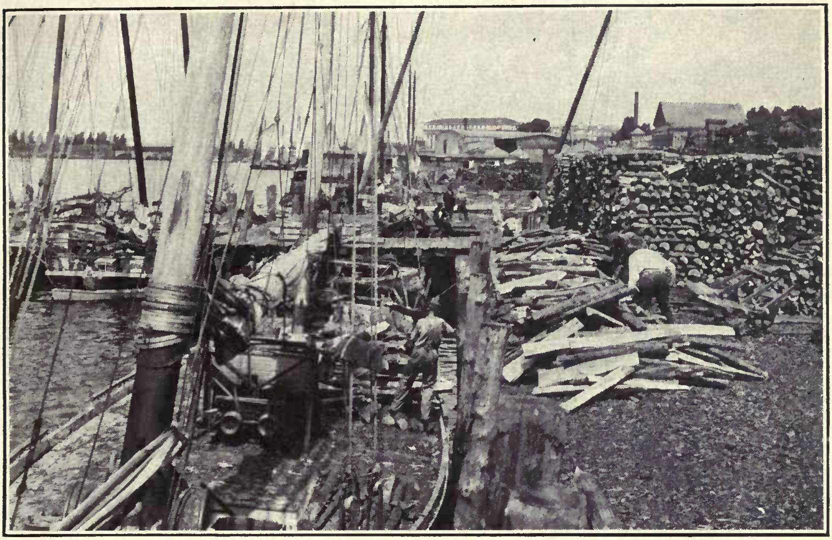

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FIG. 1.—UNLOADING CORDWOOD FOR FUEL FROM SAILBOATS AT WHARVES, WASHINGTON, D. C.

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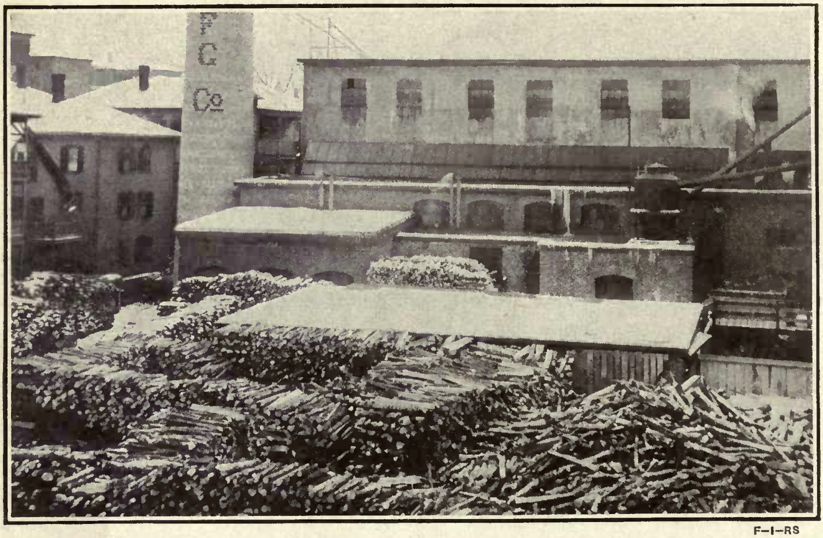
FIG. 2.—VIEW OF TOP OF STACKS OF CORDWOOD IN ONE YARD AT WASHINGTON, D. C.

Capacity of yard 5,000 cords.



F–1–RS

FIG. 1.—INDUSTRIAL USE OF WOOD FUEL. STORED WOOD FUEL RESERVE OF A NEW ENGLAND FACTORY.

This supply was obtained in anticipation of a coal shortage. Photo by W. D. Clark, published in American Forestry, June, 1918.

F–2–RS

FIG. 2.—FIRING WITH WOOD FUEL; FURNACES IN A NEW ENGLAND FACTORY EQUIPPED WITH AUTOMATIC STOKERS FOR COAL.

Photo by W. D. Clark, published in American Forestry, June, 1918.

On the farms alone the total area of woodland in the eastern United States is approximately 143,392,000 acres. The first tier of States just west of the Mississippi has a great deal of timber, especially northern Minnesota, southern Missouri, Arkansas, Louisiana, southeastern Oklahoma, and eastern Texas. In the West the wooded areas are for the most part restricted to the mountains. An average of 10 cords per acre, which seems reasonable, would give one and one-half billions of cords for the region east of the Mississippi.

At the average rate of consumption on the farm itself, 12.6 cords per year, 739 cords will last 58 years. On the average this would be ample time to replace the stands and thus continue the supply indefinitely. As a fact, however, the woodland area is in many regions constantly shrinking as a result of land clearing for agricultural use and grazing. Thus unless care is taken of that which remains the future supply of fuel wood will be materially reduced.

The supply of wood fuel in any particular locality depends on more than the total amount of timber. Part of it will be on the land which is suitable for clearing for agriculture, and which will be cleared and improved in the near future. Obviously, the timber on such tracts can all be cut. More will be found on land which should be retained in woodland, and here the question is how much can be cut out safely. As a rule, only a certain percentage can be cut without jeopardizing the forest resources of the future. There is the further question of how much of the wood cut is available for fuel. The trees which are cut may be suitable for lumber, ties, telephone poles, and other higher uses. Therefore, it is essential to know not only the total amount of wood but the amount of fuel wood which can come out without injury to the forest. Only by means of a survey covering these points can a practical and comprehensive plan be developed to coordinate the supply and use of wood fuel within a given region with other forms of fuel which may be available.

PRODUCING AND MARKETING WOOD FUEL.

STUMPAGE.

The first item of cost in producing wood fuel is the price reckoned or paid for stumpage. Stumpage for this purpose ranges in price from nothing to $5 per cord, depending somewhat upon the region, the kind and quality of timber, and the ideas of the owner. In remote districts where land is being cleared the standing cordwood material is sometimes given away. Slash from lumbering operations is also frequently given away for the cutting or is sold at a nominal price.

Timber of better quality than cordwood material may naturally be expected to sell for higher prices than seems justified when compared with reasonable cordwood stumpage prices. Such material should, however, not be so used except in cases of emergency, when other stumpage can not be secured. It is reasonable that higher prices should be paid for stumpage when the area is to be cut clear than when only an improvement cutting is to be made, since the latter method increases the cost of cutting somewhat and besides takes material of the least value, the removal of which is a distinct benefit to the forest. In many cases an owner can well afford to give material from improvement cuttings or thinnings to anyone who will cut it.

Average stumpage prices ordinarily range from 50 cents to $1.50 per cord.

ESTIMATING STANDING CORDWOOD.

While cordwood is generally sold on the basis of measurement after it is cut and corded up, it is frequently desirable, especially in case of buying entire tracts, to estimate the amount of wood while still standing. This can be done by methods similar to those used for saw timber. Table 5[1] shows roughly the number of trees of different diameters required to make a cord.

TABLE 5.—*Number of trees required to yield 1 cord.*

Diameter of tree (breast high, outside bark).	Hardwoods.		Softwoods.
	Northern (beech birch, maple, etc.).	Southern (chestnut, oak, hickory, etc.).	
Inches.			
2	....	170	....
3	....	90	....
4	....	50	....
5	35	25	....
6	20	17	....
7	15	13	20
8	11	9	13
9	8	7	10
10	6	6	8
11	5	5	7
12	4	4	6
13	3.5	3.4	4.5
14	3.0	3.0	3.7
15	2.5	2.5	3.0
16	2.0	2.2	2.5
17	1.7	2.0	2.1
18	1.5	1.8	1.9
19	1.3	1.5	1.6
20	1.2	1.3	1.5
21	1.0	1.2	1.4
22	.9	1.1	1.2
23	.8	1.0	1.1
24	.7	.9	1.0

The figures given are for trees of average height; allowances should be made in case of unusually short or tall timber.

[1] "Measuring and Marketing Woodlot Products," Farmers' Bulletin 715, by W. R. Mattoon and W. B. Barrows.

FELLING.

On the farms a time when labor can not be used at other work is the best time to cut wood; winter, late fall, and early spring are therefore generally the seasons when most wood fuel is cut. In the South, where the slack season comes at a different time, summer may prove the best season. However, there is no good reason why, if labor is available, fuel wood may not be cut at any time.

In the case of hardwoods which reproduce readily from sprouts the time of cutting is of some importance. The sprouts will start immediately if the timber is cut in the summer or early fall but will not be strong enough to stand the winter, with the result that the reproduction will be winter-killed. On the other hand, if the timber is cut in the winter the sprouts will grow during the spring and summer to such a size and hardihood as to be immune from winter-killing. Winter cutting should therefore be practiced with species which sprout, if reproduction is desired.

Cordwood is generally felled and cut into 4-foot or sled lengths with axes, or in some cases where larger trees are cut, with crosscut saws. Owing to the small size of the material generally cut this is the most economical method of felling the trees. A number of power-driven tree-felling machines have been devised, but none of them have proved practical, and even if they should become so their value would be in felling trees of large size.

The cost of cutting cordwood varies with the prevailing wages of the region and with the kind of timber cut. Woodcutters' wages run from less than $2 to more than $4 per day, or where paid by the cord, as is general in some regions, from about $2 to $3.50 per cord.

The quantity of wood which can be cut per day per man is, of course, the real basis of the cutting cost and depends most on the skill of the workman and on the kind of wood. Inefficient labor will produce but one-half cord of hardwood or 1 cord of softwood per day, whereas good skilled workmen will cut from 1½ to 2 cords of hardwood or from 3 to 4 cords of softwood per day. In one instance men inexperienced in timber work, such as business men from town, cut in hardwoods at the rate of two-thirds of a cord per day for the first day.

These figures include both felling the trees and cutting them up into 4-foot lengths. If material is cut sled length, as is frequently done, more can be cut in a day.

SKIDDING AND HAULING.

In probably the majority of cases the practice is to cut wood into 4-foot lengths and pile it close to where the trees are cut, and to haul it direct from these piles to consumers.

In many cases, however, the trees are merely trimmed or cut into sled lengths and hauled to the consumer to be sawed into stove lengths, or to central points in the woodlot or along a road to be cut up and piled for future hauling. It is possible that extension of this practice may in many instances considerably reduce the cost of producing wood fuel, both by reducing the amount of hand labor required in cutting up the material, in centralizing the work of cutting it up, and in increasing the amount which can be hauled by reducing its weight through seasoning.

Skidding or hauling out to a roadway or central point should not cost over $1 per cord.

SAWING AND SPLITTING.

Stove wood is no longer "bucked up" by hand with a bucksaw, except in isolated cases. Few men can saw more than from 1½ to 2 cords of 4-foot wood into 16-inch lengths in a day, while with power saws of from 6 to 10 horsepower a three-man crew can saw up from 10 to 15 cords per day.

For ordinary use a 24 or 26-inch circular saw, driven by a 6 to 12 horsepower gasoline or kerosene engine, is used. The engine and saw frame are mounted on a truck so as to be readily moved from place to place. Long sticks can be cut up by such a saw as easily as 4-foot pieces, except that in case of larger wood one or more additional men will be required to pass wood to the saw. At the present time complete sawing outfits cost from $200 to $500, depending on the horsepower and the size of the saw. Saw blades cost from $6 to $12, and saw frames from $30 to $40.

Farmers who do not have this equipment and whose requirements will not warrant such an investment may hire such a saw and engine and exchange the necessary labor in its operation within the community, as is frequently done in grain thrashing. Many have gasoline or kerosene engines or tractors, and a small portable saw would therefore be a comparatively minor investment and would pay for itself in working up the average wood lot. It could be used every winter in cutting the yearly supply as well as a surplus which might be marketed. Good opportunities exist for operators of thrasher and silo-filling outfits to do custom sawing during the winter.

For cutting large logs there are on the market several types of power-driven drag-saws, such as are in common use in lumber operations in the Pacific Northwest. These machines, which are generally operated by a 4-horsepower gasoline engine, can be carried from log to log by two men, and cut logs up to 7 feet in diameter. It is claimed that they can cut from 10 to 30 cords of firewood (softwoods) in 10 hours.

F-51620

FIG. 1.—SAWING BLUE GUM (EUCALYPTUS) WOOD WITH GASOLINE ENGINE.

Rate 1½ to 2 cords per hour. Santa Fe Springs, Cal.

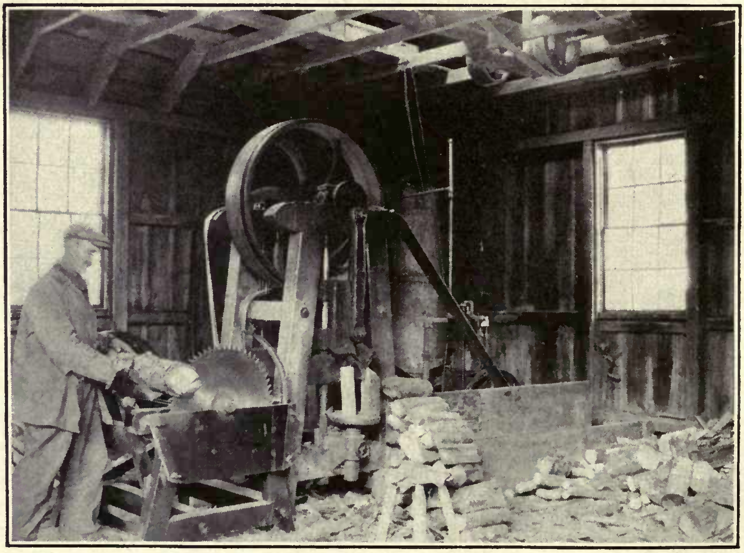
F-36792-A

FIG. 2.—LOAD OF HACKBERRY POLES ON PUBLIC SQUARE FOR SALE AT $2.50 PER LOAD, GALLATIN, TENN.

F-3-RS

FIG. 1.—BUZZ SAW, POWER SPLITTER, AND CONVEYOR, SET UP AT DOVER, MASS.

Photo by W. D. Clark.



F-4-RS

FIG. 2.—TABLE SAW AND SPLITTER OPERATED IN A MASSACHUSETTS FARMER'S WOODSHED.

Photo by W. D. Clark.

These machines weigh from 150 to 200 pounds, and cost from $170 to $200. They are probably not practical for ordinary cordwood operations where the trees are of comparatively small size. The cost of sawing with power saws depends, of course, upon the kind and size of wood sawed and upon the prevailing rate of wages. With three or four-men crews, wages of 30 to 35 cents per hour, and a cut of 16 to 20 cords per day, the average is as follows:

	Cents per cord.
Labor	50
Gasoline	9
Oil	1
Depreciation, interest, etc	10
Total	70

Charges for custom work were from 50 cents to $1 per cord, depending on the number of cuts and the kind of wood, but are now between 75 cents and $1.50.

Splitting is still largely done by hand, often by the consumer in his spare time, so that its cost is not an item to be considered in the price he pays for wood. Although much larger amounts have been split by expert axmen, an average man will seldom split more than four cords of stovewood per day. The amount depends, of course, on the species of wood. Some woods, such as birch, maple, and most conifers, split very easily; others, such as elm, sycamore, gum, and apple, are very hard to split. Most woods split more readily when green or partly dry than when dry. Splitting machines are now coming into more general use around woodyards where considerable quantities of wood are handled. These machines are driven by the same engines which run the cutting-up saws, and sawing and splitting are done at the same time. Two men with such a machine can split the wood as it comes from the saw. By installing an automatic carrier from saw to splitter one man can operate the latter. (See fig. 1.) Splitting by machine should not cost more than 75 cents per cord. By hand it costs around $1 per cord.

SEASONING.

The seasoning of wood for fuel is important, because dry wood has a somewhat greater heating value than green wood, is much more convenient to use, and is very much lighter in weight and therefore can be handled at less cost. In general it seasons more rapidly in the late spring and summer than during the remainder of the year, and most slowly when cut in late winter. The fact that checking is severe in summer does not matter, as this does not injure fuel wood.

The method of stacking depends primarily upon the rapidity with which it is desired to have the wood seasoned. A common practice is to pile the 4-foot lengths in compact piles resting on two bed pieces. This does very well when the wood is to season for six months or longer, but a different procedure must be adopted where more rapid seasoning is desired. The most open form of pile is the so-called "log-cabin" style. A pile which gives almost as good results without occupying nearly as much space has alternate tiers resting on single sticks at each end. There is ample ventilation through the alternate open layers.

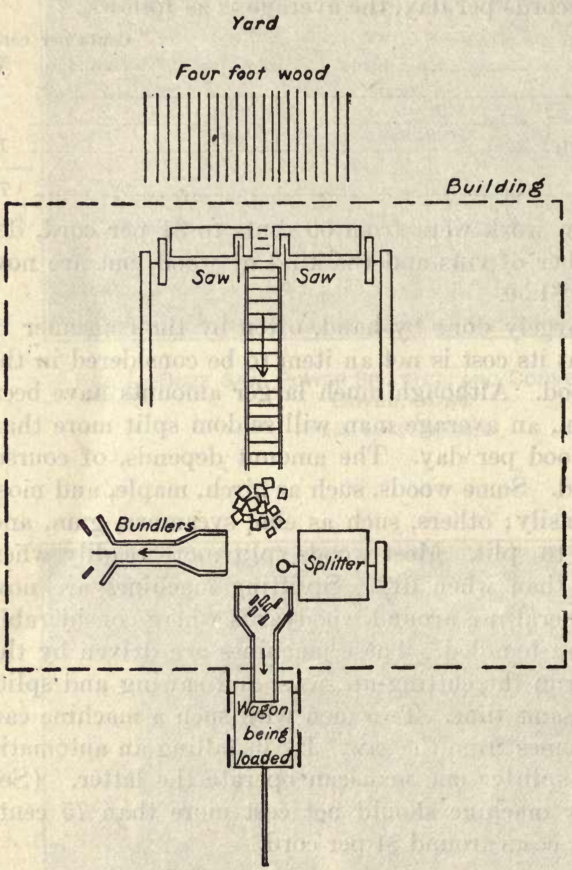


FIG. 1.—Plan of a retail wood dealer's plant for sawing and splitting cordwood.

It is very important for rapid seasoning to place the piles so that the air will circulate readily through them. The ideal place for this purpose is an open field, preferably on a hilltop. The direction toward which the piles face is not very important if there is good air circulation. The best results will be obtained in seasoning if the piles are so constructed as to shed rain as much as possible.

Cordwood of the ordinary species requires a period of from 9 to 12 months to season thoroughly, although the moisture content will be reduced to about 35 per cent in three months' time, depending somewhat on the season of the year. Wood of three months' seasoning has from 85 to 95 per cent as much fuel value as wood of the same species thoroughly seasoned. Even green wood has a heating value of 80 per cent or more of that of dry wood.

TRANSPORTATION.

Ordinarily wood fuel is used within 5 to 10 miles of the locality where it is produced, because its great bulk makes it expensive to ship.

It is commonly hauled from the woods to consumers or to dealers in towns by team or auto trucks. The cost of hauling is determined, of course, by the length of haul and by the amount that can be hauled per trip, which depends upon the condition of the roads and upon the species and dryness of the wood. The lowest cost for a given operation can be attained by letting the wood season thoroughly where it is cut and doing the hauling when the roads are best.

Where much of the haul must be over woods roads or other roads which are normally in poor condition, winter hauling on sleds is favored, since larger loads can be taken in this way. The chief disadvantage in depending on this method is the possibility of deep snow interfering with the hauling. Where the wood can be skidded out and piled beside good roads summer hauling by auto trucks is by far the most economical way to get wood to market.

Costs for hauling wood by team may be put at about 50 to 75 cents per cord per mile. The following tables,[1] which show approximate costs of hauling northern hardwoods, may be taken as fairly typical of the northern and eastern States:

TABLE 6.—*Team capacity per day for hauling various distances.*

Sizes.	Number of cords per day per team.									
	1 mile.	2 miles.	3 miles.	4 miles.	5 miles.	6 miles.	7 miles.	8 miles.	9 miles.	10 miles.
Long wood	7	6	5	3	2	1½	1½	1	1	1
4-foot wood	5	4	3	2½	2	1½	1½	1	1	1
16-inch stove wood	4	3	2½	2	1½	1½	1	1	1	1

TABLE 7.—*Cost of team-hauling per short cord of 16-inch lengths, for different distances and at different wage rates, including charge of 26 cents for handling.*

Distance from town (miles).	Trips per day.	Cords hauled per day.	Approximate cost per cord, with team wage of—		
			$4.50 per day.	$5 per day.	$6 per day.
5 and over	1	3–4	$1.40–$1.75	$1.50–$1.95	$1.75–$2.25
3 to 4	2	6–8	.80– 1.00	.90– 1.10	1.00– 1.25
2 to 3	3	9–12	.65– .75	.65– .80	.75– .90
1 to 2	4	12–16	.55– .65	.55– .65	.65– .75

Although wood fuel can not as a general thing be economically shipped to market, it is in certain instances practicable to do so, especially in districts remote from the coal regions. Since shipment by water is the cheapest method of transportation, towns on navigable rivers and inlets along which are supplies of fuel wood are in the best position to get wood at a reasonable cost. Washington,

[1] "The Price of Fuel Wood," by William K. Prudden, State fuel administrator of Michigan, Mar. 1, 1918.

D. C., uses normally about 17,000 cords of wood fuel annually, most of which is brought up the Potomac by sailboats with an average capacity of 30 cords.

Freight rates on cordwood vary in different sections of the country and on different railroads. At this time, on account of readjustments, it is not possible to give very definite information on freight rates. Recently the rate for distances of about 10 miles has averaged about 50 to 60 cents, and has sometimes reached $1. Around 100 miles the rate has averaged $1.50 per cord, but has in some cases been as low as $1 and in others as high as $2.

CAR CAPACITIES.

The minimum carload measurements on cordwood are as follows:

	Number of cords per car. Dry.	Green.
In box cars 34 feet 4 inches and less in length, inside measurement	12	12
In box cars over 34 feet 4 inches in length and 8 feet and over in height, inside measurement	[1] 17	[1] 16
In box cars over 34 feet 4 inches in length and under 8 feet in height, inside measurement	16	15
On flat or gondola cars 34 feet 4 inches and less in length	12	12
On flat or gondola cars between 36 and 34 feet 4 inches in length	18	16

WEIGHTS.

The following estimates are used for cordwood in shipments by rail when actual weights can not be obtained:

Degree of seasoning.	Pounds per cord.
Dry	3, 650
Partly seasoned	4, 600
Green	5, 200
Mixed	4, 600

Approximate weights per cord [2] of a number of the more important fuel wood species are:

	Green. Pounds.	Air dry. Pounds.
Ash, white	4, 300	3, 800
Beech	5, 000	3, 900
Birch, yellow	5, 100	4, 000
Chestnut	4, 900	2, 700
Cottonwood	4,200	2, 500
Elm	4, 400	3, 100
Hickory	5, 700	4, 600
Maple, sugar	5, 000	3, 900
Maple, red	4, 700	3, 200
Oak, red	5, 800	3, 900
Oak, white	5, 600	4, 300
Willow	4, 600	2, 300

[1] Where the wood is 16 inches or less in length, the capacities for these dimensions for dry and green wood are 16 and 15 cords, respectively.

[2] U. S. Department of Agriculture, Farmers' Bulletin 715, "Measuring and Marketing Woodlot Products."

In loading and unloading from cars or boats one man can handle from 7 to 10 cords of 4-foot wood per day and from 6 to 8 cords of 16-inch wood.

METHODS OF SELLING.

In spite of the fact that fuel wood is not transported any great distance or marketed on an extensive wholesale scale, some organization is needed for its marketing and local distribution. In communities where there are regular wood dealers the problem of bringing the producer and consumer together is simple. Such men have, of course, made a study of the problem and are better qualified than anyone else to perform this service. Unfortunately, however, in a great many communities the amount of cordwood sold has been so small in the past that it has not been worth anyone's while to go into the business of marketing firewood. In such communities the usual practice has been for the woodlot owners to make a house-to-house canvass with their loads. This is usually an expensive way of marketing wood, for the producer spends a large amount of time in finding a customer. A substitute for this canvass is the advertising of wood either in the papers or by posters at public places.

The possibility of selling cordwood through coal or lumber dealers deserves attention in every locality. This would have the advantage of making possible a reduction in cost by using power saws at their yards to cut the wood into stove lengths. A still better plan is for communities to establish and control their own municipal wood yards, at which producers can deliver wood and receive pay for it according to a regular schedule of prices.

MUNICIPAL WOOD YARDS.

Municipal wood yards, war fuel companies, and similar organizations have been tried with fair success. Their field of usefulness will doubtless be greatly increased as their need is more clearly appreciated and their effectiveness becomes more apparent. Some organization is needed to keep alive the wood-fuel idea between seasons and to see that wood is cut, even though it does not seem immediately necessary. Every community should by means of a municipal wood yard or otherwise get in a reserve of wood for the winter, sufficient to insure its members against a fuel famine. One city in New England has made plans to purchase 100,000 cords of wood as a fuel reserve for the city. In one Southern State there are already some 30 municipal wood yards in operation, and plans are being made to have one in practically every community in the State. If this is necessary in the South it is much more urgent in the North, where the winters are longer, and snow, especially in northern New England, makes it practically impossible to get out much wood in the depth of winter.

A yard established in 1917 at Durham, N. C., purchased 1,260 cords of wood at an average cost at the yard of $5 a cord. Wood was delivered at an average cost to the consumer of $7. It came from two sources—a sawmill about 14 miles distant from which slabs were shipped by rail, and a farmer's woodland from which cordwood in 8-foot lengths was secured. The slabs were mostly green pine of odd lengths, for which $2 per cord was charged f. o. b. cars. Freight charges amounted to about 75 cents per cord. The coal and wood yard is adjacent to the railroad tracks, and the wood was unloaded from the cars exactly where needed by the sawyers. The wood from the farmers' woodlands near by was green pine and oak, cut in 8-foot lengths and split in halves or quarters. The price was $3.50 per cord piled in the woods. It was hauled from the woods to the roadside by six county teams and there piled in a long rick, from which it was loaded upon motor trucks. Three trucks were used, each making four trips a day and carrying about 1 cord per ton of rated capacity, so that the total daily delivery was about 40 cords. The cost of hauling was about $1 per cord; it would have been less if there had been better loading and unloading facilities. The distance was 2½ to 3 miles. (See fig. 2.)

Cordwood was sold according to the cubic contents of the wagon boxes, most of the wood being sold at the yard. The estimated cost of sawing to stove length was 50 cents per cord on the yard.

MEASURING WOOD FUEL.

CORDS.

A standard cord of firewood is a pile 8 by 4 by 4 feet, which contains 128 cubic feet of stacked wood. It is customary to pile green wood 2 or 3 inches higher than 4 feet to allow for shrinkage and settling as it dries. In measuring piles of wood the average dimensions are taken.

A "running" cord or "face" cord, 8 feet long by 4 feet high and 12, 16, or 24 inches wide, according to the length to which it is cut for use, is frequently called a cord in the market.

Though a cord contains 128 cubic feet the space occupied includes air as well as wood. The actual solid contents of a cord is only about 70 per cent of this amount, or 90 cubic feet for wood of average size. For small sticks, where the average diameter is 4 inches or less, there are less than 80 cubic feet per cord; in the case of larger sticks 10 inches or over in diameter there may be as much as 100 cubic feet per cord. Crooked, rough sticks can not be piled as closely as straight, smooth sticks. Therefore there is less wood in a cord of crooked sticks than in a cord of straight sticks.

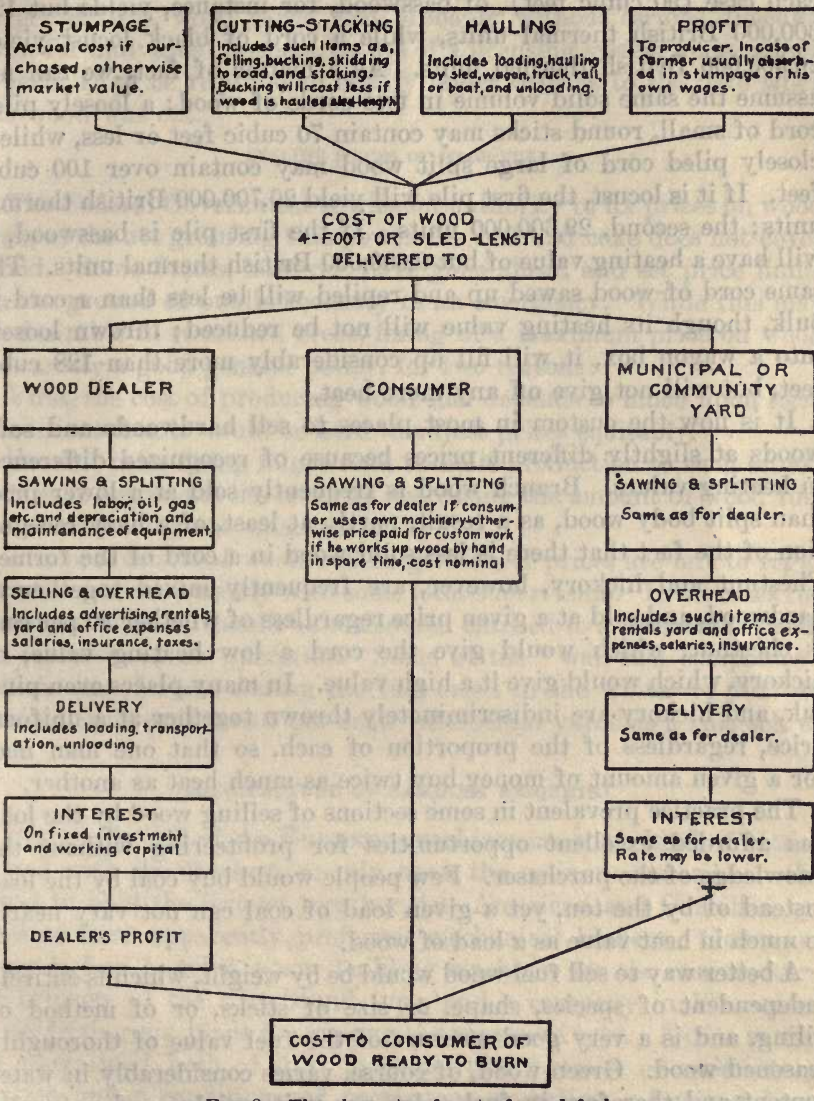


FIG. 2.—The elements of cost of wood fuel.

SELLING WOOD BY WEIGHT.

The great demand for fuel wood and the high prices during the winter of 1917–18 brought out plainly the inadequacy of the cord unit for measuring wood. The purchaser of fuel wood buys it not for its bulk but for its heating value, which depends not upon the volume of wood but upon its weight. A pound of dry wood of one species has about the same number of heat units as a pound of any other species; but a cord, assuming the same solid volume of wood in each case (90 cubic feet), of basswood, for instance, yields but 12,600,000 British thermal units, while a cord of black locust yields 26,500,000 British thermal units. As a matter of fact, we can not assume the same solid volume in two cords of wood; a loosely piled cord of small, round sticks may contain 70 cubic feet or less, while a closely piled cord of large split wood may contain over 100 cubic feet. If it is locust, the first pile will yield 20,700,000 British thermal units; the second, 29,600,000 units. If the first pile is basswood, it will have a heating value of but 9,600,000 British thermal units. The same cord of wood sawed up and repiled will be less than a cord in bulk, though its heating value will not be reduced; thrown loosely into a wagon box, it will fill up considerably more than 128 cubic feet, but will not give off any more heat.

It is now the custom in most places to sell hardwoods and softwoods at slightly different prices because of recognized differences in heating values. Branch wood is frequently sold at a lower price than split body wood, as a result, partly at least, of a hazy recognition of the fact that there is less solid wood in a cord of the former. Chestnut and hickory, however, are frequently mixed together as hardwood, and sold at a given price regardless of whether 90 per cent is chestnut, which would give the cord a low heating value, or hickory, which would give it a high value. In many places even pine, oak, and hickory are indiscriminately thrown together at a uniform price, regardless of the proportion of each, so that one man may for a given amount of money buy twice as much heat as another.

The practice prevalent in some sections of selling wood by the load has afforded excellent opportunities for profiteering without the knowledge of the purchaser. Few people would buy coal by the load instead of by the ton, yet a given load of coal can not vary nearly so much in heat value as a load of wood.

A better way to sell fuel wood would be by weight, which is entirely independent of species, shape, or size of sticks, or of method of piling, and is a very good measure of the fuel value of thoroughly seasoned wood. Green wood, of course, varies considerably in water content and therefore in fuel value per unit weight, and naturally would be sold at a price different from that for dry wood. The extreme difference in heat units per pound between green and dry wood of any species is approximately 70 per cent of the dry value; a pound of green willow, for instance, is worth about one-third as much as the same weight of dry wood. Green wood of most of the hardwoods commonly used for fuel has about half the heating value of dry wood of the same weight.

If weight instead of volume is adopted as the standard measure, it will be necessary to fix certain standards as to time of seasoning of wood offered for sale. This can easily be regulated in the case of larger dealers, wood yards, and probably without serious difficulty even for individual farmers, by use of a licensing system under which a seller shall be required to certify under oath as to the date when his wood was cut.

SELLING PRICES OF WOOD FUEL.

The Federal Government is without authority to fix prices on wood fuel, as the act granting this power for coal and coke does not cover wood. Some States, however, have gone ahead and set price limits on the ground of public necessity in an emergency. While this may be desirable in restricted areas, fixing of a maximum price on wood is scarcely a good general policy, for two reasons:

First, the cost of producing wood fuel depends so much upon local conditions that it would be hard to adjust prices equitably.

Second, price-fixing might tend to limit production to such an extent as to aggravate the crisis by decreasing the amount of wood fuel available during the emergency.

The production of wood will be greatest if prices are left to regulate themselves, possibly with some local supervision. In all cases the producer of wood should be considered entitled to a reasonable profit on the costs of his operation. Some of the "war fuel companies" which were formed during the fuel crisis in the winter of 1917–18 limited their profits to 6 per cent. Municipal yards as a rule sell at cost.

MANUFACTURE OF SAWDUST BRIQUETS.[1]

Practically all of the European machines use some kind of binder mixed with the sawdust, or rely upon the resinous material in the wood to hold the briquet together, but American and Canadian inventors have apparently preferred mechanical binders. One company in Los Angeles is now building machines for the manufacture of briquets of the wire-bound type, and a company in Vancouver is perfecting machines for making the rope-core type. As far as can be ascertained, both of these machines give promise of satisfactory service under conditions of continuous operation. Another Vancouver company is manufacturing machines for the production of briquets composed of sawdust, coal dust, and binder in about the following proportions: Sawdust, 65 per cent; coal dust, 25 per cent; binder (coal-tar pitch, petroleum refuse, or sulphite waste liquor),

[1] "Briquetting of Sawdust on a Commercial Basis," R. Thelen, forest products laboratory, Madison, Wis., in Canada Lumberman and Woodworker, vol. 36, No. 5, pp. 39–40, Mar. 15, 1916.

10 per cent. These briquets are hard and firm and resemble coal briquets in general appearance.

Although the various presses differ greatly in the details of their construction, most of them work on the cylinder-and-plunger principle, the plunger being driven by means of crank and connecting rod or by some toggle-joint system of levers so designed that it is capable of exerting a very great pressure at the end of the stroke. Practically all of them also are automatically fed. In systems in which binders such as pitch are used and in those in which the resins of the wood serve as binders, it is necessary to provide a long cooling trough, sometimes as much as 150 feet in length for the finished briquets. In systems using mechanical binders these cooling troughs are unnecessary.

The cost of manufacturing briquets is not inconsiderable, conservative estimates placing the figures at not less than $3 a ton. The bulk of the fuel prevents its economical shipment over long hauls. This applies both to the finished briquet and to the raw sawdust. It is believed that the ultimate consumer will have to pay at least $6 a ton for the briquets to make the success of their manufacture assured.

MANUFACTURE OF CHARCOAL.[1]

There are two chief methods of producing charcoal, the old kiln method and the modern method of destructive distillation in a closed retort. Most of the commercial charcoal is still made in the kiln, the erection and operation of which costs, for the labor, about 60 cents per ton of charcoal.

Wood loses 75 per cent in weight and 50 per cent in volume in charring. Two cords of hardwood will yield 1 ton of charcoal; 1 bushel of charcoal, the selling unit, weighs about 25 pounds.

For making charcoal the wood should be thoroughly seasoned, free from knots, and of but one species for each kiln charge.

The ground is prepared near water by leveling and hoeing the soil, removing roots and stones, and raising the center of the circle to be occupied by the kiln about 10 inches above its circumference. The usual diameter of the circle is from 15 to 30 feet. The best soil is loamy sand, which secures proper regulation of the draft. The site should be protected from wind.

A "chimney" is erected by placing three or four poles of even height at 1 foot distance from a central pole, and fastening them around the central pole by withes. It is cylindrical if the kiln is lighted from above, and pyramidal if the kiln is lighted from below; and is filled with inflammable substances, such as dried twigs, charcoal, etc.

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[1] Logging and Lumbering or Forest Utilization, pp. 167–168, a textbook for forest schools, by C. A. Schenck, director Biltmore Forest School.

The kiln proper is then constructed in a parabolic form. It consists of two or more tiers of billets placed more or less vertically with the bark turned outward, the big ends downward, the smallest pieces near the chimney and near the circumference, the largest pieces halfway between. These tiers are topped by a cap, consisting of smaller billets placed sloping. If the chimney is cylindrical it extends through the cap; if it is pyramidal it is closed by the cap. In the latter case a lighting channel is left on the ground running radially on the leeward side from the base of the pyramidal chimney to the circumference. This channel, like the chimney, is filled with inflammable material. All irregularities, interstices, and cracks showing on the outside of the kiln are stuffed with small kindling. The kiln is covered by two draft-proof layers so as to exclude the air; first the vegetable layer, one-fourth to three-fourths of a foot thick, made of green branches, weeds, leaf mold, and moss; second, an earth layer, 2 to 6 inches thick, consisting of loam, charcoal dust, etc. If the kiln is lighted from below, a belt about 1 foot high running around the circumference on the ground is left without the earth cover until the fire is well started. The earth layer and the vegetable layer are thoroughly joined by beating with a paddle.

The kiln is lighted early in the morning on a quiet day. The cylindrical chimney is closed on top as soon as the fire is well started in the cap. The lighting channel, in the case of a pyramidal chimney, is similarly closed.

The regulation of the fire and of the draft are the most important functions of the attendant, who guides the fire evenly and gradually from the cap down to the bottom. To check the draft the earth cover is increased. To increase draft, holes of about 1 inch diameter are made through the cover with the paddle reversed. If the wind is strong all holes are closed and the earth cover is increased. Cracks which form in the cover must be closed at once. The kiln may explode if the cover is too heavy and the draft too strong. In dry weather the kiln is continuously sprinkled. The color of smoke escaping through the punctures indicates, by turning blue and transparent, the completion of the charring process above the puncture. The old punctures are then closed and another row of punctures is made about 2 feet below the closed holes.

Refilling is required where dells are forming irregularly, while the kiln gradually shrinks to one-half of its original volume. For refilling, the cover over the dell is quickly removed, all holes having been closed beforehand, and the dell is rapidly filled with new wood.

When the bottom holes show the proper color of smoke, the charring process is completed. All holes are then closed, and the kiln is allowed to cool. The duration of the charring process is from 6 to

28 days, according to size of kiln. The contents vary from 4 to 60 cords.

Beginning at the leeward side the kiln is gradually uncovered. The crust of earth, cut into fragments, is thrown on again. The earth trickling down quenches the fire. After another 12 to 24 hours, preferably at night, the coal is taken out in patches or pockets, slowly and carefully, so as to prevent the flames from breaking out. Water must be at hand to quench incipient fires.

HOW TO USE WOOD FUEL.

Coal has been so generally used lately and furnaces and stoves have become so adapted to its use that it seems impractical to many to burn wood without going to great expense. Such is not usually the case, as simple adjustments will allow wood to be used with coal-burning equipment. The size of the firebox, of course, gives the greatest difficulty, since in many cases it may make it necessary to cut the wood into very small blocks. This trouble, however, is not insurmountable and is not so expensive as it might seem. The matter of adjusting the drafts and arranging the grates is simple.

Following are a number of practical directions which are largely the result of experience in changing from coal to wood fuel.

BURNING WOOD IN STOVES.

A coal-burning stove can be converted into a wood-burning stove by removing the fire brick and substituting lighter bricks at a cost of about $1.25. Most country cook stoves can burn wood with little trouble. If a stove grate is too coarse for wood, a sheet-iron cover over a good part of the surface will make it suitable, or a few fire bricks can be used. Wood grates made in two pieces are sold which can be inserted through the fire door and placed on top of the regular grate.

BURNING WOOD IN FURNACES.[1]

Furnaces are built especially for burning wood in 3 or 4 foot lengths. Short lengths, of course, can readily be burned in an ordinary coal furnace or in a box stove, though this is rather wasteful of fuel. Many furnace manufacturers, however, make a special wood grate for use in their furnaces. One advantage in burning wood is that on moderately cool days the furnace can be run at a lower ebb than when coal is used, consuming only enough fuel to remove the chill. When wood is used in a round pot furnace care should be taken to have each piece lie flat.

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[1]Adapted from a bulletin by E. H. Lockwood, published by P. B. Noyes, director of conservation, U. S. Fuel Administration, Washington, D. C.

USING WOOD ONLY.

There are difficulties in burning wood as a substitute for coal in a steam, hot-water, or warm-air furnace, but it can be done with a fair degree of success, especially in mild weather.

The best form of wood is short blocks, from 8 to 12 inches long, preferably of hardwood, although mixed hard and soft, or even softwood alone, can be used. Medium-sized pieces, such as those found in ordinary cord wood, are suitable, although larger pieces keep the fire better.

The best method of firing is to keep the furnace full of wood packed close with a moderate draft to give the desired amount of heat. As the wood burns more should be added in order to keep the deep bed of burning fuel, which is most economical.

Banking the fire at night requires an extra supply of the largest blocks and special attention to closing the dampers tight. Experience will show the best way, but it can be done with success in most furnaces.

It is not necessary to buy new grates for burning wood, although the ordinary coal grate is not well adapted for wood. A good way is to add a little nut coal to the fire at the start, allowing the layer of coal ashes to remain on the grates. Air required for combustion can pass through the ash layer, which can be shaken lightly without much loss of ashes. The larger the fire box the better the results.

A furnace designed for burning coal may be made into what is known as a "Wilson heater," which is one of the most economical stoves for wood burning, by removing the grate bars and laying fire brick on the floor of the ash pit. A wood fire is then built on the fire brick, and the ash pit door is kept tightly closed and the ventilator in the fuel door open. A wood fire can in this way be made to burn very slowly.

USING A COMBINATION OF WOOD AND COAL.

The simplest way to use wood in a coal furnace, and the most effective in producing heat, is to combine it with coal. The method of firing is to place blocks of wood on the fire to about the level of the fire door, instead of shoveling on coal in the usual way, then add coal on the top, which will fill the crevices between the wood, making a level fuel bed with coal on top.. A fuel charge of this kind will produce good heat but will not last as long as a fire pot full of coal, hence more frequent attention is needed.

From 25 to 50 per cent of the coal ordinarily used can be saved by substitution of wood in this way. Any kind or size of wood can be used that will go into the fire pot, and will burn with good efficiency when surrounded with coal.

Any size of coal or coke can be used, but the small sizes fill in best between the chinks in the wood. Buckwheat coal can be burned successfully in this way, and its low price will help to offset the higher price of block wood, making an economical combination.

CAUTION.—When burning the small sizes of coal take care to avoid gas explosions by always leaving a flame burning on some part of the fire; in other words, do not cover the whole fire with fresh fuel at one time.

BURNING WOOD IN FIREPLACES.

Where a fireplace is available wood can be used to good advantage, affording both heat and ventilation. Its value is to supplement a furnace, although it may replace the furnace in fall and spring with decided economy.

It is not generally realized that a wood fire can be kept burning night and day in a fireplace with very little attention and with small consumption of wood. One user reports continuous use of a fireplace in this way for over a month, with dry chestnut wood, where the amount of ashes formed by a month's use was not enough to require removal.

The secret of fireplace management is a plentiful supply of ashes, kept at the level of the andirons. As the blocks burn, an accumulation of glowing charcoal forms in the ashes. This keeps on burning slowly and assists in igniting the fresh blocks on the andirons. A pocket may be formed in the ashes into which the hot charcoal may fall, forming a heat storage. Two or three blocks on the andirons with the hot charcoal in the ashes will form an excellent fire.

To check the fire, ashes are shoveled over one or more of the blocks, covering lightly all the burning wood. This will not put out the fire; it will only check the rate of burning, so that red charcoal will be found when the ashes are removed for addition of fresh fuel.

Fireplace wood is usually cut in longer lengths than stove wood, but the ordinary 16-inch stove length is convenient. Any kind of wood can be used, provided it is dry and seasoned.

A banked fire will keep 10 or 12 hours and will send some heat from the hot bricks all the time. A well-managed fireplace will be found a great addition to the heating system in any residence.

INDUSTRIAL USE OF WOOD FUEL.

Wood is very generally used for fuel by sawmills and woodworking plants. For this purpose it is burned in the form of slabs, 4 feet or so long, or is cut up into "hog" fuel and shoveled or fed automatically into the fire box. In these cases wood fuel is a byproduct which would have to be disposed of at some cost if not burned for fuel, so that its use is economical. It is seldom economical to buy firewood for industrial use, except to keep a plant running when other fuel can not be had.

EFFICIENCY OF WOOD FUEL.

THEORETICAL HEATING VALUES OF WOOD.

The heating power or fuel value of a given volume of dry wood is in direct ratio to its specific gravity. By specific gravity is meant the ratio of the weight of a given volume of wood to that of an equal volume of water. Water weighs a little over 62 pounds per cubic foot, and wood, which weighs 31 pounds per cubic foot when perfectly dry, is said to have a specific gravity of 0.50, and so on for other weights.

In theory equal weights of wood substance will give the same amount of heat regardless of the species. In other words, a hundred pounds of absolutely dry cottonwood should furnish as much heat as a hundred pounds of hickory. In reality the varying forms of tissue found in the different species, the addition of resin, gums, tannin, oils, and pigments, as well as water present in varying amounts, cause different woods to have different heating values. The presence of rosin in wood increases the heating power materially, the results of numerous tests showing a difference ranging up to 12 per cent or more.

The composition of absolutely dry wood is approximately as follows: Carbon, 49 per cent; oxygen, 44 per cent; hydrogen, 6 per cent; ash, 1 per cent.

This is fairly constant for all species, except as modified by infiltrations, such as gums, pigments, resins, tannin, etc., so that equal weights of dry nonresinous woods give off practically the same amount of heat in burning. A pound of thoroughly dry wood will furnish under good conditions between 7,000 and 9,000 British thermal units. A pound of good coal will furnish from 12,000 to 14,000 units, making dry wood about 57 per cent as efficient as coal.

When wood containing water is burned part of the heat the wood is capable of yielding is taken up in raising the water to the boiling point and converting it into steam. The steam must then be raised to the temperature of the flue gases. All this heat is lost, and the greater the amount of water present the more heat is carried off. The water in green wood often makes up half of the total weight, especially in sapwood. After such wood is thoroughly air-seasoned there would remain about 20 per cent of water. If the wood is kiln-dried, from 2 to 5 per cent of water remains, and if it is exposed to the air, this percentage is increased by absorption (hygroscopically) from 10 to 15 per cent, depending upon the humidity.

A hundredweight of wood as sold on the market contains about 25 pounds of water, 74 pounds of wood substance, and 1 pound of ash.

These 74 pounds are made up of 37 pounds of carbon, 4.4 pounds of hydrogen, and 32 pounds of oxygen. The oxygen combines with the hydrogen in the proportion of 8 to 1, producing 36 pounds of water and leaving four-tenths of a pound of hydrogen to produce heat. The total amount of water to be evaporated becomes 25 plus 36, or 61 pounds.; the amount of wood substance left available for heat production is 37.4 pounds out of the original 100 pounds.

It is evident that the greater the proportion of water the less the amount of available heat. Only about one-half of the weight of wood substances produces heat, while every pound of water combined in the wood requires 1,108 units of heat to evaporate it, from ordinary room temperature (70° F.). Hence under the most favorable circumstances the heating efficiency of a pound of wood containing 25 per cent moisture will be less than that of dry wood not only by the 2,000 units representing the weight of wood replaced by water, but also by one-fourth of 1,108 units, or 277 units, so that its heating value is but 5,723 units instead of 8,000, or 72 per cent of that of a pound of dry wood. On the other hand, if we take the pound of wet wood and dry it out absolutely, so that it weighs three-fourths of a pound, it will have 6,000 heat units, an increase in heating value due to drying of only about 5 per cent.

COMPARATIVE VALUES OF DIFFERENT WOODS.

The comparative values of fuel of various species of American woods are shown in Table 8. These values are necessarily somewhat approximate but afford a good basis for comparison of the different species.

TABLE 8.—*Heat values of cordwood, based on Forest Products Laboratory (Madison, Wis.), weights for oven-dry, air-dry, and green woods and assuming 7,350 B. t. u. available per pound of dry wood with flue gases at 300° F.*

Species.	Available heat units per cord of 90 solid cubic feet (in millions B. t. u.).		Per cent of short-ton coal value.	
	Air-dry.	Green.	Air-dry.	Green.
Alder, red (A. oregona)	14.8	13.0	57	50
Ash, biltmore (F. biltmoreana)	20.7	20.0	80	77
Black (F. nigra)	18.5	16.5	71	64
Blue (F. quadrangulata)	21.3	20.7	82	80
Green (F. lanceolata)	20.6	19.6	79	75
Oregon (F. oregona)	19.7	19.0	76	73
Pumpkin (F. profunda)	19.4	18.2	75	70
White (F. americana)	20.5	19.9	79	77
White (second growth)	23.0	22.4	88	86
Aspen (F. tremuloides)	14.1	12.1	54	47
Largetooth (P. grandidentata)	14.2	12.4	55	48
Basswood (T. americana)	12.6	11.0	48	42
Beech (F. atropunicea)	20.9	19.7	80	76
Birch, paper (B. papyrifera)	18.2	16.7	70	64
Sweet (B. lenta)	23.3	21.9	90	84
Yellow (B. lutea)	20.9	19.4	80	75
Gray (B. populifolia)[1]	17.5	16.1	68	62
Red (B. nigra)[1]	17.5	15.7	68	60

[1] Gray and red birch estimated.

TABLE 8.—*Heat values of cordwood, based on Madison Laboratory weights.*—Con.

Species.	Available heat units per cord of 90 solid cubic feet (in millions B. t. u.).		Per cent of short-ton coal value.	
	Air-dry.	Green.	Air-dry.	Green.
Buckeye, yellow (A. octandra)	12.8	10.1	49	39
Buckthorn (R. purshiana)	20.2	18.6	78	72
Butternut (J. cinerea)	14.3	12.2	55	47
Chinquapin, western (C. chrysophylla)	17.2	13.9	66	53
Cherry, black (P. serotina)	18.5	17.3	71	67
Wild red (P. pennsylvanica)	14.2	13.5	55	52
Chestnut (C. dentata)	15.6	12.9	60	50
Cottonwood (P. trichocarpa)	12.8	10.5	49	40
Cottonwood (P. deltoides)	15.0	12.7	58	49
Cucumber (M. acuminata)	17.8	16.0	68	62
Dogwood, flowering (C. florida)	25.2	23.7	97	91
Western (C. nuttallii)	22.4	21.4	86	82
Elder, pale (S. glauca)	18.4	15.2	71	58
Elm, cork (U. racemosa)	22.6	21.5	87	83
Slippery (U. pubescens)	19.1	17.1	73	66
White (U. americana)	17.7	15.8	68	61
Gum, black (N. silvatica)	18.5	17.4	71	67
Blue (Eu. globulus)	24.1	22.4	93	86
Cotton (N. aquatica)	18.5	16.2	71	62
Red (L. styraciflua)	17.7	16.0	68	62
Hackberry (C. occidentalis)	19.1	17.7	73	68
Haw, pear (C. tomentosa)	24.8	23.1	95	89
Hickory, shellbark (H. laciniosa)	24.8	23.1	95	89
Bitternut (H. minima)	24.2	22.2	93	86
Mockernut (H. alba)	25.4	23.8	98	92
Nutmeg (H. myristicae formis)	22.0	19.9	85	77
Pecan (H. pecan)	24.2	22.5	93	87
Pignut (H. glabra)	25.9	24.7	100	95
Shagbark (H. ovata)	25.4	23.8	98	92
Water (H. aquatica)	24.5	21.6	94	83
Holly (I. opaca)	19.6	17.8	75	68
Hornbeam (O. virginiana)	24.7	23.5	95	90
Laurel, California (U. californica)	20.7	18.8	80	72
Mountain (K. latifolia)	24.9	23.2	96	89
Locust, black (R. pseudacacia)	26.5	25.4	102	98
Honey (G. triacanthos)	24.5	22.5	94	87
Mondrona (A. menziesii)	22.6	20.9	87	80
Magnolia, evergreen (M. foetida)	18.4	15.5	71	60
Maple, Oregon (A. macrophyllum)	17.7	16.3	68	63
Red (A. rubrum)	19.1	17.6	73	68
Silver (A. saccharinum)	17.9	16.4	69	63
Sugar (A. saccharum)	21.8	20.4	84	78
Oak, bur (Q. macrocarpa)	22.6	20.8	87	80
California, black (Q. californica)	20.5	17.7	79	68
Canyon live (Q. chrysolepis)	27.5	25.7	106	99
Chestnut (Q. prinus)	22.4	20.7	86	80
Cow (Q. michauxii)	24.0	22.1	92	85
Laurel (Q. laurifolia)	21.7	19.6	83	75
Pacific post (Q. garryana)	25.3	23.4	97	90
Post (Q. minor)	24.0	22.2	92	85
Red (Q. rubra)	21.7	19.6	83	75
Spanish (Q. digitata)	20.4	18.1	78	70
Spanish (Q. pagodaefolia)	24.0	21.9	92	84
Swamp white (Q. platanoides)	25.1	23.4	97	90
Water (Q. nigra)	21.7	19.7	83	76
Tanbark (Q. densiflora)	21.7	19.4	83	75
White (Q. alba)	23.9	22.4	92	86
Willow (Q. phellos)	21.2	19.3	82	74
Yellow, black (Q. velutina)	22.0	19.7	85	76
Osage, orange (Tox. pomiferum)	30.8	30.1	118	116
Persimmon (D. virginiana)	25.0	24.0	96	92
Rhododendron (R. maximum)	19.5	17.2	75	65
Sassafras (S. sassafras)	17.2	15.7	66	60
Service berry (A. canadensis)	26.1	25.2	100	97
Silverbell (Mohrodendron carolinum)	17.2	15.7	66	60
Sourwood (Oxydendrum arboreum)	19.9	18.2	77	70
Sumac (R. hirta)	17.9	16.9	69	65
Sugarberry (Celtis mississippiensis)	18.5	17.1	71	66
Sycamore (P. occidentalis)	18.5	16.6	71	64
Umbrella (Mag. fraseri)	15.5	13.8	60	53
Walnut, black (J. nigra)	20.8	18.6	80	72
Willow, black (S. nigra)	13.5	10.9	52	42
Western, black (S. lasiandra)	15.5	13.4	60	52
Witch hazel (H. virginiana)	21.8	20.1	84	77
Yellow poplar (L. tulipifera)	15.1	13.9	58	53

TABLE 8.—*Heat values of cordwood, based on Madison Laboratory weights.*—Con.

Species.	Available heat units per cord of 90 solid cubic feet (in millions B. t. u.).		Per cent of short-ton coal value.	
	Air-dry.	Green.	Air-dry.	Green.
Cedar, incense (L. decurrens)	14.5	12.3	56	47
Port orford (C. lawsoniana)	16.3	15.5	63	60
Western red (T. plicata)	12.1	11.7	47	45
White (T. occidentilis)	11.3	10.7	43	41
Cypress, bald (T. distichum)	16.4	14.5	63	56
Yellow (C. nootkatensis)	15.8	15.1	61	58
Douglas fir, Pacific coast (P. taxifolia)	17.7	17.3	68	67
Rocky Mountains	15.6	15.1	60	58
Fir, alpine (A. lasiocarpa)	12.0	11.5	46	44
Amabilis (A. amabilis)	15.1	12.9	58	50
Balsam (A. balsamea)	13.5	11.5	52	46
Lowland white (A. grandis)	15.1	13.3	58	51
Noble (A. nobilis)	14.3	13.7	55	53
Silver, white (A. concolor)	14.3	11.1	55	43
Hemlock, black (T. mertensiana)	17.2	15.7	66	60
Eastern (T. canadensis)	15.0	12.8	58	49
Western (T. heterophylla)	15.0	13.5	58	52
Larch, western (L. occidentalis)	19.3	17.9	74	69
Eastern (L. americana)	19.1	18.1	73	70
Pine, Cuban, slash (P. heterophylla)	22.4	21.6	86	83
Jack (P. divaricata)	15.7	13.4	60	52
Jeffrey (P. jeffreyi)	15.0	12.9	58	50
Loblolly (P. taeda)	19.9	18.1	77	70
Lodgepole (P. contorta)	15.0	13.8	58	53
Longleaf (P. palustris)	22.0	21.1	85	81
Norway (P. resinosa)	17.8	16.8	68	65
Pitch (P. rigida)	18.5	16.4	71	63
Pond (P. serotina)	20.0	18.7	77	72
Shortleaf (P. echinata)	19.9	18.5	77	71
Sugar (P. lambertiana)	14.3	11.7	55	45
Table Mountain (P. pungens)	19.3	17.2	74	66
Western white (P. monticola)	15.7	14.6	60	56
Western yellow (P. ponderosa)	15.0	13.1	58	50
White (P. strobus)	14.2	12.9	55	50
Spruce, Engelmann (P. engelmanni)	11.9	10.5	46	40
Red (P. rubra)	15.0	14.2	58	55
Sitka (P. sitchensis)	13.5	12.7	52	49
White (P. canadensis)	14.1	13.5	54	52
Yew, western (T. brevifolia)	24.4	23.2	94	89
Redwood (S. sempervirens)	14.3	12.9	55	50
Coal, long ton (2,240 pounds)	29.1			
Short ton (2,000 pounds)	26.0			

NOTE.—Values given for resinous woods are low, since resin adds to heating value; for instance, dry longleaf pine with 20 per cent resin has a value of approximately 26,400,000 B. t. u., instead of the 22,000,000 given in the table. The amount of bark in a cord of wood also affects the heating value; for instance, bark of birch, Douglas fir, western yellow pine, and others has a higher value than the wood. Much of the theoretical value of both wood and coal is lost in use. While anthracite and soft coal have about the same theoretical value, only from 70 to 75 per cent of this value is realized with anthracite and from 60 to 65 per cent with bituminous coal. Values decrease as temperature of flue gases increases. To get values for wood only partly seasoned it may be assumed that in most cases it will be about half seasoned in three months, two-thirds seasoned in six months, and entirely air-dry in about a year.

It may be seen from this table that the heating power of a given quantity of green wood is not so very much below that of the same wood after it has been dried. The choice of wood for fuel does not, however, depend entirely upon its calorific power; other factors, such as freedom from smoke, completeness of combustion, and rapidity of burning, play a very important part. Green wood is not only much heavier to handle but it is also harder to ignite and to keep burning, unless mixed with dry wood or with coal, and makes more smoke. For a slow fire green wood or a mixture of green and dry wood is often more satisfactory than dry wood alone, since the latter burns up rapidly and much of its heat escapes up the pipe.

Heating values of different parts of the same tree may vary considerably, because of differences in moisture content, proportion of bark to wood, and other factors. Tests made by the department of forestry of the Michigan Agricultural College gave the following results:

Position.	Moisture.	Dry matter.	British thermal units (per pound).	
			Green wood.	Dried wood.
	Per cent.	*Per cent.*		
Beech, sap, near stump	40.2	59.8	5,534.4	9,253.5
Beech, heart, near stump	25.2	74.7	7,258.0	9,718.5
Beech, sap, near top	44.1	55.9	5,086.6	9,098.5
Beech, limb, 2 inches diameter	36.2	63.8	5,888.4	9,227.1
Maple, sap, near stump	36.1	63.9	5,581.9	8,735.8
Maple, heart, near stump	32.8	67.2	5,870.8	8,735.8
Maple, sap, near top	30.8	69.2	6,099.1	8,813.3
Maple, limb, 2 inches diameter	35.7	64.3	5,817.2	9,045.8

In a number of species the bark has a higher heating value than other parts of the tree. In the Northwest, Douglas fir bark is often a principal source of fuel in firing donkey engines. The bark of shagbark hickory has a high fuel value and burns with intense heat, but with much crackling. In the case of many woods, such as the cedars, the bark has a comparatively low fuel value and leaves a large proportion of ash.

Root wood is little used for fuel, mainly because of the difficulty in getting it and its awkward form. It is interesting to note, however, that the roots of mesquite are capable of producing more heat than the average butt cut, and are commonly dug up for firewood where other wood is very scarce. Very often mesquite roots are so much more developed than the rest of the tree that the name "underground forests" has been applied to stands of the timber in semiarid regions.

The rapidity of burning may be important where quick heating is desired. As a general rule the softwoods burn more readily than the hardwoods, while the lighter hardwoods burn more readily than the heavier ones. The pines, for instance, give a quicker, hotter fire and are consumed in a shorter time than birch, but birch gives a more intense flame than oak. On the other hand, the oaks give a more steady heat. Less than 5 per cent of the wood used as fuel is consumed in the industries, the remainder, or more than 95 per cent, being used for domestic purposes, where such qualities as ease of ignition, rapidity of combustion, freedom from smoke, uniform heating, or quickness of burning, depending on the particular results desired, are more important than calorific value. A few species, such as chestnut, butternut, tamarack, and spruce, are in ill favor for open fires because they throw off sparks.

Another point worth bearing in mind in connection with the burning of wood in place of coal is the difference in the amount of ash produced. A cord of hardwood will make only about 60 pounds of ashes, while a ton of hard coal will make from 200 to 300 pounds.[1]

A pound of wood briquet, irrespective of species, should have about the same heat value as dry wood, probably a little higher, on account of the heat value of the organic binder (if one is used), which may have a greater unit heat value than wood and thus raise the average slightly. If the resins in the wood are used as binders the same result may be expected. In comparing briquets with cordwood or stove wood it must be remembered that the briquet is usually drier and will therefore generate more heat per pound of material than will wood.

In actual use wood fuel does not always show up as favorably in comparison with coal as the above heat values would indicate. This is probably due to the fact that it is not the actual heat-producing power of the fuels that is compared but the efficiency of the apparatus for utilizing the heat. Wood requires about one-third more grate surface and two-thirds more cubical space than coal for generating an equal amount of steam.

In logging engines a ton of good grade bituminous coal is considered equivalent to a cord and a half of air-dry oak or two cords of softwood. Two and a half cords of pine knots (about 125 cubic feet) are thought to furnish about the same amount of steam as 1 ton of southern soft coal. For general calculations for stationary engines 1 ton of coal is considered equivalent to 2 cords of wood, or 1 pound of coal to 2½ pounds of wood. During the winter of 1917–18

[1] Since potash is now greatly in demand, the quantity which may be obtained from wood ash is worth consideration.

The quantity of ashes obtained from a cord of wood varies with the conditions under which it is burned. About 30 cords of hardwood produce a ton of ashes equal in quantity to the Canadian wood ashes of commerce; but the same quantity of wood consumed as fuel in a cook stove or other small, closed burner would be far more completely reduced and would produce only about one-third to two-thirds of a ton of ash. On the other hand, commercial hardwood ashes contain only 5 per cent of the valuable fertilizer potash, whereas stove ashes contain from 10 to 15 per cent, so that the amount of potash to be had from a cord of wood is about the same however the wood is burned and regardless of the bulk of the resulting ash. Softwood ashes contain on an average about one-third less potash than hardwood ashes, and the quantity of ash obtained from softwoods is less than from the same bulk of hardwood. The present price of potash, about 25 cents a pound, or $500 a ton, almost prohibits its use in fertilizers.

It is important always to keep wood ashes under cover, as they leach rapidly if allowed to become damp. New ashes should be allowed to cool before they are dumped on the ash heap.

It is estimated that the ashes from a cord of northern hardwoods will furnish about 20 pounds of lime, more than 3 pounds of potash, and a half pound of phosphoric acid, and that they have a value at present prices of about $1.

H. J. Wilder, agriculturist of U. S. Department of Agriculture (letter to Mr. A. F. Hawes, July 18, 1918): Hardwood ashes which have not been wet analyze about 5 per cent potash, 30 to 35 per cent lime, both in desirable forms. Potash contents of softwoods is rarely below 3 per cent. Hardwood ashes have 600 to 700 pounds lime per ton of ashes. Mixture of coal ashes from factories would do no harm.

one factory which normally used 50 tons of soft coal a day used for a month in mid-winter a minimum of 15 tons of coal and 50 cords of mixed hardwood daily, from which the conclusion may be drawn that for steam production 1 cord of green hardwood is equal to seven-tenths of a ton of soft coal. Careful tests made in Georgia showed that to keep a room at a comfortable temperature with an open-hearth fireplace nearly 10 times as much wood must be consumed as when a stove is used. This plainly indicates that it is very uneconomical to depend on open fireplaces alone for heating houses.

WOOD FUEL FOR THE FUTURE.

GROWING TIMBER FOR FUEL.

There is probably a general impression that timber for firewood can be grown rather rapidly, within a period of 5 to 10 years. This will not hold true for general forest areas, especially hardwoods. From 20 to 50 years and even longer are required to produce a full stand. The sprout forests of southern New England will grow a crop of wood in 10 or 15 years and perhaps less; a full stand, however, requires more time. Planted catalpa on good soil will yield fairly well in 8 or 10 years; and eucalyptus or blue gum will produce a heavy growth in five or six years. Willow and cottonwood on suitable sites will yield firewood in from 10 to 15 years, but usually a longer time is required for large yields even with these rapidly growing species. Old field and white pine make rapid growth and yield heavily in a comparatively short time. With hardwoods like oak, hickory, maple, beech, birch, etc., not much can be expected in less than from 30 to 50 years.

An average of 1 cord of fuel wood per acre per annum is a large yield, taking the country as a whole. Hardwood forests will probably not average more than three-fourths of a cord growth per year and many will not make more than one-fourth of a cord. With the faster-growing species 2 cords per acre is a high average annual yield even on favorable sites. With average natural stands of cottonwood, cordwood can be obtained in about 16 years, with a total yield of approximately 42½ cords per acre, or an annual yield of 2.7 cords. Under particularly favorable conditions of growth the time may be shortened to 12 years, especially where thinning and cultivation are possible. Since stands cut for cordwood can be most easily renewed by coppicing, the second rotation should be much shorter than the first because of the more rapid growth of the sprouts. Eucalyptus in California is reported to yield as high as 7 cords per acre per annum on a comparatively short rotation. With the pines a yield of over 4 cords per acre per annum has been reached. Only on the best sites and under suitable climatic conditions can such yields be expected even with these species.

FORESTRY.

It will not do for communities in wooded regions to depend on the chance growth of wood for their future fuel supply. Already many communities, especially in the Northeast, are finding it necessary each year to go farther and farther back for their wood, or to cut smaller trees each succeeding year, because the available supply of standing wood is too small to allow the trees to grow to the proper size before they are cut.

It is not too much to expect that the time will come—and soon in some regions—when it will be necessary to provide definitely that certain areas be set aside to produce wood, and that they be so managed as to produce the maximum amount of wood possible within the shortest possible time. It is not desirable to devote good agricultural land to growing an annual supply of fuel; generally the inferior land on farms will grow sufficient fuel to supply regularly each year's needs. Farms with such land are numerous in the hilly sections of the country, and are found almost everywhere except in the prairie and plains regions and in limited areas in the river bottoms.

Meanwhile, the least that should be done is to see that fire and other destructive agents are kept out of growing woodland, and that when cutting is done for firewood only that material is taken out whose removal will not cause injury to the productive capacity of the remaining stand. Advice on these matters will be freely given by the various State forestry departments, or where they are not available, by the Forest Service of the United States Department of Agriculture.

MUNICIPAL FORESTS.

Acute need for fuel in emergencies furnishes one of the strongest arguments for maintaining municipal forests by cities or towns in wooded districts where this is possible. These emergencies may be expected periodically, and municipal forests serving as parks and pleasure grounds or as protection to water supplies can come into play as fuel reserves in time of stress when coal can not be obtained in sufficient quantities for the needs of the communities. It is a point well worth the thoughtful consideration of every community which has woodland adjacent to it suitable for this purpose. Some towns already own such tracts, and no doubt there will eventually be many of these forests in the older settled sections of the country when it is found how easily they are handled and how advantageous they are in many respects. Instead of being sources of expense, well-managed woodlands should quickly become sources of considerable revenue to the communities owning them.

PROMOTING USE OF WOOD FOR FUEL.

PUBLICITY.

Where wood fuel has been little used or its use has been discontinued for a long time, a great deal can be done toward developing a demand for it by means of newspapers, motion pictures, illustrated talks, "cut-a-cord" clubs, "cutting bees," and posters. Newspapers are usually most active in advertising the work when fuel conditions are acute. In the depth of winter when a shortage is severe it is a matter of news and is "played up" a great deal, but at other times it is difficult to use this medium of publicity. Motion pictures may be used, with short, pithy sentences embodying facts about wood fuel. Lantern slides are being used to illustrate talks on wood fuel given before clubs and various local organizations interested in the subject. Posters carrying catchy slogans and condensed information have been devised in several States and have been very effective.

"Cutting bees," so called, are organized efforts at getting out wood by a crowd and are in the nature of a picnic. They are carried on with great enthusiasm and rivalry, and well serve the purpose of advertising the need of wood fuel and the means of getting it. Other forms of organization can be used which suit the particular locality and the spirit of the people, or existing organizations can be turned in this direction.

"Cut-a-cord" club, as organized in New England and some other sections during the winter of 1917–18, carry the "cutting bee" idea still farther. Each member agrees to cut a definite amount of wood, either one cord or several. Organization is made semipermanent, so that the work is carried on more systematically than in the more or less spontaneous "bees."

Many other ways can, of course, be devised to suit local conditions and to arouse interest and action. The essential point is to arouse the public from its inertia.

When the public realizes the necessity of returning to wood fuel the advertising campaign is mainly finished. It should be succeeded by a campaign of instruction in methods of producing wood fuel and in organization for its production and distribution. With the population concentrated at a distance from its fuel supply, as a large part of it is to-day, and not accustomed to providing fuel in advance of need, individuals are not able to cope with an emergency brought on by war, prolonged congestion of transportation, or interference with coal production.

A number of different organizations have been developed to meet this situation, such as wood fuel committees, war fuel companies, municipal wood yards, and "cut-a-cord" clubs.

The wood fuel committees may be State, county, or community organizations. In some States all three are used and all work more or less closely with the Fuel Administration. Many municipalities appoint such committees temporarily during the emergency winter season to organize means of production and transportation of wood as well as to equalize its distribution and price. All these committees should be made permanent, for much effective work can be done by them during that part of the year when conditions are not so acute.

As usually organized, a war fuel company is a stock company made up of public-spirited citizens operating under a charter duly registered with the State. The object is to buy and sell wood and coal at a low rate of return on the money invested, for the purpose of alleviating the undesirable conditions that are bound to follow wherever sufficient fuel can not be had by families, business concerns, and public institutions. The rate of profit is sometimes limited to not more than 6 per cent and the proceeds are turned over to some public charity.

WOOD FUEL LEGISLATION.

Doubtless in many cases State legislation would help to promote the use of wood fuel. Price regulation, measuring, shipping, marketing, and other features may be aided by specific laws adapted to local conditions.

In Virginia an order has been issued by the Federal Fuel Administrator for the State prohibiting any person residing outside the cities or incorporated towns from obtaining coal except by special permit from the local administrator upon the execution of a statement to the effect that wood is not available. This was done to bring about the substitution of wood for coal to a very appreciable extent without imposing serious hardship on those required to use wood. Similar restrictions for most localities in the eastern United States would seem desirable as a reasonable means of bringing about a greater use of wood fuel by those who have wood around them or can obtain it readily. This method is sufficiently elastic to accomplish the object aimed at without working hardship on those who can not reach wood. It should be especially valuable in the matter of coal embargoes which may be suddenly found absolutely necessary in the depth of winter in a fuel crisis. When an embargo must be laid, it should be a flexible one and the heaviest restrictions placed on those localities where wood is available and on those consumers who can use wood fuel. In this way coal may be conserved and the evil effects of a blanket embargo avoided.

MUNICIPAL WOOD YARDS.

In many places municipalities themselves organize wood yards to purchase, manufacture, and distribute wood fuel, in order to supplement the regular supply where no other agencies exist to take the whole field. Wood handled by them is usually sold at cost.

In some States a grant of specific power is necessary before a municipality can engage in the fuel business. In many cases in the eastern United States last winter this fact was a serious obstacle which prevented cities and towns from taking active relief measures to keep the people warm and supply power to essential commercial enterprises. In two States, Maine and Mississippi, public fuel yards are specifically authorized by law. The Mississippi law, approved April 21, 1918, authorizes municipal wood and coal yards.[1] The essential features of this law are of especial interest in view of the country-wide effort being made to provide against a fuel shortage in the future. By this law—

(*a*) The authorities of every municipality are authorized to establish and operate wood and coal yards until one year after the close of the war, for the purpose of supplying the inhabitants with fuel.

(*b*) A municipality which establishes and operates a wood yard or coal yard has full power to create, fill, discontinue, or abolish all such offices or employments in connection therewith as may be deemed necessary or proper; to fix and pay salaries; to cut, purchase, transport, sell, and deliver wood or coal necessary for providing the inhabitants with fuel; from time to time to fix the selling prices and the terms of sale; and to make and enforce such rules and regulations as may be necessary for the carrying out of the act.

(*c*) The necessary funds are to be set aside out of the general municipal fund, or borrowed at interest on the credit of the municipality.

(*d*) In order to borrow money for this purpose the municipality is required to publish in local papers, for a period of ten days, a full statement of its intentions, stating the sum needed and rate of interest to be paid. In case a protest signed by at least 25 per cent of the qualified electors of the municipality is filed before the expiration of the period of advertisement, the question must then be submitted in an election requiring for passage the approval of a majority of the qualified electors.

Similar action by other States is desirable.

WOOD FUEL RESERVES.

There is considerable difficulty in getting wood into suitable form for fuel and transporting it to the market on short notice. It is only a matter of good business foresight for those communities which have the wood around them to see that some time during the season a sufficient supply is cut and hauled to where it may be easily available as a reserve for the winter season. The time to cut it is at any slack time during the year, preferably in the spring, so that it will have time to season thoroughly by the next winter.

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[1]Although Mississippi is the first State to respond with a law on the subject in the present emergency, it is not actually the first to pass such legislation. As early as 1903 Maine passed a law allowing cities to establish public yards for sale of wood, coal, and other fuel without financial profit. The Maine law has been sustained by the highest court in the State and also by the United States Supreme Court.

In this connection it is very desirable that reasonably close estimates be made in advance of the amount of wood which will be available to different communities from all sources. It would be a comparatively simple undertaking to secure estimates of the amount of fuel wood which is ready for use or which it is planned to cut for the next winter. The figures should include (1) the number of cords used in the previous year; (2) the number of cords cut, including the amount left over from the previous winter; (3) the number of cords to be cut for winter, say from September 1 to December 31. Such figures would afford valuable bases not only for organizing wood fuel work but also for allotting supplies of coal.

SUMMARY.

1. With enormous supplies of wood widely distributed over much of the United States, especially the eastern half, there is no excuse for suffering because of inability to get coal.

2. Wood is already widely used in rural districts; its use can and should be greatly extended, at least during the present crisis, to save coal and cars for more essential uses.

3. Wood can be substituted for coal with greatest public benefit in places where rail-hauled coal can be replaced with wagon-hauled wood. Long distance rail transportation of wood is not economical.

4. Domestic consumers in rural districts and small cities can most easily substitute wood fuel for coal. Most types of stoves and furnaces can be adapted to the use of wood.

5. Except in case of plants which use their own wood refuse, or others in the close vicinity of such plants, wood fuel is less economical than coal for factories. When coal can not be had, however, wood can be used with fairly satisfactory results, and is cheaper than shutting down the plant.

6 The widespread use of wood for fuel, if only such wood as is best fitted for this purpose be taken, will be of great benefit to our forests as well as a source of revenue to their owners.

7. To promote the use of wood fuel, especially where it is not now in general use, will require organized effort, preferably by community, municipal, or State organizations. Such effort should cover the stimulation of demand for wood and stimulation of production by private agencies, as well as direct organization of producing, transporting, and marketing of wood fuel by the community.

8. Reserves of wood fuel should be established in all districts where there is a possibility of fuel shortage. For the present these reserves will probably consist largely of wood purchased from producers; it may eventually be advisable for communities to own their own woodlands in order that they may more effectively regulate the cutting and the price of fuel wood.

APPENDIX.

PUBLICATIONS ON WOOD FUEL.

Early in 1917 publications began to appear treating wood fuel briefly with reference to local conditions. They were issued mostly by States, and State foresters were chiefly instrumental in getting them out. The first one appeared in June in the shape of a press bulletin by K. W. Woodward of the New Hampshire Agricultural College, Durham, N. H. This was followed by others until at least 20 have been published. Canada also published one early in 1918 modeled on those put out by the States. Future publications should go into detail as to the quantity of wood fuel available in the State and its distribution, as well as the amount of fuel wood cut and used by specific localities within the State.

RECENT PUBLICATIONS ON WOOD FUEL.

Emergency Fuel from the Farm Woodlot, by A. F. Hawes, Circular 79, Office of the Secretary, U. S. Department of Agriculture. (Contributed by the Forest Service, Washington, D. C., October, 1917.)

Firewood, by K. W. Woodward, Extension Circular 22, September, 1917, New Hampshire Agricultural College, Durham, N. H.

The Fuel Situation, by K. W. Woodward, Extension Press Bulletin 77, June, 1917, Agricultural College, Durham, N. H.

Wood Fuel, by Paul D. Kneeland and F. W. Rane, Massachusetts State Forester's Office, 1917, Boston, Mass.

Wood Fuel, by R. D. Forbes, Assistant Forester, Department of Conservation and Development of New Jersey, 1917, Trenton, N. J.

A press bulletin was issued October 13, 1917, by the State fuel administrator at Greensboro, N. C., urging the cities and towns of the State to furnish wood to consumers at cost as a war measure.

Wood as Emergency Fuel, by J. H. Foster and F. H. Millen, bulletin, department of forestry, Agricultural and Mechanical College, 3d series, vol. 4, No. 2, January 15, 1918, College Station, Tex.

Cordwood for Fuel, by J. H. Pratt and J. S. Holmes, Press Bulletin 160, North Carolina Geological and Economic Survey, January 30, 1918, Chapel Hill, N. C.

Wood Fuel, by William G. Howard, assistant superintendent of State forests, Bulletin 16, conservation commission of New York, 1918, Albany, N. Y.

Wood Fuel to Relieve the Coal Shortage in Eastern Canada, by Clyde Leavitt, chief forester, commission of conservation, Ottawa, Canada, 1918.

Municipal Woodyards, by the Federal Fuel Administrator (Wood Fuel Department for Georgia), Commerce, Ga., February, 1918.

Wood Fuel for Iowa, March, 1918, by Prof. G. B. McDonald, Iowa State College, Ames, Iowa (in cooperation with Charles Webster, Federal fuel administrator for Iowa.)

Coal Conservation and Wood Fuel, March, 1918, State fuel administrator for Minnesota.

Tamarack for Fuel, 1918, issued by the publicity department, Minnesota, commission of public safety, St. Paul, Minn.

Wood Fuel and Democracy, 1918, State fuel administrator of Minnesota, St. Paul, Minn.

Cordwood Producers, list furnished to Minnesota forest service for distribution, March 12, 1918.

Firewood to Relieve the Coal Shortage, Forestry Leaflet No. 19, February 15, 1918, by F. W. Besley, State forester, Maryland State board of forestry, Baltimore, Md.

Firewood and the Woodlot, Press Bulletin 1918, by Edmund Secrest, State forester, Wooster, Ohio.

The Price of Fuel Wood, by William K. Prudden, State fuel administrator, Lansing, Mich., March, 1918.

Wood and the Present Fuel Emergency, by John M. Briscoe, Maine Forestry Association, February 6, 1918, Bangor, Me.

Municipal Woodyards, Circular 2, by T. A. Parker and James B. Berry, of the wood fuel department of United States fuel administration for Georgia, May, 1918.

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