Whole-Tree Chips: an Additional Energy Source for Oklahoma

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This report is an assessment of the feasibility of whole-tree chips as an energy source in Oklahoma. Previous work determined that Oklahoma has a potential fuelwood resource of 250 million tons at the present time. Currently, fuelwood growth exceeds removal by 8.65 million tons annually. Two whole-tree chip operations for energy are currently operating in the state, producing fuel at costs which are competitive with the current cost of Wyoming coal and natural gas. If a low-cost method of reducing the moisture content of whole-tree chips is found this material would be a cheaper energy source than coal or natural gas. At least one large manufacturing facility in Oklahoma uses whole-tree chips for energy. The most promising application of whole-tree chips was found to be as a coal supplement. In this application whole-tree chips act as a combustion promoter and emission reducer. Used in this manner whole-tree chips could increase the use of high-sulfur Oklahoma coal, rather than the currently preferred Wyoming coal. Utilization of chipped forest residues also will have important secondary benefits in forest productivity and regional economic development. Whole-tree chips appear to be a feasible energy source for Oklahoma.

INTRODUCTION

There is probably no more volatile economic or political issue facing our nation today than questions related to energy supply. Where should we turn for our future energy needs? Which source or sources should the nation pursue? Which source or sources should Oklahoma pursue?

Oil and natural gas are currently lowcost sources of energy. But oil is nonrenewable and supply is dependent on unpredictable foreign sources. Natural gas is also nonrenewable and expected to increase in price in the near future (1). Coal is cheap, plentiful, and available in this country, but serious environmental questions surround its use. Coal is also nonrenewable. Nuclear energy is beset with serious environmental and safety problems. Most renewable sources of energy, such as solar, hydro systems, and wind, have limitations imposed by available technology.

Wood energy is this nation's original major energy source and it possesses many attractive attributes. It is renewable, available locally, low in pollutants, and can be handled easily with existing technology. Its big disadvantage is that it is less efficient in BTU production than fossil fuels.

Recent trends indicate renewed interest in wood as an energy source. In 1980, almost fifty per cent of the capacity of this nation's new industrial boiler starts were expected to use wood as their primary fuel (2).

Historically, wood residue (wood scraps generated in the production of traditional wood products) has been the primary wood used as a source of energy. There is, however, a much greater wood fuel resource that has only recently begun to be utilized: the conversion of low-value trees to wood chips for fuel.

Most forest stands contain a substantial component of trees too small or for some other reason unsuitable for production of the usual forest products. Within the last ten years, the widespread introduction of whole-tree chipping technology in the woods by the forest industry has opened the possibility of converting this previously underutilized component of the forest resource into wood energy.

Whole-tree chipping for wood energy is a highly mechanized tree-harvesting system. It generally consists of specialized machines for cutting and transporting the trees to a central location. The trees are then converted into small easily transported wood chips, each approximately one inch wide, three inches long, and one half inch thick. The wood chips are blown into truck-tractor vans by the chipping machine for transport to a boiler or storage facility.

The objective of this report is to communicate the results of an investigation into the feasibility of using whole-tree chips as an energy source in Oklahoma.

PROCEDURE

Data Needs

To determine whether or not whole-tree chips are a practical energy source, several key questions need to be answered. The most important question is whether or not the resource can provide enough energy.

If the resource is deemed sufficient to serve Oklahoma as an energy source, the costs associated with producing whole-tree chips for energy need to be determined. Not only economic costs, but also environmental costs, must be addressed. Personal interviews with representatives of whole-tree chipping firms currently operating in Oklahoma, as well as whole-tree chipping studies in other states, are the basis for this analysis.

The economic analysis utilized in this investigation consisted of a comparison of the cost of energy produced with whole-tree chips with the cost of energy produced from bituminous coal and natural gas.

Other important economic and non-economic considerations also were addressed. These included such important issues as: resource renewability, resource self-sufficiency, sociological considerations, and environmental concerns.

Review of Literature

In 1986 (3), Wheatcraft and Lewis of the Oklahoma State University Department of Forestry estimated Oklahoma's forest resource in terms of biomass. Such biomass is the total green weight of all component parts of live trees, including stumps, roots, and foliage.

Wheatcraft and Lewis (3) estimated that in 1976, Oklahoma wood biomass totaled 358 million tons. They also reported that currently, annual wood biomass growth exceeds total annual removals by over 5.7 million tons. Of the 358 million total tons, 100 million tons is located on forest land that currently has limited economic productivity, and 86 million tons of this is recoverable for fuel. This is primarily land occupying the transition zone known as the "cross-timbers" between the eastern commercial forests of Oklahoma and the western prairies. It constitutes approximately 2 million acres of Oklahoma's total 7 million acres of forest land. The timber is mostly blackjack *(Quercus marilandica* Muenchh.*)* and post oak *(Quercus stellata* Wangenh.). These species have limited economic use other than fuel. This forest land does provide many ecological services such as erosion control, CO_2 absorption, oxygen production, and wildlife habitat, but the commercial forests of southeastern Oklahoma provide the same ecological services while simultaneously providing economic benefits: lumber production, paper production, and jobs.

Of the 258 million tons of biomass inventory on productive forest land, only 145 million tons is stemwood. Of the remaining 113 million tons of biomass, 78 million tons is recoverable for fuel. These biomass estimates indicate that Oklahoma had a potential fuelwood inventory of approximately 164 million tons as of 1976. In energy value this would be equivalent to approximately 76 million tons of coal (4). Further, the fuelwood resource is growing at the rate of approximately 10 million tons per year.

Computer simulation of harvesting systems and costs by Cubbage and Granskog in 1982 (5) indicated that the typical whole-tree chipping operation in use in the South required an initial investment of $715,500. The cost of operating the system was $11.32 per ton. Although this study indicated that the whole-tree chip system yields the lowest harvest cost per ton of all forest harvesting systems, the relatively low current price of wood energy chips made the profitability of the system questionable under the conditions of their simulation.

A Louisiana study of whole-tree chips for energy by Massey, et al. (6) showed that the operation there had an initial capital investment of $919,700. The cost of producing the chips was $14.56 per ton. For costs not to exceed the product value, the operation had to maintain a high continuous volume of output, a requirement not consistently achieved during the study.

The environmental effects of harvesting forests for energy was investigated by Van Hook, et al. (7). They found that most adverse environmental effects of whole-tree chip harvesting can be minimized by intelligent use of appropriate practices. The techniques recommended were primarily those already recognized as suitable for conventional forest harvesting operations. It was indicated that the increased level of utilization attained by whole-tree chipping might make soil fertilization more desirable before replanting harvested areas.

A study conducted by Miller in the Ouachita Mountains of southeast Oklahoma in 1984 was aimed at determining sediment yields and storm flow response to clear-cut harvesting and site preparation (8). The treatments in Miller's study closely approximated conditions following whole-tree chip harvesting done in accordance with good forest management practices. In the first year following the treatment sediment yields were approximately 250 lb/acre, but in following years yield capacity dropped back toward the normal yield for the control area of 37 to 40 lb/acre. This is a very inconsequential amount when compared to the maximum acceptable yield set by the Soil Conservation Service for agricultural land of 10,000 lb/acre. In fact, the national average sediment yield for agricultural land currently exceeds that value.

The adverse environmental effects of burning wood as an energy source are low compared to that of coal (9). Sulfur emissions are virtually nonexistent, and particulate emissions are low.

The Grand Haven (Michigan) Board of Light and Power, on an experimental basis, included 35 per cent whole-tree chips by volume with the normally used high-sulfur coal (10). They found that wood chips acted as a combusion promoter, resulting in a noticeable decrease in emissions and decreased slagging of the boiler. The firm estimated that the 35 per cent whole-tree chip supplement would save $145,000 in fuel costs annually as well as eliminate the necessity of major equipment modifications to satisfy clean air standards.

RESULTS

The available information indicates a sizeable supply of fuelwood, estimated at 250 million tons, is currently available and underutilized in Oklahoma. The actual extent of usable reserves would depend on the location of the potential resource users. Although the *rate* of renewal is uncertain and dependent on factors such as species, site quality, and management practices, the resource is renewable nonetheless. This is an important consideration to any potential user.

Over 10 million tons of Oklahoma's estimated 14 million tons of annual wood biomass growth is suitable only for fuelwood production (3). Current fuelwood consumption in Oklahoma is not known with certainty. Langwig (11) estimated that current Oklahoma domestic fuelwood consumption is approximately 1.2 million tons annually. A 1986 survey, by the Department of Forestry at Oklahoma State University, of Oklahoma forest harvesting firms showed the existence of two whole-tree chipping operations for energy production. Weyerhaeuser Company operates a large paper manufacturing facility at Valliant in southeast Oklahoma that mixes whole-tree chips produced by these two operations with wood residue for energy production. The two operations produced approximately 150,000 tons of green wood chips in 1985.

Summing the current annual estimates for Oklahoma domestic and industrial fuelwood consumption, 1.2 million and 0.15 million tons respectively, shows that the current annual Oklahoma fuelwood consumption is approximately 1.35 million tons. So if the current annual growth of fuelwood is 10 million tons, fuelwood growth currently exceeds removals by 8.65 million tons, and current fuelwood consumption can increase by 700 per cent without exceeding growth.

The estimates for potential fuelwood consumption are based on present stocking levels. It has been shown, however, that Oklahoma forests are at least 50 per cent understocked (3). The development of markets for whole-tree chips could supply non-industrial landowners with incentive to practice more intensive, scientific forestry practices as well as planting more profitable, faster-growing species. Wood (12) considered that most of the cross-timbers area would support production of loblolly pine (*Pinus taeda* L.) a much faster-growing, more commercially valuable species than the native post oak and blackjack. These steps could result in dramatic increases in forest growth, and consequently the available forest resource, and could introduce species usable for other valuable forest products such as lumber and paper.

Coal is presently the fuel most consumed for the generation of electrical power in Oklahoma. According to a recent Quarterly Coal Report (11), the Oklahoma coal price paid by end users was $29.25/ton for the first quarter of 1986. Based on an average energy value of 8,500 BTU/lb for Wyoming coal (14), which is currently the predominant type used in Oklahoma, the average cost was $1.72/million BTU of energy produced. Because it produces over 12,000 BTU/pound, Oklahoma coal is somewhat cheaper than Wyoming coal, approximately $1.60/million BTU. However, in view of its relatively high sulfur content, it cannot be used in large quantities in Oklahoma because of the necessity of compliance with the current clean air standards.

The average cost of natural gas to utilities in 1986 was approximately $2.10/million BTU of energy produced (1). This is also the predicted price for 1987 (1). It is possible that the price may drop as low as $1.00/million BTU on the spot market in 1987; the Fuel Use Act of 1978 prohibited manufacturing new natural gas- or oil-fired power plants but this has now been repealed. Also, natural gas prices are expected to begin rising rapidly again by the early 1990s (15).

The average cost of whole-tree chips for energy in Oklahoma is currently $1.76/million BTU of energy produced. This figure is based on an average cost of $15.50/ton delivered to the user, and a heat value of 4400 BTU/pound of mixed hardwood at 50% moisture content (Table 1). This cost does not include stumpage, which may range from $0 to $.50/ton and could increase the cost as much as $0.06/million BTU.

The wood energy cost is based on the current industry practice in the region of burning green (approximately 50% moisture content) wood chips. The moisture content has a crucial influence on the energy value of wood since a significant amount of potential energy is used to vaporize the water prior to combustion. The danger of deterioration and spontaneous combustion of moist wood chips stored in conventional piles has resulted in the current practice of burning the chips green to maintain relatively low inventories and reduce the hazard of losses. If no-cost or low-cost means could be developed to dry the chips to approximately 20 per cent moisture content, the energy value would be approximately 6,000 BTU of energy produced (16,17). At this cost whole-tree chips would be a significantly cheaper source of energy than coal. In fact, efforts are under way to economically solve the moisture reduction problem (18).

Approximately 2.0 to 2.7 tons of green wood chips are required to equal one ton of coal in energy value, and this is a second cost consideration for potential users of wood chips. Such a user currently burning coal would need a larger storage facility to accommodate a supply of wood chips with an equivalent thermal value. Fortunately, conventional coal-handling equipment can be easily adapted to handle wood chips. Boiler and combustion chamber modifications should be minimal if a coal-wood mixture is utilized. However, converting a coal-fired system entirely to wood would require substantial changes.

The secondary economic benefits associated with a given fuel source also are a major consideration. The use of Wyoming coal may actually have negative secondary

TABLE 1. Cost and energy value comparison of coal, natural gas and whole-tree chips to Oklahoma industrial users, 1986.

	Cost	Energy Value
Wyoming coal	$1.72/million BTU	8,500 BTU/lb.
Oklahoma coal	$1.60/million BTU	12,000 BTU/lb.
Natural gas	$2.10/million BTU	1,000 BTU/cu. ft.
Whole-tree chips	$1.76/million BTU	4,400 BTU/lb.

effects; that is, its use may hurt the Oklahoma coal industry among others. The use of whole-tree chips from Oklahoma forests could have substantial secondary economic benefits. These effects are even more important when it is realized that the majority of the wood energy resource is located in one of the state's least developed economic regions, southeast Oklahoma.

There are also important secondary benefits associated with the actual harvest and removal of the branches, tops, and stumps. When one considers the fact that the forest industry is fast approaching self-sufficiency in energy through the use of wood residue and whole-tree chips, the question of why this has occurred arises. The impetus of this move is not entirely direct economic benefits derived from the use of wood as a fuel, but rather some important secondary ones.

Most forest industries own large areas of forest land that they desire to manage for high economic yield. Ten years ago, traditional forest harvesting operations could not economically utilize many small or otherwise undesirable trees. These trees had to be removed in order to establish the new forest. Removal of these trees usually meant expensive piling of residual material, herbicide applications, or a combination of these methods. The cost of site preparation work, which must be amortized over the life of the new forest, was usually very high. The cost could run from $60 to $130 per acre depending on the amount of undesirable material occupying the site.

Whole-tree chipping technology provided a means of utilizing almost all of this previously wasted material. Further, the cost of site preparation could be reduced by 50 to 100 per cent. The forest industry could run whole-tree chipping operations at a loss and still receive real economic benefit in the form of reduced site preparation costs. Some companies have in fact operated wood chipping operations at a loss.

By the very nature of Oklahoma's wood energy resource, including 2 million acres of noncommercial forest land, these secondary economic benefits hold exceptional promise. In other states where whole-tree chipping has become available, both large and small landowners have embraced it wholeheartedly. Whether the landowner desires range management, improved pasture, or establishment of a superior forest, whole-tree chipping is a tool to achieve these goals, while reducing costs and/or generating revenue. In fact, the demand for whole-tree chipping in areas where it has become available has caused some landowners to give the material away just to have it removed.

From an environmental viewpoint wood chips are a superior fuel to coal. The two principal pollutants in coal fuels are sulfur dioxide and ash. Sulfur dioxide is a pollutant in its own right and can combine with oxygen and moisture in the atmosphere to cause acid rain. Mean sulfur content of wood is .013% by weight compared to .6 to 3.1% for coal. Mean ash content is 1.12% for wood compared to 4.1 to 13.8% for coal (8). Natural gas, like wood, is a relatively clean-burning fuel.

The advantages of wood in co-combustion applications with coal should not be overlooked. Relatively low percentages of wood mixed with coal acts as a combustion aid promoting more complete burning and lower particulate emissions (10). This application has special significance to Oklahoma. Oklahoma coal is generally considered undesirable because of its high sulfur content. However, it is a high-energy coal producing almost twice as much energy per pound as Wyoming coal. Conceivably, a mixture of Oklahoma coal and Oklahoma wood chips could yield a low-priced high-energy fuel producing emissions within allowable levels.

The envirnomental effects associated with harvesting whole-tree chips have proven to be comparable to tradititional wisely managed forestry harvesting techniques (7,8). They are far less controversial than strip mining associated with western coal production.

SUMMARY AND CONCLUSIONS

Current and potential energy users need to become aware of the extent and usefulness of this renewable, locally occurring, environmentally safe natural resource. This must naturally begin with Oklahomans realizing the existence and significance of this resource and acting through public officials and promotional organizations, and as individuals, to promote the use of whole-tree chips as an energy source.

The establishment of initial markets for wood chips is crucial to the development of this resource. If initial markets can be developed many other promising uses may develop for whole-tree chips. They can be used to produce paper, fiberboard, and a variety of chemicals, including ethanol (19).

Co-generation or co-conversion, whereby the chips produce more than one product, presents interesting possibilities. In fact cogeneration of steam and electricity by the pulp and paper industry in the 1920s and 1930s became so popular and profitable that the U.S. Department of Justice instituted antitrust proceedings against several paper companies (9). Sweden and Finland currently utilize over fifty per cent of the electricity-generation potential of their pulp and paper industries. Legal barriers to efficient energy production in this country need to be modified so that this country's cogeneration potential can be fully realized.

Whole-tree chips are a real, feasible energy resource for Oklahoma.

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