2-1964

The Economics of Using Low-Quality Hardwoods for Producing Charcoal in Tennessee

Joe A. Martin

Billy G. Hicks

University of Tennessee Agricultural Experiment Station

Bulletin 375
February 1964

The Economics of Using LOW-QUALITY HARDWOODS for Producing CHARCOAL in Tennessee

by
Joe A. Martin
and
Billy G. Hicks

The University of Tennessee
Agricultural Experiment Station
John A. Ewing, Director
Knoxville

SUMMARY

THE REMOVAL OF CULL HARDWOODS is one of the principal production and management problems in Tennessee forest economy. While some cull hardwoods are used as fuel, pulpwood, fence posts, and cross ties, their annual growth rate exceeds their rate of use. The charcoal industry offers a chance to improve quality of trees growing in the state's forests, and higher forest income, as well as increase employment by converting the cull hardwoods to charcoal.

- The present trend toward increased outdoor cookery should continue, and many believe that it will as the proportion of middle class families increases. If this happens, the charcoal briquette industry could be a ready market at a paying price for cull hardwoods.

- At wages of $1.25 per hour, a cord of charcoal type wood can be cut and hauled 20 miles at a cost of $12.52. This cost diminishes to $10.66 for a farmer cutting his own wood during the off season.

- The study indicates that there are very definite cost advantages in large scale production of charcoal. The small scale plant could not pay $1.25 per hour for labor and still pay enough for wood to cover harvesting cost.

- With increased plant volume would come decreased costs of producing charcoal, including the popular charcoal briquettes. Up to $22.53 could be paid for wood for producing a ton of briquettes, which could be produced for $85.83 per ton and that would sell for $138 per ton. This was with a kiln of 1 ton per hour capacity.

- Larger capacity and more expensive charcoal-processing machinery of both foreign and domestic manufacture is available for producing charcoal at a rate of 2 tons per hour. With such machinery, wages of $1.25 and $1.00 per hour could be paid plant and wood harvesting employees and still buy stumpage for about $2.00 per cord. Depreciation, interest, and other charges would be paid for.

CONTENTS

The Economics of Using Low-Quality Hardwoods for Producing Charcoal in Tennessee

by

*Joe A. Martin and Billy G. Hicks**

INTRODUCTION

Almost 13.5 million acres of land in Tennessee are covered with commercial forest, over one-half of the State's total area.[1] Some 1.2 million acres of this forest land are publicly owned, another 6 million acres are in farms, and the remainder are held by numerous industrial and other private owners.[2] From this area of woodland there is harvested approximately $55 million worth of forest products annually.[3]

The magnitude of forestry production in Tennessee tends to mask problems of great significance. It has been estimated that a reasonable growth goal for Tennessee forests would be more than double the 1961 average net growth rate, which was one-third cord per acre annually for growing stock and 73 board feet for sawtimber.[4]

A major problem associated with the low growth rate is the forest area that is taken up by cull trees, mostly hardwoods. Some 10.3 million acres, or about 75% of the commercial forest area, are of hardwood species. Of the 15.9 billion board feet of hardwood sawtimber in Tennessee, about 70% is of a quality below that generally preferred by sawmills—that is, logs that will not be of grades No. 1 and 2.[5] A survey showed that one in every five trees of pole timber size and larger was cull quality. On a per acre basis, there was an average of 21 cull trees 6 inches and above in diameter.[6]

---

*Professor of Agricultural Economics, Agricultural Experiment Station, and Assistant Agricultural Economist, Agricultural Extension Service, respectively.

[1]Forest Service, U. S. Department of Agriculture, **Tennessee Forests**, Forest Survey Release 86, 1962, p. 3.

[2]**Ibid.**, p. 19.

[3]Forest Service, U. S. Department of Agriculture, **The Economic Importance of Timber in the United States**, Miscellaneous Publication 941, p. 38.

[4]Forest Service, **op. cit.**, p. 25.

[5]**Ibid.**, p. 24.

[6]**Ibid.**, p. 4.

Forest management studies have shown that the removal of cull hardwoods for the purpose of stand improvement may be achieved economically by several methods; which one to be used depends upon conditions found in that particular area. The most common methods recommended include girdling, chemical killing, controlled burning, or a combination of these methods.

The recommendation to use these methods is based upon the economic gains from replacing low-quality trees with higher quality ones and assumes that there is no economic loss in destroying the low-quality timber. However, the assumption that there is no economic loss in destroying the cull timber is not true if there is a market for the wood which would return to the owner a price greater than the difference between the cost of harvesting and the cost of destroying the timber.

Some of this wood is being used, primarily for pulpwood, fuel, fence posts, and cross-ties. But the annual volume going into various uses does not equal the annual rate of growth of cull trees. The problem is one of developing mass utilization outlets for low-quality hardwoods in the state.

If a sizable increase in low-quality hardwood utilization can be developed, this will not only serve as encouragement for forest stand and species improvement and for a higher level of management, but will also bring in more income. Moreover, "cull hardwoods," which are now a liability, would become a base for productive employment.

Purpose of Study

The charcoal industry is truly the scavenger of the forest. About the only quality requirement for wood used in the production of charcoal is that it be free of rot. For this reason, among others, charcoal is a use for which low-quality trees are admirably suited. Hardwoods —chiefly oak, hickory, birch, beech and maple—account for most of the wood used in charcoal production. Roundwood use amounted to about 70% of the total wood used in charcoal production in 1961; the remainder was scrap or residue from other wood-using industries.

The purpose of this study was to investigate the possibilities of expanding economic uses for low-quality hardwoods in Tennessee. Specifically the objective was to investigate the economic feasibility of utilizing low-quality hardwoods in the production of charcoal as an alternative to destroying the trees, and as a means of providing employment.

History and Outlook for the Charcoal Industry in the United States

Charcoal is one of the most ancient manufactured products and has been produced in America since early colonial days. The charcoal industry has gone through three distinct phases in the United States. Beehive kilns were the main production method through the late 19th century. Most of the charcoal produced in kilns was used for smelting iron ore.

A new reason for carbonizing wood developed in the 1830's, overlapping the era of charcoal use in the iron furnaces: expensive and elaborate plants were built primarily for the purpose of converting wood vapors and tars into chemicals for industrial uses. Charcoal was a joint product of this process and was only of secondary importance. More than 100 plants were in operation around 1920, accounting for most of the charcoal production.[7] Many commercial and industrial uses of charcoal were developed, based on an abundant and low cost supply. It was also used as a domestic fuel in larger cities.

The discovery of cheaper methods of obtaining many of these chemicals synthetically resulted in a rapid decline of the wood distillation industry. Charcoal thus became the primary product of the wood distillation industry. Only 0.3% of all pig iron output involved the use of charcoal in 1929.[8] By 1932 half of the hardwood distillation plants had closed,[9] and by 1947 the total number had shrunk to 15.[10] Today there remains a number of wood chemical plants producing charcoal, two of which are located in Tennessee, and they produce a substantial amount of the total supply. Only 4 or 5 plants attempt to recover chemicals and these are operating under unusual, favorable conditions. New investments in such plants are unprofitable for the purpose of charcoal production alone.

Just before or a short time after World War II, the industry began the third and current phase. Over the past 15 years there has been a steady decline in the industrial demand for charcoal but more than making up for this decrease in industrial demand has been the steadily increasing domestic demand. Today less than one-fourth

---

[7]John R. Warner and William B. Lord, **The Market for Domestic Charcoal in Wisconsin**, U. S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station, Station Paper Number 46, June, 1957, p. 4.

[8]Ronald Beazley, "Charcoal Marketing in the United States, Description and Analysis," **The Northeastern Logger**, Feb., 1958, p. 34.

[9]Warner and Lord, **op. cit.**

[10]Beazley, **op. cit.**

of the charcoal produced is being consumed for industrial purposes. The remainder is used chiefly for outdoor cooking and by dining cars and restaurants. During this time, the kiln has again emerged as an important producing unit.

Production

Charcoal production in the United States reached a peak of over one-half million tons in 1909 (Table 1). The general trend in production from 1909 to 1939 was downward. The trend in production since 1939 has been upward.

Table 1. Charcoal production in the United States, selected years, 1899-1961

Year	Production	Year	Production
	Tons		Tons
1899	171,543	1939	250,780
1905	266,701	1944	306,192
1909	554,785	1947	213,660
1914	448,278	1952	251,784
1921	227,033	1954	214,481
1925	438,358	1955	237,770
1929	453,550	1956	264,990
1935	328,014	1958	231,404
		1961	328,000

Source: 1955, 1956 and 1961, Forest Service, United States Department of Agriculture, **Charcoal and Charcoal Briquette Production in the United States, 1961.** All other years shown, Bureau of Census, United States Department of Commerce.

Areas of Production

About one-third of the total output in 1961 was produced in 12 Southern states. Seventy-five plants in the region reported a total production of about 100,000 tons in that year. Other major production areas are the Northeast, Lake, and Central regions, and California.[11]

Nineteen large plants accounted for about two-thirds of the 1961 U. S. production. The remaining production reported by the Forest Service survey came from 278 small producers.

Tennessee Production

The same survey showed that Tennessee had 45 producers and 5

[11]Forest Service, United States Department of Agriculture, **Charcoal Production in the United States,** p. 10.

briquette plants in operation in 1961.[12] Production in the state was concentrated primarily in the Cumberland Plateau Area in the counties of Cumberland, Fentress, Putnam, Van Buren, White, and Scott.[13] There have been many small scale ventures in charcoal production from low-quality hardwoods on the Cumberland Plateau in recent years. For a variety of reasons many of these ventures have failed. On the basis of reports by foresters and other observers closely associated with the industry, it appears that the most common causes of failure perhaps have been poor and variable quality of product; also the enterprises were so small and inefficient that cost of production often exceeded the price received for charcoal.

Most Charcoal Marketed in Briquette Form

About 70% of the charcoal produced in the United States in 1961 was converted into briquettes. Since about 1951 the number of briquetting plants in the United States has increased from 5 to 50.[14] Almost all of the charcoal used today as cooking fuel is briquettes. The major advantages of briquettes over lump charcoal for cooking are ease, convenience, and cleanliness in handling the fuel, plus better and more uniform burning qualities. In addition to these advantages for the briquette, there are savings in packaging, storage, and transportation cost of the more compact product.

MARKET DEMAND AND PRICE OUTLOOK FOR CHARCOAL

The prospective charcoal producer should be aware of the fact that the charcoal industry is keenly competitive and that the production capacity of the industry exceeds demand. Locating and maintaining profitable outlets is often more difficult than solving the technical problems of producing a high quality product.

Over the past several years the demand for charcoal has increased steadily. This has been especially true of briquettes for cook-out fuel. We might refer to this as the recreational fuel segment of the charcoal market. This is the most important use of charcoal in terms of recent growth and prospects for expansion.

The marketability of charcoal is determined by its moisture content and percentage of volatile matter. Limiting maximum values are

[12] **Ibid.**, pp. 23 and 27.
[13] **Ibid.**, p. 23.
[14] **Ibid.**, p. 7.

usually specified at about 20% volatiles and 2% moisture content. These quality requirements are not difficult to attain with properly designed and operated kiln and drying equipment.[15]

Despite rapid increases in production in recent years the price of charcoal has remained fairly stable. Wholesale price in Tennessee for lump charcoal delivered in bulk has ranged from $30.00 to $35.00 per ton for the past few years. In some cases the wholesaler contracts with the producer to do the packaging for an additional price. Briquettes have ranged from $80.00 to $90.00 per ton bulk, with additional payment for packaging where specified.

Is the Recent Upsurge in Demand Based on a Fad?

The portable grill and the backyard barbecue pit have done wonders for the charcoal briquette market. The recreational fuel market has grown from nil in the late 1940's to annual sales of more than 3 pounds per capita in 1961. This recent upsurge in demand is associated with what some people may regard as a fad. However, outdoor cooking has been gaining in popularity for the past decade, and there are no signs of its demise or decline. The point to be made here is that it is hazardous to predict future sales of charcoal on the assumption that a fad will become more popular. About the only safe assumption one can make about a fad is that it will end soon.

If on the other hand, the family cook-out is not a fad, but rather a widespread practice that is rapidly being adopted by most middle class American families, as many people believe, then one is on safer grounds in forecasting future demand for charcoal. In support of the idea that the family cook-out is not just a passing fad is the fact that charcoal broiled and barbecued meats are regarded as delicacies by many people, and have long been favorite dishes in the American diet. The only thing new or different here is that the practice of barbecuing and broiling meats with charcoal has spread from the exclusive restaurant and 4th of July picnic grounds to the family backyard.

The increased demand for charcoal as a cooking fuel is apparently associated with an increase in demand for meats cooked in this manner. Increased consumption of charcoal-cooked meats may be regarded as a manifestation of shorter working hours and of rising per capita income which makes it possible for the population to enjoy a richer and more varied diet. If this is the case, it may be concluded that future

---

[15]For a description of charcoal kiln design and construction see Forest Product Laboratory Report No. 2213, U. S. Forest Product Laboratory, Madison, Wisconsin.

increases in the demand for charcoal as a cooking fuel will depend upon advances in per capita income. Long-run projections of productivity and income trends in the United States indicate that income per capita will continue to rise, and that an increasing proportion of families will be in the financially comfortable, and affluent categories.

AN ECONOMIC ANALYSIS OF USING CULL HARDWOODS IN PRODUCING CHARCOAL

Cost of Harvesting and the Value of Cull Hardwoods

A cull hardwood tree occupying space in a forest that could be used to produce a high quality tree has, in a relative sense, a negative value when appraised in terms of the alternative use of the land. From an accounting point of view a cull hardwood tree may or may not have value, depending upon the cost of harvesting and delivering to market relative to the price received for the wood. Obviously, if the cost of harvesting and delivering a tree to market exceeds the price received, the tree has a negative value on the stump; conversely, if the price received exceeds the cost of getting it to market the tree has a value on the stump equal to the difference.

If cull hardwood does have some stumpage value, the forest land owner is in a favorable position to improve the returns from his forest by removing the cull trees and increasing the growth rate of his high-quality growing stock. On the other hand, when price of the wood is less than cost of harvesting and delivering to market, the forest owner, if he choses to remove the cull hardwood, should compare the net cost of harvesting and controlling sprouts with the cost of destroying the trees.

The major item of cost in harvesting and delivering wood to a local market is labor. Transport cost will also be important in areas where distance to market is considerable. An estimate of harvesting and hauling costs for hardwoods is shown in Table 2. This estimate assumes wages to be $1.25 per hour and that the wood is hauled 20 miles by a 2-ton truck. Round-trip cost per mile is set at 27 cents for woods road, 14 cents for graveled road, and 9 cents for paved road. Other items of cost include a 15% allowance for supervisory and capital investment cost, and operating cost and depreciation on tractor and power saw. The total cost per cord is estimated to be $12.52.

A second estimate of cost is shown in Table 3. Here it is assumed that the woodland owner will harvest and haul to his own kiln or one located within 2 miles of the forest. No charge is made for labor supervision or returns on capital items because it is assumed to be off-season work for the farm labor force and farm equipment. Allowing $1.25 per hour for labor, the estimated cost per cord under these assumptions is $10.66.

A wage rate of $1.25 per hour is apparently above the current rate in most rural areas of Tennessee. Published farm wage rates, which is the best indicator we have of the general wage level in rural areas, averaged 65 cents per hour for the first three quarters

Table 2. Estimated cost of harvesting and hauling a cord of wood 20 miles

Operation	Cost per cord
Felling, limbing, and bucking	
Labor (3.6 man-hours @ $1.25 per hour)	$ 4.50
Power saw	.54
Bunching	
Labor (.4 man-hour)	.50
Tractor, two-plow (.4 machine-hour @ $1.19 per hour)	.48
Cables, etc.	.03
Loading	
Labor (1.3 man-hours)	1.63
Hauling (Assuming: (1) the purchaser has mechanical means of unloading the truck, (2) a 2-ton truck hauling 2.77 cords of wood over 1 mile of woods road, 3 miles of graveled road and 16 miles of paved road)[a]	
Truck cost	2.13
Labor (.78 man-hour plus 10% for stand-by time = .86 man-hour)	1.08
Subtotal	10.89
Returns to capital and management (15% of above)	1.63
Total cost	$12.52

[a]Truck operating costs were taken from **Hardwood Logging Methods and Costs in the Tennessee Valley**, Report No. 232-60, Division of Forestry Relations, Forestry Investigations Branch, Tennessee Valley Authority, Norris, Tennessee, Appendix Tables J and K.

of 1962.[16] In view of the fact that reports on farm wage rates include both male and female workers and all age groups, we may surmise that wage rates for forest workers would be somewhat higher than for farm work. Therefore, a state average of $1.00 per hour would seem to be a more appropriate figure for estimating wood harvesting cost. In some areas the wage rate is below this level, while in other areas the current rate perhaps runs as high as $1.25 per hour.

[16]Economic Research Service, USDA, **The Farm Cost Situation**, Nov. 1962.

Table 3. Estimated cost of harvesting and hauling a cord of hardwood 2 miles

Operation	Cost per cord
All costs from felling through loading are the same as those in preceding budget	$ 7.68
Hauling (Assuming: a 1 ½-ton truck hauling 1.91 cords of wood over 2 miles of woods road, and a total operating cost per round-trip mile per cord of 37 cents for woods road)[a]	
Truck cost	.74
Labor	1.49
Unloading (.6 man-hour)	.75
Total cost	$10.66

[a]**Hardwood Logging Methods and Costs in the Tennessee Valley.** Report No. 232-60, Division of Forestry Relations, Forestry Investigations Branch, Tennessee Valley Authority, Norris, Tennessee, Appendix Tables J and K.

Table 4 shows estimated total cost for harvesting and hauling hardwoods 20 miles and 2 miles at wage rates ranging from 50 cents to $1.25. These estimates are based on productivity and cost assumptions other than wages shown in Tables 2 and 3. Wood harvested by contract labor and hauled 20 miles has an estimated cost range from $7.20 per cord at 50 cents per hour for labor to $12.52 per cord with wages at $1.25 per hour. Where the farmer uses his off-season labor and idle equipment and hauls wood only 2 miles, the estimated cost runs from $5.34 per cord, when 50 cents per hour is allowed for labor, up to $10.66 per cord, with a labor charge of $1.25 per hour.

Table 4. Estimated harvesting and hauling cost for hardwoods delivered 20 miles and 2 miles at varying wage rates

Wage rates	Wood delivered 20 miles	Wood delivered 2 miles
$1.25	$12.52	$10.66
1.00	10.74	8.88
.75	8.97	7.11
.50	7.20	5.34

Cost of Destroying Hardwoods

Recent research on techniques of killing hardwoods indicates that injection of undiluted herbicide into the cambium layer at the base of the tree is the least expensive method of control developed to date. Cost per acre or per cord varies with the size and number of cull trees per acre. The labor and chemical cost of $2.50 per acre, or 25 cents per cord, as shown in Table 5, is based on experimental work by the Forestry Department, Agricultural Experiment Station, University of

Tennessee. Three 35-acre plots were used in the test. There were about 100 cull hardwood trees per acre, averaging about 6 in. d.b.h. It was estimated that the test plots would yield about 10 cords of cull wood per acre. The herbicide used was 2,4,5-T, which is relatively expensive. The less expensive 2,4-D, which retails for less than one-half the cost of 2,4,5-T, has been tested in undiluted injections on four common species at one site in Mississippi and reported to be equally as effective as 2,4,5-T in the test.[17] If further testing shows the less expensive herbicide is effective on all common hardwood species, the cost may be reduced 25% below the figure indicated in Table 5.

Table 5. Labor and chemical cost per acre and per cord for hardwood control, undiluted herbicide injection method, 10 cords per acre, trees 6 inches and above d.b.h.

Items of cost	Cost	
	Per acre	Per cord
Labor		
1.47 hrs., $1.00/hr.	$1.47	14.7¢
Chemicals		
2,4,5-T, 4 lb. acid equiv., 1.12 pt., retail $7.35 per gal.	1.03	10.3¢
Total	$2.50	25.0¢

Source: Unpublished data, Department of Forestry, Agricultural Experiment Station, University of Tennessee.

A cost associated with harvesting cull hardwoods which has not been taken into account in this study is the cost of controlling sprouts on stumps. Sprouts must be controlled where stand conversion work is done or else they will become a more serious problem than the original cull trees. The problem of sprouts is not so serious where only a few trees are cut per acre for stand improvement.

The Economics of Charcoaling

The remainder of this report deals with the economics of converting wood into charcoal and briquettes. The objective was to estimate the value of low-quality hardwoods when used in this manner.

In those situations where the stumpage has a negative value, or to state it another way, where harvesting cost exceeds the residual value of the wood, a comparison was made between the cost of destroying the timber and the net loss incurred in the charcoaling operation. The loss involved in converting wood into charcoal is a justifiable forest

[17] **Mississippi Farm Research.** Agricultural Experiment Station, Mississippi State University, Aug., 1963, p. 2.

management cost only if it is no greater than the least cost method of destroying the timber. Included also is the premise set forth earlier that the least cost method of destroying the trees will return a profit in the form of higher income from the forest.

The stumpage value of the low-quality hardwoods converted to charcoal was assumed to be the residual of the value of the end product after all other costs of production and marketing have been paid. Several budgets on charcoal and briquette production are presented, ranging from a single 2½-cord kiln operation to a battery of 30 kilns or 6 retorts integrated with a briquetting plant. From these budgets and from the budgets estimating the cost of harvesting and hauling to the kiln, an estimate of the residual value of the hardwood stumpage was obtained. The estimated maximum value of the stumpage, going into each operation, is determined by several factors.

Two of the important variables are the amount received for the charcoal and the labor cost incurred in its production. Several stumpage values are estimated for each of the operations by assuming different values for these two variables. It should be emphasized that the estimates made of maximum stumpage value or maximum price that may be paid for stumpage by a charcoal producer under certain specified and assumed conditions does not suggest that these prices will or should be paid for stumpage. The prevailing price for stumpage at any given time is something entirely different and is determined by forces in the market which are outside the scope of this study.

Other variables that are more of a technical nature, such as the skill of the kiln operators and the moisture content and density of the wood, are assumed to be constant. The oven dry weight of a cord of hardwood was assumed to be 2,670 pounds. This is below the weight used by Tennessee pulpmills in purchasing hardwood. Although straight, neatly-trimmed bolts are desirable, such bolt characteristics are not critical for charcoaling. An oven dry weight of 2,670 pounds per cord would probably not be too low for the crooked and defective trees of all species that would be burned from a timber-stand-improvement cutting. Charcoal yields were calculated at 30% of the oven dry weight when produced in kilns and 34% when produced in retorts. These are not exceptionally high yield rates and if conversion of seasoned hardwood is much below these rates, it would indicate very inefficient equipment or poor operation.

The budgets were prepared by applying per unit costs to the input-output data gathered from published sources and from equipment manufacturers. The $1.25 per hour wage rate is perhaps more applicable to the larger integrated operations, but by using the same rate in all of the budgets, the per ton cost of production can be compared for the different output volumes and techniques of production.

The first three budgets were prepared for a small 2½-cord, a 7-cord, and a battery of six 5-cord kilns. These budgets have two main parts. The first is an estimate of charcoaling costs or the cost of producing bulk, lump charcoal to be sold f.o.b. kiln. The second part is an estimation of the cost of production and bagging lump charcoal in 4-pound bags also to be sold f.o.b. kiln. The cost of bags increases sharply as the bag size declines. In order to keep the calculations simple, only 4-pound bags were used in the budgets.

From these budgets and from the estimated cost of harvesting and hauling wood as shown in Table 4, equations were derived to estimate the maximum amount that could be paid for a cord of stumpage. Several estimates were made by using a combination of charcoal prices and wage rates.

Actual costs and returns will vary with the managerial ability of the producer as well as with the prevailing cost of inputs in a given area and the price received for the end product. Interpretations of the cost estimates and other calculations of this study should be made with these possible variations in mind. However, the budgets should provide helpful guides for planning charcoaling operations.

The 2½-Cord Kiln

The kiln and technique of production upon which the budget in Table 6 was based is similar to those in operation on the Cumberland Plateau. While this kiln is known by several names, it is generally referred to in literature as "The Connecticut Charcoal Kiln."

The budget in Table 6 shows charcoaling cost per ton to be $28.75 and cost of producing bagged charcoal to be $46.25, plus any consideration for wood cost, and with wages at $1.25 per hour. Witherow and Smith found labor costs to be $24.05 and depreciation on the kiln to be $3.44 per ton of charcoal when produced in an experimental 2-cord kiln.[18] Labor inputs for the 2½-cord kiln are high when compared with the other budgets. A lower wage rate would probably prevail for the smaller operations because a large portion of the tasks may be performed by family labor. Therefore, a range of wage rates from 50 cents to $1.25 per hour was used to estimate the maximum allowable stumpage cost in order to break even.

---

[18]Boyd M. Witherow and Walton R. Smith, **Cost of Operation for Three Types of Charcoal Kilns**, Southeastern Forest Experiment Station, Station Paper Number 79, p. 15.

Table 6. Estimated cost of producing a ton of charcoal in a 2½-cord cinder-block kiln (no mechanization)

Item	Cost per ton
Bulk sale f.o.b. kiln	
Labor @ $1.25 per hour	
Loading (6 man-hours)	$ 7.50
Burning and cooling (5 man-hours)	6.25
Unloading (7 man-hours)	8.75
Depreciation on kiln ($500 ÷ 100 burns; producing 1 ton of charcoal per burn)	5.00
Miscellaneous supplies (oil, mortar, sand, and re-usable bags)	.50
Returns on investment ($500 x .06 ÷ 40 burns per year)	.75
Charcoaling cost	$28.75
For sale f.o.b. kiln in 4-pound bags	
Weighing and bagging cost (labor, 6.0 man-hours)	7.50
Bags (4-pound brown paper bags @ $ .02 each)	10.00
Total charcoaling and bagging cost	$46.25

The cost figures in Table 6 may be of interest to a prospective charcoal producer, but for the problem at hand, the maximum allowable stumpage value estimates in Tables 7 and 8 are more appropriate. Wage rates for the kiln operation and wood procurement were varied and a range of prices received for the charcoal was used to make the estimates.

In order to break even from the sale of charcoal produced in the 2½-cord kiln, a producer could not have more invested in the stumpage

Table 7. Estimated maximum amount that can be paid for a cord of stumpage with varying wages and prices received for bulk charcoal f.o.b. 2½-cord kiln

Price received for bulk charcoal	Hourly wage rates			
	$ .50	$ .75	$1.00	$ 1.25
	Maximum allowable stumpage cost[a]			
$30.00	$0.56	-$2.91	-$6.58	-$10.16
35.00	2.56	- 0.91	- 4.58	- 8.16
40.00	4.56	1.09	- 2.58	- 6.16
45.00	6.56	3.09	- 0.58	- 4.16

[a]Equation used: $C = aP - bX - cY - Z$; $C = .4\,(P) - 7.2\,(X) - 7.09\,(Y) - 4.29$; C = Maximum allowable stumpage cost; P = Price received for a ton of charcoal; X = Per hour labor cost in charcoaling; Y = Per hour labor cost in wood harvesting; Z = Cost other than labor.

than that shown in Tables 7 and 8. Most of the estimates of the stumpage values are negative. The maximum allowable cost of wood on the stump ranges from a low of minus $10.16 per cord with wages at $1.25 per hour and bulk charcoal prices of $30 per ton to a high of $6.56 per cord with wages at 50 cents per hour and bulk charcoal prices of $45 per ton (Table 7). For charcoal marketed in 4-pound bags the maximum allowable stumpage costs range from minus $13.15 per cord with wages at $1.25 per hour and the price of charcoal at $40 per ton to $7.36 per cord with wages at 50 cents per hour and charcoal priced at $60 per ton (Table 8).

Table 8. Estimated maximum amount that can be paid for a cord of stumpage with varying wages and prices received for charcoal in 4-pound bags f.o.b. 2½-cord kiln

Price received for bagged charcoal	Hourly wage rates $ .50	$ .75	$1.00	$ 1.25
	Maximum allowable stumpage cost[a]			
$40.00	-$0.64	-$4.81	-$8.98	-$13.15
45.00	1.36	- 2.81	- 6.98	- 11.15
50.00	3.36	- 0.81	- 4.98	- 9.15
55.00	5.36	1.19	- 2.98	- 7.15
60.00	7.36	3.19	- 0.98	- 5.15

[a]Equation used: C = .4 (P) - 9.6 (X) - 7.09 (Y) - 8.29 (See Table 7 for definitions of variables.)

Only at the lower wage rates and/or relatively high prices for the product would the production of charcoal appear to be economically feasible in the 2½-cord kiln. With wages just under 70 cents per hour and the price of bulk charcoal at $35 per ton f.o.b. kiln, a break-even point is attained, but there is no residual revenue for the stumpage. At present, the price being paid for charcoal in this form is from $30 to $35 in Tennessee. Assuming the value of stumpage to be zero, the returns to labor must be around 55 to 70 cents per hour if the charcoal operation is to be self-sustaining (Table 7).

The price being paid for bagged charcoal at the kiln is around $50 per ton, or $40 if the bags are furnished by the purchaser. Returns to labor would be 70 cents per hour at this price if the operation is to break even, assuming the stumpage cost to be zero (Table 8).

The market for lump charcoal, regardless of the marketing channel, is extremely limited in Tennessee. Until the demand for lump charcoal is strengthened, charcoal production in the small kiln will be no more than a marginal operation. Chances for an increased demand for lump charcoal are remote. The establishment of additional briquetting plants in the state would increase the demand for lump charcoal, but the briquettors would offer very little more for lump charcoal than the cost that would be incurred if they produced their own. The budgets for the 1-ton and the 2-ton per hour integrated charcoal-briquetting operations show the cost of producing lump charcoal to be from $17 to $19 per ton plus the cost of wood and returns to capital. Total cost of producing lump charcoal in such plants would be around $30-$35 per ton; thus one could not expect the price of lump charcoal to increase greatly even with competition among buyers.

What about charcoaling in the small kiln as a tool of forest management? With the price of lump charcoal in bulk at $35 per ton and $50 per ton in 4-pound bags, the wage rate could be no more than 60 cents per hour if charcoaling is to be economically feasible, that is, if the loss is to be less than the cost of killing the timber. Therefore, if small kiln operations of this type are to be used as an outlet for cull hardwood the workers must be willing to sell their labor at a relatively low wage rate. This perhaps explains why so many small kiln operations have failed in recent years.

The 7-Cord Kiln

The type of kiln for which the budget in Table 9 was prepared is similar to the 2½-cord kiln previously discussed. It is larger, of course, and would probably be constructed with wide metal doors that would allow a tractor and scoop or forklift to enter and back out. Instructions for building this sort of kiln (no metal doors) is given in *Production of Charcoal in a Masonry Block Kiln: Structure and Operation.*[19]

The budget in Table 9 shows charcoaling cost per ton to be $25.05 and cost of producing bagged charcoal to be $42.55 per ton without any consideration of wood cost and with wages at $1.25 per hour. The average cost of producing charcoal in a 7-cord kiln for 14 experimental burns was found to be $27.44 by researchers of the Lake States Forest Experiment Station.[20] Wages of about $1.47 per hour were paid out in the experimental operation. If the difference in wages were eliminated, the experimental cost figure would not be greatly different from the estimated charcoaling cost presented here.

[19]U. S. Department of Agriculture, **Production of Charcoal in a Masonry Block Kiln: Structure and Operation,** Forest Service Report No. 2084 (Madison: Forest Products Laboratory, 1957).

[20]C. E. Boldt and Carl Abbogast, Jr., "Charcoal Kiln Operation for Improved Timber Stands," **Forest Products Journal,** Jan., 1960, p. 44.

Table 9. Estimated cost of producing charcoal in a 7-cord masonry block kiln

Item	Cost per ton
Bulk sale f.o.b. kiln	
Labor @ $1.25 per hour	
Loading (5.5 man-hours)	$ 6.88
Burning and cooling (4.5 man-hours)	5.63
Unloading (2.0 man-hours)	2.50
Depreciation on kiln ($1,250 ÷ 100 burns; producing 2.8 tons per burn)	4.46
Tractor operating cost (used for approximately .5 of an hour per ton for unloading and 1.9 hours per ton for loading)	
2.4 tractor hours @ $1.10 per hour	2.64
Miscellaneous supplies (oil, mortar, sand, etc.)	0.40
Returns on fixed investment (kiln, $1,250) + (tractor, $2,500) + (other improvements, $1,000); $4,750 X .06 ÷ 11.2 tons per year	2.54
Charcoaling cost	$25.05
For sale f.o.b. kiln in 4-pound bags	
Weighing and bagging cost (6.0 man-hours)	7.50
Bags (4-pound brown paper bags @ .02 each)	10.00
Total charcoaling and bagging cost	$42.55

The maximum allowable cost of wood on the stump ranges from a low of minus $8.67 per cord with wages at $1.25 per hour and bulk charcoal priced at $30 per ton to a high of $6.24 per cord with wages at 50 cents per hour and bulk charcoal priced at $45 per ton (Table 10). For charcoal marketed in 4-pound bags the maximum allowable stumpage costs range from minus $11.67 per cord with wages at $1.25 per hour and the price of charcoal at $40 per ton to $7.04 per cord with wages at 50 cents per hour and charcoal priced at $60 per ton (Table 11).

Table 10. Maximum amount that can be paid for a cord of stumpage with varying wages and prices received for bulk charcoal f.o.b. 7-cord kiln

Price received for bulk charcoal	Hourly wage rates $ .50	$ .75	$1.00	$1.25
	Maximum allowable stumpage cost[a]			
$30.00	$0.24	-$2.73	-$5.70	-$8.67
35.00	2.24	- 0.73	- 3.70	- 6.67
40.00	4.24	1.27	- 1.70	- 4.67
45.00	6.24	3.27	- 0.30	- 2.67

[a]Equation used: $C = .4 (P) - 4.8 (X) - 7.09 (Y) - 5.81$ (See Table 7 for definition of the variables).

The maximum allowable stumpage cost estimates for wood converted into charcoal via the 7-cord kiln are similar to those for the smaller kiln. In fact, about the same general interpretation could be made of the estimates in Tables 10 and 11 as was made for the previous operation. However, there is at least one difference: the labor input is less important in operating the 7-cord kiln than in the 2½-cord kiln due to the use of a tractor in loading and unloading. At the higher wage rates, the negative stumpage value is less for wood converted in the larger kiln. The small kiln appears to have the advantage at the lower wage rates. The difference between the maximum allowable stumpage cost on the lower wage scale for the two kilns is small compared to that of the upper wage scale.

Table 11. Maximum amount that can be paid for a cord of stumpage with varying wages and prices received for charcoal in 4-pound bags f.o.b. 7-cord kiln

Price received for bagged charcoal	Hourly wage rates $ .50	$ .75	$1.00	$1.25
	Maximum allowable stumpage cost[a]			
$40.00	-$0.96	-$4.53	-$8.10	-$11.67
45.00	1.04	- 2.53	- 6.10	- 9.67
50.00	3 04	- 0.53	- 4.10	- 7.67
55.00	5.04	1.47	- 2.10	- 5.67
60.00	7.04	3.47	- 0.10	- 3.67

[a]Equation used: C = .4 (P) - 7.2 (X) - 7.09 (Y) - 9.81 (See Table 7 for definition of the variables).

If charcoaling in the 7-cord kiln is to provide an alternative to destroying the cull trees, the wage rate in operating the kiln and in wood harvesting cannot exceed 63 cents per hour with bulk charcoal priced at $30 per ton. The stumpage still has a negative value of 73 cents per cord if the bulk price is $35 per ton and wages are 75 cents per hour. With wage rates around 75 cents per hour, a price of $50 per ton for charcoal in bags is comparable to $35 for bulk charcoal.

The Battery of Six 5-Cord Kilns

Over the country, perhaps no two kiln installations have the same number of kilns with like capacities. The kiln sizes range from 2-cord capacity up to 40 cords. About the only other difference in kiln installations is the amount of labor-saving equipment used.

The budget in this section represents cost estimates for charcoal produced in a battery of six 5-cord kilns. Individually, the kilns are similar to those previously budgeted. Capital requirements for the kilns, storage shed, tractor, and other improvements would be about

$12,000 to produce bulk charcoal. If the charcoal is to be bagged, an additional $6,000 investment in equipment would be needed.

The battery of six 5-cord kilns is not the optimum combination of number and size of kiln for the most efficient production, but the budget does indicate that cost of production per unit declines as size of plant increases.

Assuming it takes an average of 6 days to complete one full cycle (loading, coaling, cooling, and unloading), one kiln would need to be unloaded and recharged each day of a 6-day work week. Thus, one 5-cord kiln would yield approximately 2 tons of charcoal per week. To yield 500 tons of charcoal per year, the battery of kilns would need to be operated for around 290 days, allowing for Sundays or a more lengthy cycle.

The cost of labor to produce a ton of bulk charcoal, at $1.25 per hour, was estimated to be $10.64. Bagging labor cost amounted to $3.44, for a total estimated labor cost of $14.08 per ton of bagged charcoal produced. This cost was separated from the main budget and is shown in Table 12.

Table 12. Estimated labor cost in operating a battery of six 5-cord kilns producing 2 tons of charcoal per day, labor @ $1.25 per hour

Operation	Labor cost per ton
Tractor operation (used to bring wood inside the kiln from the stacks and to unload the charcoal; 4 man-hours per day)	$ 2.50
Arranging wood in the kiln (5 man-hours per day)	3.13
Unloading (3 man-hours per day of extra labor to aid the tractor-scoop operator in unloading)	1.88
Kiln operation (5 man-hours)	3.13
Charcoaling labor cost	$10.64
Bagging (5.5 man-hours per day)	3.44
Total labor cost[a]	$14.08

[a] Allowance is not made here for additional or miscellaneous labor cost as in the budgets for larger installations because this operation does not include Sundays, and by adjusting the working hours of the three laborers, the kiln may be tended for 12-15 hours each day. The air inlets may be adjusted to minimize tending needs during the remainder of the day.

Charcoaling costs were estimated to be $22.33 per ton and the cost of producing bagged charcoal to be $39.01. Both estimates are considerably below those of the preceding budgets.[21] The total yearly cost of producing 500 tons of bulk charcoal in this battery of kilns was estimated to be $11,165 and of bagged charcoal to be $19,505 (Table 13).

[21]If the cost of wood is eliminated from Shelton's estimated cost of producing bagged charcoal, the upper cost range would be around $28 per ton, excluding taxes and insurance. It was necessary to assume a rate of conversion of wood into charcoal to arrive at this figure. The assumed rate was two and one-half cords of wood per ton of charcoal — the same rate that was used in all the kiln budgets in this study. In addition to the above noted exclusion from Shelton's cost estimate, cost of tending the kiln, a major item, and repair and maintenance are also omitted. Perhaps, this explains some of the $11 differential between Shelton's estimate and the one used here. Shelton, **op. cit.**, p. 5.

Table 13. Estimated per ton and annual cost of producing 500 tons of charcoal per year in a battery of six 5-cord cinder-block kilns

Item	Cost: Per ton	Cost: Yearly
Bulk sale f.o.b kiln		
Labor @ $1.25 per hour	$10.64	$ 5,320
Depreciation on the kilns: Assume the kilns to cost $1,000 each with a minimum life of 100 burns; thus each of the 6 kilns would be used for about 42 burns each year in producing 500 tons of charcoal, lasting 2.4 years. ($1,000 ÷ 2.4 years = $416.67 per year; 42 burns X 2 tons per burn = 84 tons per kiln per year.) $416.67 ÷ 84	4.96	2,480
Tractor operating cost (used for approximately 4 hours per day @ $1.10 per hour—including fixed and variable costs) $4.40 ÷ 2 tons	2.20	1,100
Repair and maintenance on kiln and other equipment ($100 per year ÷ 500 tons per year)	.20	100
Taxes and insurance (2.0% of fixed investment)	.48	240
Miscellaneous	.25	125
Returns on fixed investment (kilns, $6,000) + (tractor and equipment, $3,000) + (shed and land improvements, $3,000) = $12,000. $12,000 X .15 ÷ 500 tons	3.60	1,800
Charcoaling cost	$22.33	$11,165
For sale f.o.b. kiln in 4-pound bags		
Depreciation on other processing and bagging equipment (cost $6,000, lasting 10 years = $600 per year or $600 ÷ 500 tons)	1.20	600
Returns on fixed investment ($6,000 X .15 ÷ 500 tons)	1.80	900
Insurance and taxes (2.0% of fixed investment)	.24	120
Bagging labor cost	3.44	1,720
Bags (4-pound brown paper bags @ $ .02 each)	10.00	5,000
Total charcoaling and bagging cost	$39.01	$19,505

The per ton cost of producing charcoal in the battery of kilns would appear to be much less than charcoal produced in the single units. The cost spread between the budgets for the 2½-cord kiln, the 7-cord kiln, and the battery operation is probably representative of the difference in costs between the multiple and single unit installations with wages at $1.25 per hour. However, at very low wage rates, the cost advantage of the battery of kilns disappears because the battery operation is more efficient in the use of labor.

The estimated amount of labor required to produce 1 ton of charcoal is less for the battery of kilns than for the 7-cord kiln. Therefore, as the wage rate declines, cost of production declines more rapidly when charcoal is produced in the single than when produced on the multiple units. At the relatively low wage rate of 50 cents per hour, there would be little difference in the maximum allowable stumpage cost per cord of wood to be converted into charcoal via the 2½-cord, the 7-cord, and the battery of six 5-cord kilns. Assuming the price of bulk charcoal to be $30 per ton and wages at 50 cents per hour, the stumpage values were estimated to be 56 cents for the 2½-cord kiln, 24 cents for the 7-cord kiln, and 28 cents per cord for the multiple kiln operation. However, for wages of around 60 cents per hour and above, the battery of kilns would have the advantage.

For the battery of kilns, the maximum allowable cost of wood on the stump ranges from a low of minus $7.58 per cord with wages at $1.25 per hour and bulk charcoal priced at $30 per ton to a high of $6.28 per cord with wages at 50 cents per hour and bulk charcoal priced at $45 per ton (Table 14). If the charcoal is marketed in

Table 14. Estimated maximum amount that can be paid for a cord of stumpage with varying wages and prices received for bulk charcoal f.o.b. battery of kilns

Price received for bulk charcoal	Hourly wage rates $ .50	$ .75	$1.00	$1.25
	Maximum allowable stumpage cost[a]			
$30.00	$0.28	-$2.34	-$4.96	- $7.58
35.00	2.28	- 0.34	- 2.96	- 5.58
40.00	4.28	1.66	- 0.96	- 3.58
45.00	6.28	3.66	1.04	- 1.58

[a]Equation used: C = .4 (P) - 3.4 (X) - 7.09 (Y) - 6.47 (See Table 7 for definition of variables.)

4-pound bags, the maximum allowable stumpage costs range from a low of minus $10.26 per cord with wages at $1.25 per hour and the price of charcoal at $40 per ton to a high of $8.43 per cord with wages at 50 cents per hour and charcoal priced at $60 per ton (Table 15). An additional 86 cents to $1.15 could be applied toward stumpage costs, depending upon the method of marketing the charcoal, if the producer were willing to accept 6% returns to capital instead of the indicated 15%.[22]

Table 15. Estimated maximum amount that can be paid for a cord of stumpage with varying wages and prices received for charcoal in 4-pound bags f.o.b. battery kilns

Price received for bagged charcoal	Hourly wage rates $ .50	$ .75	$1.00	$ 1.25
	Maximum allowable stumpage cost[a]			
$40.00	-1.57	-$4.46	-$7.36	-$10.26
45.00	0.43	- 2.46	- 5.36	- 8.26
50.00	2.43	- 0.46	- 3.36	- 6.26
55.00	4.43	1.54	- 1.36	- 4.26
60.00	6.43	3.54	0.64	- 2.26
65.00	8.43	5.54	2.64	- 0.26

[a]Equation used: $C = .4\ (P) - 4.5\ (X) - 7.09\ (Y) - 11.77$ (See Table 7 for definition of variables.)

Prices of $35 per ton for bulk charcoal and $50 per ton for bagged charcoal would allow a producer operating the battery of kilns to pay around 70 cents per hour for labor and still break even. In breaking even, the operation would be returning 15% on the fixed investment, but the stumpage value would be zero.

In summary, with charcoal prices at $35 per ton bulk or $50 bagged and with wages of about 75 cents per hour, the stumpage would have a negative value of approximately 35 to 45 cents per cord (Tables 14 and 15). This is assumed to be the maximum cost that could be attributed to forest improvement. Thus, if wages exceed this level or if other costs are higher than those assumed here, then it would most likely be cheaper for the forest land owner to kill the timber and leave it in the forest rather than harvest for stand improvement.

Briquette Production

In the past the charcoal industry offered an opportunity to earn profits with a small investment for the production of lump charcoal. Today, however, the demand is for briquettes rather than for lump charcoal as a source of fuel. An additional $75,000 to $100,000 in-

[22]The increase in charge for fixed capital investment from 6% to 15% between the smaller and larger investment is based on the assumption that higher returns to risk must be paid in order to attract the larger blocks of capital.

vestment is the minimum requirement to give the consumer this extra service. The total investment for an integrated charcoal and briquetting plant may range up to $250,000.

The budgets for three integrated charcoal-briquette plants are presented in this section. The first budget was for a briquetting plant with a capacity of 1 ton per hour and the second had a capacity of 2 tons per hour. Both of these plants had a supporting number of 9-cord kilns. Total annual production was assumed to be 2,500 and 4,000 tons, respectively, for the two plants. The third plant had a capacity of 2 tons per hour, supported by six retorts.

The same procedure as above was used to arrive at the estimated charcoaling cost minus wood cost and returns to capital for the integrated charcoal-briquette operations. This cost was carried over into the budget estimating briquetting costs to give the total integrated cost of producing briquettes.

A somewhat different procedure was used to estimate the stumpage value of low-quality hardwoods going into these operations. The retail market price for briquettes was assumed to be 69 cents for 10-pound bags or $138 per ton. Here again, for the purpose of simplicity, only 10-pound bags were used in the calculations. Jobbers' and retailers' profits were assumed to be 20% each. It was further assumed that transportation costs to the wholesaler or jobber would be an average of $12 per ton for a yearly production of 4,000 tons and $10 per ton for an output of 2,500 tons.

The above-mentioned markup and transportation costs, along with the cost of producing the charcoal, and 15% return on the fixed investment and operating capital, were deducted from the retail sales price of briquettes. The remainder was the amount that could be applied toward the cost of the wood. Wood harvesting and delivery costs were subtracted from the remainder, leaving only that portion of the revenue that could be paid for the stumpage.

Production costs were calculated using both $1 and $1.25 per hour wage rates. Wood harvesting and delivery costs were also calculated using wage rates of 50 cents, 75 cents, $1, and $1.25 per hour. After wood harvesting and delivery cost estimates were deducted from the amounts that could be paid for wood, this gave eight estimates of the residual value of the stumpage, depending upon harvesting and plant labor costs.

The output assumed for the briquetting plants does not approach the maximum. During the peak demand season the plants may double their daily output, but during the winter months, especially, the industry can send few briquettes to market. Due to the storage problem, most briquettors cease production during the lowest demand period. Each of the budgets were prepared on a one-shift basis only. The plants would operate from 250 to 300 days per year. The budgets were divided into sections so the cost of producing charcoal or the cost of briquetting could be determined separately.

Integrated Charcoal-Briquette Plant with an Output of 2,500 Tons Annually

To furnish 2,500 tons of charcoal per year, a battery of 18 kilns of 9-cord capacity would be needed. Assuming it takes approximately 7½ days to complete one full cycle, an average of 2.4 kilns would be unloaded and recharged each day. At the conversion rate of 800 pounds of charcoal per cord of wood, the kilns would yield 17,280 pounds or 8.64 tons of charcoal each day. The kilns would need to be operated for about 290 days on a continuous basis.

An estimation of labor cost for the battery of kilns is presented in Table 16. Ten percent was added to the cost of producing each ton of charcoal because of the anticipated increased cost of labor for over-time work. Total labor cost per ton of charcoal was estimated to be $10.19.[23]

[23]Labor input estimates were based on two studies: **Charcoal Survey, op. cit.,** p. 87, and Fred C. Simmons, **Guides to Manufacturing and Marketing Charcoal in the Northeastern States,** Forest Service, United States Department of Agriculture, Northeastern Forest Experiment Station, Station Paper No. 95, 1957, p. 15.

Table 16. Estimated labor cost in operating the battery of 18 kilns with an average daily output of 8.64 tons and wage rates at $1.25 per hour

Item	Cost per ton
Tending the woodyard (8 man-hours per day)	$ 1.16
Tractor, forklift and truck operator (8 man-hours per day)	1.16
Arranging wood inside the kilns (20 man-hours per day)	2.89
Unloading (12 man-hours per day in addition to the tractor-scoop operator)	1.74
Kiln operation (16 man-hours per day)	2.31
Charcoaling labor cost	$ 9.26
Miscellaneous labor costs (10% of above)	.93
Total cost	$10.19

The $10.19 labor cost was carried over in the charcoal budget in Table 17 along with other charcoaling costs to give a total cost of $19.37 to produce a ton of charcoal, and the yearly cost of producing 2,500 tons of charcoal would be $48,425. Cost of wood delivered to the kilns and returns to capital are not included.

Table 17. Estimated cost per ton and annually of producing charcoal in an integrated charcoal-briquette operation, 1 ton per hour capacity

Item	Cost	
	Per ton	Yearly
Labor	$10.19	$25,475
Amortization of kilns Assume the kilns cost $1,400 each with a minimum life of 100 burns; thus each of the 18 kilns would be used for 39 burns each year in producing 2,500 tons of charcoal, lasting 2.6 years. ($1,400 ÷ 2.6 years = $538.46 per year 39 burns X 3.6 tons per burn = 140.4 tons per kiln per year.) $538.46 ÷ 140.4	3.84	9,600
Amortization of 1 truck, 1 forklift, 1 small tractor and scoop, buildings, land improvements, etc. over a 10-year period ($18,000 ÷ 10 years = $1,800) $1,800 ÷ 2,500 tons per year	.72	1,800
Repair and maintenance on kilns, equipment and miscellaneous cost (oil, etc.)	.60	1,500
Operating (variable expense) for tractor, truck, and forklift	1.82	4,550
Property taxes and insurance (percent of fixed investment)	.35	875
Supervision @ $2.00 per hour	1.85	4,625
Total (cost does not include wood cost and returns to capital)	$19.37	$48,425

The cost of producing charcoal was carried over into the briquetting portion of the budget. Although all known items of cost were included in the budget, 10% was added to cover any contingencies. Total integrated cost minus the cost of wood and returns to capital amounted to $52.02 per ton or an annual outlay of $130,050 (Table 18).

After reducing the $138 per ton retail price for 10-pound bags of briquettes by the expected markup of jobbers and retailers and further by $10 per ton to cover transportation charges, the remainder was $85.83 (Table 19). This was assumed to be the price manufacturers could expect to receive for their briquettes f.o.b. plant. After deducting the cost of producing briquettes, $33.81 remained. Fifteen percent return on investment and operating capital further reduced the revenue to a residual of $22.53 which would be the maximum amount that could be paid for wood to produce 1 ton of briquettes.

Using the wood conversion rates assumed in this study of 2½ cords of seasoned round hardwood to yield 1 ton of charcoal, the amount that could be paid for a cord of wood would be $9.01. With plant wages at $1 per hour, instead of $1.25, the amount that could be paid would increase to $10.46 per cord.

The maximum amounts that could be paid for a cord of wood on the stump with plant wages varying from $1 to $1.25 per hour in combination with wood harvesting wages ranging from 50 cents to $1.25 per hour are shown in Table 20. With wood harvesting labor

Table 18. Estimated cost per ton and annual cost of producing briquettes in the 1-ton per hour briquetting plant

Item	Cost	
	Per ton	Yearly
Chunk charcoal cost (does not include wood cost and returns to capital)	$19.37	$ 48,425
Starch	1.00	2,500
Paper bags (white with attractive lettering, 10-pound size @ $.03 each)	6.00	15,000
Amortization of briquetting plant and equipment ($110,000 over 10 years = $11,000 per year) $11,000 ÷ 2,500 tons per year	4.40	11,000
Wages and salaries		
5 men @ $1.25 per hour	6.25	15,625
1 foreman @ $2.00 per hour	1.85	4,625
1 administrative employee	1.44	3,600
1 manager-salesman-technician	3.60	9,000
Utilities	1.00	2,500
Repair and maintenance	1.20	3,000
Operating supplies	.30	750
Taxes and insurance (2% of fixed investment)	.88	2,200
Subtotal	$47.29	$118,225
Miscellaneous costs (10% of above)	4.73	11,825
Total integrated cost (does not include wood cost and returns to capital)	$52.02	$130,050

cost at 50 cents per hour and plant labor cost at $1 per hour, $3.26 could be paid for a cord of wood on the stump. An increase up to 75 cents per hour for wood harvesting labor with plant labor at $1 per hour would bring the residual left for stumpage down to $1.49 per cord.

Table 19. Returns to the wood from the 18-kiln, 2,500-ton per year, integrated briquetting operation

Item	Per ton	Yearly
Remainder after deduction retailer's and jobber's markup[a]	$95.83	$239,575
Transportation costs, assuming producer to wholesaler average transportation costs would be	10.00	25,000
Remainder	$85.83	$214,575
Cost of production	52.02	130,050
Remainder	$33.81	$ 84,525
Returns to fixed investment (kilns, $25,200) + (charcoaling buildings and equipment, $18,000) + (briquetting plant, $110,000) = $153,000. $153,000 ÷ 2,500 tons	9.18	22,950
Remainder	$24.63	$ 61,575
Returns on operating capital $35,000 X .15 ÷ 2,500 tons	2.10	5,250
Remainder	$22.53	$ 56,325

[a]See the budget on page 46, Table 23, for the 2-ton per hour briquetting operation.

Briquette production from cull hardwood would perhaps still be economically feasible in this size plant with plant labor at $1 and wood harvesting labor at $1 per hour. The negative stumpage value of minus 28 cents per cord would be about the same as the cost of killing the timber. And finally, if the legal minimum wage rate of $1.25 per hour is assumed for plant labor, as one may expect the minimum to be for this operation, then wood harvesting cost could not exceed about $9.00 per cord, or slightly less than $1.00 per hour, in order for harvesting to be more economical than killing.

Table 20. Estimated maximum allowable stumpage costs per cord of wood channeled into a 2,500-ton per year integrated briquetting plant with variable wage rates

	Amount left to pay for a cord of wood at the plant with varying wage rates	If wood harvesting hourly wage rates are:			
		$ .50	$ .75	$ 1.00	$ 1.25
		then cost of harvesting a cord of wood will be:			
		$7.20	$8.97	$10.74	$12.52
Wages		and the maximum allowable stumpage cost would be:			
$1.00 :	$10.46	$3.26	$1.49	$ 0.28	-$ 2.06
$1.25 :	$ 9.01	$1.81	-$0.04	-$ 1.73	-$ 3.51

Output of 4,000 Tons Annually

To supply 4,000 tons of charcoal per year, a battery of 30 kilns of 9-cord capacity would be needed. An average of four kilns would be unloaded and recharged each day, assuming it takes about 7.5 days to complete one full cycle. The kilns would yield around 14.4 tons of charcoal each day. To yield 4,000 tons of charcoal per year, the battery of kilns would need to be operated continuously for about 280 days. Cost of labor per ton of charcoal has been estimated to be $9.15 when produced in the battery of 30 nine-cord kilns (Table 21).

Table 21. Estimated labor cost of operating the battery of 30 kilns with an average daily output of 14.4 tons and wage rates at $1.25 per hour

Item	Cost per ton
Tending the woodyard (8 man-hours per day)	$ .69
Forklift operator (8 man-hours per day)	.69
Arranging wood inside the kiln (32 man-hours per day)	2.78
Tractor and truck operation (8 man-hours per day)	.69
Unloading (16 man-hours per day in addition to the tractor scoop and truck operation)	1.39
Kiln operation (24 man-hours per day)	2.08
Charcoaling labor cost	8.32
Miscellaneous labor cost (10% of above)	.83
Total cost	$9.15

Total cost of producing charcoal exclusive of wood cost and returns to capital was estimated to be $17.23 or a yearly outlay of $68,920 (Table 22). The lower per ton cost of producing charcoal in the 30-kiln over the 18-kiln battery was due primarily to more efficient use of labor and lower per ton cost of supervision.

The total estimated cost of producing a ton of briquettes was $44.99 or a yearly outlay of $179,960 in producing 4,000 tons (Table 23). Briquettes are less costly to produce in the larger plant primarily because wage and salary costs are 17% less per ton in the larger operation.

Table 22. Estimated cost per ton and annual cost of producing charcoal in an integrated charcoal-briquette operation

Item	Cost Per ton	Cost Yearly
Labor	$ 9.15	$36,600
Amortization of kilns Assume the kilns to cost $1,400 each with a minimum life of 100 burns; thus each of the 30 kilns would be used for 39 burns each year in producing 4,000 tons of charcoal, lasting 2.6 years. ($1,400 ÷ 2.6 years = $538.46 per year; 39 burns X 3.6 tons per burn = 140.4 tons per kiln per year.) $538.46 ÷ 140.4	3.84	15,360
Amortization of 1 truck, 1 forklift, 1 small tractor and scoop, buildings, land improvements, etc. over a 10-year period. ($20,000 ÷ 10 years = $2,000) $2,000 ÷ 4,000 tons	.50	2,000
Repair and maintenance on kilns, equipment and miscellaneous costs (oil, etc.)	.50	2,000
Operating (variable expenses) for tractor, forklift, and truck	1.82	7,280
Property taxes and insurance (2% of the fixed investment)	.31	1,240
Supervision @ $2 per hour	1.11	4,440
Total cost (does not include wood cost and returns to capital)	$17.23	$68,920

Assuming the retail price of briquettes in 10-pound bags to be 69 cents and with jobber and retailer markup at 20%, it was estimated that the briquettor would receive $95.83 per ton or $383,320 yearly for delivered briquettes. It is further assumed that transportation costs would average $12 per ton—$2 higher than for the 2,500 ton operation because the larger producer would reach out into the more distant markets. After subtracting transportation costs, the residual as indicated in Table 24 was $83.83 per ton. There were $29.76 per ton remaining to pay for wood after subtracting cost of production and returns on investment and operating capital. This gave a figure of $11.90 per cord that could be paid for wood (Table 25). With wages at $1 per hour instead of $1.25, $13.09 could be paid for a cord of wood.

The maximum amounts that could be paid for a cord of wood on the stump is shown in Table 25. Plant labor cost and wood harvesting labor cost were varied as indicated in the table in order to make the estimates. With plant wages at $1.25 per hour and wood harvesting wages at $1, about $1.16 would remain to pay for each cord of wood on the stump. At lower wage rates, as shown in Table 25, the estimated stumpage value would be considerably higher. Even if both plant and wood harvesting were to cost $1.25 per hour, briquette production would still be economically feasible if the forest owner were willing to invest an estimated 62 cents per cord to remove the cull hardwood.

Table 23. Estimated cost per ton and annual cost of producing briquettes in the 2-ton per hour briquetting plant

Item	Cost	
	Per ton	Yearly
Chunk charcoal cost (minus wood cost and returns to capital)	$17.23	$ 68,920
Starch	1.00	4,000
Paper bags (white with attractive lettering, 10-pound size @ $.03 each)	6.00	24,000
Amortization of briquetting plant and equipment ($130,000 over 10 years = $13,000 per year) $13,000 ÷ 4,000 tons	3.25	13,000
Wages and salaries		
7 men @ $1.25 per hour	4.38	17,520
1 foreman @ $2 per hour	1.11	4,440
1 administrative employee	.90	3,600
1 manager-engineer	2.25	9,000
1 salesman	2.00	8,000
Utilities	.88	3,520
Repair and maintenance	1.00	4,000
Operating supplies	.25	1,000
Property tax and insurance (2% of fixed investment)	.65	2,600
Subtotal	$40.90	$163,600
Miscellaneous costs (10% of above)	4.09	16,360
Total integrated cost (does not include wood cost and capital returns)	$44.99	$179,960

Table 24. Returns to the wood from the 30-kiln, 4,000-ton per year integrated briquetting operation

Item	Per ton	Yearly
Retail sales @ $.69 for 10-pound bags	$138.00	$552,000
Retailer's markup (20%)	23.00	92,000
Remainder	$115.00	$460,000
Jobber's markup (20%)	19.17	76,680
Remainder	$ 95.83	$383,320
Transportation costs, assuming producer to wholesaler average transportation cost would be	12.00	48,000
Remainder	$ 83.83	$335,320
Cost of production	44.99	179,960
Remainder	$ 38.84	$155,360
Returns to fixed investment (kilns, $42,000) + (charcoaling buildings and equipment, $20,000) + (briquetting plant, $130,000) = $192,000. $192,000 X .15 ÷ 4,000 tons	7.20	28,800
Remainder	$ 31.64	$126,560
Returns to operating capital ($50,000) X .15 ÷ 4,000 tons	1.88	7,520
Remainder	$ 29.76	$119,040

Table 25. Maximum allowable stumpage cost per cord of wood channeled into a 4,000-ton per year integrated briquetting plant with variable wage rates

		If wood harvesting rates are:			
		$ .50	$ .75	$ 1.00	$ 1.25
	Amount left to pay for a cord of wood at the plant with varying wage rates	then cost of harvesting a cord of wood will be:			
		$7.20	$8.97	$10.74	$12.52
Wages		and the maximum allowable stumpage cost would be:			
$1.00 :	$13.09	$5.89	$4.12	$ 2.35	$ 0.57
$1.25 :	$11.90	$4.70	$2.93	$ 1.16	-$ 0.62

Briquetting Plant Integrated with Charcoal Retorts

New types of retorts have been developed that are reportedly more efficient in converting wood into charcoal than previous methods of manufacture in relatively small units.[24] Apparently, the outside

[24]Fred C. Simmons, "Three New Charcoal Retorts," **Forestry Equipment Notes, Food and Agriculture Organization of the United Nations,** Rome, Italy, October, 1960.

source of fuel used to bring the heat up to the optimum coaling temperature and maintaining it is a major factor contributing to the increased efficiency. It is not necessary to burn a portion of the carbon as in the kiln to coal the wood. Reported yields of 35% to 38% of the oven dry weight from seasoned hardwoods are not uncommon.[25] An increase in the conversion rate of 4% means an additional 107 pound yield of charcoal from each cord of wood, or an increase in revenue of $1.60 per cord of wood coaled when the price of charcoal is $30 per ton f.o.b. per kiln.

The number of man-hours required to produce a ton of charcoal in retorts is very low in comparison to the kiln operations. In retorts, only about 4 man-hours are required to produce a ton of charcoal.[26] However, in order to approach this low labor requirement, the charcoaling operation must be mechanized. Amortization costs and the added cost of fuel boosts the cost of producing a ton of charcoal in retorts almost to a level equal to the production cost in a battery of kilns. Therefore, it would probably be difficult to justify the higher capital investment of the retorts solely on the basis of the small reduction in charcoaling cost. But for large, continuous operations the increased efficiency of wood conversion would give the retorts the advantage.

Charcoal retorts are sold and leased in the United States by both domestic and foreign manufacturers. If purchased from commercial manufacturers, even the small, simple retorts are quite expensive. A cost of $15,000 per unit, or a total investment of $90,000 for six retorts, was assumed in this study. Several sources indicate that the plant cost can be lowered considerably if a producer has ingenuity and is mechanically minded enough to build his own retort.[27]

There are a number of basic differences in the production processes of these retorts. One type features a continuous process whereby wood is introduced through the top and charcoal is removed at the bottom. The weight of the wood breaks the charcoal into pieces, forcing it out discharge orifices into quenching drums. The hot drums must be stored for several hours before further processing. Some of the gases given off from the wood pass into a carburetor where they are mixed with a limited amount of air and burned. Once started,

---

[25]W. M. Pritchard, "A Simplified Charcoal Retort," **Forest Products Journal**, December, 1960, p. 641.

[26]Simmons, **loc. cit.**

[27]Henry E. Steitz, "Ingenuity and Hard Work Go Into Rapidly Expanding Charcoal Business," **Texas Forest News**, April-May-June, 1959, Volume 38, p. 3; and Robert S. Aries, "Charcoal Manufacture in Small Continuous Retorts," **Southern Lumberman**, January, 1956, p. 39.

enough heat is generated from the gases to carbonize the wood without an outside source of fuel.[28]

Another type of commercial retort recently put on the market operates on a batch basis. Because the retort does not operate continuously, an outside source of fuel is needed to bring the retort up to the optimum temperature and maintain it. The carburetor is designed with automatic controls to cut in gases from the wood upon their release. Quenching drums are also used with these retorts.

The budget in Table 26 was based on batch retorts as described above. However, the retorts were to be cycled only once about every 24 hours, eliminating the need for quenching drums and the extra labor involved. Preheating and coaling time would be around 6 to 8 hours, leaving 16 to 18 hours for the charcoal to cool.

Six retorts producing 2.5 tons of charcoal each day would need to be operated for about 267 days to produce 4,000 tons of charcoal. The wood would be placed on a conveyor and dumped into the retort.

[28]Aries, **ibid.**

Table 26. Estimated cost of producing briquettes in an integrated retort-briquette operation

Producing 4,000 tons per year— 2-ton per hour briquetting capacity	Cost	
Item	Per ton	Yearly
Labor (two 3-man shifts @ $1.25 per hour)	$ 4.00	$ 16,000
Supervision and retort operation (@ $2 per hour)	2.13	8,520
Amortization of retorts (6 retorts @ $15,000 each over five years)	4.50	18,000
Amortization of other buildings and equipment ($30,000 over 10 years)	.75	3,000
Fuel cost	3.25	13,000
Operating expenses for tractor and scoop	.75	3,000
Taxes and insurance (2% of fixed investment)	.60	2,400
Repair and maintenance (3% of fixed investment)	.90	3,600
Charcoaling cost (does not include wood costs and returns to capital)	$16.88	$ 67,520
Briquetting cost[a]	23.67	94,680
Subtotal	$40.55	$162,200
Miscellaneous costs (10% of above)	4.06	16,240
Total integrated cost (does not include wood costs and returns to capital)	$44.61	$178,440

[a]The briquetting cost, excluding miscellaneous cost, is the same as in the 2-ton per hour briquetting budget, Table 23.

After coaling, the bottom of the retort would be opened, allowing the charcoal to fall onto a conveyor and be carried to a small storage bin. To reduce the fire hazard, the charcoal should remain in the small bins for several hours before being made into briquettes.

The cost of producing charcoal in the small retort was estimated to be $16.88 per ton, not including the cost of wood and returns to capital (Table 26). This compares favorably with the $17.28 per ton cost estimate for charcoal produced in the 30-kiln battery. Adding briquetting and miscellaneous costs to the cost of charcoaling gave a total integrated cost of $44.61 per ton without any consideration for wood cost and returns to capital, or a total yearly outlay of $178,440.

After subtracting production costs and 15% returns on the fixed investment and operating capital, $27.96 remained to pay for the wood necessary to produce a ton of charcoal (Table 27). Less revenue

Table 27. Residual returns to wood from the six-retort, 4,000-ton per year briquetting operation

Item	Cost	
	Per ton	Yearly
Price received for the charcoal f.o.b. kiln[a]	$83.83	$335,320
Cost of production	44.61	178,440
Remainder	$39.22	$156,880
Returns to fixed investment ($250,000 X .15 ÷ 4,000 tons)	9.38	37,520
Remainder	$29.84	$119,360
Returns to operating capital ($50,000 X .15 ÷ 4,000 tons)	1.88	7,520
Remainder	$27.96	$111,840

[a]See Table 24. This is the remainder of the retail sales after deducting retailer and jobber markup and transportation costs.

remains to pay for the total amount of wood going into the retorts to produce a ton of charcoal than if it were going into the kilns because of the higher capital charge on the increased investment and fuel costs. However, the amount of wood required to produce a ton of charcoal in the retort is sufficiently less than the kiln requirement so that more revenue remains to pay for each cord of wood.

Assuming it takes 2.2 cords of seasoned hardwood to yield 1 ton of charcoal, the maximum amount that could be paid per cord of wood to break even would be $12.71 (Table 28). With wages at $1 per hour instead of $1.25, the maximum allowable cost would be $13.55 per cord.

Table 28. Maximum allowable stumpage cost per cord of wood channeled into an integrated retort-briquetting plant with variable wage rates

	Amount left to pay for a cord of wood at the plant with varying wage rates	If wood harvesting wage rates are:			
		$ .50	$ .75	$ 1.00	$ 1.25
		then cost of harvesting a cord of wood will be:			
		$7.20	$8.97	$10.74	$12.52
Wages		and the maximum allowable stumpage cost would be:			
$1.00 :	$13.55	$6.35	$4.58	$ 2.81	$ 1.03
$1.25 :	$12.71	$5.51	$3.74	$ 1.97	$ 0.19

The estimated maximum amounts that could be paid for a cord of wood on the stump with varying plant and wood harvesting wage rates have been estimated and are shown in Table 28. All of the stumpage value estimates were positive. With plant wages at $1.25 per hour and wood harvesting wages at $1.00 per hour, about $1.97 would remain to pay for each cord of wood on the stump.

(3M 6-64)

THE UNIVERSITY OF TENNESSEE AGRICULTURAL EXPERIMENT STATION KNOXVILLE, TENNESSEE

STATION OFFICERS

Administration

Andrew D. Holt, President
Webster Pendergrass, Dean of Agriculture
J. A. Ewing, Director
Eric Winters, Associate Director
J. L. Anderson, Budget Officer

Department Heads

T. J. Whatley, Agricultural Economics and Rural Sociology
J. J. McDow, Agricultural Engineering
L. F. Seatz, Agronomy
C. S. Hobbs, Animal Husbandry-Veterinary Science
Ruth L. Highberger, Child Development and Family Relationships
J. T. Miles, Dairy
M. R. Johnston, Food Technology
Bernadine Meyer, Foods and Institution Management
Myra L. Bishop, Home Management, Equipment, and Family Economics
B. S. Pickett, Horticulture
R. L. Hamilton, Information
K. L. Hertel, Physics
J. O. Andes, Plant Pathology
O. E. Goff, Poultry
Anna J. Treece, Textiles and Clothing

University of Tennessee Agricultural Research Units

Main Station, J. N. Odom, General Superintendent of Farms, Knoxville
University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory, Oak Ridge, N. S. Hall, Laboratory Director

Branch Stations

Dairy Experiment Station, Lewisburg, J. R. Owen, Superintendent
Highland Rim Experiment Station, Springfield, L. M. Safley, Superintendent
Middle Tennessee Experiment Station, Spring Hill, E. J. Chapman, Superintendent
Plateau Experiment Station, Crossville, J. A. Odom, Superintendent
Tobacco Experiment Station, Greeneville, J. H. Felts, Superintendent
West Tennessee Experiment Station, Jackson, B. P. Hazlewood, Superintendent

Field Stations

Ames Plantation, Grand Junction
Cumberland Plateau Forestry Field Station, Wartburg
Friendship Forestry Field Station, Chattanooga
Highland Rim Forestry Field Station, Tullahoma
Milan Field Station, Milan