UMR-MEC Conference on Energy / UMR-DNR Conference on Energy

16 Oct 1980

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Abstract

In order for wood to be considered a feasible energy source for power generation, it must prove to be economical, meet society's pollution criteria, and provide sufficient energy to meet its regional demand applications or requirements. This report looks at wood's availability, its potential as a fuel source, the different methods of energy conversion, and lastly, submits conclusions and recommendations concerning wood-fueled power generation.

The information and background was supplied and supported by actual application, government publications and documentations, and other sources. The availability report includes living biomass, wood residues, and potential biomass expansion. Once availability was determined, the portion of wood and wood waste that could serve as a fuel supply was calculated. Then actual power generation techniques were studied to see how gasification and direct combustion could be applicative. This led to a comparative economic analysis of the systems and methods leading to conclusions and recommendations.

In the six-county study region, yearly unused residues total 145 million pounds of wood which could support a 10 MW power generation unit. It was noted that wood chips have the lowest average cost per million Btu's when compared to other common fuels. The study also broke the two major wood conversion processes--combustion and gasification--into four wood systems, a spreader-stoker system combined lowest capital cost with the lowest operating cost, while retaining environmental advantages, to be chosen as the best alternative. All of the mentioned wood systems are superior to coal units when renewability, environmental considerations, and the ease of meeting small municipal or rural demand are considered.

Wood in the south central Missouri region surrounding the city of Lebanon is available and appears to be a feasible energy source for power generation.

I. INTRODUCTION

The era of inexpensive energy has past, replaced instead with current shortages that have led to skyrocketing prices, and a subsequent need to alleviate the United States' dependence on foreign energy resources. The energy problems facing the nation have led to indepth rewiews of renewable resources, such as biomass, for power generation. This report will deal specifically with wood as an energy source for possible power generation.

Wood as an energy source on an industrial scale, especially in developed countries, has almost been completely replaced by the more convenient fossil fuels. Now that the real costs of fossil fuels in terms of unit costs for energy, reliability of supply, and future depletion have become apparent, there has been a resurgence of interest in wood as an energy source, because of its relatively low cost, abundance, and renewability.

In order for wood to be considered a feasible energy source, it must prove to be economical, meet society's pollution criteria, and provide sufficient energy to meet its demand application or requirements. Therefore, wood as an energy source will be critiqued in terms of availability, potential as fuel source, different modes of energy conversion, and lastly, the submission of conclusions and recommendations concerning the question at hand, power generation utilizing wood.

II. POTENTIAL WOOD RESOURCES

Fuel choices of the future will be governed by two fundamental considerations, cost and availability. Therefore, these are the areas in which present emphasis will be placed. The primary industrial fuels since the 1950's have been fuel oil and natural gas. The major concern facing the world now is how long will these finite resources last.

At the present time, using known consumption rates, these reserves would last approximately 50 and 90 years respectively. (1) Today with oil and natural gas providing approximately 75 percent of our nation's energy, it becomes evident that alternative forms of energy must be developed and then utilized more heavily in order to avert the impending crisis. This energy need has brought about the re-examination of wood as a fuel.

A. MATERIAL AVAILABILITY

The supply picture for fuel wood is difficult to quantify since there are many competing end uses for wood. Using the Aerospace Research Corporation's approach to estimating the availability of these forests after lumber and pulpwood needs are met, ther is an apparent yield of 308 million excess acres of biomass for fuel. (2) Approximately 41 percent of the forest land or 308 million acres would be available for fuel use, because of ongoing needs for lumber and pulpwood. The average electrical energy yield per acre of rough forest can be determined as being 2516 kw hours using the following data: (2)

Average higher heating value of wood, Btu/lb	7680
Average power plant thermal efficiency,%	32.5
Average biomass yield per acre, tons	1.72

Since not every region throughout the United States possesses the same potential for biomass production, this paper shall now pertain more specifically with southern Missouri, the area of interest.

The initial step was to compile Table I, which has wood residues by county, noting that 47 percent of this region is wooded. This unsold wood residue amounts to 884.35 billion Btu's or 86.7 million kw hours of energy that goes unutilized each year. (3)

The following facts should give a better indication as to the amount of energy available from wood residues. In order to supply Lebanon's approximate 9000 people with a monthly amount of 1000 kw hours per person of power, it would require about 190 millions pounds (OD) of wood or equivalently 114 million kw hours of power. With adequate forest management, this potential power supply could indefinetely serve Lebanon and its residents.

All comparisons made in this text will hold true for a 50 MW unit, since scaling up to present the worse case while lowering incremental costs.

B. COST ANALYSIS

At present, the biggest drawback to widespread use of wood waste for power generation is the lack of a developed supply line. As of late, tremendous advances have been made in both harvesting and packaging of wood fuel.

One way to increase feasible transportation distances is achieved by enriching the fuel wood through pelletization. Pelletizing removes the moisture from the wood, therby compacting the fuel and increasing the energy yield per pound of fuel. (4) The manufacturing of wood pellets eases fuel handling and could be the key to commercialization of wood-fired plants, since existing facilities can be easily converted to burn wood pellets.

Transportation is the key to pelletizing, since within the 50-mile radius of a wood-fired plant it results in an unneeded cost. But for distances greater than 50 miles, pelletizing becomes necessary for wood to complete economically with other conventional fuels. Table II shows the comparative costs of fuels within a 50-mile radius, while Table III emphasizes how pelletization increases effective transport radii. (1)

C. CONVERSION METHODS OF WOOD FOR ENERGY

Wood can be used directly for generation of energy by direct combustion or gasification.

1. Direct Combustion. Direct combustion for process steam or electricity is an old technology that is commercially proven.

In direct combustion, all organic wood components are combined with oxygen to form carbon dioxide and water byproducts. It has been roughly estimated that one oven-dry ton of wood is required for each 12,000 pounds of steam.

Three basic approaches exist for complete combustion of wood: (1) the Dutch oven, (2) the spreader-stoker, and (3) the fluidized bed combuster. Each system seeks to maximize and achieve complete oxidation of the volatiles and the fixed carbon of the wood fuels, while providing: (1) the flexibility of furnace operation, (2) wet fuels handling, and (3) pollution control from stack gas emissions.

In the first technique, the Dutch oven system, a heavy bed of wood is placed on the combuster grate. Under fire air flows through the grate to the fuel on the bed, where partial combustion occurs. Volatiles are given off by heating the bed and are combusted with overfire air. Either natural or forced circulation can be used with ashes dropping through the grate into a cleanup area.

The second approach, the spreader-stoker system, is the most popular wood-burning system presently employed. The fuel is fed into the fire box above the grate and begins to burn while falling to the grate. Moisture contained in the fuel is partially driven off while in suspension. The depth of the fuel bed is proportional to the fuel's moisture content. Fluidized beds (Figure 1) have a large heat flux rate and can burn wet, dirty and non-uniform fuels. Air is forced by a blower through flow nozzles into the air plenum and up through the sand bed.

2. Gasification. Gasification is a major modification of fundamental pyrolysis. This process produces fuel gases to meet fuel demands and burns the remaining char to provide heat for gasification.

Some of the potential advantages for gasifiers are:

1. Energy conversion efficiency is quite high, maximum about 80%.
2. High water content wastes, including wet wood and even sewage sludge, can be completely converted to a low Btu gas and ash.
3. Char combustion eliminates the need for a treatment plant for the produced fuel gases.

The major disadvantage of a gasifier is the low Btu rating of the gas, only about 10 to 50 percent of that of natural gas. Another potential disadvantage for wood gasification is its limited experience with large-scale systems.

D. SYSTEMS UTILIZING WOOD FOR ENERGY

The produced energy must now be coupled to useful purposes. Some of the most important systems for the potential utilization of energy from wood shall be discussed below.

1. Process Steam. The direct combustion of wood to produce process steam is a well-developed technology, with manufacturers of hogged fuel boilers remommending 300,000 pounds of steam per hour as a desirable size for a single large-capacity unit. Boilers are an integral part of the conversion system. The boilers are in turn coupled to steam turbines which produce electric power and lower-quality steam.

2. Gas Turbine. Gas turbines are one type of system that does not use steam. This system being only applicable for wood gasifiers, receives and burns the gasifier's fuel gases to drive the turbine.

3. Cogeneration. Cogeneration involves simultaneously generating electricity with process steam or process heat by burning the same fuel, which is usually accompanied by increased energy efficiency gains.

III. EVALUATION

It can be said that wood fuels can be efficient and highly desirable sources of energy if the correct conditions exist, such as: (1) extraction costs are minimized, (2) transportation distances are held down (usually a 50-mile radius with a vehicle, or possibly a 200-mile radius with rail), and (3) thermally efficient conversion processes are employed. As an added note, the radius boundaries can be kept small by utilizing the idea of co-conversion. The basis behind this principle is that wood and another fuel substance such as coal, would be burned together, thus decreasing the overall dependance on one fuel or another.

A. DIRECT COMBUSTION

All existing wood-based electric plants use direct combustion and most of them were built in the early 1930's. Therefore, the level of investment associated with them is not representative of the current cost experience. Thus, the cost of produced electricity at these older plants is extremely low. In one plant (1931 vintage) the annual operating cost is expected to be approximately 2.7 mills/kwh. (7)

B. GASIFICATION

The largest wood gasification research unit in use in this country is the University of Missouri-Rolla's GROW (Gasification Research on Wood) unit. GROW, which started operation in the fall of 1979, has already achieved a low Btu gas production of approximately 200 Btu's per cubic foot using sawdust as feedstock. The GROW project uses a fluidized bed gasifier. One major advantage of this unit is its suitability of gasifying all types of biomass including wood chips, sawdust, animal manure, corn cobs, and other agricultural by-products which would normally result in waste.

C. ENVIRONMENTAL CONSIDERATIONS

The increased use of wood for energy by the utility sector can affect the environment in two general areas. The first being the impact on the forest resources with increased withdrawal of wood, specifically if whole tree chipping is utilized. The other would be the environmental impact on both air and water quality. Since trees recycle most of their nutrients through leaf fall, harvesting on a twenty-year cycle for continous yield coupled with leaving the foliage behind should minimize nutrient depletion. As wood usage increases, forestry techniques concerning soils, watersheds, wildlife, and other natural phenonenas, will have to improve so yield can stay abreast of demand. (6)

Emission control for wood-fired systems is normally limited to particulate control. Particulate emissions can be controlled by either preventing the formation of fire particulates or by actually collecting the particulates to meet environmental constranints. Meanwhile, it appears as though gasification of wood is probably the most satisfactory process from an environmental point of view. When the product gas is cleansed by cyclone separators the tar and char content of the produced gas is reduced by re-feeding into the fluidized bed. Therefore, when the gas is burned it has very low emissions, well within EPA standards.

D. ECONOMICS

Despite the escalation in fossil fuel prices which make the life-cycle economics of wood-fueled electricity production increasingly attractive, a major financial constraint is the higher capital investment per kilowatt required for wood plants compared to that of fossil plants. This is basically caused by wood's higher transportation costs combined with its lower heating value limits, which in turn economically limits the feasible wood plant size to the 50 megawatt range.

In addition to the aforementioned problems, the wood fuel supply line is still in the drawing board stages. Assurance of longterm wood supplies at reasonably stable prices is a critical issue for commercialization. This barrier can be overcome by issuing longterm supply contracts and by working jointly with local entrepreneurs in establishing this new enterprise.

In all probability, the decisions whether or not to use wood for energy for power generation will not be based entirely on technical feasibility or classical marketplace economics. Government incentives and disincentives will influence these decisions. An incentive for wood energy would be the Energy Tax Act of 1978 as it provides an additional 10 percent "energy percentage" business investment tax credit. This credit, which applies during the period of October 1, 1978 through December 31, 1982, may be claimed for investment in "alternative energy property" (5) This is defined to be property such as boilers whose primary fuel will be an "alternate substance", non- boiler burners for alternative fuels, and equipment used for the unloading, transfer, storage, reclaiming from storage, and preparation of an alternative fuel for burning.

IV. CONCLUSION

It has become appearent that fossil fuels will soon be depleted at present consumption rates. Therefore, mankind will have to learn to utilize renewable resources such as solar energy or fusion energy for their future energy needs.

Wood is a form of solar energy that, with proper forest management is both renewable and abundant. Another major advantage for wood is its energy has already been stored and does not require expensive capital investment for storage facilities.

When looking at Missouri's six-county region centered around Lebanon, it is noted that annual unused wood residues total 145 million pounds, and annual growth totals 4.5 billion pounds. This figure combined with the fact that 47 percent of this region is wooded insures a secure supply for power generation for years to come.

Systems using direct combustion or gasification of wood to generate electricity are technically ready, although further research and development is warranted to advance fluidized-bed technology. Wood technology would be most compatible with municipal and rural electric utilities' smaller power requirements.

There are no real inherent barriers to the use of wood for energy, since all so-called constraints are only relative in comparison to the cost or properties of fossil fuels such as wood's low-density and high-moisture content, making it more expensive to transport than fossil fuels. For economic reasons, the cost of transportation combined with not exceeding the regional wood resources available place limits on the maximum size of individual wood processing installations, which in turn prevents attaining the economics of scale available from fossil fuels. This barrier can be partially offset with the use of pelletization technology, which increases transportation distances while stabilizing costs.

Looking more specifically at the city of Lebanon, as of 1980 a 10 MW wood unit could be 99.2 percent powered by unutilized wood residue produced in this region. Using the minimum biomass yield of 1.72 tons per acre, the study region could support a 50 MW unit in addition to meeting the wood industry's demand. A 50 MW unit would totally satisfy Lebanon's power needs and would lower their incremental costs, since Lebanon receives power from Laclede Electric, who receives power from Show-Me Electric, and who purchases power from Associated Electric Cooperative for 2.5¢/kwh.

BIBLIOGRAPHY

1. Tillman, David A. Wood as an Energy Resource. Academic Press, Inc., 111 Fifth Avenue, New York, N.Y. 1978
2. Hamrick, Joseph T. Development of Wood as an Alternative Fuel for Large Power Generating Systems. Aerospace Research Corporation, Roanoke, VA, October 1978.
3. Spencer, John S. and Burton L Essex. Timber In Missouri. Forest Service, U.S. Department of Agriculture, 1976.
4. Gallagher, Alissa M. "The Feasibility of Using Wood Wastes as Fuel for Steam Generators." Paper prepared for English 160, UMR, May 5, 1980.
5. Branch. "Solid Fuels Technology Workshop." Paper prepared for Georgia Office of Energy Resources, May 15, 1979, Georgia Institute of Technology.
6. Pierce, Bill. "Economic, Social, and Environmental Advantages of a Wood-Fired Electrical Cogeneration Plant for the Laclede Electric Cooperative." Paper prepared for Laclede Electric Cooperative, October, 1979, Elridge, Missouri.
7. Gordon, Judith and others. Commercialization of Wood Combustion Systems. MITRE Corporation, 1820 Dolly Madison Blvd., McLean, VA, August 1979.

BIOGRAPHIES

Dr. Yildirim Omurtag is an Associate Professor of Engineering Management at the University of Missouri-Rolla. He received his B.S. and Ph.D degrees from Iowa State University in Mechanical and Industrial Engineering. He is a registered Professional Engineer with significant industrial and consulting experience both in the United States and abroad.

Lawrance Wray Wetzel was born on October 30, 1956 in St. Louis, Missouri. He received his primary and secondary education from the Hazelwood School District in St. Louis County, Missouri. He has received his college education from the University of Missouri-Rolla, in Rolla, Missouri. He received dual Bachelor of Science degrees in Engineering Management and Mechanical Engineering from the University of Missouri-Rolla in May 1979 and May 1980, respectively. He has been enrolled in the Graduate School of the University of Missouri-Rolla since January 1979 and has held a Graduate Research Assistanship for the period of August 1979 to July 1980.

Michael James McEvilly was born on September 29, 1958 in Newburgh, New York. He received his primary and secondary education from the Newburgh School District in Orange County New YOrk. He received a Bachelor of Science degree in Civil Engineering in May 1980 from the University of Missouri-Rolla, and expects to receive a Masters in Engineering Management in May 1981. He has been enrolled in the Graduate School of the University of Missouri-Rolla since June 1980, and has held a Graduate Research Assistantship for the period August 1980 to present.

TABLE I

SOUTH CENTRAL MISSOURI WOOD RESIDUES BY COUNTY

COUNTY	AREA (thousand acres) Total	Forest	ANNUAL PRODUCTION OF WOOD RESIDUES OVEN DRY BASIS (millions of lbs)	VOLUME OF EXISTING WOOD RESIDUES--OD (millions of lbs)	USABLE HEAT FROM ANNUAL PRODUCTION (billion Btu)	USABLE HEAT FROM EXISTING RESIDUES (billion Btu)
CAMDEN	409.6	230.9	15.54--total 6.90--unsold	121.43	95.55--total 42.42--unsold	746.66
DALLAS	343.7	131.2	5.58--total 2.75--unsold	0.10	34.03--total 16.78--unsold	0.61
LACLEDE	492.8	204.2	25.92--total 14.06--unsold	4.66	159.24--total 86.38--unsold	28.63
PULASKI	352.3	183.5	21.81--total 12.60--unsold	54.78	134.01--total 77.42--unsold	336.60
TEXAS	757.1	384.3	159.96--total 86.14--unsold	106.52	972.61--total 523.76--unsold	647.68
WRIGHT	437.7	166.9	44.30--total 22.39--unsold	43.86	272.23--total 137.59--unsold	269.53
TOTALS	2793.2	1301.0	273.11--total 144.79--unsold	331.35	1667.67--total 884.35--unsold	2029.71

TABLE II

AVERAGE FUEL COST PER MILLION BTU'S

No. 2 Fuel Oil	$2.95
No. 6 Fuel Oil	$2.30
Natural Gas	$1.75
Coal	$1.65
Wood Chips	$1.55
Pelletized Wood	$1.80

Reference (1)

These prices were estimated as average for Southeastern United States, and represent costs to a typical industrial customer, delivered within a 50-mile radius. While these figures are simply rough averages that are dependent on location and time, it still becomes apparent that wood can compete with fossil fuels on a cost basis.

TABLE III

EFFECTIVE TRANSPORTATION RADII FOR WOOD FUELS (1977)

Fuel	Transport Method	Energy Available For a Transport (as a % of total energy content)	Effective Transport Radii (in miles)
Softwood (45% moisture)	Truck	1.3	20
		2.2	30
		4.0	40
	Rail	1.3	70
		2.2	110
		4.0	150
Hardwood (35% moisture)	Truck	1.3	25
		2.2	40
		4.0	50
	Rail	1.3	90
		2.2	150
		4.0	200
Softwood Pellets (15% moisture)	Truck	1.3	30
		2.2	60
		4.0	90
	Rail	1.3	120
		2.2	200
		4.0	260
Charcoal	Truck	1.3	60
		2.2	100
		4.0	170
	Rail	1.3	220
		2.2	370
		4.0	490

Reference (1)

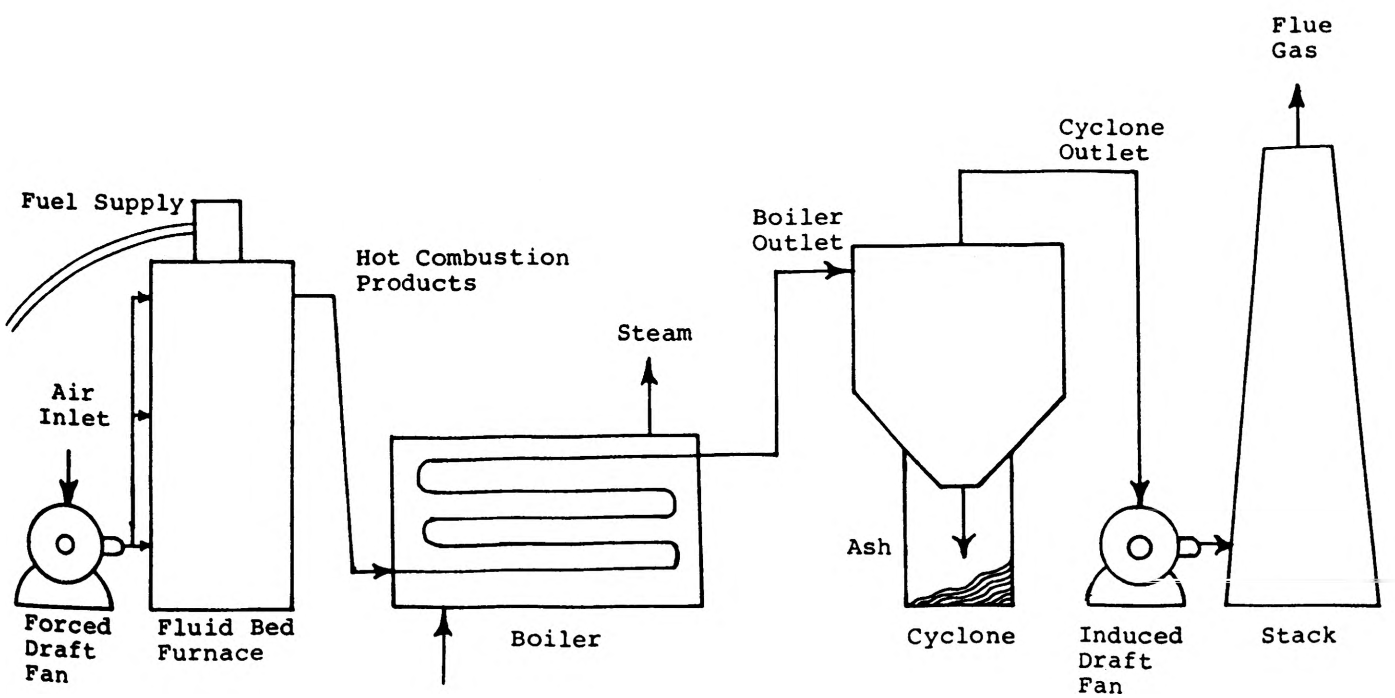

Figure I. Schematic of a Fluidized-Bed Combustion Module.

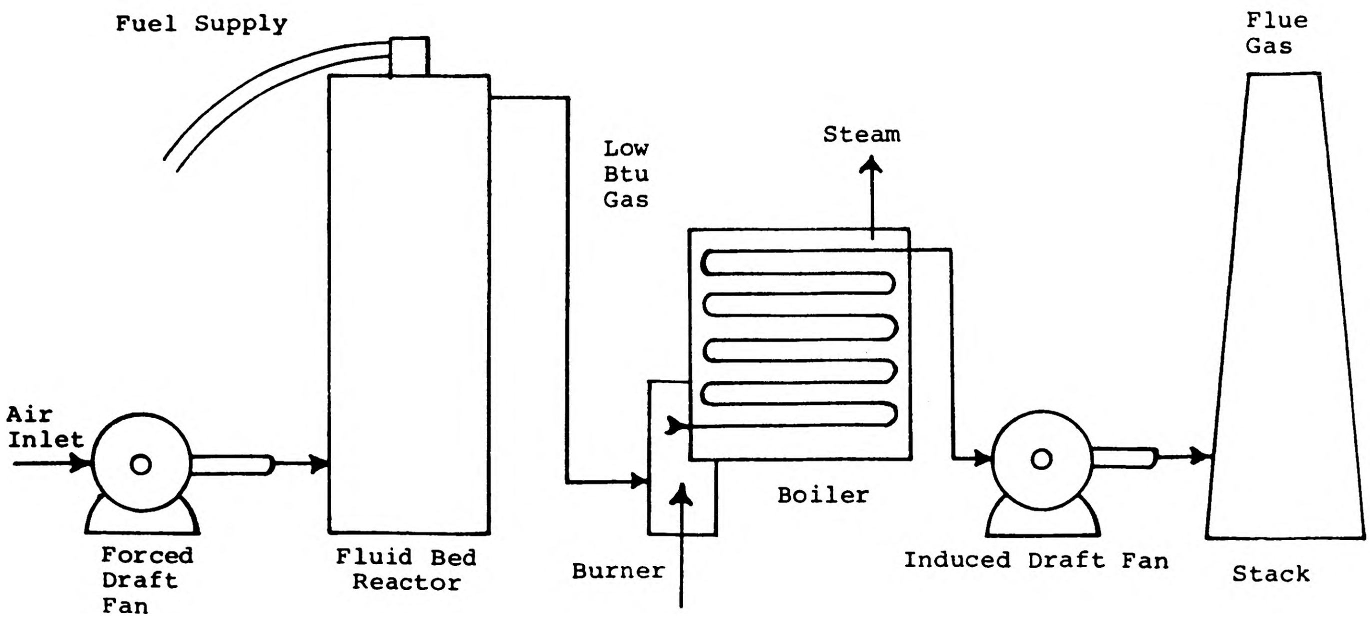

Figure II. Schematic of a Gasification Unit.