PROJECT ADMINISTRATION DATA SHEET

Project No. A-3397

Project Director: Bill Bulpitt
Sponsor: City of Tallahassee, FL. 32301

Type Agreement: Research Project Agreement dated 10/27/82, Addendum dated 10/27/82

Award Period: From 10/27/82 To 1/30/83
Sponsor Amount: Total Estimated: $9,000* (Reports) Funded: $9,000
Cost Sharing Amount: $2,158.33

Title: Biomass Fuel Resource Study

ADMINISTRATIVE DATA

OCA Contact John W. Burdette x4820

1) Sponsor Technical Contact: Mr. Calvin Sherman
(904) 599-8100
City of Tallahassee
City Hall
Tallahassee, FL 32301

Defense Priority Rating: NA

2) Sponsor Admin/Contractual Matters:

Military Security Classification: NA
(or Company/Industrial Proprietary:

REstrictions

See Attached Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with

ComMENTS:

*The sponsor has made an advance payment of $3,000 to GTRI. This advance payment will be applied to the final invoice and any remaining balance will be refunded at the end of the project.
Date: 3/22/83

Project Title: Biomass Fuel Resource Study
Project No: A-3397
Project Director: Bill Bulpitt
Sponsor: City of Tallahassee, Fl.

Effective Termination Date: 3/15/83
Clearance of Accounting Charges: 3/15/83

Grant/Contract Closeout Actions Remaining:

- [x] Final Invoice and Closing Documents
- [ ] Final Fiscal Report
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Assigned to: TAL (School/Laboratory)

COPIES TO:

Administrative Coordinator
Research Property Management
Accounting
Procurement/EES Supply Services

Research Security Services
Reports Coordinator (OCA)
Legal Services (OCA)
Library

EES Public Relations (2)
Computer Input
Project File
Other
FINAL REPORT
PROJECT A-3397

BIOMASS FUEL RESOURCE STUDY

By
William S. Bulpitt, P.E.
E. C. Frazer, III, A.C.F.
D. E. Harris, P.E.
C. H. Houder, III
T. F. McGowan, P.E.

Prepared for
THE CITY COMMISSION
CITY OF TALLAHASSEE, FLORIDA

March 1983

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332

1983
FINAL REPORT

BIOMASS FUEL RESOURCE STUDY

Presented to:

The City Commission
City of Tallahassee, Florida

Authors
W. S. Bulpitt, P.E.
E. C. Frazer, III, A.C.F.
D. E. Harris, P.E.
C. H. Houder, III
T. F. McGowan, P.E.

Georgia Institute of Technology
Engineering Experiment Station
F & W Forestry Services, Inc.

January 1983
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>1</td>
</tr>
<tr>
<td>I. EXECUTIVE SUMMARY</td>
<td>1</td>
</tr>
<tr>
<td>II. INTRODUCTION</td>
<td>11</td>
</tr>
<tr>
<td>III. GEORGIA TECH CONTRACT REQUIREMENTS</td>
<td>15</td>
</tr>
<tr>
<td>A. Review of the Preliminary Wood Biomass Availability and Feasibility Study</td>
<td>16</td>
</tr>
<tr>
<td>B. Factors Affecting the Btu Content of Wood</td>
<td>21</td>
</tr>
<tr>
<td>C. Description of Wood Fired Utility Plants</td>
<td>36</td>
</tr>
<tr>
<td>D. Barge Transportation and Wood Supply Analysis</td>
<td>51</td>
</tr>
<tr>
<td>E. Use of Garbage as an Alternative Fuel</td>
<td>59</td>
</tr>
<tr>
<td>F. Socioeconomic Analysis</td>
<td>71</td>
</tr>
<tr>
<td>IV. FRAZER AND WETHERBEE FORESTRY SERVICES, INC. CONTRACT REQUIREMENTS/FUEL WOOD AVAILABILITY STUDY</td>
<td>81</td>
</tr>
<tr>
<td>A. Introduction</td>
<td>82</td>
</tr>
<tr>
<td>B. Current and Projected Fuel Wood Prices</td>
<td>83</td>
</tr>
<tr>
<td>C. Amount of Fuel Wood Potentially Available</td>
<td>92</td>
</tr>
<tr>
<td>D. Environmental Effects of Fuelwood Harvesting</td>
<td>102</td>
</tr>
<tr>
<td>E. Potential Wood Suppliers and Contract Considerations</td>
<td>108</td>
</tr>
<tr>
<td>F. Potential Loggers/Haulers and Contract Considerations</td>
<td>111</td>
</tr>
<tr>
<td>V. CONCLUSIONS AND RECOMMENDATIONS</td>
<td>117</td>
</tr>
<tr>
<td>VI. APPENDICES:</td>
<td></td>
</tr>
<tr>
<td>A. List and Regression Analysis of F&amp;W Timber Sales</td>
<td></td>
</tr>
<tr>
<td>B. Florida Law Concerning Endangered and Threatened Plants</td>
<td></td>
</tr>
<tr>
<td>C. Forest Industry Landowners and Approximate Holdings within 50 Miles of St. Marks, Florida</td>
<td></td>
</tr>
<tr>
<td>D. Mills and Dealers within 75 Miles of St. Marks, Florida</td>
<td></td>
</tr>
<tr>
<td>E. Correspondence from Potential Suppliers</td>
<td></td>
</tr>
<tr>
<td>F. Sample Wood Cutting, Timber Sale, and Purchasing Contracts</td>
<td></td>
</tr>
<tr>
<td>G. Wood Fired Boiler Emissions</td>
<td></td>
</tr>
<tr>
<td>H. Wood Fuel Storage</td>
<td></td>
</tr>
<tr>
<td>I. Wood Harvesting</td>
<td></td>
</tr>
<tr>
<td>J. Wood Fuel Handling</td>
<td></td>
</tr>
<tr>
<td>K. General Comments on Boilers and Wood Use</td>
<td></td>
</tr>
<tr>
<td>L. Wood Transportation by Water</td>
<td></td>
</tr>
</tbody>
</table>
DISCLAIMER

The contents of this report are offered as guidance. The Georgia Institute of Technology, The Engineering Experiment Station, F&W Forestry Services, Inc., and all technical sources referenced in this manual do not (a) make any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe on privately owned rights; (b) assume any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report. This report does not reflect official views or policy of the above mentioned institutions. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.
ABSTRACT

The use of biomass to displace conventional fuels for generation of electricity is being done at many utility plants throughout the country. Due to the large capital investment required to build a wood fuel power plant, every parameter must be thoroughly investigated.

In this Biomass Fuel Resource Study, a team consisting of the Georgia Institute of Technology Engineering Experiment Station (Georgia Tech), and F&W Forestry Services, Inc., investigated all of the major parameters affecting the availability and use of biomass resources for the firing of steam boilers at the Sam O. Purdom plant in St. Marks, Florida. The 40 MW retrofitted utility plant would augment the electrical supply capability of the City of Tallahassee, and provide an economic alternative to current gas and oil-fired power generation.
I.

EXECUTIVE SUMMARY
I. EXECUTIVE SUMMARY

This report represents the findings of a wood energy study carried out by a team composed of personnel from the Georgia Institute of Technology, Engineering Experiment Station, Technology Applications Laboratory (referred to as Georgia Tech) in Atlanta, Georgia, and the forestry consulting firm of F&W Forestry Services, Inc., of Gainesville, Florida, and Albany, Georgia. The purpose of the study was to expand upon a preliminary investigation carried out in 1982 by personnel from the City of Tallahassee who were examining the feasibility of retrofitting a wood-fired steam boiler to the existing Purdom Generating Station in St. Marks, Florida. Each of the pertinent aspects of the study are considered in detail in the various chapters of the report, and the highlights are presented in the paragraphs below.

1. The Wood Fuel Resource

The Tallahassee area has an abundance of woody biomass which could be economically used for fuel. All of the current price information indicates that hardwood chips could be bought and delivered to the plant for less than $20 per green ton. Over the next 20 years, the stumpage component of this price is not expected to rise significantly beyond general rate of inflation, since in the Southeast, supply will continue to be sufficient to meet demand. The future costs of fuel, labor, and equipment are, in general, unknowns which will determine the collection and transportation components of the delivered price.

The forest products industry within the Tallahassee timbershed produces roughly 4,800,000 green tons of raw material annually. Of this, about 1,900,000 green tons are from hardwood and low grade pine residue which are currently cost competitive with conventional fuels. With incentives and improved collection systems for the retrieval of small and low grade material, the yield from the same acreage now logged could be increased by
almost 1,600,000 green tons. An additional 1,600,000 green tons of fuelwood could be produced annually, on a sustained basis, if all of the area's net annual growth was harvested.

The harvesting of these 3,200,000 green tons of fuelwood represents both opportunities and drawbacks in terms of environmental alteration. The most positive aspect appears to be that fuelwood harvesting will make conversion of upland hardwood stands to pine operationally and economically feasible. The most serious problem is likely to be the loss of site productivity due to the depletion of nutrients, particularly phosphorous. Comprehensive management will be the key to minimizing negative aspects.

With regard to purchasing fuel for the Purdom power plant, there are several procurement structures under which the City of Tallahassee could operate. These range from direct wood purchasing and management of logging and hauling, to the employment of a single broker. There appears to be possibilities for significant long term supply agreements with one or more forest industry landowners, mills with low grade residue, and wood dealers with whole tree chipping crews.

Positive and negative aspects of the possible arrangements are discussed in detail in this report.

2. Analysis of Previous Work

The critique of the Preliminary Wood Biomass Availability and Feasibility Study submitted to the Tallahassee City Commission discusses the factors which must be considered in evaluating a wood-fired utility plant proposal for the first time. It is noted that this previous work provided a good starting point for the
present project. Besides approximate fuel availability figures, the budget cost figures enable the reader to understand the large magnitude of the project. Fuel cost trends for past, present, and future are provided for the purposes of approximating the cash flow of the project when it is analyzed in the final feasibility study.

Wood must be compared with the other fuels on a projected basis since the present fuel mix includes natural gas, oil, and nuclear fuels. Hence, it is not correct to attempt to justify wood entirely on the higher cost of only one of the other fuels in the mix.

The alternatives are to retrofit the present boilers for wood burning or to "do nothing." According to the City's Electrical Department, the present turbines and generators in Purdom units 1 through 4 have many more functional years left and are not scheduled to be retired in the near future. Hence, the large capital costs of retrofitting will have to be justified in the final feasibility analysis.

It is thus recommended that if the City Commission considers the findings of this study and its predecessor to be favorable, a detailed plant feasibility study should be carried out by a consulting engineer experienced in the design and construction of wood-fired steam plants. The detailed feasibility study would need to result in accurate numbers for cost estimates, an extensive analysis of the cost of power generated from wood, and some preliminary work on obtaining firm commitments for long term fuel supply.
3. Characteristics of the Fuel Resource

It has been estimated that approximately 500,000 green tons of wood will be required for the proposed wood boiler at the Purdom Generating Station. This material would arrive at the plant from a variety of sources, and quality control of the fuel will need to be closely monitored by plant personnel if the targets for electricity generation are to be achieved.

The effect moisture content (m.c.) has on the heating value of wood is significant. The higher the m.c., the lower the number of Btu's per pound; hence, a greater number of pounds of green wood are required by a boiler than are required of the same species of wood that is dry. Since only green wood is being considered, the lower heating value of the wood fuel being burned will vary from species to species. The analysis of the quantity and quality of wood biomass available in Florida indicates an average of 10.8 million Btu's available per ton (as delivered). The number of Btu's available would be an average significantly higher if the wood were dried. Drying apparatus adds mechanical complexity and cost to a large boiler plant, however, and for this reason it is recommended that the wood be burned "as received."

It is understood that the wood pellet manufacturing plant located in Liberty County, Florida, produces 6% moisture content wood pellets for the hospital in Chattahoochee, Florida, and has enough capacity to supply other wood fuel requirements in the area. However, due to the higher cost of the wood pellets and the special storage requirements, green wood chips and unprocessed residue are preferred over pellets for burning at the Purdom plant in St. Marks, Florida.

4. Transportation of Wood Fuel

The moisture content of wood increases the costs of truck transportation of the fuel. Barge transportation, in addition to
trucking, is a possible alternative since it is a mode which can move much larger quantities of wood at once from long distance suppliers. According to information gathered during this study, the price range of hardwood pulpwood stumpage in the vicinity of one of five ports (Pensacola, FL; Tampa, FL; Columbus, GA; Mobile, AL; and New Orleans, LA) is $1.25 to $1.96 per ton. The cost of delivered whole tree chips is in excess of $11.00 per ton. The delivered price for the chips includes the cost of stumpage, harvesting, and trucking the chips from the field to the barge loading dock. Additional costs to consider include the unloading of trucks; the loading of the barges; the leasing and operation costs of the barges; and unloading the barges.

The total of the additional costs mentioned in the previous paragraph would have to be less than the cost difference between the delivered wood fuel cost to the distant port and the present delivered costs to St. Marks by truck in order to show a net savings by barging wood. Hence, if the present delivered cost is $20 per ton, the total costs involving barging (load, unload, lease, insurance, fuel, etc.) could not exceed $9 per ton if the delivered cost to the distant port by truck is $11 per ton. According to the barge cost analysis, for a $9 per ton barging cost, the economical distance for barging is approximately 138 miles. The barge budget cost figures given by vendors are subject to change when the final negotiations occur.

The capital costs for the equipment to load and unload the barges significantly reduce any fuel cost savings. It is believed that barging should not be used since the marginal transportation savings are far less than the socioeconomic benefits of harvesting and transporting wood fuel locally.

-6-
5. Present Status of Electricity Generation from Wood

Pulp and paper mills have been generating electricity from "waste" for many years, since they have been faced with two major problems in their normal operations—the need for large amounts of electric power to run the mills and the need to deal with the wood residue resulting from the pulping operations.

As a result of the evolution of pulp and paper mill steam plants, wood-fired boilers have reached a state-of-the-art that has begun to rival that of many utility plants. Advances in control systems, emission control equipment, and combustion technology has resulted in sophisticated steam plant designs which are available from a number of manufacturers. Equipment is available from the "traditional" boiler vendors and a number of relative newcomers who have specialized in the design and construction of wood-fired plants. As was evident in the Preliminary Wood Biomass Availability and Feasibility Study, a number of firms would be willing to build a new wood boiler for the Purdom plant. Many of these firms have had previous experience in the construction of wood-fired power plants throughout the United States, and details of these plants have been researched as part of this study. Several wood-fired power plants have been in operation for some time in the Northwest and North Central states, and a 50 MW plant is now under construction in Burlington, Vermont.

As electricity generation from wood has become a more popular subject, pressures for the resource have begun to be felt in the Tallahassee area. A small (7.5 MW) electricity-from-wood plant is now being built in Monticello, Florida, and there are plans for an additional plant in Madison, Florida. In addition, wood fuels will be needed for the Chattahoochee, Florida hospital facility in Jackson County and the steam plant at Florida A&M University. The demand for fuel for all of these facilities must be considered during the final feasibility study for the Purdom plant, although
preliminary resource estimations conclude that there will be enough fuel available for all the plants.

6. Use of Garbage as Alternate Fuel

Approximately 200 tons per day of garbage is available in the Tallahassee area. At an average heating value of 5,500 Btu/lb, this represents an energy source of \( 57.3 \times 10^{11} \) Btu annually which could supply over 10% of the Purdom plant's needs. However, factors working against the use of municipal waste such as the cost of extra pollution control equipment, the cost of transporting the garbage to St. Marks, the inconsistency of the Btu/lb value, and the chances of explosion from hazardous materials must also be considered. Designers employing the latest technologies and municipal waste fired plant operators find these factors costly to deal with in the operation of complete power plants. Hence, garbage cannot compete with wood when both are available alternatives. Therefore, it is not recommended that the use of garbage as a fuel be seriously considered for the Purdom plant at this time.

7. Socioeconomic Impact of a Wood Fuel Project

The increased utilization of wood residues in the vicinity of Tallahassee will have a significant social and economic impact on the area. The new business of selling wood residues to the City of Tallahassee will create over 100 jobs for the lower income citizens who will receive on-the-job training in harvesting and handling wood. Using a multiplier of 2, the total impact for the construction phase of the plant is $6,300,000 of personal income for 180 employees. The direct impact of the harvest phase shows that over eight crews will be required if only whole tree chips are used. Using the multiplier, over 120 jobs will result from
the harvesting operation. If wood is not barged to St. Marks, over 75 truckloads of chips per day will be required at the Purdom plant. Hence, transportation jobs will also be created.

Other economic and social impacts include better prices for landowners who grow wood and are presently having to sell in a soft market. Sawmill owners will profit from selling their wood by-products in a more competitive market. Florida has always been a fuel importing state; however, by using its renewable wood resources to generate a portion of its electricity needs, it reduces its dependency on foreign fuel prices and limited supplies. The net savings from using wood as a fuel can apply to the costs of operating the city.

In summary, there is presently plenty of woody biomass fuel available in the Tallahassee timbershed to supply the proposed Purdom Generating Station for the next twenty (20) years at a price below that of conventional fuels. Even if and when all of the plants (Madison, Liberty County, Monticello, Florida A&M, Chattahoochee Hospital) start up, they will consume approximately 1,000,000 green tons of the 3,200,000 green tons potentially available annually. However, it should be noted that only a fraction of the area within the economical radius of these plants fall within the economical hauling area of the plant in St. Marks. Hence, the 1,000,000 green tons are not necessarily going to be harvested from the 3,200,000 green tons identified by F&W Forestry Services in this study. Therefore, it is conservative to say that at least 2,200,000 green tons will be available annually in the vicinity of the Purdom plant at competitive prices. This represents a resource of approximately four times more than will be needed.

The competitive prices of wood fuel versus coal and rapidly escalating natural gas and oil prices make wood more attractive than ever. F&W projects wood fuel prices to remain fairly level for many more years to come. According to DOE projections for conventional fuels, there is little
change expected in the future from the historically rapidly rising fuel costs. Hence, wood is the one fuel that is feasibly available and offers more long term economic security for Tallahassee than any other fuel.

The proposal to retrofit the Sam Purdom plant to use wood fuel with natural gas backup should be aggressively pursued. Using the information found in this Biomass Fuel Resource Study, Georgia Tech recommends that an in-depth feasibility study be conducted. The study should include several reputable boiler vendor detailed quotations, financial analyses of the cost of power, and firm commitments from wood fuel suppliers.
II.
INTRODUCTION
II. INTRODUCTION

The City Commission of the City of Tallahassee, Florida, has decided to investigate the possibility of retrofitting the Sam O. Purdom Power Plant with wood-fired facilities. The plant, located in St. Marks, Florida, has provided power to the city's electrical system for many years. After the submittal of two reports to the Commission which were entitled, Long-Range Power Supply Study (December 1981), and Preliminary Wood Biomass Availability and Feasibility Study (July 1982), it became more apparent to the Commission that a wood fuel-fired power plant might be cost effective to the city and economically favorable to the neighboring counties. The next step was to have an in-depth study conducted of the Biomass Fuel Resource in the vicinity of Tallahassee.

This report provides information on many of the major parameters involved including a review of the Preliminary Wood Biomass Availability and Feasibility Study presented in Section IIIA.

Section IIIB discusses the factors which affect the Btu content of wood. The Btu content of dry wood varies only a small amount from specie-to-specie. However, since green wood is proposed as the primary fuel, careful consideration has to be given to the Btu content due to the variable moisture content of the wood being used. Both the proximate and ultimate analysis should be performed to define relevant factors such as carbon, hydrogen, and ash content. Because the tons available of each specie in the area can be approximated, a more accurate analysis can be made of the total Btu's available.

Section IIIC presents the results of an investigation of other wood-fired utility plants operating or under construction in the United States. These plants vary in size, sources of fuels, and other parameters, yet they have similar modes of operation, methods of construction, and problems. Nonetheless, each plant is proof of the feasibility of using biomass as the primary fuel for electric power generation.

Section IIID includes an investigation of the potential for using river barges to transport wood chips up the St. Marks River to the power
plant. This method has been used before by paper companies that have plants near navigable waterways. Due to the lower cost of barging versus trucking chips on a per ton basis (provided the distances involved are long enough), barging wood is considered an alternative for wood supply from further distances. The capital costs of barge loading and unloading equipment are not considered in this report; however, it is believed that these costs would play a major role in determining the feasibility of barging.

Section III E considers the use of garbage as an alternative fuel. More specifically, this section addresses the possibility of firing a power plant with municipal solid waste (MSW) supplied from the area of Tallahassee, Florida. As in the procurement and combustion of wood, MSW has many variables to consider. MSW is usually inconsistent in Btu value, contains contaminants that can shut down a plant without notice, and can be dangerous to handle. This section also describes some of the state-of-the-art technologies that are using MSW for energy.

Section III F analyzes the economic and social impacts on the area of Tallahassee, Florida, that would result from the operation of a wood-fired power plant in the area. These impacts include better market prices for landowners who grow wood; increased sawmill profits from the sale of wood waste; new jobs for low income citizens in the procurement and harvesting of wood; keeping some city revenues in the local vicinity by purchasing less fuel from outside the State of Florida; and reduction of the threat of fuel curtailment. Expenses involved in a whole tree harvesting operation are outlined in detail for the benefit of private investors who will consider going into the wood procurement business. Problems that may occur are also addressed in this chapter.

Section IV contains the wood availability study produced by F&W Forestry Services, Inc. F&W has investigated the current and projected price of fuel wood available, the environmental effects of fuel wood harvesting, and identified the sources of fuel supply. This chapter is important to the project since it answers some basic questions that interested the City Commission enough to pursue the possibility of using
local wood to help generate electricity for the City.

The Appendices include further material to support the findings of this report. Details of the wood fuel resource are included as are reference articles dealing with the various technology issues which must be considered when a wood-fired steam plant is constructed.

Information presented in this report discusses the major factors in determining whether or not the idea of producing electricity from wood for the City of Tallahassee can be a reality. Careful consideration of these factors will enable the City Commission to arrive at the best decision for future action concerning this project.
III.

GEORGIA TECH CONTRACT REQUIREMENTS
A. REVIEW OF THE "PRELIMINARY WOOD BIOMASS AVAILABILITY AND FEASIBILITY STUDY"

The Preliminary Wood Biomass Availability and Feasibility Study published by the City of Tallahassee on July 15, 1982 covered two main areas. These were wood availability in the Tallahassee area and the cost of capital equipment to repower the Purdom plant with wood fuel. Other areas were discussed in less depth, and are generally less important to the overall feasibility of the project. The report was informative and contained an excellent data base, but certain aspects of the study needed to be examined in greater depth. These aspects are discussed in this review and addressed in the remainder of the report.

Executive Summary

This report is a preliminary review of fuel resources, transportation wood harvesting, wood fired boiler plant capital cost, and projected system economics. This section discusses gross fuel availability which provided a good start for the study team. It was decided by the team that the amount of existing hardwoods for whole tree chips, and pine for sawdust and bark residue needed more attention and these items are addressed in a later section of the report. Future projections of the wood market are highly dependent on growth of the pulp and saw timber industries, and projections of this growth will also be discussed at greater length.

The report discusses the need to store a 30 day to 60 day supply of wood on the ten acres available around the Purdom plant. Assuming an average pile height of ten feet (based on 20' high row shaped piles) and 75% coverage (25% for fire lanes and retrieval access), 36,000 tons of wood could be stored, or approximately 24 days storage. The Pulp and Paper Industry generally uses an average pile height of ten feet to prevent widespread spontaneous combustion episodes and to allow easier access to the fire areas should a fire develop. These guidelines are only used as rules of thumb, however, and it is possible to find much higher piles at
many pulp and paper mills. The danger of fire will depend on the actual mix of wood fuel to be used, as some forms (green sawdust, for example) have a tendency to produce higher in-pile temperatures than other forms (such as total tree chips). In the final analysis, experience will dictate the desirable fuel storage strategy, and in any event, 24 days storage should be adequate under most conditions, assuming no lengthy interruptions in supply. Since the supply of wood is less likely to be subjected to embargoes or strikes, the likelihood of supply interruption is low, but a remote "dead storage" area might be considered if practice indicates that more storage area is needed.

Good practice will dictate adequate fire protection for the wood piles including easily accessible hydrants and perhaps portable fire fighting apparatus. "No smoking" provisions should be adhered to, and reasonable security should be observed to prevent arson.

While price projections of competing fuels are of interest, these projections are often speculative at best. An attempt at quantification of competing fuel prices is worthwhile and these figures are shown in Table 1.

Energy Office Report

The values given for the "excess wood resource" were not specific as to their nature, and the actual wood available will be discussed in greater detail in a later section. This number is useful in assessing the potential resource for whole tree chipping. However, the annual growth rate includes small trees which may be too expensive to harvest.

The basis for economic evaluation is stated as No. 6 oil, however mention is made of natural gas use and cost. The fuel mix (gas/oil) at the plant is not noted. The energy equivalents of coal, oil, and wood can be clarified by translation into a uniform $ per million Btu basis, use of appropriate efficiencies, and projection of the particular quantity of each fuel used in the mix.

Competing wood fueled facilities and current use of the wood fuel by the sawmill and pulp and paper industry are a matter of concern regarding
availability.

The statement on the cost margin of wood over oil is not precise. Wood is economically viable if the total cost to generate power (fuel cost, cost of capital, operation, maintenance, etc.) is less than oil (fuel, cost of capital, O&M, etc.). Besides, only 15% of the 1982 fuel consumed by Tallahassee's system was oil; 80% was natural gas. Therefore, wood will have to be competitive with the average cost of other alternative fuels.

Other transportation systems (rail, barge) may aid in finding lower cost fuel and cause more competition between local suppliers, thereby lowering prices.

The employment estimates resulting from wood harvesting appear high. At approximately 41,000 annual tons per crew, 12 crews will be needed, with each crew hiring 8 to 10 crew members. In our opinion, less than 10 City employees will be required for fuel procurement. The option of contracting out part of the procurement process may reduce the cost.

**Conclusion**

The discussion of economics uses payback period to assess the viability of this investment.

"Payback Period" is a useful concept when comparing a replacement of an existing, working system with a new, more economical system. We suggest using Net Present Value, which is inversely proportional to the cost per kilowatt of power generated. The system which has the highest positive cash flow will have the highest NPV, the lowest cost of power delivered, and be the best choice.

The importance of economic parameters, in decreasing order, are (i) cost of wood fuel, (ii) plant utilization, and (iii) capital cost. A sensitivity analysis is useful in assessing their relative importance. Wood supplier survey responses offer a starting point for availability assessment. A consulting forester's report will add depth and overall perspective to the supply picture, and this is included in the present report.
The relative costs of chipping the waste left behind by logging operations vs burning it in the field are subject to particulars such as stumpage price, forest density, landowner's objectives, average tree size, etc. The Georgia Forestry Commission claims that site preparation costs for preparing and planting land after a typical logging operation are $150 to $200 per acre. Of this, only $3 to $5 per acre is attributable to the burning operation. If the waste were chipped and used for fuel, the remainder of the operations would still be needed, saving only the $3 to $5 per acre in burning cost. The cost to chip the material is not easily quantified. Existing chippers are designed for large, whole trees. Limbs, branches, and stumps are hard to handle and have lower throughput. One might guess that the cost is in excess of $30 per wet ton for chipping field waste; however, no firm data exists on this operation.

The capital cost estimates vary by approximately a factor of two, not suprising due to the variation in detail and equipment specification shown by the prospective vendors. More detailed specifications are needed to obtain more dependable quotes.
<table>
<thead>
<tr>
<th>Year</th>
<th>National Domestic Oil</th>
<th>Actual 3 (Projected)</th>
<th>National Wellhead Gas</th>
<th>Actual 3 (Projected)</th>
<th>National Nine-Month Coal</th>
<th>Actual 3 (Projected)</th>
<th>1983 Delivered Wood 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>$1.17</td>
<td>.38</td>
<td>.46</td>
<td></td>
<td></td>
<td></td>
<td>$2.00</td>
</tr>
<tr>
<td>1973</td>
<td>1.12</td>
<td>.37</td>
<td>.67</td>
<td></td>
<td></td>
<td></td>
<td>2.00</td>
</tr>
<tr>
<td>1979</td>
<td>2.36</td>
<td>1.24</td>
<td>1.26</td>
<td></td>
<td></td>
<td></td>
<td>2.00</td>
</tr>
<tr>
<td>1980</td>
<td>3.64</td>
<td>1.45</td>
<td>1.29</td>
<td></td>
<td></td>
<td></td>
<td>2.06</td>
</tr>
<tr>
<td>1983</td>
<td>4.80</td>
<td>4.18 5</td>
<td>2.87 5</td>
<td>1.32</td>
<td>2.30 5</td>
<td>2.06 2</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>5.58</td>
<td>4.86</td>
<td>4.34 4</td>
<td>1.34</td>
<td>2.34</td>
<td>2.06</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>8.18</td>
<td>7.12</td>
<td>5.95</td>
<td>1.43</td>
<td>2.50</td>
<td>2.06</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>11.55</td>
<td>10.05</td>
<td>6.79</td>
<td>1.47</td>
<td>2.57</td>
<td>2.20</td>
<td></td>
</tr>
</tbody>
</table>

Footnotes

1. DOE 1981 Annual Report to Congress, #DOE/EIA-0173(81)/1-3
3. Figures are based on the 1983 actual cost to the City of Tallahassee and projected into the future using DOE escalation rates.
4. The present natural gas contract ends in 1985; hence, the City will then begin paying a price comparable to the rest of the nation.
5. Oil currently costs between $4.04-$4.32 per million Btu, depending upon the sulfur content. The table uses $4.18/MMBtu as an average oil price in 1983. Coal is presently costing between $1.85 (spot market) and $2.60/MMBtu depending on its sulfur content. An average cost of $2.30/MMBtu is used in the table.

Note that the actual 1983 prices are escalated to future prices at the same rate the DOE figures for the same fuels are projected nationally.
B. FACTORS AFFECTING THE BTU CONTENT OF WOOD

The chemical composition of wood varies little from one species to another. As shown in Table B.1, the ultimate analyses for different species are virtually indistinguishable. On this basis, we would expect the heat content of different species to be quite similar.

In fact, when wood is dried there is little species-to-species variation in Btu content. What little variation there is is due mainly to differences in resin content. Thus if the wood were oven dried, the species mix would have little effect on the total weight of the fuel required to fire a power plant.

However, the green wood derived from different species does differ significantly in its moisture content, and the amount of water contained in wood fuel has a major influence on its effective heat value in a boiler. Estimates of the total fuel required by a wood fired power plant (WFPP) thus mandate detailed analysis of the moisture content of the wood it is likely to burn.

Two methods exist for defining moisture content. The first, known as the dry basis, expresses the weight of the wood as the percentage of the wood's oven-dry weight. The second, called the wet basis, indicates the weight of water in the wood as a percentage of its total green weight. Figure B.1 shows the relationship between these two systems. At moisture levels normally expected of green wood (40 to 60 percent, wet basis), small increments in water content result in large increases in dry basis percentages. For example, 50 percent wet basis is equivalent to 100 percent dry basis. The increase to 67 percent wet basis raises the dry basis figure to 200 percent. The wet basis is preferred for engineering computation and is used throughout this report unless otherwise noted.

The moisture content (M.C.) of wood on the wet basis is to be calculated as the weight of water in a wood sample divided by the total weight of the sample:

\[
M.C. \text{ (wet basis)} \% = \frac{100 \times \text{weight of water}}{\text{weight of dry wood} + \text{weight of water}}
\]
TABLE B.1: CHEMICAL ANALYSIS OF SOME DIFFERENT SPECIES

ULTIMATE ANALYSIS
(Wood fiber excluding waste and bark)

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>H₂</th>
<th>S</th>
<th>O₂</th>
<th>N</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Pine</td>
<td>52.55</td>
<td>6.08</td>
<td>-</td>
<td>41.25</td>
<td>-</td>
<td>0.12</td>
</tr>
<tr>
<td>White Ash</td>
<td>49.73</td>
<td>6.93</td>
<td>-</td>
<td>43.04</td>
<td>-</td>
<td>0.30</td>
</tr>
<tr>
<td>Beech</td>
<td>51.64</td>
<td>6.26</td>
<td>-</td>
<td>41.45</td>
<td>-</td>
<td>0.65</td>
</tr>
<tr>
<td>White Birch</td>
<td>49.77</td>
<td>6.49</td>
<td>-</td>
<td>43.45</td>
<td>-</td>
<td>0.29</td>
</tr>
<tr>
<td>Maple</td>
<td>50.64</td>
<td>6.02</td>
<td>-</td>
<td>41.74</td>
<td>0.25</td>
<td>1.35</td>
</tr>
<tr>
<td>Red Oak</td>
<td>49.49</td>
<td>6.62</td>
<td>-</td>
<td>43.74</td>
<td>-</td>
<td>0.15</td>
</tr>
<tr>
<td>Poplar</td>
<td>51.64</td>
<td>6.26</td>
<td>-</td>
<td>41.45</td>
<td>-</td>
<td>0.65</td>
</tr>
</tbody>
</table>
Example: A one pound sample of wood is found to be 50% M.C. (wet basis). The results of laboratory analysis showed:

water: \[ \frac{1}{2} \text{ pound } \text{H}_2\text{O} \]

wood: \[ \frac{1}{2} \text{ pound bone dry wood} \]

\[ \text{M.C.} = \frac{\frac{1}{2} \text{ lb}}{\left(\frac{1}{2} + \frac{1}{2}\right) \text{ lb}} \times 100 = 50\% \text{ wet basis} \]

The dry basis moisture content is favored by foresters and producer/manufacturers of wood products (a prime source of mill residues). The M.C. of wood on the dry basis is the fractional water content or the weight of water divided by the sample weight when dried:

\[ \text{Moisture Content (dry basis)} \% = \frac{\text{weight of water}}{\text{weight of dry wood}} \times 100 \]

Using the same example, a one pound sample which is half water and half bone dry wood by weight would have a wet weight of one pound, a bone dry weight of one half pound, and a M.C., dry basis, of 100%.

\[ \text{M.C. (dry basis)} \% = \frac{\frac{1}{2} \text{ lb water}}{\frac{1}{2} \text{ lb bone dry wood}} \times 100 \]

To find wet basis from dry basis:

\[ \text{M.C. (wet basis)} \% = \frac{\text{M.C. Dry}}{\text{M.C. Dry} + 100} \]

To find dry basis from wet basis:

\[ \text{M.C. (dry basis)} \% = 100 \times \frac{\text{M.C. Wet}}{100 - \text{M.C. Wet}} \]

\[ -23- \]
Figure B.1 illustrates graphically the relationship between wet basis and dry basis moisture contents. Table B.2 covers the normally encountered range of conversion.

Moisture content affects the heat value of the wood in two ways. First, the energy required to heat the water in the wood to boiling (one Btu per pound of water per degree Fahrenheit) and to evaporate the water (1,000 Btu per pound of water) must come from the heat content of the wood fiber. A useful rule of thumb subtracts 1,100 Btu per pound of water in the fuel. This heat is normally lost from the facility via water vapor in the stack gases.

Second, water in the wood will lower the temperature of the combustion gases from which energy is extracted in the boiler. Perfectly dry wood may produce temperatures in excess of 3,000 degrees Fahrenheit. Usually, wood that is 50 percent moisture will produce gases at only about 2,500°F. Since the efficiency of the boiler depends in large measure on the difference between the temperature of the input and the exhaust gases, a reduction of 500 degrees in the temperature of the input gas will significantly raise wood requirements. Figure B.2 indicates the relation between fuel moisture content and the efficiency of the boiler. To produce a given amount of steam requires nearly 30 percent more wood at 50 percent moisture content than would be required if the fuel were perfectly dry. Figure B.3 indicates the effect of the moisture of wood on heating value.

Those concerned with power generation most often consider moisture content on a wet basis because the wet basis moisture content directly reflects the fuel value of wood. Knowledge of both methods of calculating moisture content will be important when arranging wood fuel purchases—especially mill residues.
FIGURE B.1: RELATION BETWEEN MOISTURE CONTENT EXPRESSED ON DRY AND WET BASIS

FORMULA: $MC_{O.D.} = \frac{100 \times MC_{O.W.}}{100 - MC_{O.W.}}$

$MC_{O.W.} = \frac{100 \times MC_{O.D.}}{100 + MC_{O.D.}}$
Table B.2

Moisture Content: Comparison Wet/Dry Basis (1)

<table>
<thead>
<tr>
<th>Wet Basis</th>
<th>Dry Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>10%</td>
<td>11%</td>
</tr>
<tr>
<td>15%</td>
<td>18%</td>
</tr>
<tr>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>30%</td>
<td>43%</td>
</tr>
<tr>
<td>40%</td>
<td>67%</td>
</tr>
<tr>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>60%</td>
<td>150%</td>
</tr>
</tbody>
</table>

Unless noted, all moisture contents in this volume are cited on a wet basis.
FIGURE B.2: EFFECTS OF FUEL MOISTURE ON BOILER EFFICIENCY

BOILER EFFICIENCY (%)

RESIDUE MOISTURE CONTENT (%) (2)

TYPICAL BLACKOUT AREA
FIGURE B.3: EFFECT OF MOISTURE ON HEATING

% Moisture – Wet Basis

9,500 Btu/lb dry wood

9,000 Btu/lb dry wood

8,500 Btu/lb dry wood

As-Fired Heating Value – Btu/lb

0 20 40 60 80 100

0 2,000 4,000 6,000 8,000 10,000
Table B.3 shows higher heat values for various wood fuels. High moisture content fuelstock reduces combustion efficiency. The vaporization of water to steam requires a heat input of 1,100 Btu/lb of water. Energy which could otherwise be useful in steam production is thus diverted to drying the wood fuel in the combustion chamber prior to actual burning of the wood. Overall boiler capacity is affected as illustrated in Figure B.2. Because of the cost of equipment for pre-drying the fuel is high, use of green wood fuels (M.C. between 50% and 65%) is often justifiable.

The species of the tree, the month of its harvest, and the mode of its storage at the WFPP can all influence the moisture content in the wood fuel. Information on the quality of biomass in Florida was calculated from the data supplied by F&W Forestry Services, Inc. on December 17, 1982 and is presented in Table B.4. Note that moisture content of the Florida species range from 42-91% for green wood. Also note that the available heat per cord of green wood varies from 21 to 29 million Btu's per solid cord.

Since the data in Table B.4 is taken from average volumes of all species found in the State, there will be some error in the fuel analysis since it is recommended that the WFPP burn only the cheaper hardwoods. The 179,745,000 ft³ (54,027 x 10⁹ Btu's) of net annual growth of Florida hardwoods indicates that the WFPP may be attractive to North Florida if the wood price of the fuel is acceptable.

Moisture content will also change during storage. Moisture variations are hard to quantify because of unpredictable weather and different methods of storage. If the wood is stored inside, the moisture content will normally decrease because the wood is protected from rain. However, if the wood is stored outside without cover, the common procedure for a large plant, precipitation may increase the moisture content. Green wood can reportedly be dried to 25 percent (wet basis) after a year of outside storage (Fryling 1966, pp. 14-20), but this has not been demonstrated in Florida.

The exhaust gas from a boiler could, in theory, be used to dry the wood before it is introduced into the boiler. However, current
Table B.3

Higher Heat Values of Some Wood Fuels (1)

<table>
<thead>
<tr>
<th>Wood Fuel</th>
<th>Moisture Content</th>
<th>Higher Heating Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Tree Chips</td>
<td>50%</td>
<td>4,500</td>
</tr>
<tr>
<td>Dry Planer Shavings</td>
<td>13%</td>
<td>7,800</td>
</tr>
<tr>
<td>Green Sawdust</td>
<td>50%</td>
<td>4,500</td>
</tr>
<tr>
<td>Dry Sawdust</td>
<td>13%</td>
<td>7,800</td>
</tr>
<tr>
<td>Wood Pellets</td>
<td>10%</td>
<td>8,100</td>
</tr>
<tr>
<td>Species</td>
<td>Net Annual Growth ft³ x 10³</td>
<td>Weight per Green Cord Containing 90 ft³ of Solid Wood, lbs</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>Softwood:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow Pine</td>
<td>543,892</td>
<td>4770</td>
</tr>
<tr>
<td>Cypress</td>
<td>58,506</td>
<td>5000</td>
</tr>
<tr>
<td>Other Eastern Softwoods*</td>
<td>3,355</td>
<td>4600</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>605,753</td>
<td></td>
</tr>
<tr>
<td>Hardwood:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White and Red Oaks</td>
<td>61,415</td>
<td>5720</td>
</tr>
<tr>
<td>Hickory</td>
<td>3,960</td>
<td>5670</td>
</tr>
<tr>
<td>Hard Maple</td>
<td>489</td>
<td>450</td>
</tr>
<tr>
<td>Sweetgum</td>
<td>17,696</td>
<td>4860</td>
</tr>
<tr>
<td>Ash Walnut and Black Cherry</td>
<td>8,840</td>
<td>4320</td>
</tr>
<tr>
<td>Yellow Popular</td>
<td>2,336</td>
<td>5130</td>
</tr>
<tr>
<td>Tupelo and Blackjam</td>
<td>34,417</td>
<td>4950</td>
</tr>
<tr>
<td>Bay Magnolia</td>
<td>25,702</td>
<td>4950</td>
</tr>
<tr>
<td>Other Eastern Hardwoods*</td>
<td>24,890</td>
<td>4950</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>179,745</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>785,498</td>
<td></td>
</tr>
</tbody>
</table>

*Collections of rare species which represent, by weight, only a small percentage of the total
technologies may pose problems of particulate emissions and precombustion of the wood. We are not aware of any current installations drying fuel wood on a scale of 500,000 green tons per year. The potential effect of reduced moisture will be illustrated later.

**Particle Size**

The particle size of wood fuel entering the combustion chamber (more specifically the surface area/mass ratio of the discrete pieces), will have great effect on combustion efficiency, boiler design, and excess air requirements. Improperly sized fuel may not burn completely and valuable heat energy can be lost in the form of carbon rich bottom ash and excess flyash. Combustion units are designed specifically for certain size ranges of fuels, and close attention should be paid to maintaining particle equipment size requirements.

**Wood Ash**

Wood contains, in addition to organic materials, small quantities of minerals that are not burned in the combustion process and are left as ash. The amount of ash from wood is variable and depends on the following factors:

a. The species of the tree and where it was grown
b. The proportion of stemwood to bark
c. The methods of logging and handling that produced the wood fuel

The ash content of stemwood is lower than that of barkwood. Ash contents are based on specimens dried to zero moisture content. Typical values for U.S. forests are as follows:

Stemwood - 0.1 - 1.3%
Barkwood - 0.5 - 5.0%
Logging procedures such as dragging the logs on soil or mud or transporting them in salt water can increase the ash content to 10%. Wood generally contains less ash than coal and lignites, and even heavy fuel oils. However, wood has more ash than distillate fuel.

Note that the total weight of ash for both softwood and hardwood growing in Florida annually is $138.7 \times 10^6$ pounds. This computes to approximately 0.35% of the total weight of green wood. However, since mostly hardwood will be used to fuel the WFPP boiler, the weighted mix of hardwood species in Table B.4 resulted in 0.43% ash when completely burned.

**Composition of Ash**

The published data on the composition of the ash in wood shows wide variations in concentrations of several major constituents. In general, the main component of the ash is CaO which accounts for 30% to 80% of the ash and is typically present at about 50%. Many wood ashes contain 10% to 40% of K$_2$O, however some data show only a fraction of a percent.

Other components such as Na$_2$O, SiO$_2$, and Al$_2$O$_3$ also vary widely between zero and 30%. It is possible that these components are not integral parts of the wood structure but derive from the sand that clings to the wood during logging and transportation. Mg is found between a fraction of a percent to 15%, with typical values of 5% to 8%. Fe$_2$O$_3$ is found in small percentages, between 0.5% to 3% (typically 1.5%-2.0%). Other minerals such as MnO, TiO$_2$, etc., are found in small fractions of a percent or only in traces.

**Summary**

As the preceding sections have shown, wood can be a highly variable fuel whose quality depends on a number of factors. The variable of most interest is moisture content, but it is highly likely that the proposed wood-fired power plant will depend heavily on green wood as a fuel. This wood can be burned quite satisfactorily in boiler designs that are
currently available, so long as good operating practices are followed and adequate attention is paid to boiler maintenance and operator training.

In addition, should the City of Tallahassee decide to build a wood-fired boiler, it will be imperative that wood contacts be written with suppliers which specify acceptable quality for the wood received. This fuel should be monitored constantly and spot analyses of the fuel should be made and recorded, as is done with conventional fuels. Published standards are currently under development by the American Society of Testing and Materials (ASTM) and these should be useful as guidelines.
REFERENCES - SECTION III B


C. DESCRIPTION OF WOOD FIRED UTILITY PLANTS

The rising costs of conventional fossil fuels have caused many industries throughout the United States to seriously consider alternative fuels for the operation of their plants. The utility industry is no exception, and this section consists of data sheets on wood fired utility plants that are presently either in operation or under construction. The data sheets include information on boilers, fuels, transportation, storage, economics, and ash handling. Also, comments are made that are relevant to that particular plant. Each plant that is in operation has proven to be a successful part of the community it serves.

The concept of using wood as energy for industrial power is as old as industry itself. The United States and other industrial nations around the world know that wood fuels can be used to effectively generate electrical power. The energy crisis of 1974 was not necessarily when the current interest in biomass fuels began, as is evidenced by the 230 boilers, with wood burning capability, sold in the United States between 1965 and 1975 (1). The largest shift to wood fuel is in the forest products industry. In 1974, 1.3 quads (1 x 10^{15} Btu) of gas and oil fuels were used by the forest products industry, the majority by the pulp and paper manufacturing groups (2).

The forest products industry in the area of Tallahassee, Florida, is presently burning wood because of its large annual energy requirements, ready access to residues, and expertise in the use of wood fuels. Most of these plants have installed an electric generating capacity in the range of 10 to 20 megawatts (MW) (3,4).

Since 1974, nonforest industries have effectively pursued the use of biomass fuels. The amount of electric generating capacity has ranged from 1 MW to 50 MW; the largest being the 50 MW utility plant under construction in Vermont. The feedstock requirements for the plant will be approximately 2,000 green tons per day (550,000 green tons annually).

Of the plants mentioned in this report, the one most similar in size to the proposed plant is the 40 MW Kettle Falls Generation Station. The
500,000 tons per year of wood fuel required by this plant will come from local sawmills. This plant will be on line in the Fall of 1983 and supply the electrical needs of 18,000 customers. Its fuel cost is unknown at this time.

The Lake Superior District Power Company is generating 25 MW to 30 MW from two 20 MW units. Its low wood fuel cost of $3.00 per ton delivered gives the project an attractive simple payback period of 5 years.
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Name: Gator Gasifier Co., Dunellon, Florida
Location: Monticello and Madison, Florida
Size: Total 15 MW net output
Construction Dates: Start - 1982 Monticello
Startup Date: N/A
Boilers: Size - both are 80,000 lb/hr steam boilers
Turnkey boiler; Contractor-Perry Smith Co. of Chattanooga, TN
Turbine: Two 7.5 MW each
Fuel: 30% peanut hulls and 70% wood chips
120,000 tons/year of wood consumed per unit
$12.50 to $13.00 per ton of wood; 2/3 necessary fuel has been committed
Transportation Mode: Truck
Storage: N/A
Operational Cost: N/A
Economics: Florida Power Corporation buys back electricity at 6¢/kWh
and is interested in purchasing up to 80 MW of biomass produced power over the next 10 years
Ash Handling: N/A
Comments: Both of these sites will compete for fuel with the proposed wood fired plant at St. Marks
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Name: Florida A&M University
Location: Tallahassee, Florida
Supplies Steam To: Florida A&M University
Feasibility Study Consultant: Energy Management Consultants, Inc.
Birmingham, AL
205/823-4209
Size: N/A megawatt net output
Construction Dates: N/A
Startup Date: N/A
Boilers: Size - One 446 boiler horsepower (bhp) and one 877 bhp
Type - HRT
Pressure - 100 psig
Turbines: None
Fuel Source: $12-$15/ton in 1981 dollars
Type - sawmill by-products
Transportation Mode: Live bottom trailers
Storage: Utilize existing vacant building proposed
Economics: Net estimated first year energy savings $129,780
Cost of Plant - $2,353,100
Internal Rate of Return - 16.8%
Ash Collection: Two multi-tube cyclones operating in series
Comments: Steam heat only, generation of electricity was not recommended
Steam Load: Off-season 15,000 lb/hr, 32,000 lb/hr peak, 20,000 summer
Max. wood fired rating 25,000 lb/hr and use natural gas to shave peaks
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Name: Liberty Power Co., Inc.
Location: Hosford, Florida
Power Supplied To: Florida Power Corporation
Plant Contact:
Name: Earl Yancy
Phone: 904/643-2292
Construction Dates:
Start - 7/83; Finish - 2/84
Startup Date: 2/84
Boilers: N/A
Turbine: 7.5 MW
Fuel:
Cost - $13/ton, Types - wood chips, peanut hulls
Transportation Mode:
Storage: N/A
Operational Cost: N/A
Economics:
Energy saved $ NA/yr
Cost of Plant NA
Ash Handling: NA Fertilizer
Comments: This plant would compete for wood fuel with the plant at St. Marks, Florida, if both are built
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Name: Health and Rehabilitative Services at Chattahoochee State Hospital
Location: Chattahoochee, Florida in Jackson County
Supplied by: Wood pellet refinery owned by Guaranty Fuels, Inc. in Liberty County
Contacts: Health & Rehabilitation Services (state agency)
Name: Danny Lipscomb, Plant Manager
Phone: 904/643-2292
Wood Pellet Supply Contact: Andrew Livingston, Independence, Kansas 316/331-0027
Construction Dates: Began tests on first completed boiler in February 1983
Startup Date: 10/82 first pellets delivered
Boilers: Two boilers, 60,000 lb/hr each, Riley Stoker Suspension Burners
Turbines: None
Fuel Source: Local sawmill, pellets produced from sawmill residue
Wood pellet cost $59/ton delivered, 2-year contract
Transportation Mode: Truck
Storage: Storage bins, 8500 Btu/lb, 6% moisture content, supply capacity ranges from 50,000 tons/year minimum to 87,000 tons/year maximum
Economics: Energy cost savings $800,000/year
Cost of Plant $2,000,000 for both 60,000 lb/hr boiler systems
Ash: Ash content in fuel is 1.29% received and 1.38% dry
Comments: Present application is to use steam for heating. Convert coal boiler to wood boiler; 3,000 tons produced in last 4 months with no die wear according to pellet manufacturer. Due to the present lack of adequate storage capacity, sheltering the dry pellets from the weather requires more consideration.
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

| Plant Name: | Burlington Electric |
| Location: | Burlington, Vermont |
| Supplies Power To: | City of Burlington |
| Size: | 50 MW |
| Construction Dates: | 35% completed in January 1983 |
| Startup Date: | 1984 |
| Contact: | Thomas R. Carr, Burlington Electric Department, Burlington, VT |
| Boilers: | Size 480,000 lb/hr steam, 1,275 psig, 950°F, 500,000 tons/yr of wood @ 55% moisture content consumed at a 70% capacity factor. The furnace has a traveling grate. |
| Fuel: | Source - Whole tree harvesters. Type - wood chips. |
| Transportation Mode: | By order of the Vermont Public Service Board, 75% of the wood fuel is to be transported to the plant by rail. (Central Vermont Railroad). Rail cars are loaded from trucks at a satellite railroad yard 35 miles north of the new plant |
| Storage: | 30 day pile at the station and 1 week supply at the satellite yard. |
| Unloading: | Bottom dump railroad cars |
| Economics: | Cost of the plant is less than the estimated $85,000,000 Bonds were issued to finance the plant |
| Ash Handling: | Mechanical collector and electrostatic precipitator; emissions are guaranteed to be 0.003 gr/acf or about 22 tons/yr at rated capacity |
| Comments: | The new wood-fired plant will replace the old. The plant will also have the ability to burn pulverized coal. The plant can be converted to burn coal within an 8 week period. The wood availability study was conducted by Booz Allen and Hamilton Inc., Bethesda, MD. |
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Name: Kettle Falls Generation Station
Ownership: W.P. Energy, Inc., a subsidiary of the Washington Water Power
Company will be sole owner of the facility.
Prime
Plant Contacts: Gary Normoyle and Robert Escalante
Washington Water Power Co.
1983 (Fall) Plant will be completed.
For Further
Information: Contact Washington Water Power Public Relations Department
P.O. 3727, Spokane, WA 99220. 489/0500-Ext. 2465
Location: The Kettle Falls Generating Station is located in northern
Stevens County, 3 miles northwest of Kettle Falls and 86
miles north of Spokane in the State of Washington. The
plant, first of its kind to be constructed for electric
generation, will utilize wood-waste, with natural gas
available as a back-up fuel.
Capacity: 40 megawatts, utilizing one unit. A boiler will produce
steam to generate electric energy by means of turbine genera-
tor. A plant of this capacity, operating at a 75 percent plant
factor capacity, will generate enough electricity to supply
the needs of 18,000 average Washington Water Power customers.
Estimated Cost: $70 million
Waste Wood
Supply: Northeast Washington and Canadian sources
Wood Usage: 500,000 tons per year (bark, sawdust and other mill waste)
Wood Shipment: Independent contractors.
Water Source: A well located in Kettle Falls.
Air Pollution
System: The system is designed to meet all federal, state and local
air quality requirements. Electrostatic precipitators will
be installed to remove particulate matter.
Condenser Heat
Rejection: Mechanical draft cooling towers.
Solid Waste
Disposal: Nearby land-fill for ash.
Kettle Falls (Continued)

Stack Height: 180 feet

Transmission Line: A 115kv transmission line will be interconnected with company lines in the area.

Land Use: Forty-six acres will be used for the plant and on-site facilities.

Construction Workforce: Average 80-90.

Permanent Employees: Approximately 30.
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Name: Madera Generating Station
Owner: California Power & Light, San Francisco, CA
Location: Madera, California (San Joaquin Valley)
Supplies Power To: Pacific Gas & Electric
Size: 50 megawatt net output
Construction Dates: Start 6/1/83 Finish 12/30/84
Startup Date: 12/30/84
Contact: Mr. Robert Whitley, Chief Engineer
Boilers: Two 250,000 lb/hr each, Type-Traveling grate stoker
         Make N/A
Turbines: Two 25 MW General Electric
Fuel: Source - cotton stalks, wood waste, vineyard prunings,
      orchard trimmings, nutshells
      Cost - $15 to $30 per ton
      Supply - 500,000 tons/yr
Transportation Mode: Truck
Storage: Open Piles, Day Bunkers
Crew: 4 full-time crews
Operational Cost: N/A
Economics: Energy saved $/yr N/A
           Cost of Plant-N/A
Ash Handling: N/A
Comments: Financing of plant currently under negotiation. The plant will be built when financing is placed.
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Owners: Lake Superior District Power Company
Location: South shore of Lake Superior in Wisconsin
Present Output: 25-30 MW
Startup Date: 1979 (Plant designed in 1950)
Contact: J.A. Musso, Northern States Power Company
Boilers: Two 20 MW units
Fuel Source: Local Wood milling operations such as Louisiana-Pacific Corp. Type - wood chips
Cost-$1.00/ton plus transportation costs of $2/ton for a total of $3/ton
Approximately 375,000 tons/year are required for 30 MW production.
Transportation Mode: Trucked within 60 mile radius
Storage: Front end loader pushes open storage against shear wall near live bottom drag chain
Economics: Energy saved - Fuel costs were initially cut in half
Cost of Plant: $800,000 for wood handling (1979)
$50,000 Boiler modification
5 year payback period
Comments: Wood is co-fired with coal, the ratio in 1983 is 75% wood.
5 year contract with Louisiana-Pacific Corp. (20,000 tons/year) Overfire occurs higher up in boiler rather than at grate level to reduce fly ash
DATA SHEET FOR A WOOD FIRED UTILITY PLANT

Plant Name: French Island Power Plant
Plant Owners: Northern States Power Company, La Crosse, Wisconsin
Location: Southern tip of French Island in Lacrosse, Wisconsin
Size: 15 MW, 43,000 MWh/yr
Construction Dates: Start 11/1/80, Finish-10/1/81
Startup Date: 12/1/81
Plant Contacts: J.R. Zylkowski, Northern States Power Company
Boilers: One 125,000-150,000 lb/hr steam, thermal efficiency 71.5%-75.8%
Furnace: Fluidized-bed combustor 7.5 x 10⁶ Btu/hr
Furnace temperature - 2000°F to 2100°F
Turbines: Size 13.5-16.0 MW
Fuel Source: Local sawmills, type - bark, wood, sawdust
Fuel cost - $0.70/million Btu's in 1982 dollars
53,000 to 81,000 tons/yr of wood consumed
Transportation Mode: 5-20 covered truck vans/day
Storage: 1 day bin with auger bottom
Economics: Operational cost-1.5¢/kWh
Cost of Plant-$6,500,000 financed entirely by private funds
Simple Payback Period-10 to 12 years
Ash Handling: 730-928 lb/hr, 1.5-1.8% by weight, 4 collection points
Comments: 5 day/week operation
2 to 4 hours of natural gas burning during "cold start".
Moisture analyzer is used on the delivered wood fuel.
Minimum turndown-2:1.
Gravel-bed filter system for final particulate control.
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Owners: Molokai Electric Company
Location: Island of Molokai in the Hawaiian Islands
Size: 4 MW; 5 MW peak demand, 3 MW average load
Construction Dates: Start-N.A., Finish-N.A.
Startup Date: May 1982
Contact: T. Vorfeld, Thermal Engineering Corporation
Boilers Size-40,000 lb/hr, No.-one, type-N.A.
Turbines: 4 MW condensing turbine
Fuel: Type-Straw, wood chips, pineapple waste, waste paper with coal facilities for standby
Economics: Energy Saved: N.A.
Cost of Plant N.A.
Ash Handling: N.A.
Comments: 1/2 the fuel supply in straw from Molokai Ranch Ltd.
Suspension firing and erratic fuel feeding causes furnace puffing
DATA SHEET FOR A
WOOD FIRED UTILITY PLANT

Plant Name: Eugene Water and Electric Board (EWEB)
Location: 111 miles south of Portland, Oregon in Lane County
Supplies Steam To: The City of Eugene, Oregon
Plant Contacts: Mr. Herbert Hunt, (EWEB), 503-484-2411
Boiler Capacities: One 120,000 lb/hr, and one 180,000 lb/hr steam rate.
Boiler Type: N/A
Fuel Source: Sawdust and wood waste from forest industries in the City of Eugene and surrounding area. Firing rate is 126,000 tons/year at present capacity. Maximum capacity is 1,000 tons/day (350,000 tons/year).
Transportation Mode: Self dumping trucks, 5-10 mile range. Wood waste is generally hogged by a hammer mill at the wood processing facility before delivery to EWEB.
Storage: Outdoor storage pile where independent fuel dealers unload their trucks.
Economics: Energy saved $ /yr N/A
Cost of Plant N/A
Average fuel cost - $9.52/ton
Ash Handling: 1% ash is collected by multicyclone collectors and hauled to a land fill
Comments: Steam is sold via a 9 mile system in the City of Eugene. Electricity has not been generated in over 2 years due to the lower cost of hydro-power.
REFERENCES - SECTION IIIC


D. BARGE TRANSPORTATION

Transporting wood by barge to a utility plant for the purpose of burning it in boilers to make steam for generating electricity is not a common practice in the United States. Most plants which utilize biomass energy have the fuel brought to the site by truck or, as in the case with industries, such as timber mills, the refuse is generated on site and transferred to the boiler conveyor systems.

Paper mill sites along the coast use the waterways for transporting materials to and from the plants. Scott Paper Company and International Paper Company have transported wood chips down the Mobile River to their plants in Mobile, Alabama according to water transportation companies in the area. The method used for maximizing the load per barge consisted of building up the sides of the barges with wire fences. In this manner they were able to substantially increase the volume carried and partially make up for the low density of the chips. This method can be used with barges in the Florida waterways if caution is taken for bridge clearances, navigability, and stability to keep the barge from rolling over in rough seas.

Navigable waterways flowing from dense forest areas to the St. Marks River include the Chattahoochee River and Apalachicola Rivers, Choctawhatchee River, and the Gulf of Mexico. Wood can be supplied by barge from as far north as Columbus, Georgia and as far west as Mobile, Alabama. The companies that took immediate interest in working with the City of Tallahassee mailed information (see Appendix L) to Georgia Tech allowing Tech to analyze the potential of barging wood.

Loading equipment must be available at each loading dock. Chip vans will be needed to bring the wood from the field to the loading dock. A hydraulic lift will unload the trucks into a hopper which will have a live bottom to convey the wood to docked barges. Belt conveyor and/or pneumatic systems are most preferable. The two to four barge units will be filled and navigated by push boat to the Gulf of Mexico and up the St. Mark River.

Each barge will normally carry approximately 1000 tons of payload.
Barges with wire fences which haul low density materials such as wood can carry 70% of the normal load or 699 tons/barge (see Barge Cost Analysis). Barges which have to have a deep enough draft to be ocean going are called "load line" hopper barges. These load line hopper barges carrying 699 tons of wood should have a nominal draft of 7 feet which will work on shallow rivers such as the Apalachicola and still maintain stability in the Gulf.

Unloading equipment would be located at the plant site on the St. Marks river, preferably on the peninsula near the existing oil barge unloading dock. A bucket crane and/or pneumatic system will be used to unload the barges. The crane will probably be the most expensive of the two unloading methods; especially if it is not used continuously. From the unloading dock the wood could be conveyed to the proposed 10 acre storage site next to the plant.

A careful design and economic analysis must be made of the loading and unloading equipment due to the technical parameters involving the material and maritime regulations. Also, the equipment has to be designed such that it loads and unloads the barges quickly.

The time required to load and unload a barge should be 8 hours. This means that a four barge unit may take up to 32 hours from the time it docks to the time it can depart. The units are leased on a daily basis which means that lengthy loading and unloading periods as well as two way trips must be accounted for. Hence, the loading and unloading time can be a substantial part of the costs of a round trip for a unit that moves at only 5 miles per hour. It is estimated that the barges will be held up due to weather or bad navigational conditions one day out of seven.

If the loading and unloading capital and operational costs are not prohibitive, transporting wood by barge is competitive with trucking cost, especially outside the 60 mile radius of the site. A cost analysis of a two barge unit (see Barge Cost Analysis) indicated a cost between $3.25-$4.89 per ton for a 100 mile haul. If trucking costs are kept at a constant $1.30/mile the cost/ton is $6.50 for the first 100 miles. Hence, trucking cost could be over twice the cost of barge transportation depending on the number of barges per unit, distance traveled, and other
variable costs. However, since Tampa, Pensacola, Columbus, Georgia, Mobile, and New Orleans are considered as potential staging points for the barging of fuelwood to the Purdom plant, it was necessary to examine not only the mechanics and economics of barge transport, but also the availability and cost of fuelwood delivered to each of the ports.

Availability has two components. The first is the level of sustainable harvest which could occur within haul distance of the port. All of the ports grow a sufficient volume within their timberlands to support a new user, although none may have an available resource equal to that of St. Marks. For example, rough estimates of excess hardwood growth for the areas within 50 miles of Tampa and Pensacola, based on forest survey data, are in the range of 200,000 to 300,000 green tons. This is compared with about 500,000 green tons for the St. Marks area. Obviously, part of the explanation is that half of the area within 50 miles of the port lies in the Gulf of Mexico. According to Paul Fry of the Louisiana Forestry Commission, an additional problem in the case of New Orleans is that much of the timber there is located in inoperable swamps (notice the high volumes of tupelo, ash, and soft maple on the enclosed maps). Pat Jarvis of Forest Energy Systems, however, believes that the resource could be expanded by moving to barge facilities further up river. A fuelwood chip supplier for Richhold Chemical Co. and Armstrong Cork Co. in southern Alabama, Jarvis notes the existing of a barge facility with chip unloading capabilities at Millers Ferry, 100 miles north of Mobile.

The other aspect of availability is the existence of suppliers, willing and able to provide the fuelwood. We contacted a state forester within the area of each port and found that in each case fuelwood harvesting as a commercial enterprise is still in its infancy. Paul Fry indicated that Crown Zellerbach and International Paper had been involved in whole tree chipping, but only on their own lands and for their own use. Mark Hebb, district forester in Lakeland, Florida, thought that one of the area utilities was chipping material from their rights of way, while another local concern was chipping hardwood for mulch. Although Columbus, Pensacola, and Mobile each have a few whole tree chipping operations
providing fuelwood on a commercial basis, well ordered markets do not yet exist. As with St. Marks, however, suppliers should appear quickly once a stable demand is established.

The lack of a vigorous market makes the estimation of a price for fuelwood delivered to the port rather difficult. Timber Mart-South lists prices for hardwood whole tree chips only in two of the five areas being considered. It is known, however, that hardwood pulpwood stumpage varies little across the south and logging and transportation costs should be at least comparable. Therefore, the price of fuelwood delivered to any of these ports should be about the same as fuelwood delivered to St. Marks directly by truck. Pat Jarvis, for instance, quoted a current price of about $18.50 green ton for whole tree chips delivered to a Mobile area facility. Barging then, does not appear to have any advantage over procurement of local material. Hence, it is recommended that barge transportation not be pursued any further by the City of Tallahassee as an alternative mode of wood fuel transportation. Even if the barging cost were less than trucking costs, the net cost savings could not be greater than the overall socioeconomic benefits of procuring fuelwood from the Tallahassee vicinity.
Table D.1
BARGE COST ANALYSIS

Annual Cost Basis
Two Barges plus Insurance $150.00/day
One Push Boat Fully Found 1850.00/day
(No extra charges)
Total Cost per Two Barge Unit 2000.00/day

Shipment Size:

Inside Dimensions: 160 ft x 27 ft = 4320 ft²
Standard Height: 11 ft
Added Wire Cage: 10 ft
Total Height: 22 ft

\[ \times 22 \text{ ft} \]
\[ 97040 \text{ ft}^3/\text{barge} \]

\[ 30\% \text{ Safety (Factor)} \]
Average Barge Volume
\[ \times 0.7 \]
\[ 66528 \text{ ft}^3/\text{barge} \]

\[ 66,528 \text{ ft}^3/\text{barge} \times 21 \text{ lb/ft}^3 \times 1 \text{ ton/2000 lb} = 699 \text{ tons/barge} \]

\[ \frac{2 \text{ barges} \times 699 \text{ tons}}{\text{unit}} = 1398 \text{ ton/搪} \]

\[ \frac{2300 \text{ ton/day demand}}{1398 \text{ ton/unit}} = 1.65 \text{ units/day (3.3 barges/day)} \]

\[ \frac{3.3 \text{ barges} \times 7 \text{ days}}{\text{week}} = 23 \text{ barges/week} \]

\[ \frac{23 \text{ barges} \times 1 \text{ delivery}}{2 \text{ barges/week}} = 11.5 \text{ units/week} = 46 \text{ units/month} \]

Time required for one round trip:

Example:

Travel time 100 mile trip one way
\[ \times 2 \text{ way} \]
\[ 200 \text{ miles round trip} \]

\[ 200 \text{ miles} / 5 \text{ mile/hr} = 40 \text{ hours/trip} \]

Loading and Unloading Time:

Load: \[ \frac{2 \text{ barges} \times 8 \text{ hours}}{\text{unit barge}} = 16 \text{ hours/unit} \]

Unload: \[ \frac{2 \text{ barges} \times 8 \text{ hours}}{\text{unit barge}} = 16 \text{ hours/unit} \]

Total Transfer Time \[ 32 \text{ hours/unit} \]
Total Time for Round Trip: 40 hours + 32 hours = 72 hours

72 hours x 1 day x $2000 = $6000/round trip
24 hr day

P & S Marine estimates that there will be suitable weather for navigational purposes 6 out of 7 days. Hence, the barges will be in a holding pattern 1/7 (14%) of the time.

Total Actual Cost:

$6,000 x 1.14 = $6840/round trip

Total Annual Transportation

Costs/Ton:

$6840 x 1 trip = $4.89/ton for 200 miles round trip
trip 1398 ton

Cost/ton-mile: 489/ton = $0.05/ton-mile
100 miles

Formula for transporting biomass in a 2 barge unit:

(N # of miles one way) x 38 + 3040 = $/round trip

Cost/ton

<table>
<thead>
<tr>
<th>One Way distance (miles)</th>
<th>$/mile</th>
<th>$/ton delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>68.40</td>
<td>4.89</td>
</tr>
<tr>
<td>200</td>
<td>53.20</td>
<td>7.62</td>
</tr>
<tr>
<td>300</td>
<td>48.13</td>
<td>10.33</td>
</tr>
<tr>
<td>400</td>
<td>45.60</td>
<td>13.05</td>
</tr>
</tbody>
</table>

Present Trucking Cost in the South Georgia area:

$1.30/mile which includes the two-way trip.

Trucking costs/ton @ 20 ton/truck

<table>
<thead>
<tr>
<th>One way distance (miles)</th>
<th>$/mile</th>
<th>$/ton delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.30</td>
<td>6.50</td>
</tr>
<tr>
<td>200</td>
<td>1.30</td>
<td>13.00</td>
</tr>
<tr>
<td>300</td>
<td>1.30</td>
<td>19.50</td>
</tr>
<tr>
<td>400</td>
<td>1.30</td>
<td>26.00</td>
</tr>
</tbody>
</table>

The break even distance for bargings vs. trucking is calculated as follows:

\[
\frac{N(38) + 3040}{1398 \text{ tons/unit}} = N(0.65) \times \frac{$1.30}{\text{mile}} \times 1 \text{ unit}
\]

-56-
Hence, trucking transportation cost is less than barge transportation cost if the distance from the loading site to the delivery site is less than 21 miles.

Note that the breakeven distance is based upon the ability to increase the depth of the barge, maintain a 5 mile/hr speed, carry a 70% full volume capacity, and have navigational problems only 14% of the time. However, according to other transportation companies, a four barge unit traveling 200 miles one way can deliver wood at $3.75/ton which is 71% less than the cost of trucking wood.
REFERENCES - SECTION IID

1. Personal Communication to Charles Houder at F&W Forestry Services by Mark Hebb, District Forester, Florida Division of Forestry, February 1983.

2. Personal Communication to Charles Houder at F&W Forestry Services by Tom Serviss, Escambia County Forester, Florida Division of Forestry, February 1983.


E. USE OF GARBAGE AS AN ALTERNATE FUEL

Introduction and Background

As stated in previous sections, the primary purpose of this study is the investigation of the use of wood as a power plant fuel for the City of Tallahassee's Purdom Generating Station. The use of wood will represent a radical departure from the conventional fuels that have been in use for many years, namely fuel oil and natural gas. It will be shown in a later chapter that more than enough wood should be available to meet the energy needs at the plant. Thus, the design of the boiler plant will be centered around the use of wood as the primary fuel. While considering the subject of solid fuels, however, it makes sense to consider the other possible fuels—coal and municipal solid waste (garbage). Coal has been dismissed as a primary fuel because of the high cost of obtaining it. The City of Tallahassee is not a large enough customer to negotiate very favorable prices, the transportation of the fuel to Tallahassee requires a lengthy path and the environmental regulations in Florida would make the permitting process very costly and time consuming.

The other fuel which might be considered is municipal solid waste (MSW). This potential fuel has already been the subject of studies in Leon and Wakulla counties (1,2). The Leon County study was particularly extensive and included a review of the state-of-the-art of MSW processing technologies and a detailed look at the magnitude of the resource in the Tallahassee area. Briefly, the conclusions and recommendations of the study were as follows:

- Many governmental bodies and private companies in the United States have built or were building MSW plants at the time of the study (1979)

- Virtually all of the MSW processing plants had some problems, and many of the plants had major problems
• The Leon County landfill has a useful life of 20-30 years, so there is no immediate chance of landfill closure

• The study team recommended the appointment of a joint city/county commission to study the question of solid waste management and resource recovery in Leon County

• The study team recommended that a county employee be designated as the person responsible for ongoing evaluation of resource recovery technologies

• The study team considered the concept of modular incineration to be one of the most promising technologies

As of today, (early 1983) the joint City/County Commission has not been appointed and the county employee no longer monitors developments in the MSW state-of-the-art. There has been no further serious progress on the question of actually building an MSW plant for the City of Tallahassee (3).

Resource Estimates

It has been shown elsewhere in this report that 500,000 to 600,000 tons per year of wood will be necessary to provide fuel to the new wood fired boiler at the Purdom Plant. Studies have shown that approximately 200 tons per day of garbage are available in the Tallahassee Area (1, 2). At an average heating value of 5,500 Btu/lb, this represents an energy source of $57.3 \times 10^{11}$ Btu which could supply up to approximately 10% of the Purdom Plant's needs. Various sources have indicated that the thermal efficiency of a boiler fired with garbage should be nearly equivalent to the efficiency of a boiler fired with green wood, or approximately 60-65% (4).

Since it appears that garbage might be an attractive fuel, shouldn't
it be burned along with wood in the Purdom Plant's new boiler? The answer to this question is not simple, and an attempt to answer it will be made in the following sections.

MSW Plant State-of-the-Art

During the early 1970's the disposal and recycling of MSW became a motherhood-and-apple pie issue, a result of the enthusiasm at the time for the protection of the environment. It seemed that almost overnight a whole host of potential new processes for managing garbage were developed. In their haste for ultimate solutions, many municipalities and other government bodies invested in unproven technologies which turned out to be white elephants. Indeed, of the 28 systems examined by the Institute of Science and Public Affairs in 1979 (Reference 1), many are out of business today or very close to being out of business, and virtually all of the facilities have undergone major changes since the report was published.

A current article in Waste Age magazine (November 1982) offers the following update on facilities: Ninety-one energy and materials recovery facilities are operating or are under construction and seventy-five additional communities in the U.S. are committed to resource recovery operations in the future. Of these ninety-one facilities, sixty are mass burning facilities, twenty two are 300 plus tons per day mass burning facilities and thirty eight are mass burning in modular incinerators. Twenty are facilities recovering materials and RDF. Forty three plants are currently operating, nine are in startup, thirteen are under construction, and ten are shut down for various reasons. (5)

The capacity of the systems looked at in the 1979 ISPA report varied from a low of 19 tons per day of MSW to a high of 3500 tons per day. Categories of systems used for the report were as follows:

- Composting
- Material recovery
- Methane recovery
- Modular combustion
- Pyrolysis
- RDF
- Waterwall incinerator

-61-
Several of these categories can be dismissed immediately as being inappropriate for the present study. For example, composting is used to produce fertilizer and is not germaine to producing fuel for a powerplant, and the production of methane gas from a landfill is of no interest since the potential landfills are some distance from the Purdom powerplant.

The other categories of plants bear further examination, and there is considerable overlap of the categories. These plants will be considered in more detail in the following sections.

RDF/Material Recovery

The subjects of refuse derived fuel (RDF) production and material recovery are so intertwined that it is virtually impossible to separate them. Basically, the idea of material recovery is usually considered to offset the cost of operation of MSW plants through the sale of scrap materials separated from the trash and garbage. Many schemes for accomplishing this separation have been tried, but none has been completely successful. Two of the main problems associated with RDF production are:

- Volatility of by-product markets
- Catastrophic failures of processing equipment

The main by-products producible through separation techniques are ferrous metals, non-ferrous metals, and glass. All of these markets are very volatile, and some projects, such as the MSW plant in Ames, Iowa, made the mistake of grossly overestimating potential income from this source (6). The fact is, ferrous metals produced by most RDF facilities are sufficiently contaminated that they are not saleable at premium prices, non-ferrous metals have practically dried up due to aluminum can drives, and glass companies rarely accept any glass residue contaminated with colored glass. It is virtually impossible to separate all the colored glass in an RDF plant. Thus, while many RDF facilities have estimated high incomes from by-products, many have found these incomes impossible to
obtain.

The other major drawback to RDF plants are catastrophic failures. Most RDF designs require shredding of the garbage as a first step. This step can be downright dangerous, since it is virtually impossible to determine if a given load contains material that is highly combustible or explosive. One source separation plant listed forty major shredder explosions during the first seven years of operation (7). These explosions can result from small propane tanks, half empty cans of lawnmower gasoline, black powder thrown away by the home firearms loader, and cans of volatile liquids. In addition, other items such as bazooka rounds have been removed by alert personnel upstream of the shredder. Ames, Iowa has also had major shredder fires (6). These episodes take the plants off line and make them very difficult to operate. For these reasons, it is not recommended that the City of Tallahassee plan to build an RDF facility at the Purdom power plant. Since Tallahassee is not a heavy industrial area, it is unlikely that a market exists for more reclaimed metal than is already being sold by Reynolds Aluminum Recycling Company and Meyer's New Steel and Metals (1).

Without a detailed feasibility study, it is difficult to estimate what the cost per ton of RDF would be to the Purdom power plant as fuel. There are some parallels between the situation that might exist if RDF were burned in a new solid fuel boiler in Tallahassee and the situation that has existed in Ames, Iowa since the startup of an RDF plant in that city (6). At Ames, the solid waste recovery system is co-sited with the municipal power plant, and the "light fraction" RDF is conveyed directly to the power plant to be used as boiler fuel. Originally, the shredded RDF was to be burned in the Utility's 33 MW pulverized coal boiler. Problems with fuel retention time and the existing grate systems forced the utility to switch over to the two smaller (20 MW) spreader stoker boilers, which are much less efficient. The pulverized coal boiler was retrofitted with dump grates, and RDF firing was resumed successfully. Another suspension fired boiler at 65 MW capacity was started up at the power plant in May 1982 and has been operating quite successfully (8).

In 1980, the Ames Solid Waste Recovery System "sold" 40,076 tons of
RDF to the utility for an average at $9.48 per ton. There was no transportation cost in this figure since the facilities are co-sited; and only a minimum tipping fee was paid by users of the facility. It is not hard to imagine that, adding transportation costs, RDF delivered to the Purdom Plant could easily be in the same cost range as the wood fuel that is available ($15-20 per ton) It is likely that the RDF would have a slightly higher heat value (5,000-5,500 Btu/lb) and would thus burn with a slightly better efficiency than wet wood (4,000-4,500 Btu/lb), but RDF also brings penalties in higher ash contents and possible corrosive and erosive elements in the fuel.

There are many other examples of RDF facilities that have been operated in the U.S. with varying degrees of success. Some of these are discussed in some detail in Reference 5, and as already stated, some of these plants have ceased operation. In summary, the following can be said about RDF fuel for power production:

1. RDF has been successfully burned in suspension in pulverized coal boilers

2. RDF has been successfully burned in traveling grate spreader stokers

3. Operation of shredding facilities for RDF production can involve high maintenance and potentially hazardous conditions

4. RDF has properties which are similar to wood waste in some respects (more detail will be given on this point later).

Modular Incineration

Modular Incineration systems have been installed in many solid waste disposal facilities in this country, and in most cases these facilities have been quite successful. There are a number of manufacturers of modular
incinerators in business at present, but most use similar designs which employ two stage combustion. These systems are shipped as packages, much like package boilers, and most modules have a capacity of 10 to 50 tons of garbage per day. Heat recovery boiler systems can be added to the basic incinerators which allow the production of low pressure (less than 300 psi) steam.

Modular incinerators have no application to the Purdom plant since they are incapable of producing the quality steam necessary for power production, and the capabilities per unit are too small to be effectively used. As a result of these limitations, modular incineration will be discussed no further.

Pyrolysis Systems/Advanced Systems

A number of processes have been developed in the past ten years which have as their goal the production of alternate fuels from garbage which can be used more flexibly in place of fossil fuels. These systems often employ a pyrolysis process (pyrolysis refers to the decomposition of a material in the absence of oxygen) and produce char and liquid fuels that can be burned in other locations.

Most of these systems have been somewhat developmental in nature, and have met with only limited operational success. They have tended to be expensive to build and expensive to maintain due to their unproven nature and the shut down of some of the plants has shown that they were bad investments for the municipalities involved. Examples of unsuccessful pyrolysis facilities include Baltimore, Maryland (Monsanto process), San Diego, California (Occidental process), and South Charleston, West Virginia (Union Carbide process).

Alternative methods of RDF production (which might be called "advanced" systems) have also run into trouble. The Bridgeport, Connecticut facility which was built to produce an RDF called "Eco-fuel" has been shut down, and the Hempstead, New York facility that was built to produce RDF through a wet pulping process has been shut down and the $130
million investment has been essentially written off.

The lesson to be learned from these episodes is that the City of Tallahassee does not need to get involved with an unproven technology, because the city taxpayers will ultimately have to bear the burden of failure.

Mass Burning/Waterwall Incinerators

The most successful large municipal solid fuel facilities have utilized the "mass burning" technique and this seems to be the direction most new facilities are taking. Mass burning involves a minimum of handling and processing and essentially consists of stoking a fairly conventional furnace and boiler system with garbage after refrigerators and other obvious foreign matter are removed. There is still a danger of explosion from hazardous materials, but the occurrence of this in a large furnace is less catastrophic than a confined explosion in a shredder.

Mass burning facilities have been used successfully for power production and district heating in Europe for many years (10). In West Germany, several plants have used the approach of having two furnaces side-by-side. The smaller of the two burns garbage only and the flue gases are used to heat the economizer in the feedwater system. This heated water is then fed into a conventional boiler which burns fossil fuels. Of course, the overall system is quite complex and is probably only cost effective for large steam loads (4). European furnace designs have been applied with some success in the U.S. such as the Saugus, Massachusetts 1300 tons/day facility.

Other mass burning facilities which are particularly worthy of note include the facility in Hampton, Virginia which processes approximately 200 tons per day of garbage, producing steam for the NASA Langley Research Center. Recent articles have cited this plant as a successful operation (11,12). As indicated earlier, most of the new facilities being constructed at present that are too large to employ modular incineration are using some form of mass burning.
Burning Garbage In Wood Boilers

Since the percentage of wood fired boilers is a small portion of the total U.S. boiler population, there have been many more instances of MSW being substituted for coal as a boiler fuel than for wood, but the limited experience with garbage firing in wood boilers warrants a closer look.

Lane County, Oregon built a resource recovery system and started it up in 1976. It has ran an intermittent schedule since that time and is now shut down indefinitely (13). Markets were established for the metals and recovered glass, but no definite market could be established for the RDF. The major potential customer for the RDF was the Eugene Water and Electric Board (EWEB) and some test burns were actually performed using unprocessed MSW and RDF from several sites. These test burns were conducted by Sandwell International, Inc. in 1972 and 1974 in several of the EWEB boilers. EWEB has been generating electricity using wood as the primary fuel since the 1940's. Basically the Sandwell report came to the following conclusions:

- MSW can be burned in the EWEB hog fuel boilers to provide up to 30% of heat input

- Major modifications would be required to the conveyors and storage facilities for steady state operation with an MSW/wood mix

- Salts containing chlorides, fluorides and sodium can be formed in high temperature furnaces when garbage is burned, and effects of these salts on boiler tube corrosion and boiler tube fouling would have to be monitored

- Slags consisting of oxides of aluminum, calcium, silica and iron can result in increased tube erosion and boiler plugging

- Higher ash content found in MSW will require increased capacity of ash handling systems
There will be higher formation of small particulates when firing a mixture of wood and garbage than firing wood alone.

In short, Sandwell found a number of areas for concern when burning garbage, but the final recommendation was that it could be burned successfully in the EWEB hog fuel boilers. EWEB has chosen not to use the fuel, however primarily due to concern over possible tube damage to their boilers (15).

Another recent study was performed on the subject of co-firing wood and MSW in New England (16). One of the major conclusions coming from this study was that it is much easier to use wood as a supplement to MSW in a mass burning garbage facility than it is to burn garbage in a furnace designed primarily for wood. Potential problem areas cited were essentially the same as those in the EWEB study.

Conclusions and Recommendations

In view of the above information the study team offers the following suggestions to the City of Tallahassee and the Tallahassee Electric Department:

1. There is enough garbage available within a reasonable hauling distance at the Purdom plant to allow it to be considered a "major" source of fuel.

2. Indications are that there is enough low quality wood available to be considered as the primary fuel for the power plant.

3. Therefore, a retrofit boiler for the Purdom plant should definitely be designed as a wood burning facility primarily.

4. The Tallahassee Electric Department should not consider establishing or investing in an RDF processing facility due to the nature of the problems involved.
5. If an outside agency or corporation does establish a source separation/RDF production facility the Electric Department should consider purchase of the RDF fuel if the price is attractive. Test burns should be done in the wood fired boiler (under consideration) before any definite commitments are made.

6. The designer of the wood fired boiler should address the possible future use of MSW as a supplemental (less than 20% heat input) fuel in the future, by allowing for addition of material handling, boiler feed, emission control, etc.

In general, it appears from the literature that interest in the co-firing of wood and MSW is on the rise, and it would be well for those responsible for the wood fired boiler at Purdom to stay abreast of new developments.
REFERENCES - SECTION IIIE


2. Sherman, Calvin, City of Tallahassee, Summary Letter on Wakulla County Landfill, December 10, 1982.

3. Personal Communication to W.S. Bulpitt of Georgia Tech from Calvin Sherman of City of Tallahassee, January 11, 1983.


13. Personal Communication to W.S. Bulpitt of Georgia Tech from M. Turner, Lane County Solid Waste Management Division, January 6, 1983.


F. SOCIOECONOMIC ANALYSIS

Introduction

This chapter analyzes the economic and social impacts upon the Tallahassee, Florida area of the conversion to wood fuel of the Sam Purdom Generating Plant. The effects of the new plant construction over the short-term and employment and fuel purchases over the long-term are examined.

Population and Economy

The most important direct and immediate economic benefit to the area is the creation of a new business - the sale of wood residues. In the past this resource was considered only a waste by-product of the wood products industry. This resource is becoming a marketable product and opens up a new area for enterprise in this industry.

The future potential for wood energy use is great and as this resource is developed as a fuel, its price will begin to rise in relation to other fuel prices. Because of this increase in productivity and utilization of a formerly wasted resource, sawmill profits will increase.

There are many indirect socio-economic benefits due to the creation of this new product. The most obvious will be the new employment that will result. The primary employment increases will be in the harvesting and transportation of the wood to the generating facility.

Other employment will be created due to the construction of the generating facility. The plant itself will employ people in both skilled and unskilled positions. The people who fill these jobs will most likely come from the Tallahassee Area.

With the increase in employment are many associated benefits. Because of the rise in permanent employment there will be a slight rise in personal income for the county and therefore a rise in bank deposits. With more money available, retail sales will increase. These economic benefits will
also result from the increase in profits to the area sawmill owners.

Several long term economic benefits could accrue from completion of a wood fueled electric generating station at St. Marks. This project will help establish the feasibility of a new technology for the utility industry in which natural resources are used more efficiently. It will also help demonstrate energy consciousness on the part of the utility industry by helping to promote the use of a renewable fuel.

Florida is a fuel deficient state which has no source of conventional fuel for its electrical utilities. Utilizing native wood fuel at present day cost can initiate a move to decrease fuel imports and help boost the local economy.

Shifting from conventional fuels to the native wood fuel could also help reduce the area's fuel dependency. This effort towards independence is clearly important as the availability of conventional fuels becomes more limited.

Because wood-fueled stations by nature are smaller and generate less power, they reduce the otherwise necessary large reserve requirements.

**Government and Community Services**

Development of the facility will add thousands of dollars directly to the area each year. Since there are virtually no added services to the plant paid for by the city the revenue goes directly to benefit services to the people of the county such as upgrading schools and police and fire protection.

**Employment and Earnings Impacts**

Wood energy production involves employment in such varied activities as wood harvesting, forestry operations, boiler room operation, transportation, and marketing. Truck drivers, heavy equipment operators, unskilled laborers, and highly trained technicians and managers are among the occupational groups represented. In some cases the employment
generated by a biomass energy activity is insignificant in comparison to the overall operation of a large industrial facility. For other activities a sizable stimulus to local employment is created.

High wood energy production levels would be associated with correspondingly greater employment and earnings impacts. It should be pointed out, however, that not all of the impacts can be considered to be net additions to employment and earnings. While wood harvesting and transportation jobs represent net additions to employment, most of the operation and maintenance workers would be employed in the operation of the conventional facilities being replaced by wood-fired facilities. Compared to coal-fired systems, few if any additional workers are needed for plant operation and maintenance. Oil- or gas-fired systems, on the other hand, require fewer operation and maintenance workers primarily because of fewer maintenance and fuel-handling problems. Thus, the net addition to operation and maintenance employment associated with the growth of wood-fired systems as a substitute for conventional fuel systems is uncertain. Most of the net employment and earnings impacts are generated by wood harvesting and transportation activities rather than plant operation and maintenance activities.

**Occupational Skill Requirements**

An important feature of wood-energy related employment is that few highly skilled workers are involved. While some foresters, forestry technicians, licensed boiler and turbine operators, craftworkers, managers, and clerical workers are needed, the majority of the jobs are for unskilled and semi-skilled workers.

As shown in Table F.1, the harvesting of fuel wood (generally in the form of wood chips) requires primarily heavy equipment operators to cut, move, and chip the trees being harvested. Specially designed front-end loaders (referred to as feller bunchers) and large chipping machines are used for these tasks. To help service these machines a ground crew is also needed. A wood harvesting crew can typically produce between 40,000 and
50,000 tons of chips per year. Depending on the distance moved, three or four full-time truck drivers would be needed to transport the fuel wood to the user. With the exception of a secretary/bookkeeper and possibly supervisors, no formal training is required for any of these positions.

<table>
<thead>
<tr>
<th>Position</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor</td>
<td>1</td>
</tr>
<tr>
<td>Heavy equipment operators</td>
<td>4</td>
</tr>
<tr>
<td>Chipper operator</td>
<td></td>
</tr>
<tr>
<td>Shear operator</td>
<td></td>
</tr>
<tr>
<td>Two skidder operators</td>
<td></td>
</tr>
<tr>
<td>Laborers (ground crew)</td>
<td>2-4</td>
</tr>
<tr>
<td>Secretary/bookkeeper</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>8-10 Personnel</td>
</tr>
</tbody>
</table>

For the operation of wood-fired industrial and utility boilers, the number and skill level of workers varies with size. While a licensed boiler operator is often required to be present at all times, the job may include other responsibilities outside of the boiler room. Thus, for around-the-clock operation of small industrial boilers (under 500 horsepower) one person per shift may be all that is required. Larger industrial boilers (over 1000 horsepower) may, on the other hand, require a full-time crew of four or five workers per shift. In addition to boiler operators, some assistant boiler operators, and laborers may be needed. If electricity is generated, then turbine operators and assistants may also be required. Large electric generating plants usually require crews staffed with fully qualified maintenance workers, operators, assistants, supervisors, and laborers.

So while the regional employment and earnings impact of the use of wood by the City of Tallahassee may be substantial, only a small percentage of the jobs require a great deal of formal education and training. Training for most of the positions can be received on the job and in many
cases little previous experience is necessary.

The injection of additional outside money into a local community has a positive, multiplicative effect on the economy. The recipients of these expenditures make additional expenditures themselves on goods and services within the region which, in turn, generate additional incomes, etc. This ripple effect is commonly called the multiplier effect. There have been numerous studies and extensive empirical work in which specific multipliers have been calculated. Multipliers have been calculated from the national level to the county level and for various stages between the two. Most of these have fallen within a range of values from 2.0 to 3.5 when applied to nonrural regions. In the calculations designed to estimate the socioeconomic impacts of the construction and operation of this plant, the assumed multiplier is 2.0. This means that for every one dollar of externally financed expenditures in the region, an additional two dollars will be generated. It has been determined in previous studies that these additional impacts occur over a one to three year period following the initial expenditure. We have specifically stated the expected direct impacts in the following sections, followed by the indirect, or multiplier effects; the total impact is the sum of the direct and indirect impacts.

Plant Construction

According to vendor quotes in the Preliminary Wood Biomass Availability and Feasibility Study submitted to the Tallahassee City Commission, the estimated value of the plant to be constructed falls in the range of $14-28 million.

Of the $14-28 million expenditure, it has been determined by a similar study conducted by Georgia Tech that approximately 30% of this will be spent in the local economy, or $4.2-8.4 million. Of this amount we assume 50% is labor and 50% is materials. Since most of the labor necessary in such a fabrication and construction project requires highly skilled manufacturing, construction, design, and engineering personnel, the average wage and salary level is significantly higher than the average wage and
salary level for all workers in the area. Consequently, the following direct construction impacts are estimated using an average expenditure of $21 million:

Personal Income: $3.15 million
Employment: 90 (people)

Applying the multiplier to the direct construction impacts above, the following indirect impacts from construction can be calculated:

Personal Income: $4.77 million
Employment: 135 (people)

The total impact (direct plus indirect) for the construction phase of the plant is:

Personal Income: $6.30 million
Employment: 180 (people)

It should be pointed out that these are maximum values for the potential impacts. As in any large city with a strong economy, construction and production goes on continually. The construction phase is a transient form of impact, but is a positive impact nonetheless. Construction of a facility of this size has beneficial impacts because of the support it provides as an ongoing stimulus to the local economy. Therefore, the direct and indirect impacts on employment should not necessarily be viewed as "new" jobs this construction will create. What it does do, however, is generate some new-hires and some continued employment in those areas which may or may not be present without this particular construction project. The positive and substantial injection to the overall personal income and tax revenues is a real addition to the economy. The long-lasting, permanent impacts come from the continued operation and maintenance of such a plant. These issues are addressed in the following section.
Annual Expenditures At the Plant

The annual expenditures at the plant are divided into two sections: annual expenditures on labor and annual expenditures on fuel.

Annual Expenditures for Labor

It is estimated that four four-person shifts will be required to run the wood-fired plant with an average cost per person of $25,000. The total annual wage and salary impact, therefore, is $400,000.

Annual Fuel Expenditure

It is estimated in the study performed by F&W Forestry Services, Inc. that hardwood chips in the Tallahassee area range in price from $14.85 to $18.55 per ton delivered. Because of the range of fuel costs and because the amount of wood fuel to be purchased annually ranges from approximately 500,000 to 600,000 tons, the potential direct and indirect impacts will be calculated as a range of values. The minimum impact would be for 500,000 tons of wood fuel purchased at $14.85 per ton, and the maximum impact would be for 600,000 tons purchased at $18.55 per ton. The minimum and maximum annual fuel expenditures would be $7.4 million and $11.1 million, respectively.

In previous feasibility studies of the applicability of wood-energy utilization (1), it has been estimated that labor costs are approximately 9.5% of the total per ton cost of wood fuel when whole-tree chipping is the harvesting technique. This value excludes benefits, insurance, workman's compensation, etc.; 9.5% relates directly to wage and salary personal income.

It is unknown at this writing exactly what percentage of the wood fuel purchased for this plant will be whole-tree chips and what percentage will be wood wastes. Also, the percentage of fuel wood that comes from wood operation outside of Florida is unknown. To carry out the analysis, the
research team has estimated that approximately 50% of the wood fuel will be waste wood with the other 50% from whole tree chipping operations. The utilization of waste chips will have no appreciable impact on increased economic activity in the region, except to provide a more economically efficient operation for the firms selling the waste wood. Therefore, increased economic activity will be generated only from the portion of wood-fuel expenditures on whole-tree chipping. The revised minimum and maximum annual wood-fuel expenditures are $3.7 million and $5.55 million, respectively. The wage and salary income effect can be calculated directly using the 9.5% value cited above. Because the labor force for whole-tree chipping and transportation is different from the labor force necessary in the design and construction of the plant, a lower annual income level is assumed again based on previous feasibility research. The associated direct impacts are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal income:</td>
<td>$351,000</td>
<td>$527,250</td>
</tr>
<tr>
<td>Employment: (People)</td>
<td>23</td>
<td>41</td>
</tr>
</tbody>
</table>

ADDITIONAL SOCIOECONOMIC IMPACTS

Water, Sewer, Housing and Other Infrastructures

The plant is to be built on the existing Purdom plant site. The infrastructure to handle such a plant is in place and no additional, measurable effects are expected. There should be no adverse impact on housing either in the short or long-term. Adequate water and sewer facilities are in place to cope with existing activity.

Traffic Congestion

It is estimated that if all of the wood fuel were brought onto the site by truck, over seventy five trucks per day, would move onto the site
if all transportation of wood fuel took place during daylight hours. Hence, there will be a substantial increase in traffic.

In addition to current traffic conditions in the area, it is doubtful that all of the wood fuel would be transported to the site by truck. The City of Tallahassee can barge wood up the St. Marks (See the chapter on Barge Transportation). It is believed that some, if not most, of the fuel can be shipped in by barge; whatever percentage of the fuel is brought in by barge would yield a corresponding percentage decrease in truck traffic. Since only one or two barge units per day are required; barge traffic on the St. Marks River is not expected to increase significantly.

Local Wood Waste, Wood Chip Infrastructure

The wood-fuel purchases would make a positive impact on the current level of wood-chip, wood-waste activity in the region, and numerous companies (loggers, brokers, purchasers, contract haulers, etc.) in the area will receive the business. Therefore, there is a "marketplace" of buyers, sellers, and middlemen in the area. The introduction of the proposed facility and its anticipated wood-fuel demand will require additional whole-tree chipping operations. Either existing operations will add new machinery and crews or new chipping operations will be generated. The precise extent of this positive impact is not known.

CONCLUSIONS

The Tallahassee region, including the city and adjoining areas have experienced generally good growth in terms of population, labor force, and economic activity. The proposed plant conversion at the St. Marks site is to an existing utility region and no adverse impacts on the local infrastructure or housing market are anticipated. The economy is sufficiently established to absorb the construction of such a plant as well as the ongoing operation. There is an existing market in wood chips and wood waste in this region of the state. Consequently, the necessary market
infrastructure is in place and the presence of a wood fuel facility would have only a small impact.

The plant construction will have a transient positive impact on wage and salary incomes, sales tax revenues, and local tax revenues. The primary, long-term impact will come from the annual operation. There will be a small positive impact on employment in the area, as well as healthy impacts, both direct and indirect, on income levels and tax revenues.

If the cost of wood chips remains fairly level, as forecasted by F&W Forestry Services, Inc., electric rates should also cease to escalate at the accelerated rate it has in the past, mainly due to the rise in the cost of conventional fuels. Hence, the city and all of its citizens should greatly benefit from a wood-fired utility plant. As the future costs of natural gas and oil rise, the spread between these costs and wood fuel costs will increase and become more vivid.
IV.

FRAZER AND WETHERBEE FORESTRY SERVICES, INC.
CONTRACT REQUIREMENTS/FUEL WOOD AVAILABILITY STUDY
INTRODUCTION

This study augments the July 15, 1982 Preliminary Wood Biomass Availability and Feasibility Study prepared for the Tallahassee City Commission by City staff and the Florida Division of Forestry. Our primary purpose herein is to review the Energy Office report and to use additional data to amplify or adjust its findings. Our specific areas of examination are: the current and projected price of fuelwood, the magnitude of the available fuelwood resource, the possible environmental effects of fuelwood harvesting, and the potential suppliers of fuelwood. The text of this report is divided accordingly and is followed by supplementary and supporting information.

For the first section we collected the available wood product prices for the Tallahassee area in terms of both stumpage and raw material delivered to the mill. For the material considered potential fuelwood, we found a range of stumpage prices from $1.35 to $5.53 per green ton. For the delivered product, there is a potential range of $10 to $25 per ton, while it is expected that the actual price would fall between $15 and $20 per ton. These prices are exclusive of unloading. Information on past trends and expectations for the future are then presented as indicators of future price behavior.

The section on potential supply details our interpretation of forest survey and other data concerning the wood resources within the St. Marks' timbered area. We describe the assumptions and the computations which led to our conclusion that, at present, area timber producers annually encounter about 1,554 thousand green tons (MGT) of woody biomass, which are not used. In addition, it appears that there is in excess of 1,600 MGT, which could be produced for fuelwood annually on a sustained basis.

We then examined the possible impact on the forest of a fuelwood harvest. Primarily, we looked at the site for specific effects of soil disruption and biomass removal on the stand composition, soil quality, wildlife, water quality, and related environmental components. All of these may be significantly affected, but whether the net impact is positive or negative depends on how fuelwood harvesting is integrated into a comprehensive land management scheme.

Finally, we reviewed the Energy Office supplier survey and attempted to isolate some specific contract considerations, which the City is likely to encounter. Although potential suppliers are unwilling to make firm commitments to the City at this time, those interviewed indicated that a full range of procurement options are available. Individual dealers feel certain that the resource is there and that they each could provide about 10% of the anticipated need. Their primary concerns center around securing a commitment of at least three years for delivery of at least 1,000 tons per week. Brokers are available to manage the entire procurement process including, if desired, the unloading and storage facilities.

In general, we found the Energy Office report to be well prepared and comprehensive. Since it covered some areas (particularly potential suppliers) in as complete a manner as is practical at this level investigation, we concentrated our time and efforts into those areas where we could provide the most additional information.
Current and Projected Fuelwood Prices

Table 1 presents current prices for stumpage and delivered products applicable within 75 miles of St. Marks. The figures are derived from three sources:

1. **Timber Mart South**, the market bulletin for reporting prices of raw forest products.


3. A regression analysis of stumpage prices received in Southwest Georgia and North Florida timber sales made by F & W Forestry Services, Inc. between 1970 and 1982.

These sources are used to corroborate the findings of the Tallahassee Energy Office Survey of forest products mills and wood suppliers. The survey indicated an interest in providing a variety of wood fuels at delivered prices ranging from about $13 to $30 per ton. The form of the fuel offered ranged from green bark to compressed bales at 30% M.C. The bulk, however, were mill residues and whole tree chips, which could be delivered for $15 to $25 per ton.

The sources above indicate that potential fuelwood materials are currently selling below the prices quoted by survey respondents. Delivered hardwood pulpwood logs appear to be bringing only about $10.60 per green ton while clean hardwood chips command $13.50 per ton. The current price for clean pine chips is $25 per ton. The depressed state of the forest products industry is probably being reflected somewhat in these figures so the F & W model is helpful in suppressing market peaks and valleys. The stumpage prices generated through the model are the reflection of trends, which developed over the past 10 years.

To arrive at a delivered price, logging and transportation costs were added to the F & W stumpage estimates. Clifton and Bulpitt (1979) estimated the cost of whole tree chipping and transportation, 50 miles via chip van, to be $10.48 per ton. This figure was increased 25%, to $13.10 per ton, to offset inflation. The resulting range of prices for hardwood whole tree chips was $14.85 to $18.55; the upper end of the range representing the stumpage price of hardwood sawtimber. For comparison, the indicated price of whole tree chips derived from pine pulpwood was $23.68.

Future fuelwood prices depend to a large degree on the cost of alternative fuels, i.e. oil, natural gas and coal. The U.S. Forest Service, (Review Draft: An Analysis of the Timber Situation in the U.S., 1952 - 2030) expects the base level supply of hardwoods to be sufficient to meet demand through the year.
2000. They admit, however, that a rise in fuelwood demand above that expected could significantly alter the situation. Not only regional, but local supply and demand must be considered since their report states:

"Because the fuelwood requirements of even small electric plants would be very large, the potential impact of a single such installation on the local timber supply could be great."

Supply factors specific to the Tallahassee area will be treated in a separate section.

The Forest Service regional projections for the Southeast are summarized on the graph of roundwood supply and demand (Figure 2). Notice that the production of both softwood and hardwood are expected to increase rather dramatically relative to that experienced over the last 30 years. This will strain softwood supplies while the hardwood resource appears sufficiently large to meet increased demand.

The use of hardwoods will rise in all segments of the forest products industry. Consumption of hardwood for lumber, plywood, paper and board is expected to almost double by the year 2000. Although products such as oriented strand board are so new that trends are not yet visible, it is thought they will become an important substitute for conventional structural plywood. This will be particularly true if softwood stumpage prices escalate as expected. Overall, hardwood particle board consumption is predicted to more than double in the next 20 years.

Yet in spite of the above, the Forest Service projects that the South will grow about 4.6 billion cubic feet more hardwood than it will cut in the year 2000. Little, if any, real increase in hardwood prices should occur. The graph of Stumpage Index for the Southeast (Figure 1) shows only small changes in the real price of hardwood sawtimber. It is assumed that hardwood pulpwood will follow a similar trend. The graph for softwood sawtimber stumpage, meanwhile, clearly illustrates the emphasis on hardwoods when examining potential fuelwood supplies.

The myriad of unknowns thwarts any attempt to predict actual prices 20 years hence. Even given that the real price of the commodity will not rise, we can arrive at no more than a sense of its potential future price relative to substitutes. To this end, however, we can look at several indicators of hardwood prices here, while an examination of coal gas and oil will be made within the Georgia Tech report.

Although such extrapolations are subject to sever limitations, F & W timber sale regression equations were used to predict stumpage prices in current dollars between 1980 and 2000 (Figure 3). Should trends exhibited over the last 10 years prevail, pine pulpwood prices will increase about 2 1/2 times. The stumpage price of hardwood sawtimber will nearly double, while hardwood pulpwood will increase by only about 45%. Realistically, these are probably the minimum increases which can be expected. The price behavior of these products relative to one another is probably quite valid.

-85-

F & W FORESTRY SERVICES, INC.
Other data which might indicate future price behavior include producer price indices for allied commodities and the price for southeastern hardwood pulpwood (Figure 4). With regard to hardwood pulpwood, region wide and considering all pricing points, current dollar prices have about doubled since 1970. In contrast, prices rose only about 26% over the preceding 10 year period.

1970 appears to be the approximate point at which the rise in producer prices for all commodities began to accelerate. They had increased about 35% over the 20 year period following 1950, but thereafter doubled in less than 10 years. The producer price indices for most forest products followed commodities, as a whole, rather closely. The woodpulp index, however, ascended much more quickly, increasing more than 2 1/2 times between 1970 and 1975 (Ulrich, 1981). By relating the economic conditions of a given period to the price behavior of commodities reflected in the graphs, the effect on prices of an expected future economic scenerio can be tested to a limited degree.
### TABLE 1

**CURRENT STUMPAGE AND DELIVERED PRICES - $/GREEN TON**

<table>
<thead>
<tr>
<th>Product</th>
<th>F &amp; W</th>
<th>DOF</th>
<th>TMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardwood Pulpwood</td>
<td>$1.35</td>
<td>$1.82</td>
<td>$1.52</td>
</tr>
<tr>
<td>Soft Hardwood Sawtimber</td>
<td>$5.45</td>
<td>$5.40</td>
<td>$5.53</td>
</tr>
<tr>
<td>Hard Hardwood Sawtimber</td>
<td>$4.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pine Pulpwood</td>
<td>$10.58</td>
<td>$8.95</td>
<td>$8.92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>F &amp; W</th>
<th>DOF</th>
<th>TMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine Pulpwood</td>
<td>$18.57</td>
<td>$17.57</td>
<td></td>
</tr>
<tr>
<td>Hardwood Pulpwood</td>
<td>$9.95</td>
<td>$11.25</td>
<td></td>
</tr>
<tr>
<td>Clean Pine Chips</td>
<td></td>
<td>$25.00</td>
<td></td>
</tr>
<tr>
<td>Clean Hardwood Chips</td>
<td></td>
<td>$13.50</td>
<td></td>
</tr>
<tr>
<td>Pine W.T. Chips</td>
<td>$23.68</td>
<td>$11.50</td>
<td></td>
</tr>
<tr>
<td>Hardwood W.T. Chips</td>
<td>$14.85-$18.55</td>
<td>$11.00</td>
<td>$25.00</td>
</tr>
<tr>
<td>Firewood</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. October, 1982, Average of South Georgia and Florida Panhandle.
3. F & W stumpage plus $13.10 logging and transportation.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>SOFTWOOD EQUILIBRIUM*</th>
<th>SOFTWOOD BASE**</th>
<th>HARDWOOD EQUILIBRIUM*</th>
<th>HARDWOOD BASE**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>57.8</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>83.3</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>111.6</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td>138.9</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>229.6</td>
<td>132.9</td>
<td>113.9</td>
<td>100</td>
</tr>
<tr>
<td>2000</td>
<td>280.0</td>
<td>139.1</td>
<td>99.1</td>
<td>100</td>
</tr>
<tr>
<td>2010</td>
<td>358.0</td>
<td>145.8</td>
<td>101.7</td>
<td>100</td>
</tr>
<tr>
<td>2020</td>
<td>434.6</td>
<td>152.9</td>
<td>112.9</td>
<td>100</td>
</tr>
</tbody>
</table>

*Past indices or projection of indices related to prices which will force future supply to equal expected future supply.

**Based on historical relationship between stumpage and product prices. Assumes stable elasticity over time and is valid if supply is sufficient to meet demand.

PAST AND PROJECTED STUMPAGE PRICES FOR SOUTHWEST GEORGIA AND NORTHEAST FLORIDA (CURRENT $ PER GREEN TON)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PINE</th>
<th>HARDWOOD</th>
<th>HARD HDWD.</th>
<th>SOFT HDWD.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>2.54</td>
<td>1.06</td>
<td>1.33</td>
<td>2.33</td>
</tr>
<tr>
<td>1975</td>
<td>5.74</td>
<td>1.18</td>
<td>2.62</td>
<td>3.66</td>
</tr>
<tr>
<td>1980</td>
<td>9.15</td>
<td>1.30</td>
<td>4.00</td>
<td>4.94</td>
</tr>
</tbody>
</table>

PROJECTIONS

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PINE</th>
<th>HARDWOOD</th>
<th>HARD HDWD.</th>
<th>SOFT HDWD.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>12.78</td>
<td>1.43</td>
<td>5.45</td>
<td>6.19</td>
</tr>
<tr>
<td>1990</td>
<td>16.64</td>
<td>1.56</td>
<td>7.00</td>
<td>7.40</td>
</tr>
<tr>
<td>1995</td>
<td>20.71</td>
<td>1.71</td>
<td>8.64</td>
<td>8.58</td>
</tr>
<tr>
<td>2000</td>
<td>25.00</td>
<td>1.86</td>
<td>10.37</td>
<td>9.72</td>
</tr>
</tbody>
</table>

Source: Regression Analysis of F & W Forestry Services, Inc.
Timber Sales, 1970-1982
## PRODUCER PRICE AND INDUSTRIAL PRODUCTION INDICES, AND HARDWOOD PULPWOOD PRICES INDEX (1967=100)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>WOODPULP</th>
<th>ALL COMMODITIES</th>
<th>INDUSTRIAL PRODUCTION</th>
<th>HDWD. PULPWOOD ALL PRICING POINTS $ PER GREEN TON</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>81.0</td>
<td>81.8</td>
<td>44.9</td>
<td></td>
</tr>
<tr>
<td>1955</td>
<td>95.7</td>
<td>87.8</td>
<td>58.5</td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>102.2</td>
<td>94.9</td>
<td>66.2</td>
<td>4.85</td>
</tr>
<tr>
<td>1965</td>
<td>100.1</td>
<td>96.6</td>
<td>89.8</td>
<td>5.12</td>
</tr>
<tr>
<td>1970</td>
<td>109.6</td>
<td>110.4</td>
<td>107.8</td>
<td>6.12</td>
</tr>
<tr>
<td>1975</td>
<td>283.4</td>
<td>174.9</td>
<td>117.8</td>
<td>8.77</td>
</tr>
<tr>
<td>1980</td>
<td>388.6</td>
<td>265.2</td>
<td>141.5</td>
<td>10.87</td>
</tr>
</tbody>
</table>

PAST PRODUCTION AND PROJECTIONS FOR SUPPLY AND 
DEMAND FOR ROUNDWOOD IN THE SOUTHEAST (BILLION CU. FT.)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PRODUCTION OR EQUILIBRIUM</th>
<th>BASE DEMAND</th>
<th>BASE SUPPLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOFTWOOD</td>
<td>1952</td>
<td>1.65</td>
<td>2.82</td>
</tr>
<tr>
<td></td>
<td>1962</td>
<td>1.50</td>
<td>2.92</td>
</tr>
<tr>
<td></td>
<td>1970</td>
<td>1.71</td>
<td>3.22</td>
</tr>
<tr>
<td></td>
<td>1976</td>
<td>1.79</td>
<td>3.38</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>2.63</td>
<td>3.62</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>2.92</td>
<td>3.73</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>3.22</td>
<td>3.73</td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>3.38</td>
<td>3.73</td>
</tr>
</tbody>
</table>

HARDWOOD | 1952 | 0.77 | 1.13 | 1.13 |
| 1962 | 0.62 | 1.42 | 1.42 |
| 1970 | 0.63 | 1.78 | 1.73 |
| 1976 | 0.64 | 2.06 | 2.00 |
| 1990 | 1.14 | 2.09 | 2.00 |
| 2000 | 1.44 | 2.09 | 2.00 |
| 2010 | 1.74 | 2.09 | 2.00 |
| 2020 | 2.06 | 2.09 | 2.00 |

Amount of Fuelwood Potentially Available
ESTIMATE THE AMOUNT OF FUELWOOD POTENTIALLY AVAILABLE TO THE PURDOM GENERATING PLANT.

It has been estimated that the annual fuelwood requirements of the Purdom generating plant would be approximately 600,000 green tons. This material, depending on the price of alternative fuels, might be available from various sources. These include surrounding forest lands, forest industry mills, and the Tallahassee landfill. Herein we shall concentrate on that material on forest lands within 50 miles of the power plant and from mills within 75 miles. The Georgia Tech report will address the feasibility of transporting material from more distant sources and utilizing the City's refuge.

Table 2 summarizes our estimates of the woody biomass produced within the Tallahassee timbershed which could be harvested on a sustained basis without depleting the present volume inventory. It is primarily based on the computer generated table set prepared by the U.S. Forest Service Southeast Forest Experiment Station for the area within 50 miles of St. Marks. This is the same information used by the Florida Division of Forestry in the City Energy Office Report, but our approach in the analysis of the data was somewhat different. We were, thereby, able to compare the effect of differing assumptions on our respective estimates.

In essence, our analysis supports the Division of Forestry's findings in terms of the existence of a large untapped resource. There are about 4,800 thousand green tons (MGT) of woody material annually being cut from the forests within 50 miles of the plant or produced as additional byproducts from mills within 75 miles. Current removals represent about 60% of the total weight of wood that could be utilized. By merely harvesting the excess hardwood growth, with no increases in the current standards of utilization, 542 MGT would be available to the Purdom plant on a sustained basis.

To specifically summarize our findings, we estimate that 468 MGT of hardwood and 2,003 MGT of pine are now being cut from commercial forest lands within 50 miles of St. Marks each year. The bark from this wood and the sum of all mill residue produced, between 50 and 75 miles from St. Marks, amounts to 363 and 1,967 MGT for hardwood and pine, respectively. Assuming a lack of contractual constraints, these 4,800 MGT could be produced and delivered to St. Marks without any expansion in the industry. At some given price, producers should be willing to sell the City wood they now send elsewhere.

According to the Energy Office analysis of the comparative economics of oil and wood, a price of $22 per ton would be attractive to the City in the face of oil prices of $27.70 per bbl. Our investigation of delivered prices indicates that at such a price level all hardwood stumpage and all mill residue, except pine chips and shavings, should be available. Therefore, the industry currently produces 1,921 MGT annually, which could potentially be captured by the City.
### TABLE 2
AVAILABLE WOODY BIOMASS BY TYPE & SOURCE
ASSUMING CURRENT LEVEL OF MANAGEMENT
M GREEN TONS

<table>
<thead>
<tr>
<th>Species</th>
<th>Annual Amount Currently Available</th>
<th>Available With Increased Utilization</th>
<th>Available With Expanded Harvest</th>
<th>Too Expensive Now Produced</th>
<th>Too Expensive Potential Production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardwood</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Removals</td>
<td>467.97</td>
<td></td>
<td>542.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Excess Growth</td>
<td></td>
<td>252.70</td>
<td>292.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Logging Debris</td>
<td>4.06</td>
<td></td>
<td>4.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Mortality</td>
<td>363.26</td>
<td></td>
<td>404.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Mill Residue</td>
<td></td>
<td>98.05</td>
<td>116.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rough and Rotten</td>
<td>68.98</td>
<td></td>
<td>83.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Premerchantable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Softwood</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Removals</td>
<td></td>
<td></td>
<td>2,002.51</td>
<td>176.37</td>
<td>536.41</td>
</tr>
<tr>
<td>Annual Excess Growth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Logging Debris</td>
<td>1,063.77</td>
<td></td>
<td>93.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Mortality</td>
<td>11.76</td>
<td></td>
<td>0.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Mill Residue</td>
<td>1,089.50</td>
<td></td>
<td>58.18</td>
<td>877.17</td>
<td>102.04</td>
</tr>
<tr>
<td>Rough and Rotten</td>
<td>54.75</td>
<td></td>
<td>4.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,920.73</td>
<td>1,554.06</td>
<td>1,600.77</td>
<td>2,879.68</td>
<td>278.41</td>
</tr>
<tr>
<td>Amount on Industrial Lands</td>
<td>124.05</td>
<td>716.56</td>
<td>294.08</td>
<td>1,318.87</td>
<td>223.93</td>
</tr>
<tr>
<td>Amount on Public and Non Industrial Land</td>
<td>1,796.68</td>
<td>837.50</td>
<td>1,306.69</td>
<td>1,560.81</td>
<td>502.34</td>
</tr>
</tbody>
</table>

1. That portion encountered in conjunction with annual removals.
2. That portion encountered in conjunction with excess growth.
3. That portion from mills within 75 miles and not counted in annual removals or excess growth.
4. Bark and fines.
5. Minus residue from primary processing (non bark).
6. Logging debris, mortality, rough and rotten, and premerchantable hardwood.
7. Hardwood removals.
8. Plus excess hardwood growth.
Rather than compete through price within the current productive capacity, it would be preferable, if possible, to expand into an area of unutilized resources. Given that there is to be no reduction in the productive capability of the forests themselves, (i.e. the inventory of trees able to maintain the present rate of growth), net annual growth and wood considered unmerchantable is still potentially available. These are the categories into which the forest products industry, as a whole, will expand to meet the expected growth in demand over the next 20 years.

A portion of this material is available using the conventional logging technology available today. At present, forests in the St. Marks timberedshed are producing 542 MGT of hardwood and 218 MGT of pine per year, beyond the amount removed. If all of this wood was cut and processed by mills similar to those operating today, an additional 160 MGT of pine and 404 MGT of hardwood residue would result. There is no reason to believe that the price of pine will fall within the range of fuelwood, so the potential supply from excess growth is restricted to that attributable to hardwood and about 462 MGT of lowgrade pine residues.

Technical advances relative to fuelwood harvesting are centered around two operations: the efficient collection of small stems and logging debris, and transportation of bulky and irregular shaped materials to the mill. The most advanced commercial operation uses a tree shear/accumulator to sever stems as small as three inches in diameter and lay them in bunches. A rubber tired skidder, employing a grapple, then drags the bunches to the loading ramp. There the material is fed into a chipper and blown into a semi van. This system allows the utilization of not only small diameter stems, but branches, trees, which have died, and trees considered too rough or rotten to be used for other products. Although no efficient system exists for the harvesting of brush or the collection of standard logging debris, there are many under development. Further, an integrated operation using the above described equipment could chip sawlog tops and low grade stems for fuel while separating and loading better material for shipment to the appropriate mill.

If such a system was used to harvest current annual removals, about 1,554 MGT of fuelwood would be produced. If harvesting expanded to encompass excess growth, 596 MGT more of this source of fuelwood could leave the woods.
Although we both conclude that there are sufficient quantities of fuelwood to support the Purdom plant, the differences between our method of analysis and that of the Division of Forestry are great enough to bear examination. The Division estimates that there are now 2,715 MGT annually available for fuelwood. On the other hand, using those of our categories which are most closely comparable to the Division's, we arrive at an estimate of 3,155 MGT. However, after the removal of mill residue, which the Division does not count, our estimate is in very close agreement with theirs. The following is a summary of our assumptions and calculations.

**Current Annual Removals**

Using the U.S.F.S. forest survey data, the removals of pine and hardwood growing stock volume (merchantable stemwood in desirable and acceptable trees) were converted to weight. The conversion factors employed were 55 pounds/cubic foot for hardwood and 57 pounds/cubic foot for pine (Cliffon and Bulpitt, 1976) (note: unless stated otherwise, pine is used in a general sense to refer to all softwoods, including cypress).

As mentioned previously, we assume that unless otherwise constrained, loggers will use the equipment they now have to produce wood for the buyer offering the highest price. Therefore, at least a portion of the area's current production capacity could be enticed to supply fuelwood for the City. Of course, creation of new markets will cause an expansion into the utilization of excess growth. Removals do, however, give an indication of the immediate supply base, or present productive capability of the area relative to the City's needs. For example, if current removals of the desired resource were extremely small, it would suggest that the needed equipment, expertise, and support facilities were lacking. A great deal of inertia might then be encountered as the new buyer attempted to develop the supply infrastructure.

Specifically, there is a high level of forestry activity in the St. Marks' area. Still, the City's expected needs amount to about 25% of the wood now produced and actually exceeds annual hardwood removals by about 100 MGT. The infrastructure exists, but the City's demand could strain the supply capacity until additional crews can be set up and placed in the woods.

**Annual Excess Growth**

The resource into which harvesting may expand is the difference between the total amount of wood produced each year and the amount currently utilized. Given the current level of management and technology, excess growth represents the maximum sustainable harvest.
We extracted excess growth of growing stock from the forest survey data (combining all classes of hardwood and all classes of softwood) and converted the volume to weight as we had for removals. The hardwood was considered to be the available source of future supply while the softwood was expected to remain too expensive to be used as fuel. From the hardwood we also subtracted the growth that is occurring within the deep swamps. The cost of logging in such difficult areas would probably drive the price of wood growing there beyond the limit of fuel as well.

This left 542 MGT of hardwood, which is currently produced each year, falls within the price range of fuelwood, and is compounding at the rate of about 2% per year for the lack of utilization. This is the amount for which all new users of hardwood will be competing. If the City's entire supply was to come from this source, it would need to capture the total unutilized production.

Annual Logging Debris

With the advent of whole tree chipping systems, those who can utilize low grade material have the opportunity to stretch the yield of a stand beyond the volume traditionally considered merchantable. Bark, branches, and foliage can be collected and transported to the mill. Inclusion of these materials increases the weight of a tree by 43%, if it is a softwood, and 54%, if it is a hardwood, (North Central Forest Experiment Station, 1978).

The majority of this material is left in the woods at present and could be recovered if either whole tree harvesting or some other debris collection system was employed. Being of low quality, i.e. unsuitable for most pulp or particle board processes, the tops of both pine and hardwood would be available for fuel. In terms of current removals, logging debris amounts to about 1,316 MGT after applying the above percentages to corresponding removal volumes. The same can be done to the volume of excess growth. An expanded harvest would produce approximately 294 MGT of logging debris annually.

Annual Mortality

Due to age, disease, insect attack and various other casual agents, a certain number of trees die each year. For some period after their death, these trees are sound enough to be utilized for pulp or fuel. By converting the mortality volume found in the forest survey data to weight, we estimate that about 445 MGT of this material becomes available each year. Since the wood's value for pulp decreases rapidly as decomposition begins, most can be considered as fuelwood.

It will not be practical to collect all of this wood, however. Trees die as individuals or in small groups. There are stands which have a higher than average rate of mortality due to their age or condition, but to a large extent, mortality is spread rather randomly across the entire forest area. If we assume that the trees must be harvested within a year (which is probably a practical limit for sale and efficient handling), then logging crews would have to enter each acre each year.
Instead, we assumed that mortality would be encountered in the same proportion to its total amount as removals to total inventory. In the case of an expanded harvest, the additional amount of mortality, which could be salvaged, is the total amount multiplied by the ratio of excess growth to total inventory. This is a somewhat conservative estimate in that it does not recognize that a portion of the removals are the result of selective harvests rather than clearcuts, i.e. the proportion of harvested acres to total acres is greater than that of harvested volume to total volume. In addition, the stands with the highest rates of mortality are those most likely to be harvested. Still, our estimate is probably a realistic recovery rate, particularly when the value of dead trees to wildlife is taken into account.

Annual Mill Residue

The mill residue figures represent the bark from trees harvested within 50 miles of St. Marks and the total amount of residue produced by mills situated between 50 and 75 miles from St. Marks. The slabs, edgings, sawdust and other wood residues that would be produced by milling the wood cut within 50 mile radius is accounted for within the growth and removal figures.

In calculating mill residues, our first assumption was that the flow of roundwood leaving an area for milling was equal to the flow of roundwood entering that area. Although not strictly true, due to an irregular distribution of mills, its validity should be within the accuracy limits needed for general planning. As a comparison, our estimate of the residue within 50 miles of St. Marks exceeds an estimate of residue within 50 miles of Live Oak, Florida by about 24%. The latter estimate was based on phone interviews of all known mills in the area (F & W Forestry Services, Inc., unpublished report, 1980).

The assumption accepted, we took the 1979 residue production and commodity drain figures for Florida from the Division of Forestry's most recent Commodity Drain Report (Friensehner, 1979), and calculated residue yield per ton of roundwood harvested. A separate factor was calculated for each classification of residue; bark, coarse particles, fine particles and shavings. The factors were also specific as to the species group.

For the bark from trees cut within 50 miles of St. Marks, we merely applied the appropriate factor to our figures for removals and excess growth. These figures were lacking for the specific area between 50 and 75 miles from St. Marks so the drain data for counties whose industrial center fell within the circle were used. The drain information for Florida came from the report cited above, while that for the Georgia counties was taken from Georgia's Wood Energy Program (Georgia Forestry Commission, 1979). This report also provided figures for residue production, specific to Southwest Georgia, and was used in conjunction with drain figures for the same area to produce a more localized set of residue factors.
Growth figures for the area of Florida, beyond the 50 mile radius, were derived from Forest Statistics for Florida, 1980 (Bechtold and Sheffield, 1981). For the area of Georgia between the two radii, we assumed the ratio of growth to removals applicable within 50 miles would remain valid in Southwest Georgia. This factor was then applied to the residue yield previously calculated for removals in the same area.

Once the amount of residue was calculated, we attempted to determine what portion would be available to the City. With regard to current production, the same conditions exist relative to residue as to removals. About 97% of all residues produced in Florida are utilized (Friesehnner, 1979). Therefore, although the City could probably capture some of this supply, reliance should be placed primarily in the amount associated with the increased timber production of the future.

An additional consideration is that some residues, such as pine chips and shavings, can be used for pulp and particle board. This increased their price beyond that economical for fuel. Coarse residues and shavings from softwoods were therefore removed from consideration as fuelwood.

Rough and Rotten

The category of rough and rotten includes those trees which due to their condition or species are unacceptable for traditional forest products. They are an excellent source of fuelwood, therefore, and would be retrieved in a manner similar to that described for mortality. In the City Energy Office Report, a growth rate, and thereby, an annual removal rate of 5% of the total volume was assumed.

On the other hand, our thinking is that this material will be removed whenever it is encountered, regardless of the growth rate. The exhaustion of this resource will only increase the opportunity to grow better quality timber. This in mind, we applied our ratios of removals (or growth) to total inventory to the total rough and rotten inventory. The figures for softwood rough and rotten found in the table, then, represent a removal rate of about 7% and 0.5% of the total volume for removals and growth respectively. The hardwood figures account for 1.5% and 2% of total inventory for current production and an expanded harvest, respectively. The forest survey data indicates the actual growth rate of this material to be about 2%. Therefore, at all but the present hardwood production rate, the rough and rotten inventory will decline, but should still provide a source of fuelwood for sometime to come.

Premerchantable Trees

The final source of fuelwood are those trees which are currently considered too small for harvest. Many of these trees are planted pines or naturally established pines which are being counted upon for the regeneration of the stand. We therefore dropped all premerchantable softwood from our consideration as potential fuelwood. Most hardwoods, on the other hand, are regenerated in clearcuts through coppicing and seed in place. Saplings standing in a hardwood stand prior to harvest are seldom retained as the base for a new stand.
We treated premerchantable hardwood, then, as a randomly distributed fuelwood resource, as we had mortality, and rough and rotten. The forest survey data provided the acreage and number of premerchantable trees per acre by forest type. From this we were able to calculate the total number of saplings within the 50 mile radius. As with all other categories, the material occurring in deep swamps was disregarded.

A certain number of saplings occur in young stands which are expected to attain merchantability, and others, regardless of their location, are simply too small to be harvested economically. We made a rough estimate that one third of all the saplings would be suitable for harvest as fuelwood. We then estimated that the typical fuelwood sapling would have a diameter, breast height, of three inches and a total height of 30 feet. Its total above ground weight would then be about 50 pounds (Schlaegel, 1981). We multiplied the available number of trees by this weight and our respective ratios for growth and removals to arrive at the estimates found in the table.

Additional Remarks Concerning Supply

There are several potential sources of fuelwood that were addressed in the Division of Forestry analysis but not included in our tabulation. The first of these is the volume occurring on nonstocked land. This material may be available, as may quantities of land clearing debris and other noncommercial removals, but it will probably be found in relatively small quantities and sporadically in terms of location and time. It may be difficult to find an economical method for retrieving this material.

Neither have we considered the volume to be found in the stumps of trees to be removed. This is due to the possibility that large scale removal of stumps may unduly exacerbate soil erosion. In addition, the soil which clings to the stumps will accelerate the wearing of chippers unless steps are taken to remove it.

Finally, our figures assume a static level of forest management. Improvements in the utilization of the forests' inherent capacity to produce will no doubt occur. The improvements will require a change in the behavior of individual landowners, however, the rate and ultimate degree of which is difficult to estimate. And since it appears that there is an adequate supply of fuelwood at the present level of management it may be preferable to plan using a conservative approach in this regard.

Area Fuelwood Users

The available resource herein described has attracted and will continue to attract other users. Foremost among these is probably the forest products industry itself. Owensillinois and Buckeye Cellulose are both buyers of wood fuel. Other mills also use a portion of their own residue for fuel. It can be expected that their use of a fuel, which is nearby and under their control, will increase.
Current users of fuelwood outside the forest products industry include:

Florida State Hospital, Chatahoochee - estimated consumption 50,000 tons of wood pellets per year.

Florida Power Corporation, Ellaville - estimated consumption of gasifier, 25,000 tons per year.

Gold Kist, Quitman Georgia

Projects under construction or study include:

Florida State Prison, Union County

Florida A & M University, Tallahassee

City of Monticello (Peanut hulls are to provide 100 MGT of fuel per year while wood is to supply 30 MGT)

In addition, there are potential projects in Liberty and Madison counties. Numerous individuals may turn to small scale gasifiers or other wood fired systems to provide the energy for needs such as crop drying and irrigation.

Competition from the projects cited above would probably not have a serious impact on supply for the Purdom Plant. On the contrary, the increase in demand may provide enough incentive for the establishment of new suppliers, thereby providing easier access to the resource. Should the number of such projects continue to grow unabated, however, this would eventually impinge on the City's supply.
Environmental Effects of Fuelwood Harvesting
ASSESS THE ENVIRONMENTAL EFFECTS TO THE FOREST OF FUELWOOD HARVESTING

Changes in an ecosystem which result from the harvesting of fuelwood take two major forms: alteration of the vegetative cover and disturbance of the physical structure of the soil. From these basic changes are most of the various impacts, positive and negative, derived. The impacts are in terms of such environmental components as composition of the future vegetative cover, soil quality, wildlife abundance and diversity, water quality and aesthetic consideration. We have reviewed a portion of the vast body of literature relevant to this topic and have isolated some of the most important impacts and implications concerning their management.

Stand Composition and Vegetative Cover

When beginning to think about the vegetative composition of the forest, we should not assume that the goal is the maintenance of the status quo. Neither should we assume that the present composition of some unmanaged stand is more balanced, productive, or ecologically opportune than a managed stand. The early Florida forests were far different than those seen today. The uplands were dominated by extremely open longleaf pine stands which were maintained by frequently occurring fires. The moister, more fertile sites supported communities of magnolia and beech. Today's forests, and particularly the abundance of hardwoods, are the result of such human practices as exploitive logging, fire suppression, and cultivation (Harris and Smith, 1978).

So changes in stand structure are not in themselves deleterious, provided that other aspects of environmental quality are maintained. In terms of economic benefits accruing to the landowner as a result of the removal of low quality hardwoods, the positive impact of fuelwood harvesting is great. It will allow the reconversion of many sites to pine by providing a market for previously unwanted products and by eliminating the need for costly site preparation. The economy, as a whole, benefits in that by making species conversion feasible, fuelwood harvesting may initiate a cycle of commercial production that may otherwise have been indefinitely delayed (McMinn and Nutter, 1981).

Fuelwood harvesting can aid the conversion to pine in other ways as well. First, by harvesting in summer, sprouting of some hardwood species can be inhibited. In addition, more soil will be exposed, thereby facilitating the establishment of pine seedlings (McMinn and Nutter). Roberts Pichette (1979), however, warns that fuelwood harvesting may create a harsher microclimate near the ground which may reduce the growth and survival of seedlings.

Besides the rather obvious effects on the overstory, the removal of overstory vegetation and the disturbance of the soil may affect the understory and groundcover. Swindel, et. al. (1982) found that in a coastal pine-cypress-titi forest the number
of plant species inhabiting the site doubled after clearcutting and site preparation. Both the frequency and density of herbaceous species increased. Although woody species decreased, they coppiced freely. When they sampled slash pine plantations of various ages, the combined list of plant species encountered was greater than one for the typical unmanaged stand.

Soil Quality

Soil quality may be affected physically, chemically or biologically. An example of a physical effect is the loss of porosity due to compaction. Although not a problem on most of Florida's sandy soils, some soils in the Tallahassee area have a high enough clay content to warrant caution.

A physical effect with consequences for the nutrient content of the soil is the increase in soil erosion (RobertsPichette, 1979). Disruption of the litter layer increases the loss of topsoil to both wind and water. Further, the overstory, once removed, no longer acts to blunt the velocity of incoming rain drops. Florida's soils are inherently low in fertility and systems such as the flatwood forests are balanced by the storage and gradual release of nutrients from the litter. A severe disruption of the litter can seriously restrict the reserves available to a young stand (Morris and Pritchett, 1982).

The major concern associated with the effects of fuelwood harvesting on the site is the removal of nutrients and the subsequent loss of productivity. Morris and Pritchett (1982) determined that the removal of timber from a pine flatwoods sites removed the following amounts of soil nutrients:

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59 kg./ha.*</td>
<td>5</td>
<td>20</td>
<td>80</td>
<td>17</td>
</tr>
</tbody>
</table>

These figures represent losses from a traditional harvest and they estimate that the addition of branches and foliage would increase the loss by 30 to 40%. McMinn and Nutter (1981) found that fuelwood harvest in the Georgia Piedmont removed several times this amount.

The movement of nutrients is not exclusively away from the site, however, precipitation and weathering of minerals both add nutrients to the available pool. Carlisle and Methven (1979) reported the results of a study on the nutrient content in precipitation which found Tallahassee rainwater to add 3.0 kg./ha./Yr. of nitrogen, 1.8 kg. of potassium and 6.0 kg. of calcium. Using the estimates of depletion above, it appears that a rotation of 30 years would compensate for the losses to whole tree removal for those elements contained in the rainwater. There would still be a net loss of phosphorus and magnesium, however. Indeed, even with rotations as long as 60 years, and with which there should be little soil deterioration, phosphorus depletion may still be a problem (Carlisle and Methven).

*(1 kg./ha. = 0.89 lb./ac.)*
Nutrient removal can be treated through fertilization. Pritchett and Morris (1982) maintain that since harvest losses of phosphorus approach one half of the extractable reserves in the soil organic matter and that complete biomass utilization or short rotations can seriously deplete available nitrogen, "productivity of intensively managed flatwoods sites cannot be maintained without fertilization." Carlisle and Methven do not feel that fertilization is a completely satisfactory answer. They cite its high cost in dollars, and energy and the rapid leaching that occurs where soil organic matter and cation exchange capacity are low.

The final effect of fuelwood harvesting on the soil relates the organisms found therein. Nutrients are often available to plants only after they have been released from organic matter by the action of microorganisms. A removal of organic material from the soil could cause a deficit of soil microorganisms and thereby a reduction in nutrient cycling and availability (Roberts-Pichette, 1979). In addition, Pritchett and Morris (1982) found that forest floor disruptions, such as site preparation, caused the soil temperature to rise enough to influence microbial action.

**Wildlife**

There is not a particular state of forest composition which benefits all wildlife. One species may utilize and even require clearcuts or other openings while another may require large expanses of mature timber. Within a stand, all of the levels of vegetative cover may be used by one species or another. In addition, individual species require habitat variation within their home range, which may be anything from 1 to 1,000 acres. The key is to maintain diversity at the smallest level within a stand and landscape diversity among stands (Harris, et. al., 1978).

Specific considerations are applicable to each class of animal. For bird species, for instance, diversity is maximized in mid-successional forests (Evans, 1978) although some species depend on large areas of near climax bottomland hardwood, 100 years old or more (Dickson, 1978). Within a stand, a variety of plant species and foliage heights promotes bird diversity. Practices which destroy the understory and promote a monoculture are disadvantageous to bird populations (Wood and Niles, 1978). Many birds rely on the presence of dead and dying trees (Harris, et. al.).

Between stands, creation of an abrupt edge is beneficial to the bird population. Marion and O'Meara (1982) found bird populations low in slash pine stands prior to harvest. Clearcutting appeared to increase the area's use by winter residents and the edges of the clearcut were used much more frequently by breeding birds than were the stand interiors. Cypress ponds left standing within the clearcut area became an important refuge.

Wildlife, such as deer, utilize different habitats and food sources at different times of the year. Whitetail deer use turkey oaks in the sandhills during the late summer but move to planted pine stands in the spring (Harris, et. al.). With regard to planted pines, the deer prefer stands between five and 15 years old, due to the vegetative complex occurring in the stand during this period (Marion and O'Meara).
The lower animals may be the ones most harmed by intensive forest practices. Clearcutting and intensive site preparation significantly reduce populations of reptiles and amphibians (Marion and O'Meara). Somewhat more generally, Roberts-Pichette maintains that removals of residues from the forest reduces the abundance of organic life which uses this material as habitat and energy source.

Harris, et. al. summarizes some of the most important considerations for wildlife management, as a whole. They estimate that the most effective wildlife management area may be about 10,000 acres and that within such an area:

1. There should be a wide variety of timber types.

2. The stands of varying types should be well distributed.

3. The amount of interface between stands should be maximized.

4. The difference between adjoining stands should be maximized.

5. Spatial arrangements should bring as many different types of stands together as possible.

**Water Quality**

Two sources of water pollution applicable to forest harvesting are addressed in the Federal Water Pollution Control Act Amendments (P.L. 92-500). These are dredge and fill discharges (Section 404) and nonpoint source pollution discharges (Section 208). In addition, the State Department of Environmental Regulation and the Department of Natural Resources has jurisdiction over dredge and fill activities.

Dredging and filling is usually encountered in connection with the logging of swamps and therefore not of particular importance with regard to fuelwood harvesting. It should be noted, however, that permitting may be required through the Corps of Engineers and the State for any such activity affecting a navigable waterway or any of its tributaries up to the point at which stream flow falls below five cubic feet per second.

Nonpoint source pollution results primarily from soil erosion which accompanies careless logging and site preparation. The federal government has charged each state with the development of a set of Best Management Practices (BMP) to be applied to silvicultural operations. Those developed for Florida limit, according to soil type and slope, the practices which are acceptable within 300 feet of any significant watercourse. The only direct impact these BMP's have on fuelwood harvesting is to exclude clearcutting within 35 feet of a significant stream or lake.
Other Qualities

In certain instances, aspects of the human environment such as aesthetic quality or recreation use will need to be considered. In other cases, the presence of threatened or endangered species or the preservation of their potential habitat will be of primary importance. In the Addenda is a list of some of the plants and animals which may occur in areas of potential fuelwood harvest and which are in need of special protection.

Conclusions

Each of the instances and principles cited has potential application in terms of the environmental effects of fuelwood harvesting. Not all of the possible effects are adverse, nor are any so severe as to totally preclude the use of wood as a fuel. It is the responsibility of those directing fuelwood harvests and those managing the land on which such harvests are to take place, to manage the various impacts, maximizing the positive and minimizing the negative. Boyce (1979) describes the type of management which may be required:

"A large number of other states of forest organization offer opportunities to limit environmental costs, reduce investments in fossil energy, and improve the desirable combinations of multiple benefits. These states of organization are holistic, because they maintain a wide variety of forest types in a wide variety of age classes and they regulate the size of stands in relation to habitat requirements for endemic species and for the least destructive extraction methods. The dispersion of forest types in combination with other land uses and regulation of age and area classes of stands can create, over time, an enormous variety of habitats. If the areas of stands are kept relatively small, less than about 30 ha., and regeneration after harvest is rapid, many adverse consequences of extraction can be contained.

Artificial stands, even intensively cultured single species for short rotations, can be interspersed among natural stands. The use of superimposed rotation periods provides the opportunity for the same piece of land to be used for an intensively cultured plantation, then a natural forest for 80 to 200 years, then food crops for several years and eventually back into an intensively cultured plantation. An enormous number of combinations, forest types, age and area classes, and alternate land uses are possible. The important constraint is not to dissipate by extraction and adverse consequences more energy than can be trapped from the sun."

These are management and land use aspects over which the City will have little direct control. Their consideration and implementation by society, however, are essential to protect all interests in the future. The City can encourage responsibility on the part of its procurement contractors. It can also promote environmental education and the location and preservation of critical habitats in the Tallahassee area.
Potential Suppliers and Contract Considerations
LIST FIRMS WHO ARE WILLING TO ENTER INTO LONG TERM AGREEMENTS FOR WOOD SUPPLY AND PROVIDE SAMPLES AND TERMS OF CONTRACTS INTO WHICH THOSE FIRMS ARE WILLING TO ENTER.

The Energy Office report offered two fuelwood procurement options: develop a city staff to handle this function or contract with a broker. Within the framework of these basic options are several possible arrangements requiring differing degrees of input from the City:

1. City procurement personnel could negotiate the purchase of each tract of timber with direct City financing and then use contract loggers and haulers.

2. The City could contract to buy fuelwood procured by several dealers, each of whom is responsible for the location and purchase of stumpage (perhaps with City financing). The dealers would provide their own logging crews and haulers.

3. There could be a combination of 1 and 2, with the City entering into a direct arrangement with major forest landowners.

4. The City could turn complete control for procurement over to a fuelwood broker, even to the extent of the broker operating unloading and storage facilities at the plant.

It is beyond the scope of this report to examine the various implications to the City of each of these alternatives. We have, however, reviewed the Energy Office list of potential suppliers, asked for further information or clarifications from several survey respondents, and tried to determine the type of contract stipulations the City would be likely to encounter.

Mills

The Energy Office survey was mailed to most of the mills within a 75 mile radius of St. Marks. Our list, by county, is in the Addenda. A number of firms expressed interest in providing residues in amounts that ranged from about 10,000 to 75,000 tons per year. Contract terms offered by these firms were as long as 10 years.

Mill residues appear to be an attractive and currently available source of fuel. As noted previously, however, almost all of this material is being used by someone at the present time. Buckeye Cellulose and Owens-Illinois are both buyers of fuelwood and Weyerhaeuser buys sawdust and shavings for particle board. Additional residue is used on site or is sold for pulp chips, bedding or mulch. The U.S. Forest Service in its Review Draft: An Analysis of the Timber Situation in the U.S., 1952-2030 states:

"With increasing use of sawmill and veneer mill by-products for pulp and particle board furnish, or for fuels by wood processing plants themselves, there will probably be few locations in the U.S. where sufficiently large concentrations of mill residues will be available for utility operation."
So careful consideration should be given before relying on the forest products industry as a constant source of supply over the life of the plant.

Brokers

To look at companies which could manage the entire fuelwood procurement process, we recontacted the two regional brokers, Econ Company and Fiber Fuels, Inc. Correspondence from the latter is in the Addenda. Mr. Scott of Econ spoke in terms of a five year contract with price escalations pegged to one of various measures including the price of coal, the consumer price index, or the GNP deflator index. Pricing might also be varied according to the moisture content of the fuel delivered and whether or not actual deliveries fell within a given range around specified requirements.

Dr. Robert Harris of Fiber Fuels was interested in whether or not they would be sole procurement agents for the City. He also wondered whether they were to assume the unloading and storage facilities at the plant. These are services which Econ does not provide.

General Contract Considerations

Through discussions with the potential suppliers and information gleaned from existing contracts provided in confidence, a list of general contract provisions developed which should be applicable in dealing with residue or Greenwood suppliers. We have also included a copy of an invitation to bid distributed by the State of Florida to secure a supplier of wood fuel for the State Hospital at Chattahoochee. It contains several applicable provisions and includes specific testing procedures.

Any supply contract would contain all or most of the following provisions.

Time Frame - What will be the length of the contract? What provisions will be made for cancellation or extension?

Volume Requirements - What is the minimum amount for which the supplier is guaranteed to be paid? What is the minimum amount the supplier will be required to deliver? How large a reserve is to be maintained?

Delivery Schedule - During what hours and days will deliveries be accepted? What will be the maximum or minimum amount delivered during a given time period?

Delivery Mechanism - Will delivery be by truck, rail or barge? What will be the method of unloading, e.g. live bottom truck? Who is responsible for the provision and maintenance of unloading equipment?
<table>
<thead>
<tr>
<th>Topic</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content</td>
<td>What is the acceptable range of values?</td>
</tr>
<tr>
<td></td>
<td>How will moisture content be determined?</td>
</tr>
<tr>
<td>Particle Size</td>
<td>What is the average size expected?</td>
</tr>
<tr>
<td></td>
<td>What are the acceptable maximums and minimums?</td>
</tr>
<tr>
<td></td>
<td>How will particle size be determined?</td>
</tr>
<tr>
<td>Fuel Quality</td>
<td>How much foreign material will be allowed?</td>
</tr>
<tr>
<td>Price</td>
<td>What will be the price be for delivered material?</td>
</tr>
<tr>
<td></td>
<td>What provisions will be made for an adjustment in price for variations in</td>
</tr>
<tr>
<td></td>
<td>moisture content or chip uniformity?</td>
</tr>
<tr>
<td></td>
<td>Will there be price adjustments over time and what economic index will be</td>
</tr>
<tr>
<td></td>
<td>used as a standard?</td>
</tr>
<tr>
<td>Weight Determination</td>
<td>Will public or plant scales be used?</td>
</tr>
<tr>
<td></td>
<td>Over what period will loads be tallied before payment is made?</td>
</tr>
<tr>
<td></td>
<td>What procedure will be used if scales are inoperable or a discrepancy</td>
</tr>
<tr>
<td></td>
<td>between buyer's and seller's tally arises?</td>
</tr>
<tr>
<td>Notice</td>
<td>How much notice must be given prior to the fulfillment of a request by</td>
</tr>
<tr>
<td></td>
<td>either party?</td>
</tr>
<tr>
<td></td>
<td>Within what time period after a disagreement arises must written protest</td>
</tr>
<tr>
<td></td>
<td>be filed?</td>
</tr>
<tr>
<td></td>
<td>To whom will notice be sent?</td>
</tr>
<tr>
<td>Liability</td>
<td>To what extent will one party be responsible for the actions and obligations</td>
</tr>
<tr>
<td></td>
<td>of the other?</td>
</tr>
<tr>
<td></td>
<td>What type of bond or insurance will be secured and for what amount?</td>
</tr>
<tr>
<td></td>
<td>What safety measures will be taken?</td>
</tr>
<tr>
<td>Assignment</td>
<td>To what extent and under what conditions will the agreement be assignable?</td>
</tr>
</tbody>
</table>

All those interviewed indicated that the specifics of any agreement with the City could begin once a firm commitment to the project had been made.
POTENTIAL LOGGERS/HAULERS
AND CONTRACT CONSIDERATIONS
LIST FIRMS WHO ARE WILLING TO ENTER INTO LONG TERM AGREEMENT FOR LOGGING, STUMPAGE AND HAULING, AND PROVIDE SAMPLES AND TERMS OF CONTRACTS INTO WHICH THOSE FIRMS ARE WILLING TO ENTER.

Several of the procurement options listed in the previous section would require that the City deal directly with landowners, loggers and haulers. The general contract considerations will be the same as those cited in conjunction with mills and brokers. It would probably not be in the City’s interest, due to the potentially large staff requirement, to attempt the coordination of separate logging and hauling operations and/or the direct procurement of small quantities of wood (less than about 50,000 tons per year). There are several large landowners who could provide a significant portion of the City’s needs and dealers who will manage logging crews and haulers, and procure smaller tracts of timber.

Landowners

It has already been reported that there are about 2.7 million acres of commercial forest land within a 50 mile radius of St. Marks. Of this, about 18% is in the National Forest, 46% is controlled by the forest industry, and the remainder is in smaller public and private holdings.

In the Addenda you will find a listing by county of the forest industry landowners in the area and a map showing the location of their holdings. Buckeye Cellulose Corp. and St. Joe Paper own a combined acreage of about one million acres. A direct long term agreement with either would aid greatly in assuring a continuing supply of fuelwood. Both have expressed an interest to Mr. Sherman in making fuelwood from their lands available to the City and Buckeye Cellulose appears willing to supply a significant portion of the City’s needs, delivered to the Purdom plant. The terms under which Buckeye Cellulose would be willing to work with the City are outlined in Mr. L. S. Woodward’s June 2nd letter to Mr. Sherman. Other companies may prefer to sell fuelwood on a tract by tract or year by year basis, with the buyer providing loggers and transportation. A contract for this type of operation may resemble the Southwest Forest Industries Miscellaneous Cutting Agreement found in the Addenda.

Smaller landowners and the National Forest will be willing to sell fuelwood on a periodic basis but few will be able to provide significant volumes on a regular basis. Still it is likely that a majority of the fuel procured will come from these sources. The City procurement staff, local dealers or a fuelwood broker will have to bid for or negotiate the purchase of parcels as they are placed on the market. The size of individual sales may vary widely. A sampling of sales made by F & W Forestry Services, Inc. over the last 12 years included sale values ranging between $6,000 and $450,000. In the Addenda is a sample of the type of contract used by our firm in the sale of timber for our clients.

Due to its large size and proximity to the Purdom plant, the National Forest is of particular interest as a potential source of supply. Annual removals attributable to this source amount to about 240 MGT. None of this material was hardwood, however,
and according to information supplied to the Energy Office the average sale is about 10 MGT. Further, no long term contracts are possible if each sale is awarded through competitive bidding. There were removals of hardwood from other public lands which totaled about 35 MGT. Presumably, the St. Marks National Wildlife Refuge was the source, and if so, the material was sold under the same procedures used by the National Forest. To anticipate the amount of fuelwood which might become available, the timber management plans and sales schedules can be consulted.

Dealers

There are approximately 30 to 40 timber dealers operating within 75 miles of St. Marks. Many of these would be willing to supply fuelwood if a large enough commitment was made by the City to insure that the dealer could support a logging crew through the depreciation period on his equipment. We contacted M. A. Rigoni and John Cruce, two dealers with whole tree chipping experience, to determine what they would be able to provide and what they would require from the City.

Mr. Cruce estimated his potential production at 2,000 tons per week or about 80,000 tons per year. He would need from the City a guarantee that he could deliver at least 1,000 tons per week. In order to justify the purchase of new equipment, he would require a contract with a term of three to four years.

Mr. Rigoni's contract term and minimum delivery guarantee were the same as those required by Mr. Cruce. His estimated weekly production, however, was 1,200 to 1,500 tons. He suggested that a provision for price escalation would be needed and that renegotiation might be triggered by escalations in his costs for fuel, labor or stumpage beyond a certain percentage. Another of his concerns was an assurance that he could receive advances against future deliveries in case some unforeseen event closed the plant.

We also spoke with Earl F. Jones of Mutual Lumber Company. Mutual supplies residues to Florida Power Corp. in Ellaville, Florida for use in their wood gasifier. He has contracted with F & W Forestry Services, Inc. for fuelwood procurement services and intends to put whole tree chipping crews in the woods once his market for fuelwood increases. Copies of his and Mr. Rigoni's correspondence can be found in the Addenda.
REFERENCES


U. S. Forest Service, Southeast Forest Experiment Station, Forest Survey Data for the Area within a 50 Mile Radius of St. Marks, Florida.


Cruce, John, personal communication, December 10, 1982.


Schroeder, Richard, Florida Division of Forestry, personal communication, November 5, 1982.

Florida Resource and Environmental Assessment Center, Florida State University, Maps and List of Forest Landowners, 1980.


V.

CONCLUSIONS AND RECOMMENDATIONS
CONCLUSIONS AND RECOMMENDATIONS

The information gathered in this study indicates that enough alternative fuels are available at competitive prices. There are produced each year about 5,000,000 green tons of woody biomass which is cost competitive with other sources of fuel. At present, about 1,900,000 green tons of this material is used. The remaining 3,200,000 green tons await only the development of a fuelwood market stable enough to entice investments in whole tree chipping systems. All classes of forest landowners appear willing to sell fuelwood and the environmental impacts of fuelwood harvesting are manageable.

In the future there will be increasing competition for the resource as evidenced by the number of wood fueled projects being built or studied. In addition, it is likely that the forest products industry will retain more of the resource under its control for use as raw material for products. Therefore, although supply appears adequate for the foreseeable future, the total sustainable production could very likely be committed by the year 2000. Until that time, the real price of stumpage is not expected to rise significantly and this should work to keep wood competitive with conventional fuels.

Approximately 500,000 tons/year would be required by the proposed wood-fired utility plant in St. Marks, Florida. When the approximate prices of delivered wood at $2.25/MMBtu is compared to natural gas at $3.07/MMBtu (noting that natural gas makes up 80% of the present fuel mix and is also one of the cheapest fuels in the mix), it is conservative to say that wood is at least $0.82/MMBtu cheaper than present fuels being used. This equates to a fuel cost savings of over $2,810,000 in the first year. Each year the fuel savings is expected to get larger as the price of natural gas rises faster than the price of local wood chips. Such a savings must be carefully considered when the final feasibility study analyzes the cash flow and capital costs of the proposed plant.

The competition for wood is present in the St. Marks area, yet so is adequate supply. Paper companies presently own a moderate percentage of
the woodland in the area; however, their needs center mostly around pine pulpwood. Due to the lack of competition in the area, hardwood by-products from local sawmills can be purchased at low rates and used to fuel the paper mill boilers.

There is one 7.5 MW wood-fired power plant coming on-line in Monticello, Florida; Florida State Hospital in Chattahoochee; Florida A&M University in Tallahassee; Liberty County; and another in Madison, Florida. All plants are in the wood procurement range of St. Marks. However, according to F&W Forestry Services, Inc., these new plants are not a hindrance to the St. Marks project, but a welcome addition to the area since the plants will help make wood harvesting operations a more common business in the area. Hence, the brokering and procurement of wood will be an easier and more economical task.

Since wood is a lower grade of fuel than natural gas, oil, etc., the wood-fired boiler is expected to have a lower efficiency of approximately 65%; whereas a conventional fuel fired boiler efficiency is around 75% to 85%. Green wood with 50% moisture content will have approximately half the Btu's per pound it would have if it were dry. Hence, knowledge of the moisture content of the more popular wood species will help in the estimation of the expected average operating boiler efficiency and better define the number of green tons required for the system.

Each of the presently operating wood-fired utility plants mentioned in this report have been a success for the community it serves. In most cases, the biomass fuel would have been wasted if it were not for the local power plant's ability to burn it. The advantages and disadvantages of each plant should be considered when deciding on the specific design criteria best suited for the Purdom plant.

The convenient location of the Purdom plant on the navigable St. Marks River makes barging an alternative mode of transportation for wood fuel. With the combination of lower cost wood fuel at distance ports and lower transportation cost per ton, barging could compete on a marginal basis with the trucking of wood. Due to the much larger volume transported at one time, one double barge unit could easily supply a full day's requirement.
that would ordinarily take over 75 truck deliveries. The delivered wood fuel cost to the ports considered is approximately $11/ton. Using an average $18 per ton of green wood delivered by truck allows for a total of $7/ton to be spent on barge transportation just to break even with trucking. According to budget quotes from barging companies, $7/ton is within reasonable limits. Note, however, that the capital cost of loading and unloading equipment will significantly reduce any fuel cost savings. Hence, it is recommended that the proposal to barge wood be abandoned. The small marginal fuel and transportation savings, if any, would be far less than the socioeconomic benefits of harvesting and transporting the wood fuel locally.

The complications that are present when using garbage as an alternative fuel makes wood look even better as a fuel. The present 200 tons per day of garbage could supply almost 10% of the Purdom plant's energy needs; however, the higher capital costs of the extra equipment and the higher risks of downtime make it difficult to justify the low cost of garbage.

Florida, as well as the rest of the country, is committed to reducing its energy consumption per capita. Energy conservation is one tool to be used in reaching this goal, the use of alternative energy is another. The socioeconomic benefits of harvesting local wood fuel are multitudinous. Over 120 jobs will result from the harvesting and transportation of wood. These jobs have low skill requirements and would greatly benefit low income citizens. Landowners could get better prices for their wood. Sawmill owners could also sell their wood by-products at competitive prices to increase their profit margin and increase their ability to expand.

The city's taxpayers will benefit from the fuel cost savings wood fuel will provide. Increased savings mean less tax burden on the citizens for the city's operating expenses. Independence from foreign fuel prices and curtailments will allow the City of Tallahassee to control its own destiny.
Appendix A

LIST AND REGRESSION ANALYSIS OF F&W TIMBER SALES
ANALYSIS FOR HDWD PW

PARAMETERS:
STATE(S) 1
COUNTY(IES) 40 101 125 4 43 101 65 35 136 137 37 14 92
YEAR(S) 71 72 73 74 75 76 77 78 79 80 81 82
SALE TYPE(S) 0 1 2 3 4

TOTAL VOLUME LIMITS: MINIMUM 0.0, MAXIMUM 50000
VOLUME PER ACRE LIMITS: MINIMUM 0.0, MAXIMUM 500.00
SALE COMPOSITION CODE AND LIMITS: 1 0 100
AVE.UNIT LIMITS: MINIMUM 0.00, MAXIMUM 50.00

DATA:

<table>
<thead>
<tr>
<th>SALE</th>
<th>PRICE/UNIT</th>
<th>AVE.UNIT</th>
<th>VOLUME/acre</th>
<th>* TOTAL VOLUME *</th>
<th>FOR HDWD</th>
<th>* TOTAL VALUE *</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>3.38</td>
<td>0.0</td>
<td>***</td>
<td>223</td>
<td>438338</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>3.80</td>
<td>0.0</td>
<td>***</td>
<td>386</td>
<td>10952</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>3.27</td>
<td>0.0</td>
<td>***</td>
<td>507</td>
<td>72571</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>209</td>
<td>3.00</td>
<td>0.0</td>
<td>0.85</td>
<td>273</td>
<td>0</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>213</td>
<td>3.90</td>
<td>7.0</td>
<td>2.29</td>
<td>468</td>
<td>85500</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>262</td>
<td>5.00</td>
<td>0.0</td>
<td>***</td>
<td>94</td>
<td>10003</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>283</td>
<td>2.36</td>
<td>9.0</td>
<td>0.64</td>
<td>60</td>
<td>27383</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>294</td>
<td>3.22</td>
<td>8.0</td>
<td>***</td>
<td>209</td>
<td>77989</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>296</td>
<td>3.00</td>
<td>8.0</td>
<td>3.79</td>
<td>296</td>
<td>6173</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>304</td>
<td>2.97</td>
<td>8.0</td>
<td>0.66</td>
<td>46</td>
<td>6500</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>319</td>
<td>3.39</td>
<td>7.0</td>
<td>3.68</td>
<td>757</td>
<td>56364</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>343</td>
<td>3.15</td>
<td>9.0</td>
<td>0.41</td>
<td>345</td>
<td>128947</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>345</td>
<td>3.27</td>
<td>8.0</td>
<td>0.04</td>
<td>44</td>
<td>141919</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>346</td>
<td>5.11</td>
<td>7.0</td>
<td>0.93</td>
<td>416</td>
<td>81054</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>367</td>
<td>2.75</td>
<td>7.0</td>
<td>1.82</td>
<td>142</td>
<td>10000</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>369</td>
<td>3.00</td>
<td>9.0</td>
<td>4.01</td>
<td>196</td>
<td>27345</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>377</td>
<td>2.34</td>
<td>7.0</td>
<td>2.19</td>
<td>160</td>
<td>24662</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>390</td>
<td>2.52</td>
<td>8.0</td>
<td>1.73</td>
<td>294</td>
<td>59235</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>410</td>
<td>2.91</td>
<td>6.0</td>
<td>0.62</td>
<td>44</td>
<td>17258</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>411</td>
<td>3.03</td>
<td>8.0</td>
<td>3.85</td>
<td>185</td>
<td>36288</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>420</td>
<td>3.92</td>
<td>7.0</td>
<td>0.46</td>
<td>97</td>
<td>92568</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>423</td>
<td>4.14</td>
<td>9.0</td>
<td>0.92</td>
<td>56</td>
<td>10500</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>426</td>
<td>5.30</td>
<td>7.0</td>
<td>2.54</td>
<td>165</td>
<td>25550</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>431</td>
<td>3.35</td>
<td>9.0</td>
<td>0.18</td>
<td>6</td>
<td>29390</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>433</td>
<td>4.17</td>
<td>8.0</td>
<td>1.48</td>
<td>157</td>
<td>112855</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>434</td>
<td>3.59</td>
<td>7.0</td>
<td>0.26</td>
<td>63</td>
<td>132271</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>437</td>
<td>3.36</td>
<td>9.0</td>
<td>0.44</td>
<td>103</td>
<td>81392</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>446</td>
<td>3.07</td>
<td>10.0</td>
<td>0.35</td>
<td>43</td>
<td>29600</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>469</td>
<td>3.15</td>
<td>8.0</td>
<td>1.69</td>
<td>84</td>
<td>6233</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>470</td>
<td>3.21</td>
<td>9.0</td>
<td>2.06</td>
<td>54</td>
<td>7350</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>
FOR THE DEPENDENT VARIABLE  P/U*1.0

THE PREDICTIVE EQUATION AND RELEVANT STATISTICS ARE

\[ y = 6.737 + 1.16188 \times YR \times 0.5 \quad (T = 1.072) \]

RSQ: 0.033  XY CORRELATIONS: 0.181

XX CORRELATION MATRIX:

\[
\begin{array}{cc}
YBAR & XBAR \\
3.545 & 8.050
\end{array}
\]

N: 36  F: 1.15 WITH 1 AND 34 DEGREES OF FREEDOM
SE OF YBAR: 0.127  SE OF YHAT (WHERE X'S=XBARS): 0.127

FOR THE DEPENDENT VARIABLE  P/U*1.0

THE PREDICTIVE EQUATION AND RELEVANT STATISTICS ARE

\[ y = 0.818 + 0.00044 \times YR \times 2.0 \quad (T = 1.107) \]

RSQ: 0.035  XY CORRELATIONS: 0.187

XX CORRELATION MATRIX:

\[
\begin{array}{cc}
YBAR & XBAR \\
3.545 & 6.140 \, 333
\end{array}
\]

N: 36  F: 1.23 WITH 1 AND 34 DEGREES OF FREEDOM
SE OF YBAR: 0.127  SE OF YHAT (WHERE X'S=XBARS): 0.127
### ANALYSIS FOR PP PW

**PARAMETERS:**

STATE(S): 1  
COUNTY(IES): 49 100 125 4 43 101 65 35 136 137 37 14 92  
YEAR(S): 71 72 73 74 75 76 77 78 79 80 81 82  
SALE TYPE(S): 0 1 2 3 4

**TOTAL VOLUME LIMITS:** MINIMUM 0, MAXIMUM 500000  
**VOLUME PER ACRE LIMITS:** MINIMUM 0.00, MAXIMUM 500.00  
**SALE COMPOSITION CODE AND LIMITS:** 2 0 100  
**AVE.UNIT LIMITS:** MINIMUM 0.00, MAXIMUM 50.00

**DATA:**

<table>
<thead>
<tr>
<th>SALE</th>
<th>PRICE/UNIT</th>
<th>AVE.UNIT</th>
<th>VOLUME/ACRE</th>
<th>FOR PP PW</th>
<th>TOTAL VOLUME</th>
<th>TOTAL VALUE</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>8.62</td>
<td>0</td>
<td>***</td>
<td>2859</td>
<td>24650</td>
<td>7317</td>
<td>72</td>
</tr>
<tr>
<td>34</td>
<td>9.73</td>
<td>0</td>
<td>***</td>
<td>752</td>
<td>7317</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>43</td>
<td>8.26</td>
<td>0</td>
<td>***</td>
<td>2859</td>
<td>24645</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>48</td>
<td>8.00</td>
<td>0</td>
<td>***</td>
<td>972</td>
<td>7779</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>55</td>
<td>9.36</td>
<td>0</td>
<td>***</td>
<td>138</td>
<td>11632</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>58</td>
<td>9.00</td>
<td>0</td>
<td>***</td>
<td>1304</td>
<td>21609</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>69</td>
<td>20.23</td>
<td>0</td>
<td>***</td>
<td>502</td>
<td>430338</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>80</td>
<td>11.30</td>
<td>0</td>
<td>***</td>
<td>82</td>
<td>35250</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>99</td>
<td>13.07</td>
<td>0</td>
<td>***</td>
<td>464</td>
<td>72571</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>122</td>
<td>17.00</td>
<td>0</td>
<td>***</td>
<td>767</td>
<td>13039</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>150</td>
<td>17.00</td>
<td>0</td>
<td>***</td>
<td>325</td>
<td>5525</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>154</td>
<td>17.53</td>
<td>0</td>
<td>***</td>
<td>1487</td>
<td>50640</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>165</td>
<td>18.00</td>
<td>16.0</td>
<td>8.22</td>
<td>863</td>
<td>15530</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>190</td>
<td>17.10</td>
<td>0</td>
<td>10.74</td>
<td>730</td>
<td>12483</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>204</td>
<td>15.62</td>
<td>15.0</td>
<td>6.09</td>
<td>687</td>
<td>10732</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>231</td>
<td>19.43</td>
<td>16.0</td>
<td>3.46</td>
<td>539</td>
<td>16787</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>257</td>
<td>17.00</td>
<td>9.0</td>
<td>.65</td>
<td>200</td>
<td>59094</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>288</td>
<td>19.94</td>
<td>15.0</td>
<td>1.59</td>
<td>257</td>
<td>60272</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>301</td>
<td>20.80</td>
<td>15.0</td>
<td>2.96</td>
<td>422</td>
<td>17894</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>304</td>
<td>15.96</td>
<td>16.0</td>
<td>1.69</td>
<td>118</td>
<td>6500</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>312</td>
<td>18.49</td>
<td>14.0</td>
<td>15.12</td>
<td>5745</td>
<td>103680</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>341</td>
<td>21.22</td>
<td>17.0</td>
<td>.15</td>
<td>96</td>
<td>63644</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>355</td>
<td>19.95</td>
<td>15.0</td>
<td>.77</td>
<td>257</td>
<td>60212</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>358</td>
<td>16.00</td>
<td>19.0</td>
<td>.35</td>
<td>76</td>
<td>49000</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>375</td>
<td>26.35</td>
<td>11.0</td>
<td>9.23</td>
<td>1908</td>
<td>50285</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>408</td>
<td>18.58</td>
<td>8.0</td>
<td>1.99</td>
<td>155</td>
<td>30001</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>410</td>
<td>19.43</td>
<td>22.0</td>
<td>7.33</td>
<td>520</td>
<td>17258</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>415</td>
<td>21.36</td>
<td>10.0</td>
<td>2.44</td>
<td>1177</td>
<td>90072</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>421</td>
<td>29.80</td>
<td>16.0</td>
<td>2.89</td>
<td>358</td>
<td>10678</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>428</td>
<td>24.08</td>
<td>17.0</td>
<td>6.35</td>
<td>816</td>
<td>19659</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>
FOR THE DEPENDENT VARIABLE P/Ux1.0

THE PREDICTIVE EQUATION AND RELEVANT STATISTICS ARE

\[
\begin{align*}
265.701 & + 32.53616 \times \text{YR} \times 0.5 \\
\end{align*}
\]

\[(T = 11.058)\]

RSQ: 0.777

XY CORRELATIONS: 0.882

XX CORRELATION MATRIX:

1.000

YBAR: 18.942

XX CORRELATION MATRIX:

1.000

N: 37

F: 122.29 WITH 1 AND 35 DEGREES OF FREEDOM

SE OF YBAR: 1.082

SE OF YHAT (WHERE X'S=XBARS): 0.518

FOR THE DEPENDENT VARIABLE P/Ux1.0

THE PREDICTIVE EQUATION AND RELEVANT STATISTICS ARE

\[
\begin{align*}
52.813 & + 0.01222 \times \text{YR} \times 2.0 \\
\end{align*}
\]

\[(T = 11.096)\]

RSQ: 0.777

XY CORRELATIONS: 0.882

XX CORRELATION MATRIX:

1.000

YBAR: 18.942

XX CORRELATION MATRIX:

5872.027

N: 37

F: 123.12 WITH 1 AND 35 DEGREES OF FREEDOM

SE OF YBAR: 1.082

SE OF YHAT (WHERE X'S=XBARS): 0.516
### ANALYSIS FOR POP ST

#### PARAMETERS:
- **STATE(S)**: 1
- **COUNTY(IES)**: 49 100 125 4 43 101 65 35 136 137 37 14 92
- **YEAR(S)**: 71 72 73 74 75 76 77 78 79 80 81 82
- **SALE TYPE(S)**: 0 1 2 3 4

#### VOLUME LIMITS:
- MINIMUM: 0
- MAXIMUM: 500,000

#### VOLUME PER ACRE LIMITS:
- MINIMUM: 0
- MAXIMUM: 5000.00

#### SALE COMPOSITION CODE AND LIMITS:
- 4 0 100

#### AVE. UNIT LIMITS:
- MINIMUM: 0
- MAXIMUM: 500.00

#### DATA:

<table>
<thead>
<tr>
<th>SALE</th>
<th>PRICE/UNIT</th>
<th>AVE.UNIT</th>
<th>VOLUME/ACRE</th>
<th>FOR POP ST</th>
<th>TOTAL</th>
<th>VALUE</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>23.25</td>
<td>.0</td>
<td>***</td>
<td>33564</td>
<td>31759</td>
<td>22437</td>
<td>71</td>
</tr>
<tr>
<td>58</td>
<td>15.35</td>
<td>.0</td>
<td>***</td>
<td>28603</td>
<td>21609</td>
<td>11570</td>
<td>72</td>
</tr>
<tr>
<td>99</td>
<td>44.05</td>
<td>.0</td>
<td>***</td>
<td>87537</td>
<td>72571</td>
<td>60272</td>
<td>72</td>
</tr>
<tr>
<td>172</td>
<td>25.36</td>
<td>101.4</td>
<td>14.40</td>
<td>1013</td>
<td>11570</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>288</td>
<td>44.32</td>
<td>117.0</td>
<td>56.92</td>
<td>24730</td>
<td>60272</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>296</td>
<td>27.63</td>
<td>.0</td>
<td>433.45</td>
<td>33896</td>
<td>6173</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>346</td>
<td>30.21</td>
<td>82.0</td>
<td>8.63</td>
<td>3840</td>
<td>81054</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>355</td>
<td>44.32</td>
<td>118.0</td>
<td>73.91</td>
<td>24730</td>
<td>60212</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>356</td>
<td>76.10</td>
<td>125.0</td>
<td>131.83</td>
<td>35462</td>
<td>49675</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>358</td>
<td>35.00</td>
<td>67.0</td>
<td>.93</td>
<td>209</td>
<td>49000</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>362</td>
<td>5.16</td>
<td>162.0</td>
<td>39.59</td>
<td>1940</td>
<td>27345</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>390</td>
<td>63.07</td>
<td>128.0</td>
<td>1210.73</td>
<td>205824</td>
<td>59235</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>410</td>
<td>58.20</td>
<td>138.0</td>
<td>322.20</td>
<td>22844</td>
<td>79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>411</td>
<td>50.50</td>
<td>118.0</td>
<td>212.25</td>
<td>10188</td>
<td>36288</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>430</td>
<td>101.9</td>
<td>101.0</td>
<td>16.12</td>
<td>503</td>
<td>29390</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>434</td>
<td>62.12</td>
<td>154.0</td>
<td>570.59</td>
<td>60957</td>
<td>112855</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>437</td>
<td>41.96</td>
<td>214.0</td>
<td>21.45</td>
<td>5286</td>
<td>132271</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>440</td>
<td>72.77</td>
<td>174.0</td>
<td>497.92</td>
<td>116514</td>
<td>81392</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>450</td>
<td>59.98</td>
<td>198.0</td>
<td>365.16</td>
<td>42358</td>
<td>48000</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>469</td>
<td>47.25</td>
<td>148.0</td>
<td>558.88</td>
<td>27944</td>
<td>6233</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>470</td>
<td>37.75</td>
<td>72.0</td>
<td>13.71</td>
<td>362</td>
<td>7350</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>477</td>
<td>58.80</td>
<td>297.0</td>
<td>397.22</td>
<td>29871</td>
<td>22320</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>479</td>
<td>63.00</td>
<td>181.0</td>
<td>2495.22</td>
<td>52150</td>
<td>38667</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>482</td>
<td>60.00</td>
<td>72.0</td>
<td>27.51</td>
<td>1788</td>
<td>13561</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>495</td>
<td>51.60</td>
<td>106.0</td>
<td>504.62</td>
<td>31791</td>
<td>16000</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>
THE PREDICTIVE EQUATION AND RELEVANT STATISTICS ARE

\[-581.204 + 71.20542 \times YR \times .5 \quad (T= 5.039) \]

RSQ: \(0.514\)  \(XY\) CORRELATIONS: \(0.717\)

XX CORRELATION MATRIX:

\[
\begin{array}{cc}
1.000 & \\
YBAR: & 46.941 \quad XBAR: & 8.822 \\
N: & 26 \quad F: & 25.39 \quad WITH \ 1 \ AND \ 24 \ DEGREES \ OF \ FREEDOM \\
SE \ OF \ YBAR: & 3.187 \quad SE \ OF \ YHAT \ (WHERE \ X'S=XBARS): & 2.267 \\
\end{array}
\]

FOR THE DEPENDENT VARIABLE \(P/U\times1.0\)

THE PREDICTIVE EQUATION AND RELEVANT STATISTICS ARE

\[-116.422 + 0.02692 \times YR \times 2.0 \quad (T= 5.061) \]

RSQ: \(0.516\)  \(XY\) CORRELATIONS: \(0.719\)

XX CORRELATION MATRIX:

\[
\begin{array}{cc}
1.000 & \\
YBAR: & 46.941 \quad XBAR: & 6067.846 \\
N: & 26 \quad F: & 25.61 \quad WITH \ 1 \ AND \ 24 \ DEGREES \ OF \ FREEDOM \\
SE \ OF \ YBAR: & 3.187 \quad SE \ OF \ YHAT \ (WHERE \ X'S=XBARS): & 2.262 \\
\end{array}
\]
## ANALYSIS FOR SH ST

### PARAMETERS:
- **STATE(S)**: 1
- **COUNTY(IES)**: 49 100 125 4 43-101 65 35 136 137 37 14 92
- **YEAR(S)**: 71 72 73 74 75 76 77 78 79 80 81 82
- **SALE TYPE(S)**: 0 1 2 3 4

### TOTAL VOLUME LIMITS:
- **MINIMUM**: 0
- **MAXIMUM**: 500000

### VOLUME PER ACRE LIMITS:
- **MINIMUM**: 0
- **MAXIMUM**: 5000.00

### SALE COMPOSITION CODE AND LIMITS:
- **4**: 0
- **0 100**:

### AVE.UNIT LIMITS:
- **MINIMUM**: 0.00
- **MAXIMUM**: 500.00

### DATA:

<table>
<thead>
<tr>
<th>SALE</th>
<th>PRICE/UNIT</th>
<th>AVE.UNIT</th>
<th>VOLUME/acre</th>
<th>TOTAL VOLUME</th>
<th>TOTAL VALUE</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>18.06</td>
<td>1.00</td>
<td>***</td>
<td>211734</td>
<td>31759</td>
<td>71</td>
</tr>
<tr>
<td>58</td>
<td>15.35</td>
<td>1.00</td>
<td>***</td>
<td>22171</td>
<td>21609</td>
<td>72</td>
</tr>
<tr>
<td>99</td>
<td>35.24</td>
<td>1.00</td>
<td>***</td>
<td>127300</td>
<td>72571</td>
<td>73</td>
</tr>
<tr>
<td>105</td>
<td>18.10</td>
<td>96.00</td>
<td>108.91</td>
<td>12841</td>
<td>12400</td>
<td>74</td>
</tr>
<tr>
<td>172</td>
<td>30.57</td>
<td>115.9</td>
<td>1517.21</td>
<td>106660</td>
<td>11570</td>
<td>75</td>
</tr>
<tr>
<td>215</td>
<td>37.16</td>
<td>164.0</td>
<td>32.33</td>
<td>6595</td>
<td>95500</td>
<td>76</td>
</tr>
<tr>
<td>237</td>
<td>35.00</td>
<td>81.00</td>
<td>6.06</td>
<td>1874</td>
<td>59094</td>
<td>77</td>
</tr>
<tr>
<td>262</td>
<td>50.00</td>
<td>0.00</td>
<td>***</td>
<td>11267</td>
<td>10003</td>
<td>77</td>
</tr>
<tr>
<td>288</td>
<td>43.32</td>
<td>86.00</td>
<td>46.12</td>
<td>20039</td>
<td>60272</td>
<td>77</td>
</tr>
<tr>
<td>294</td>
<td>28.70</td>
<td>136.0</td>
<td>***</td>
<td>7859</td>
<td>77989</td>
<td>77</td>
</tr>
<tr>
<td>304</td>
<td>21.49</td>
<td>67.00</td>
<td>411.85</td>
<td>32207</td>
<td>6173</td>
<td>77</td>
</tr>
<tr>
<td>319</td>
<td>56.44</td>
<td>112.0</td>
<td>87.11</td>
<td>17909</td>
<td>56364</td>
<td>78</td>
</tr>
<tr>
<td>343</td>
<td>44.51</td>
<td>147.0</td>
<td>92.51</td>
<td>77250</td>
<td>128947</td>
<td>78</td>
</tr>
<tr>
<td>345</td>
<td>41.90</td>
<td>144.0</td>
<td>2.48</td>
<td>2730</td>
<td>141986</td>
<td>78</td>
</tr>
<tr>
<td>346</td>
<td>37.71</td>
<td>135.0</td>
<td>586.38</td>
<td>260940</td>
<td>81054</td>
<td>78</td>
</tr>
<tr>
<td>355</td>
<td>44.32</td>
<td>88.00</td>
<td>59.89</td>
<td>20039</td>
<td>60212</td>
<td>78</td>
</tr>
<tr>
<td>356</td>
<td>76.10</td>
<td>87.00</td>
<td>309.01</td>
<td>83338</td>
<td>49675</td>
<td>78</td>
</tr>
<tr>
<td>358</td>
<td>35.00</td>
<td>125.0</td>
<td>21.67</td>
<td>4767</td>
<td>49000</td>
<td>78</td>
</tr>
<tr>
<td>369</td>
<td>40.00</td>
<td>96.00</td>
<td>41.29</td>
<td>2023</td>
<td>27345</td>
<td>78</td>
</tr>
<tr>
<td>377</td>
<td>34.67</td>
<td>113.0</td>
<td>320.07</td>
<td>23365</td>
<td>24662</td>
<td>79</td>
</tr>
<tr>
<td>390</td>
<td>42.05</td>
<td>64.00</td>
<td>39.05</td>
<td>6639</td>
<td>59235</td>
<td>79</td>
</tr>
<tr>
<td>410</td>
<td>48.50</td>
<td>211.0</td>
<td>14.89</td>
<td>1056</td>
<td>17258</td>
<td>79</td>
</tr>
<tr>
<td>411</td>
<td>35.35</td>
<td>88.00</td>
<td>180.54</td>
<td>8666</td>
<td>36288</td>
<td>79</td>
</tr>
<tr>
<td>420</td>
<td>45.68</td>
<td>124.0</td>
<td>25.37</td>
<td>5327</td>
<td>92568</td>
<td>80</td>
</tr>
<tr>
<td>423</td>
<td>48.27</td>
<td>89.00</td>
<td>129.51</td>
<td>7861</td>
<td>10500</td>
<td>80</td>
</tr>
<tr>
<td>426</td>
<td>37.11</td>
<td>72.00</td>
<td>92.66</td>
<td>5995</td>
<td>25550</td>
<td>80</td>
</tr>
<tr>
<td>433</td>
<td>48.62</td>
<td>88.00</td>
<td>160.12</td>
<td>17005</td>
<td>112855</td>
<td>80</td>
</tr>
<tr>
<td>434</td>
<td>35.88</td>
<td>152.0</td>
<td>100.75</td>
<td>24625</td>
<td>132271</td>
<td>80</td>
</tr>
</tbody>
</table>
FOR THE DEPENDENT VARIABLE P/U*1.0

THE PREDICTIVE EQUATION AND RELEVANT STATISTICS ARE

$-302.133$
$+ 38.47848 \times YR \times 0.5 \quad (T= 3.457)$

RSD: 0.239  X Y CORRELATIONS: 0.489

XX CORRELATION MATRIX:

1.000

YBAR: 37.383  XBAR: 8.824

N: 40  F: 11.95 WITH 1 AND 38 DEGREES OF FREEDOM
SE OF YBAR: 1.783  SE OF YHAT (WHERE X'S=XBARS): 1.576

FOR THE DEPENDENT VARIABLE P/U*1.0

THE PREDICTIVE EQUATION AND RELEVANT STATISTICS ARE

$-48.910$
$+ 0.01422 \times YR \times 2.0 \quad (T= 3.385)$

RSD: 0.232  X Y CORRELATIONS: 0.481

XX CORRELATION MATRIX:

1.000

YBAR: 37.383  XBAR: 6070.625

N: 40  F: 11.46 WITH 1 AND 38 DEGREES OF FREEDOM
SE OF YBAR: 1.783  SE OF YHAT (WHERE X'S=XBARS): 1.584
### PARAMETERS:
- **STATE(S):** 1
- **COUNTY(IES):** 49 100 125 4 43 101 35 135 137 37 14 92
- **YEAR(S):** 71 72 73 74 75 76 77 78 79 80 81 82
- **SALE TYPE(S):** 0 1 2 3 4
- **TOTAL VOLUME LIMITS:** MINIMUM 0, MAXIMUM 500000
- **VOLUME PER ACRE LIMITS:** MINIMUM .00, MAXIMUM 5000.00
- **SALE COMPOSITION CODE AND LIMITS:** 4 0 0 100
- **AVE_UNIT LIMITS:** MINIMUM .00, MAXIMUM 500.00

### DATA:

<table>
<thead>
<tr>
<th>SALE</th>
<th>PRICE/UNIT</th>
<th>AVE_UNIT</th>
<th>VOLUME/ACRE</th>
<th>TOTAL VOLUME</th>
<th>TOTAL VALUE</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>11.34</td>
<td>.0</td>
<td>***</td>
<td>351757</td>
<td>313759</td>
<td>71</td>
</tr>
<tr>
<td>40</td>
<td>12.27</td>
<td>.0</td>
<td>***</td>
<td>101366</td>
<td>22439</td>
<td>72</td>
</tr>
<tr>
<td>58</td>
<td>9.72</td>
<td>.0</td>
<td>***</td>
<td>138948</td>
<td>21609</td>
<td>72</td>
</tr>
<tr>
<td>69</td>
<td>22.31</td>
<td>.0</td>
<td>***</td>
<td>62654</td>
<td>438338</td>
<td>73</td>
</tr>
<tr>
<td>75</td>
<td>37.74</td>
<td>142.0</td>
<td>1261.42</td>
<td>324184</td>
<td>32000</td>
<td>73</td>
</tr>
<tr>
<td>99</td>
<td>18.09</td>
<td>.0</td>
<td>***</td>
<td>159393</td>
<td>72571</td>
<td>73</td>
</tr>
<tr>
<td>135</td>
<td>13.28</td>
<td>109.0</td>
<td>88.80</td>
<td>10469</td>
<td>12400</td>
<td>74</td>
</tr>
<tr>
<td>172</td>
<td>19.85</td>
<td>208.2</td>
<td>2046.33</td>
<td>143857</td>
<td>11570</td>
<td>75</td>
</tr>
<tr>
<td>209</td>
<td>28.99</td>
<td>.0</td>
<td>362.14</td>
<td>116610</td>
<td>0</td>
<td>76</td>
</tr>
<tr>
<td>213</td>
<td>21.53</td>
<td>127.0</td>
<td>410.61</td>
<td>83764</td>
<td>85500</td>
<td>76</td>
</tr>
<tr>
<td>257</td>
<td>25.00</td>
<td>119.0</td>
<td>16.57</td>
<td>5124</td>
<td>59094</td>
<td>77</td>
</tr>
<tr>
<td>262</td>
<td>25.00</td>
<td>.0</td>
<td>***</td>
<td>10591</td>
<td>10003</td>
<td>77</td>
</tr>
<tr>
<td>283</td>
<td>12.06</td>
<td>111.0</td>
<td>113.65</td>
<td>10672</td>
<td>27383</td>
<td>77</td>
</tr>
<tr>
<td>288</td>
<td>33.24</td>
<td>133.0</td>
<td>192.02</td>
<td>83432</td>
<td>66272</td>
<td>77</td>
</tr>
<tr>
<td>294</td>
<td>19.58</td>
<td>191.0</td>
<td>***</td>
<td>104789</td>
<td>77989</td>
<td>77</td>
</tr>
<tr>
<td>296</td>
<td>12.96</td>
<td>.0</td>
<td>482.74</td>
<td>37750</td>
<td>6173</td>
<td>77</td>
</tr>
<tr>
<td>304</td>
<td>19.83</td>
<td>70.0</td>
<td>74.29</td>
<td>5193</td>
<td>6500</td>
<td>77</td>
</tr>
<tr>
<td>343</td>
<td>35.60</td>
<td>179.0</td>
<td>155.39</td>
<td>129750</td>
<td>128947</td>
<td>78</td>
</tr>
<tr>
<td>345</td>
<td>36.97</td>
<td>104.0</td>
<td>5.40</td>
<td>5940</td>
<td>141919</td>
<td>78</td>
</tr>
<tr>
<td>346</td>
<td>28.25</td>
<td>199.0</td>
<td>216.56</td>
<td>96370</td>
<td>81054</td>
<td>78</td>
</tr>
<tr>
<td>355</td>
<td>33.24</td>
<td>133.0</td>
<td>249.35</td>
<td>83432</td>
<td>60212</td>
<td>78</td>
</tr>
<tr>
<td>356</td>
<td>53.27</td>
<td>119.0</td>
<td>386.88</td>
<td>104071</td>
<td>49675</td>
<td>78</td>
</tr>
<tr>
<td>358</td>
<td>25.00</td>
<td>274.0</td>
<td>31.07</td>
<td>8636</td>
<td>49000</td>
<td>78</td>
</tr>
<tr>
<td>367</td>
<td>27.51</td>
<td>140.0</td>
<td>439.23</td>
<td>34260</td>
<td>10000</td>
<td>78</td>
</tr>
<tr>
<td>377</td>
<td>27.08</td>
<td>125.0</td>
<td>637.05</td>
<td>46505</td>
<td>24662</td>
<td>79</td>
</tr>
<tr>
<td>390</td>
<td>33.64</td>
<td>188.0</td>
<td>16.61</td>
<td>2623</td>
<td>59235</td>
<td>79</td>
</tr>
<tr>
<td>410</td>
<td>33.95</td>
<td>140.0</td>
<td>144.68</td>
<td>10258</td>
<td>17258</td>
<td>79</td>
</tr>
<tr>
<td>411</td>
<td>45.45</td>
<td>122.0</td>
<td>450.83</td>
<td>21640</td>
<td>36288</td>
<td>79</td>
</tr>
<tr>
<td>420</td>
<td>36.54</td>
<td>150.0</td>
<td>7.84</td>
<td>1647</td>
<td>92568</td>
<td>80</td>
</tr>
<tr>
<td>426</td>
<td>37.11</td>
<td>113.0</td>
<td>296.07</td>
<td>19156</td>
<td>25550</td>
<td>80</td>
</tr>
<tr>
<td>431</td>
<td>33.54</td>
<td>74.0</td>
<td>2.37</td>
<td>74</td>
<td>29390</td>
<td>80</td>
</tr>
<tr>
<td>433</td>
<td>34.73</td>
<td>133.0</td>
<td>114.11</td>
<td>12118</td>
<td>112855</td>
<td>80</td>
</tr>
<tr>
<td>434</td>
<td>35.84</td>
<td>151.0</td>
<td>79.28</td>
<td>19535</td>
<td>132271</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>469</td>
<td>470</td>
<td>477</td>
<td>479</td>
<td>482</td>
<td>494</td>
</tr>
<tr>
<td>---</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>31.50</td>
<td>32.10</td>
<td>29.40</td>
<td>31.63</td>
<td>30.00</td>
<td>37.10</td>
<td>25.80</td>
</tr>
<tr>
<td>117.0</td>
<td>113.0</td>
<td>120.0</td>
<td>185.0</td>
<td>131.0</td>
<td>113.0</td>
<td>130.0</td>
</tr>
<tr>
<td>166.00</td>
<td>90.08</td>
<td>102.09</td>
<td>397.13</td>
<td>480.38</td>
<td>296.07</td>
<td>8.25</td>
</tr>
<tr>
<td>8300</td>
<td>2378</td>
<td>7677</td>
<td>8300</td>
<td>31225</td>
<td>19156</td>
<td>520</td>
</tr>
<tr>
<td>6233</td>
<td>7350</td>
<td>22320</td>
<td>38867</td>
<td>13561</td>
<td>25550</td>
<td>16000</td>
</tr>
</tbody>
</table>

The Predictive Equation and Relevant Statistics are:

\[ y = 324.783 + 40.08918 \times \text{YR} \times 0.5 \]

\( T = 5.193 \)

RSE: 0.403

XY Correlations: 0.635

XX Correlation Matrix:

\[
\begin{pmatrix}
    1.000 &
    28.141 &
    8.803 &
    26.96 &
    1.476 &
    1.155
\end{pmatrix}
\]

N: 42

F: 26.96 with 1 and 40 degrees of freedom

SE of YBAR: 1.476

SE of YHAT (where X'S = XBARS): 1.155

The Predictive Equation and Relevant Statistics are:

\[ y = 62.452 + 0.01506 \times \text{YR} \times 2.0 \]

\( T = 5.192 \)

RSE: 0.403

XY Correlations: 0.635

XX Correlation Matrix:

\[
\begin{pmatrix}
    1.000 &
    28.141 &
    6016.762 &
    8.803 &
    26.96 &
    1.476 &
    1.155
\end{pmatrix}
\]

N: 42

F: 26.96 with 1 and 40 degrees of freedom

SE of YBAR: 1.476

SE of YHAT (where X'S = XBARS): 1.155
Appendix B

FLORIDA LAW CONCERNING ENDANGERED AND THREATENED PLANTS
indexed and certified as free from citrus diseases, including, but not limited to, tristeza, necrotic ring spot, exocortis, xyloporesis, psorosis, and vein enation. The cost of indexing shall be paid by the person desiring to have the tree indexed. Any tree offered for sale or sold which was propagated from a tree which is not indexed is contraband and shall be confiscated and destroyed by the department without compensation.

History.—s. 2, ch. 77-98; s. 2, ch. 77-386.

581.185 Preservation of native flora of Florida.—
(1) PROHIBITIONS; PERMITS.—
(a) With regard to any plant on the Endangered Plant List provided in subsection (2), it is unlawful for any person:

1. To willfully injure or destroy any such plant growing on the private land of another without first obtaining the written permission of the owner of the land or his legal representative.

2. To willfully injure or destroy any such plant growing on any public land or water without first obtaining the written permission of the superintendent or custodian of such land or water and a permit from the department as provided in this section.

3. To willfully harvest, collect, pick, or remove less than three individual plants of a given species listed on the Endangered Plant List from the private land of another without first obtaining the written permission of the owner of the land or his legal representative or from any public land or water without first obtaining the written permission of the superintendent or custodian of such land or water.

4. To willfully harvest, collect, pick, or remove three or more individual plants of a given species listed on the Endangered Plant List from any native habitat without first obtaining the written permission of the owner of the land or his legal representative or, in the case of public land or water, the written permission of the superintendent or custodian of such land or water, and a permit from the department as provided in this section.

5. To transport, carry, or convey on any public road or highway or sell or offer for sale in any place any such plant collected in violation of this section.

(b) With regard to any plant on the Threatened Plant List provided in subsection (3), it is unlawful for any person:

1. To willfully harvest, collect, pick, remove, injure, or destroy any such plant growing on the private land of another without first obtaining the written permission of the owner of the land or his legal representative or to willfully harvest, collect, pick, remove, injure, or destroy any such plant growing on any public land or water without first obtaining the written permission of the superintendent or custodian of such land or water.

2. To transport, carry, or convey on any public road or highway or sell or offer for sale in any place any such plant collected in violation of this section.

(c) The purpose of the permitting requirements imposed under paragraph (a) is to encourage the propagation of endangered or depleted species of flora and provide an orderly and controlled procedure for restricting harvesting of native flora from the wilds, thus preventing wanton
exploitation or destruction of Florida native plant populations. Permits shall be issued according to rules adopted by the Department of Agriculture and Consumer Services, except that the written permission of the owner, superintendent, or custodian required by paragraph (a) must be presented as a prerequisite to the issuance of a permit. The department may require such additional justification as it deems necessary when a permit is sought with respect to any plant on the Endangered Plant List which is of very limited distribution, is very rare, or is in imminent danger of becoming extinct in the wilds. Permits may be granted subject to conditions deemed necessary by the department to minimize environmental damage, provide for natural regeneration, protect against erosion or hazard of fire, and ensure that the plants removed are harvested, transported, and stored in such a way that they will be likely to survive and meet the purpose intended when they reach their ultimate destination.

(d) Any person willfully destroying, injuring, harvesting, collecting, picking, or removing any endangered or threatened plant; transporting, carrying, or conveying any such endangered or threatened plant on any public road or highway; or selling or offering for sale on any place any such endangered or threatened plant must have the permit, if applicable, and the written permission required by this section in his immediate possession at all times when engaged in any of such activities.

(2) ENDANGERED PLANT LIST.—The following plants shall be included in the Endangered Plant List:

(a) Asimina pygmaea (pink pawpaw).
(b) Asimina tetramera (four-petal pawpaw).
(c) Asplenium auritum (auricled spleenwort) (fern).
(d) Blechnum occidentale (sinkhole fern).
(e) Camygoneum angustifolium (narrow swamp fern).
(f) Cassia keyensis (Key cassia).
(g) Catesbaea parviflora (dune lily-thorn).
(h) Catopsis sp. (bromeliad).
(i) Cercocephalum gracilis (prickly apple cactus).
(j) Cereus robinii (tree cactus).
(k) Chionanthus pygmacus (fringe tree or granny-graybeard).
(l) Clusia rosea (balsam apple).
(m) Coccolithrinax argentea (silver palm).
(n) Cucurbita okeechobensis (Okeechobee gourd).
(o) Cupania glabra (cupania).
(p) Cyrtostachys pumilata (cowhorn or cigar orchid).
(q) Dispersa sp. (cuplet fern).
(r) Encyclia boothiana (Epidendrum boothianum) (dollar orchid).
(s) Epigaea repens (trailing arbutus).
(t) Gualacum sanctum (lignum vitae).
(u) Guzmania sp. (bromeliad).
(v) Ionopsis utricularioides (delicate ionopsis orchid).
(w) Magnolia ashei (Ashe magnolia).
(x) Magnolia pyramidata (pyramidal magnolia).
(y) Maxillaria crassifolia (orchid).
(z) Ophiochlaena palmatum (hand fern).
(aa) Parnassia grandifolia (grass-of-Parnassus).
(bb) Polyrrhiza lindenii (ghost orchid).
(cc) Rhododendron australis (orange azalea).
Rhododendron chapmanii (Chapman's rhododendron).
Ribes echinellum (Miccocouee gooseberry).
Rostonea elata (Florida royal palm).
Sarracenia leucophylla and Sarracenia rubra (pitcher plants).
Scaevola plumieri (scaevola).
Strumpfia maritima (pride-of-big-pine).
Suriana maritima (bay cedar).
Taxus floridana (Florida yew).
Tillandsia fasciculata (wild pine bromeliad) (included because of very high harvest rate).
Torreya taxifolia (Florida torreya).
Tournefortia qanaphelodes (sea lavender).
Trillium lancifolium (trillium).
Zephryranthes Simpsonii (zebyr lily).

THREATENED PLANT LIST.—The following plants shall be included in the Threatened Plant List:

(a) Bromeliads—all species of the bromeliad family, sometimes known as air plants, or wild pines, native to the state except Tillandsia usneoides, the Spanish moss, and Tillandsia recurvata, the ball moss, which are specifically excluded from this section, and except those included in the Endangered Plant List under subsection (2).

(b) Cacti—all native species of cacti, except the spreading or prostrate-growing species of Opuntia, which are specifically excluded from this section, and except those included in the Endangered Plant List under subsection (2).

(c) Orchids—all species of the orchid family, both epiphytic and terrestrial, native to the state, except those included in the Endangered Plant List under subsection (2).

(d) Ferns—all species of the fern families native to the state, except Blechnum serrulatum (swamp fern), Osmunda (cinnamon and royal fern), Polypodium aureum (serpent fern), Polypodium polypodioides (resurrection fern), Pteris aquilinum (common bracken), Thelypteris normalis (shield fern), and Woodwardia virginica (Virginia chain fern), which are specifically excluded from this section, and except those included in the Endangered Plant List under subsection (2).

(e) Ilex—all species (holly), except Ilex cassine (cassine), Ilex coriacea (large gallberry), Ilex glabra (gallberry), Ilex myrtifolia (myrtle-leaved holly), Ilex opaca (American holly), and Ilex vomitoria (yaupon), which are specifically excluded from this section.

(f) Palms—all species of the palm family native to the state, except Sabal palmetto (cabbage palm) and Serenoa repens (saw palmetto) and except those included in the Endangered Plant List under subsection (2).

(g) Peperomia—all species native to the state (pepper).

(h) Rhododendron—all native species (azalea), except those included in the Endangered Plant List under subsection (2).

(i) Zamia—all species native to the state (coontie).

(j) Zephyranthes—all white species (zebyr lily), except those included in the Endangered Plant List under subsection (2).

(k) Aristolochia tomentosa (Dutchman's pipe).

(l) Asclepias curitisii (sandhill milkweed).

(m) Calycanthus floridus (strawberry bush).

(n) Chrysophyllum olivaeforme (satlinleaf).
(o) Cienfuegosia heterophylla (yellow hibiscus).
(p) Commelina gigas (giant dewflower).
(q) Cordia Sebestena (geiger tree).
(r) Cornus alternifolia (dogwood).
(s) Frythronium americanum (dogtooth lily or violet).
(t) Eugenia confusa and Eugenia simpsonii (redberry and Simpson eugenia).
(u) Garberia fruticosa (garberia).
(v) Hippomane mancinella (manchineel).
(w) Illicium floridanum and Illicium parviflorum (anise shrubs).
(x) Jacquinia keyensis (joewood).
(y) Kalmia latifolia (mountain laurel).
(z) Liatris ohlingerae (gayfeather).
(aa) Licaria triandra (gulf licaria).
(bb) Lietneria floridana (corkwood).
(cc) Lilium catesbaei (pine lily).
(dd) Lobelia cardinalis (cardinal flower).
(ee) Malus angustifolia (crabapple).
(ff) Nemastylis floridana (fall-flowering ixia).
(gg) Pavonia spinifex (yellow hibiscus).
(hh) Pinckneya pubens (fever tree).
(ii) Sphenostigma coelestinum (Bartram's ixia).
(jj) Swietenia mahagoni (mahogany).
(kk) Tetrazygia bicolor (tetrazygia).

(4) REVIEW.—

(a) Beginning in 1980, a comprehensive review of this section and of the lists of plants provided in subsections (2) and (3) shall be made by the department and the Endangered Plant Advisory Council at 4-year intervals. The department shall report to the Legislature its findings and recommendations and those of the Endangered Plant Advisory Council by January 31 prior to the convening of the regular legislative session following each such review; however, an initial review and report under this section shall be made by January 31, 1980.

(b) The department shall notify the Legislature prior to the next ensuing regular legislative session of any species of plant that should be placed on the Endangered Plant List or the Threatened Plant List which is in danger of disappearing from its native habitat within the foreseeable future throughout all or a significant portion of the range of the species because of:

1. Present or threatened destruction, modification, or curtailment of the range of the species.

2. Overutilization of the species for commercial, scientific, or education purposes.

3. Disease or predation.

4. Any other natural or manmade factor affecting the continued existence of the species.

(c) In carrying out reviews and arriving at recommendations under paragraphs (a) and (b), the department and the advisory council shall use the best scientific and commercial data available and shall consult with interested persons and organizations.

(5) DEFENSE.—In any prosecution under this section, it shall be a defense that plants or the flowers, roots, bulbs, or other parts thereof transported, carried, or conveyed or sold or offered for sale by the party were legally imported from another country. In any prosecution under this section
involving the destruction, injuring, harvesting, collecting, picking, or removing of any plant on the Endangered Plant List or the Threatened Plant List without written permission, it shall be an affirmative defense that actual permission was given prior to such destruction, injury, harvesting, collection, picking, or removal. In any prosecution under this section involving the destruction, injuring, harvesting, collecting, picking, or removing of any plant on the Endangered Plant List without written permission and a permit, it shall be an affirmative defense that written permission and a permit had in fact been granted prior to such destruction, injury, harvesting, collection, picking, or removal.

(6) SALES BY NURSERYMEN.—Licensed, certified nurserymen who grow from seeds or by vegetative propagation any of the native plants on the Endangered Plant List provided in subsection (2) or the Threatened Plant List provided in subsection (3) are specifically permitted to sell these commercially grown plants and shall not be in violation of this section if they do so, as it is the intent of this section to preserve and encourage the growth of these native plants which are rapidly disappearing from the state.

(7) LOGGING AND UTILITY OPERATIONS.—Any person or business removing, trimming, or transporting any of the native plants on the Endangered Plant List provided in subsection (2), or the Threatened Plant List provided in subsection (3), as an incidental part of installing or maintaining a public utility service as defined in s. 876.37(3) or as an incidental part of a logging operation shall not be in violation of this section.

(8) DUTIES OF PLANT INSPECTORS.—Plant inspectors of the department shall, as part of their regular inspection of nurseries and roadside stands, be on the alert for any of the native plants on the Endangered Plant List provided in subsection (2) or the Threatened Plant List provided in subsection (3), which plants appear suddenly in a given nursery in a mature stage or a stage showing several years of growth, and are empowered to request proof of where and how the plants were obtained.

(9) AGENTS OF DIVISION.—Agents of the Division of Plant Industry shall have the authority to enter upon properties where harvesting or storage of endangered or threatened plants is suspected, to inspect vehicles which may be transporting endangered or threatened plants, and to preserve and take custody of plants harvested or moved in violation of this section, in order to assure compliance with the provisions of this section.

(10) NOTICE OF HIGHWAY CONSTRUCTION.—The Department of Transportation shall notify the Department of Agriculture and Consumer Services and the Endangered Plant Advisory Council created by s. 581.186 of advertised bids for highway construction at the time those bids are first advertised, describing the project, the location of the project, and the representative of the Department of Transportation who can answer questions regarding the project and the plant life immediately affected by the construction. The Department of Agriculture and Consumer Services shall seek and utilize the services of the Endangered Plant Advisory Council and of any other state agencies, clubs, associations, or organizations or individuals that may offer support and services for the
preservation of the plants on the Endangered Plant List or Threatened Plant List that may be affected by the construction project and shall provide by rule for the appropriate disposal of such plants.

History.—s. 1, ch. 78-72; s. 160, ch. 79-164; s. 1, ch. 80-23.

581.186 Endangered Plant Advisory Council; organization; meetings; quorum; compensation.—
(1) The Endangered Plant Advisory Council is hereby created, consisting of five persons to be appointed by the Commissioner of Agriculture. One member shall be a representative of the Florida Federation of Garden Clubs, Inc.; one member shall be a representative of the Florida Nurserymen and Growers Association, Inc.; one member shall be a representative of the Committee for Rare and Endangered Plants and Animals; one member shall be a representative of the Florida Forestry Association; and one member shall be a botanist from a Florida university. Members shall be appointed for terms of 4 years, except that the terms of members initially appointed shall expire on June 1, 1980.
(2) Immediately after their appointment, the members of the council shall meet and organize by the election of a chairman, a vice chairman, and a secretary, each for a term of 1 year.
(3) The council shall meet at the call of its chairman or the department, or at the request of a majority of its membership, and at such times as may be prescribed by its rules.
(4) A majority of the members of the council shall constitute a quorum for all purposes, and an act by a majority of the members present at any meeting at which there is a quorum shall constitute an official act of the advisory council.
(5) The members of the advisory council shall receive no compensation for their services, except that they shall be entitled to receive travel allowances and per diem as provided in s. 112.061 when actually traveling on the business of the council.
(6) The council shall advise the department concerning revising and updating of this section and of the Endangered Plant List and the Threatened Plant List.
(7) The Division of Plant Industry, the Department of Natural Resources, the Department of Transportation, and the Game and Fresh Water Fish Commission shall cooperate with the council whenever necessary to aid it in carrying out its duties under this section.
History.—s. 2, ch. 78-72.

581.187 Exemptions from s. 581.185.—All Florida Indians, as defined in s. 285.11, shall be exempt from the prohibitions and penalties of s. 581.185.
History.—s. 3, ch. 78-72.

581.188 Sale of cypress products prohibited without permit.—No person shall sell or offer for sale articles made from unfinished cross-sectional slabs cut from the buttress
PARTIAL LIST OF ENDANGERED OR THREATENED ANIMALS WITH POSSIBLE HABITATS IN THE TALLAHASSEE AREA

Amphibians and Reptiles

Pine Barrens Treefrog - *Hyla andersonii*
Florida Gopher Frog - *Rana areolata*
Gopher Tortoise - *Gopherus polyphemus*

Birds

Wood Stork - *Mycteria americana*
Osprey - *Pandion haliaetus*
Florida Sandhill Crane - *Grus canadensis*
Bald Eagle - *Haliaeetus leucocephalus*
Eastern Brown Pelican - *Pelecanus occidentalis*
Southeastern American Kestrel - *Falco sparverius paulus*
Red-cockaded Woodpecker - *Picoides borealis*
Appendix C

FOREST INDUSTRY LANDOWNERS AND APPROXIMATE HOLDINGS WITHIN 50 MILES OF ST. MARKS, FLORIDA
### APPENDIX C

FOREST INDUSTRY AND PUBLIC LANDOWNERS AND APPROXIMATE HOLDINGS WITHIN 50 MILES OF ST. MARKS

<table>
<thead>
<tr>
<th>COUNTY</th>
<th>ACRES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jefferson County</strong></td>
<td></td>
</tr>
<tr>
<td>St. Joe</td>
<td>92,000</td>
</tr>
<tr>
<td>Buckeye</td>
<td>48,000</td>
</tr>
<tr>
<td>Gilman</td>
<td>3,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>143,000</strong></td>
</tr>
<tr>
<td><strong>U.S. Fish and Wildlife</strong></td>
<td>2,000</td>
</tr>
<tr>
<td><strong>Franklin County</strong></td>
<td></td>
</tr>
<tr>
<td>St. Joe</td>
<td>70,000</td>
</tr>
<tr>
<td>St. Regis</td>
<td>9,000</td>
</tr>
<tr>
<td>Southwest</td>
<td>10,000</td>
</tr>
<tr>
<td>Elberta</td>
<td>3,000</td>
</tr>
<tr>
<td>Buckeye</td>
<td>168,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>260,000</strong></td>
</tr>
<tr>
<td><strong>U.S. Forest Service</strong></td>
<td>20,000</td>
</tr>
<tr>
<td><strong>Other Public</strong></td>
<td>7,000</td>
</tr>
<tr>
<td><strong>Wakulla County</strong></td>
<td></td>
</tr>
<tr>
<td>St. Joe</td>
<td>47,000</td>
</tr>
<tr>
<td>Container Corporation</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>48,000</strong></td>
</tr>
<tr>
<td><strong>U.S. Forest Service</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>135,000</td>
</tr>
<tr>
<td><strong>U.S. Fish and Wildlife</strong></td>
<td>32,000</td>
</tr>
<tr>
<td><strong>Liberty County</strong></td>
<td></td>
</tr>
<tr>
<td>St. Joe</td>
<td>140,000</td>
</tr>
<tr>
<td>Southwest</td>
<td>27,000</td>
</tr>
<tr>
<td>Neel Lumber</td>
<td>16,000</td>
</tr>
<tr>
<td>Buckeye</td>
<td>14,000</td>
</tr>
<tr>
<td>Hardaway</td>
<td>2,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>199,000</strong></td>
</tr>
<tr>
<td><strong>U.S. Forest Service</strong></td>
<td>220,000</td>
</tr>
<tr>
<td><strong>Leon County</strong></td>
<td></td>
</tr>
<tr>
<td>St. Joe</td>
<td>54,000</td>
</tr>
<tr>
<td>Buckeye</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>55,000</strong></td>
</tr>
<tr>
<td><strong>U.S. Forest Service</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>104,000</td>
</tr>
<tr>
<td>COUNTY</td>
<td>ACRES</td>
</tr>
<tr>
<td>----------------</td>
<td>-------</td>
</tr>
<tr>
<td>Gadsden County</td>
<td></td>
</tr>
<tr>
<td>St. Joe</td>
<td>51,000</td>
</tr>
<tr>
<td>Coastal</td>
<td>14,000</td>
</tr>
<tr>
<td>Grief Bros.</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>75,000</td>
</tr>
<tr>
<td>Madison County</td>
<td></td>
</tr>
<tr>
<td>St. Regis</td>
<td>34,000</td>
</tr>
<tr>
<td>Gilman</td>
<td>36,000</td>
</tr>
<tr>
<td>Buckeye</td>
<td>35,000</td>
</tr>
<tr>
<td>Container</td>
<td>24,000</td>
</tr>
<tr>
<td>Southwest</td>
<td>16,000</td>
</tr>
<tr>
<td></td>
<td>145,000</td>
</tr>
<tr>
<td>Taylor County</td>
<td></td>
</tr>
<tr>
<td>Buckeye</td>
<td>494,000</td>
</tr>
<tr>
<td>Gilman</td>
<td>25,000</td>
</tr>
<tr>
<td>St. Joe</td>
<td>18,000</td>
</tr>
<tr>
<td>Container</td>
<td>10,000</td>
</tr>
<tr>
<td>St. Regis</td>
<td>8,000</td>
</tr>
<tr>
<td>Georgia-Pacific</td>
<td>2,000</td>
</tr>
<tr>
<td>Southwest</td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td>558,000</td>
</tr>
</tbody>
</table>
Derived from maps provided by Florida Resource and Environmental Assessment Center
Florida State University

Buckeye Cellulose Corp.
St. Joe Paper Co.
Southwest Forest Indus.
St. Regis Paper Co.
Gilman Paper Co.
Container Corp.
Elberta Crate Co.
Neal Lumber Co.
Grief Bros.
Coastal Lumber Co.
Georgia-Pacific Corp.

FOREST INDUSTRY LAND HOLDINGS WITHIN 50 MILES OF ST. MARIS
Figure 1. Sweetgum (Liquidambar styraciflua).

Numbers above indicate total round growing stock volume within designated areas (million cu.ft.)
Figure 2. Tupelo (*Nyssa aquatica, N. ogeche, N. sylvatica var. sylvestris, N. sylvatica var. biflora*).
Each dot represents an average of 1,000,000 cubic feet

Figure 3. Select white oaks (Quercus alba, Q. bicolor, Q. durandii, Q. macrocarpa, Q. michauxii, Q. muehlenbergii).
Figure 4. Select red oaks (Quercus falcata var. pagodaefolia, Q. rubra, Q. shumardii).
EACH DOT REPRESENTS AN AVERAGE OF 500,000 CUBIC FEET

Figure 5. Ash (Fraxinus americana, F. pennsylvanica, F. profunda, F. quadrangulata).
Each dot represents an average of 500,000 cubic feet.

EACH DOT REPRESENTS AN AVERAGE OF 500,000 CUBIC FEET

Figure 7. Cottonwood (*Populus deltoids, P. heterophylla*).
Figure 8. Sycamore (*Platanus occidentalis*).
EACH DOT REPRESENTS AN AVERAGE OF 500,000 CUBIC FEET

Figure 9. Soft maple (Acer rubrum, A. saccharinum).
Figure 10. Magnolia (Magnolia acuminata, M. grandiflora, M. virginiana).

Each dot represents an average of 500,000 cubic feet.
Each dot represents an average of 500,000 cubic feet

Figure 11. Yellow-poplar (Liriodendron tulipifera).
Figure 12. Beech (Fagus grandifolia).

EACH DOT REPRESENTS AN AVERAGE OF 500,000 CUBIC FEET
Appendix D

MILLS AND DEALERS WITHIN 75 MILES OF ST. MARKS, FLORIDA
- APPENDIX D-

MILLS AND DEALERS WITHIN
75 MILES OF ST. MARKS

FLORIDA MILLS AND DEALERS

Jefferson County

Balfour Pulpwood Co.
Rt. 2, Box 222
Monticello, Florida 32344
904/997-2604

Joiner Brothers Timber Co.
Rt. 1, Box 199-A
Monticello, Florida 32344
904/997-5729

Southland Timber Co.
P.O. Box 15
Monticello, Florida 32344
904/997-2005

Leon County

A. B. Taff & Sons
P.O. Box 500
Woodville, Florida 32362
904/421-3410

Liberty Lumber Company
P.O. Box 7
Hosford, Florida 32334
904/379-3331

Rudy Sumner
P.O. Box 72
Teelogia, Florida 32360

Ronald Sykes
Hosford, Florida 32334
904/379-8620

Wakulla Wood Products
P.O. Box 450
Woodville, Florida 32362
904/421-2280

Pine, Hardwood pulp, Sawtimber
Broker, Dealer, Buyer

Pine, Hardwood, pulp and Sawtimber
Dealer, Buyer, Logger

 pine, Hardwood Pulp and Sawtimber
Dealer, Buyer

Pine Pulp and Sawtimber
Hardwood Pulp and Sawtimber
Logger, Broker, Dealer

All Species Pulp and Sawtimber
Dealer, Yard, Sawmills (2)

Pine Pulp and Sawtimber
Buyer, Logger

Pine and Hardwood Pulp and Sawtimber
Buyer, Logger

Pine and Hardwood, Pulp and Sawtimber
Dealer, Buyer, Logger
Calhoun County

C. L. Anders Pulpwood, Inc.
P.O. Box 408
Blountstown, Florida 32424
904/674-8125

Pine Pulp Timber, Pine and Cypress Sawtimber
Dealer, Buyer, Broker

Charles Arrant
Rt. 1, Box 161-A, B-1
Blountstown, Florida 32424
904/674-8471

Pine Pulp Timber
Buyer, Logger

Raymond Dudley
Rt. 1, Box 192
Grand Ridge, Florida 32442
904/674-8067

Pine Pulp Timber
Buyer, Logger

Georgia Timberlands, Inc.
P.O. Box 265
Blountstown, Florida 32424
904/674-5445

Pine Pulp Timber
Broker, Dealer, Logger, Yard

Don Johnson
139 Morningside Circle
Blountstown, Florida 32424
904/674-4336

Pine Pulp Timber
Buyer, Logger

Layne-Shuler and Valley Sawchip
P.O. Box 633
Blountstown, Florida 32424
904/674-5968

Pine Pulp Timber, Pine Sawtimber
Broker, Dealer, Logger, Sawmill

C. T. Terry
Blountstown, Florida 32424
904/674-8137

Pine and Hardwood Pulp Timber and Sawtimber
Buyer, Logger

Odis Pullam
126 Morningside Circle
Blountstown, Florida 32424
904/674-8704

Pine Pulp Timber
Buyer, Logger

Warren Pulpwood
P.O. Box 263
Blountstown, Florida 32424
904/674-8159

Pine and Hardwood Pulp Timber and Sawtimber
Buyer, Logger

Jimmy Yon
Rt. B
Youngstown, Florida 32466
904/674-8899

Pine and Hardwood Pulp Timber and Sawtimber
Dealer, Buyer, Logger
Franklin County

Buckeye Cellulose, Inc.
P.O. Drawer 709
Carrabelle, Florida 32322
904/697-3614

Coastal Lumber Co.
Dubarco Division
P.O. Box 558
Havana, Florida 32333
904/539-6443

Fletcher-Willis Lumber Co.
P.O. Box 97
Greensboro, Florida 32330
904/442-6121

Georgia Timberlands, Inc.
P.O. Box 206
Chattahoochee, Florida 32324
904/633-2192

Florida Pulpwood Co.
P.O. Box 246
Wewahitchka, Florida 32465
904/639-2731

Whitfield Timber Co.
P.O. Box 674
Wewahitchka, Florida 32465
904/639-2640

Dixie County

Georgia Pacific Corporation
P.O. Box 3-F
Cross City, Florida 32628
904/498-4253

Lafayette County

James West
Rt. 2
Mayo, Florida 32066
904/No Phone

Pine Pulp Timber
Logger, Chipmill, Sawmill
Pine Sawtimber, Pine Chip-N-Saw & Timber
Dealer, Logger, Mills
Pine Pulp Timber and Pine Sawtimber
Broker, Dealer, Logger, Sawmill
Pine Pulp Timber and Pine Sawtimber
Dealer, Buyer, Yard
Pine and Hardwood Pulp Timber
Dealer
Pine Timber, Chip-n-Saw
Pine, Oak, and Sweetgum Pulp Timber
Buyer, Logger
Madison County

Greenville Timber Corp.
Rt. 2, Box 630
Greenville, Florida 32331
904/973-6981

Sherrod Lumber Co., Inc.
P.O. Box 308
Greenville, Florida 32331
904/948-2101

Lamb and Kelly Timber Co.
506 S.E. Oak Drive
Madison, Florida 32340
904/973-6643

Suwanee County

Lamar Hancock
P.O. Box 516
Live Oak, Florida 32060
904/362-2461

Duke McCallister, Jr.
P.O. Box 375
Live Oak, Florida 32060
904/362-4706

Poole Timber Co.
P.O. Box 667
Live Oak, Florida 32060
904/362-4719

Suwannee Wood Products, Inc.
P.O. Box 627
Live Oak, Florida 32060
904/362-4339

Taylor County

Bennett Timber Co.
P.O. Box 41
Perry, Florida 32347
904/584-4907

M. A. Rigoni, Inc.
Rt. 3, Box 577
Perry, Florida 32347
904/584-7030

Pine, Cypress, and Hardwood Pulp and Sawtimber

Broker, Dealer, Buyer

Pine Pulp and Sawtimber

Chip-N-Saw Mill

Pine and Hardwood Pulp and Sawtimber

Broker, Dealer, Buyer

Pine, Pulp Timber, Sawtimber, Pole Timber

Buyer, Broker, Logger

Pine, Pulp Timber, Sawtimber, Pole Timber

Buyer, Broker, Dealer

Pine, Pulp Timber, sawtimber, Pole Timber

Buyer, Dealer, Logger

Pine and Hardwood Pulp Veneer and Sawtimber, Pine Pole Timber

Buyer, Broker, Dealer

Pine and Hardwood Pulp, Sawtimber, Cypress Sawtimber

Buyer, Dealer

Pine Pulp, Pine Sawtimber

Logger, Buyer
GEORGIA TIMBER DEALERS

Thomas County

Balfour Pulpwood Co.
101 W. Clay St.
Thomasville, Georgia 31792
912/228-1991

Bowers Pulpwood & Timber
Coolidge, Georgia 31738
912/346-3450

Secrest Pulpwood & Timber
218 Fleming St.
Thomasville, Georgia 31792
912/226-3986

Grady County

Secrest Pulpwood & Timber
10th Street
Cairo, Georgia 31728
912/377-3214

Brooks County

Secrest Pulpwood & Timber
P.O. Box 674
Quitman, Georgia 31643
912/263-4763

Decatur County

Brunswick Pulp & Paper
Rt. 1
Brunswick, Georgia 31520
912/246-7910

Decatur Pulpwood Yard
923 W. College St.
Bainbridge, Georgia 31717
912/246-4860

Flintwood, Inc.
427 Sims St.
Bainbridge, Georgia 31717
912/246-5838
Southwest Forest Industries  Pulpwood
Carter Street
Bainbridge, Georgia 31717
912/246-0751

Baker County

McDowell Pulpwood Co.  Pulpwood
Newton, Georgia 31770
912/734-5333

Mitchell County

Eubanks Pulpwood Co.  Pulpwood
P.O. Box 467
Pelham, Georgia 31779
912/294-4972

Donald Hays, Inc.  Pulpwood
Box 345
Pelham, Georgia 31779
912/294-8935

ITT Rayonier, Inc.  Pulpwood
P.O. Box 476
Camilla, Georgia 31730
912/336-0212

Colquitt County

Container Corporation  Logs, Pulpwood
Industrial Park
Moultrie, Georgia 31768
912/985-5970

Moultrie Pulpwood & Timber  Logs, Pulpwood
Doerun Highway
Moultrie, Georgia 31768
912/985-5727

Secrest Pulpwood & Timber  Logs, Pulpwood
Industrial Drive
Moultrie, Georgia 31768
912/985-1631
<table>
<thead>
<tr>
<th>County</th>
<th>Company Name</th>
<th>Address</th>
<th>Telephone</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decatur County</td>
<td>Bainbridge Tie &amp; Lumber</td>
<td>P.O. Box 581, Fowlstown, GA 31752</td>
<td>912/246-4764</td>
<td>Chips, Residue, Rough Lumber, Crossties</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gum, Oak, Poplar</td>
</tr>
<tr>
<td></td>
<td>Great Southern Paper Co.</td>
<td>P.O. Box 94, Calvery, GA 31729</td>
<td>912/465-3396</td>
<td>Chips, Logs, Veneer Logs</td>
</tr>
<tr>
<td>Grady County</td>
<td>Lacey Lumber Co.</td>
<td>Rt. 2, Whigham, GA 31797</td>
<td></td>
<td>Chips, Residue, Rough and Dressed Lumber</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yellow Pine, Oak, Gum, Poplar</td>
</tr>
<tr>
<td>Thomas County</td>
<td>Baker Lumber Co.</td>
<td>Pavo, GA 31709</td>
<td>912/859-2222</td>
<td>Dressed Lumber</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yellow Pine, Poplar</td>
</tr>
<tr>
<td></td>
<td>Balfour Lumber Co.</td>
<td>Box 1337, Thomasville, GA 31792</td>
<td>912/226-0611</td>
<td>Chips, Dressed Lumber</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yellow Pine</td>
</tr>
<tr>
<td></td>
<td>Metcalf Lumber Company</td>
<td>Rt. 4, Box 241, Thomasville, GA 31792</td>
<td>912/228-0707</td>
<td>Chips, Residue, Dressed Lumber</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yellow Pine</td>
</tr>
<tr>
<td>Brooks County</td>
<td>N. B. Jones &amp; Son, Inc.</td>
<td>Box 97, Dixie, GA 31629</td>
<td>912/263-7279</td>
<td>Chips, Residue, Rough and Dressed Lumber</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yellow Pine</td>
</tr>
</tbody>
</table>
Lowndes County
J. T. Griffin Lumber Co.
P.O. Box 1467
Valdosta, Georgia 31601
912/242-5691
Chips, Residue, Pallets, Rough Lumber
Gum, Oak
The Langdale Company
Box 1088
Valdosta, Georgia 31601
912/242-7450
Chips, Residue, Dressed and Treated Lumber
Yellow Pine and Cypress

Decatur County
Elberia Crate and Box Co.
Box 795
Bainbridge, Georgia 31717
912/246-2266
Chips, Residue, Crates, Pallets, Veneer Boxes
Yellow Pine, Gum, Oak, Hickory, Poplar

Mitchell County
Keadle Brothers Lumber Co.
P.O. Box 193
Camilla, Georgia 31730
912/336-0501
Chips, Residue, Rough and Dressed Lumber
Yellow Pine
Simpson Lumber Co.
401 Thomas Street
Camilla, Georgia 31730
912/336-7200
Residue, Rough Lumber, Crossties
Gum, Oak, Hickory, Poplar
Escambia Treating Co.
131 Bennett Street
Camilla, Georgia 31730
912/336-0181
Chips, Crossties, Poles
Yellow Pine
Alexander-Harris Co.
Box 381
Pelham, Georgia 31779
912/292-8512
Residue, Rough Lumber
Poplar, Other Hardwood

Colquitt County
Beadles Lumber Co.
6th Street N.E.
Moultrie, Georgia 31768
912/985-6996
Chips, Residue, Dressed Lumber

Thomas County
Georgia Crate & Basket
P.O. Box 46
Thomasville, Georgia 31792
912/226-2541
Chips, Residue
Cypress, Gum, Poplar, O Hardwood
Appendix E

CORRESPONDENCE FROM POTENTIAL SUPPLIERS
November 9, 1982

Mr. Charles H. Houder, III
P&W Forestry
P.O. Box 3610
Albany, Georgia 31706

Dear Charles:

I enjoyed your visit to the office the other day, and it was a pleasure to talk of the role wood has in the production of energy. We both know there is ample supply of wood for this purpose and it's use would improve the quality and economic value of hardwood stands.

I would be glad to be considered as a potential supplier of wood for fuel in the Tallahassee area. We would deliver by truck carrying 22 Tons each, for the customer to unload. These chips would be so called green, that is approximately 50% moisture content. The current delivered price per ton would be $20.50. Our crew would produce approximately ten truck loads per day or total of 220 tons.

The market on wood is very stable from year to year, as you know, however it maybe wise to have a escalation clause to protect your client and the producer such as tying the price to the rate of inflation, or to the general cost of wood in the area.

Charlie, this is kind of rambling, but it may contain some information you want, if not, please let me know.

Sincerely,

Earl F. Jones
EFJ/jb
December 13, 1982

Mr. Charlie Houder
F & W Forestry Services
P. O. Box 13321
Gainesville, FL 32604

Dear Charlie:

Thank you for your call regarding the supply of wood fuel for the proposed wood-energy system at Tallahassee. As per our discussion, I will outline several considerations in contracting for wood fuel.

Of course, the very basic requirements are such things as price, quantity required, fuel specifications (i.e. moisture content, particle size, etc.), length of contract, unloading facilities, etc.

Some of the more obscure, yet equally important, aspects include:

Are we to have sole responsibility for supply?

Will you guarantee a minimum purchase amount?

Do you want us to purchase and install any of the receiving, storage, and reclaim system?

Do you want us to manage the storage yard for you?

Who is responsible for the inventory?

How much inventory is required?

These are a few of the questions which would need to be answered prior to an agreement. The answers would also have an influence on the price. We generally negotiate these terms in face-to-face meetings, rather than simply sending in a proposal for acceptance or rejection.

There are many ways to structure a wood fuel contract. We have even, on occasion, offered a wood fuel management contract for providing the procurement services necessary to assure a supply of wood to an energy consumer. The bottom line is to supply the consumer with a contract at a reasonable cost, while building in the proper incentives for the wood fuel supplies to perform as expected.
I realize that these comments are very general, and I regret that I cannot be more specific at this time. Fiber Fuels, Inc. is very interested in working with the Tallahassee people in the procurement of the necessary wood fuel and look forward to the project progressing to the point where more specific negotiations can begin.

Let me hear from you as planning proceeds.

Sincerely,

Robert A. Harris, Ph.D.
13 December 1982.

Mr. Charles Louder,
F & W Forest Services,
P. O. Box 13321,
Gainesville, Fla., 32604.

Dear Mr. Louder:

I enjoyed our talk Friday regarding possible future fuel chip deliveries. Some pertinent points to us are listed below.

We have one fuel chip crew (1200-1500 tons/week) in operation at present. On any future chip business we would hope to field a new operation, although it is possible we would use our present operation.

We would like to work with a 3-5 year contract if possible, that specifies volume per week. The cost of equipment necessary makes it important to know what volumes per year can be delivered in order to set up equipment payments.

Of course, with contracts of this length, both parties are concerned with any escalation clauses to allow for inflation. Contracts are necessary also to allow for adequate provision of timber stumpage that maintains timber production. We have ideas for timber procurement within a land clearing service to the public that we believe can dovetail together with work on large land owners.

All of the above is, of course, in general terms. But they are considerations I believe of anyone thinking about producing wood chips for fuel. We feel wood fuel is a fact of the future and intend to be part of it.

We will be happy at any time to discuss in more detail the specifics of your project. Looking forward to hearing from you, I remain,

Sincerely,

M. A. Rigoni
President.

MAR/bbf.
Appendix F

SAMPLE WOOD CUTTING, TIMBER SALE, AND PURCHASING CONTRACTS
CONTRACT FOR SALE & PURCHASE OF WOOD WASTE CHIPS

This CONTRACT, executed in duplicate originals, is made and entered into this ___ day of __________, 19__ between
(hereinafter called "Buyer") and
(hereinafter called "Seller").

Seller agrees to sell and deliver to Buyer and Buyer agrees to purchase and receive from Seller waste wood chips of the quantity and quality hereinafter set forth upon the following terms and conditions:

Term of Agreement

This agreement shall cover the period from through If Seller or Buyer fails to fully perform as specified in this agreement, the affected party may terminate this agreement on 30 days written notice to the other party.

Estimated Requirements

Buyer estimates that ___ trailer loads of waste wood chips will normally be required for each 24 hour period, with each trailer load containing approximately 25 tons of waste wood chips. Number of trailer loads required during each 24 hour period will depend on the operation of the Scheduling and number of deliveries to be made each day will be mutually agreed upon between Buyer and Seller. Commencement of deliveries shall also be agreed upon between Buyer and Seller.

Delivery

Delivery will be in semi-trailer motor trucks either owned and operated or otherwise provided by Seller and will be so scheduled as to arrive and be off-loaded and deposited by Seller or Seller's agent at Buyer's Plant designated point of delivery if self-unloading.
trailers are used. If self unloading trailers are used, Buyer and Seller will first agree on additional cost of delivery prior to their use. If self unloading trailers are not used and the Plant truck dumper is required then Buyer will unload trailers.

Title to the waste wood chips and risk of loss thereof shall transfer to Buyer only after the waste wood chips have been delivered at Buyer's Plant designated point of delivery.

Quality

Wood chips delivered hereunder shall be whole tree chips (either hardwood or softwoods or manufacture refuse, i.e. slabs) with as much as 50 percent (50%) moisture content, with moisture content determined by the following formula:

\[
\% \text{ M.C.} = \frac{\text{wt. of water in wet fuel} \times 100}{\text{total weight of wet fuel}}
\]

Individual wood chips should be the size produced by a properly maintained whole tree wood chipper, i.e. wood chips should normally be 2" x 2" x ¼" with occasional chips being no larger than 3" x 3" x 1". Excessive amount of sawdust or chips smaller than ¼" x ¼" x ¼" will also not be permitted. Chips shall be reasonably free of tramp material contaminants, such as dirt, rocks, concrete, metal, glass and other such non-fibrous materials. Either express or implied waiver of any quality provisions herein shall not constitute a continuing waiver of such provisions.

Price

Buyer shall pay Seller a based price per ton as described below for delivered waste wood chips to the Plant site. Changes in moisture content and screening shall be mutually agreed upon by both parties:

<table>
<thead>
<tr>
<th>Moisture Content</th>
<th>Screened</th>
<th>Unscreened</th>
</tr>
</thead>
<tbody>
<tr>
<td>30% or less</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>40%</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>50%</td>
<td>$</td>
<td>$</td>
</tr>
</tbody>
</table>
Seller must notify Buyer of any request for changes in this base price in writing and Buyer must agree in writing to any changes prior to such price change becoming effective.

If mutual agreement can not be reached on price, Buyer or Seller can terminate this agreement on 30 days written notice to the other party.

Weighing

The net weight of waste wood chips sold and delivered hereunder shall be determined by Buyer at point of delivery from Buyer's or public scales at Buyer's discretion; provided, however, that if Buyer's and public scales are both inoperable for any given truckload, the average weight of the five previous truckloads of comparable size shall be used until such weight scales become available.

Seller may monitor Buyer's weighing procedures at Seller's discretion. The aggregate weights determined during any payment period shall be accepted as the quantity of waste wood chips sold and purchased during such period for which invoices are to be rendered and payments are to be made.

Payment

Payment shall be due ten (10) days from receipt of invoice and supporting documents.

Notices

Any notice, request, protest, consent, demand, report or statement given by one party to the other shall be in writing and, unless otherwise shown to the contrary, deemed duly received seventy-two (72) hours after it is deposited in the United States mails, by registered mail, postage prepaid, and properly addressed as follows:

(a) If the notice is to purchaser, to:
(or to such other person or address as Buyer shall have designated by due notice to Seller.)

(b) If the notice is to Seller, to:

(or to such person or address as Seller shall have designated by due notice to Buyer.)

**Indemnification**

Seller shall indemnify, defend, and hold Buyer harmless from and against any claim, demand, loss, damage or injury caused by or resulting from any act or omission, whether negligent or otherwise, of Seller. Buyer shall indemnify, defend, and hold Seller harmless from and against any claim, demand, loss, damage or injury caused by or resulting from any act or omission, whether negligent or otherwise, of Buyer. However, notwithstanding the above, neither party assumes any responsibility for damage or injury to officers, agents or employees of the other party.

**Applicable Law**

This agreement is to be governed by and construed under the laws of the State of

**Insurance**

Seller shall insure against losses resulting from this work under a general liability policy with a $ combined single limit for property damage and bodily injury and this policy shall list as an additionally insured. In addition, Seller shall maintain a motor vehicle
liability policy with a limit of $ per person, $ per occurrence for bodily injury and a $ limit per occurrence for property damage.

**Force Majeure**

Neither Buyer nor Seller shall be responsible to the other for any loss, damage, delay or failure in performing hereunder occasioned or caused by reason of an act of God, act of war, act of public enemy, or due, occasioned or caused by labor strikes, lockout, or stoppage or other restraint of labor from whatever cause, either partial or general; riot or civil commotion; or any other or similar cause beyond their control.

**Assignment**

This agreement shall inure to the benefit of and be binding upon the parties to this agreement and to and upon their respective successors and assigns. This agreement shall not be assignable in whole or in part by either party without the written consent of the other party. Such consent shall not be unreasonably withheld.

**Inspection-Safety**

Each party shall allow employees or agents of the other access to its property or facilities at reasonable hours for any purpose associated with administration of this agreement. Employees and agents of each party, while on the property, or around the facilities, of the other shall obey, and conduct themselves in accordance with, all applicable rules and regulations of the owner or operator of the facilities.

**Entire Agreement**

This contract as amended and supplemented from time to time by mutual written consent, shall contain the entire agreement between both parties.
CUTTING AGREEMENT

THIS AGREEMENT, made this __________ day of __________, 19__, by and between
SWF Gulf Coast, Inc., a corporation under the laws of the State of Nevada, d.b.a.
Southwest Forest Industries, Inc., Southeastern Division, with place of business
in Panama City, Florida, herein called "LICENSOR," and ______________________,
a(n) __________________________ whose address is __________________________,
herein called "LICENSEE:"

WITNESSETH:

For and in consideration of the premises and other good and valuable considerations, the receipt and sufficiency whereof are mutually acknowledged, it is stipulated and agreed by and between the parties as follows:

1. LICENSOR does hereby give and grant unto LICENSEE the right to cut and remove certain timber from certain lands, all as provided herein, and to the extent necessary for the exercise of the foregoing, the rights of ingress and egress over, across and upon the hereinafter described lands of LICENSOR.

2. LICENSEE agrees to cut, remove, and pay for the timber licensed for cutting hereunder upon the terms and conditions hereinafter set forth.

3. The timber licensed for cutting under the terms of this Agreement is located on the hereinafter described lands owned by or under lease to LICENSOR in the County of __________________________, State of __________________________ as follows:

(a) Description of Timber:

(b) Description of Land:

4. All timber licensed for cutting hereunder shall be paid for by LICENSEE, to LICENSOR, at its office located at __________________________, based on stumpage prices hereinafter provided, in the manner following:

5. Title to all timber licensed for cutting hereunder shall remain vested in LICENSOR until the same is cut by LICENSEE, at which time the title to the aforesaid severed timber shall vest in LICENSEE.

6. LICENSEE shall cut, remove, and pay for all of the timber licensed for cutting hereunder on or before __________________________, 19__, at which time the license granted hereby shall automatically terminate. Time is of the essence of this agreement.

________________________
7/80

________________________
7. All cutting hereunder shall begin at such point or points and upon such area or areas as shall be agreed upon between LICENSOR and LICENSEE, and all cutting thereafter shall only be done upon areas contiguous to that upon which the cutting shall have been completed before moving on to another area, and the failure so to do shall give LICENSOR a right to stop further cutting until this provision is complied with.

8. LICENSOR makes no warranty or representation nor covenant as to the value, quality or quantity of any timber covered hereby nor the logging conditions in connection therewith.

9. LICENSEE shall conduct all of its operations hereunder so as to avoid or minimize damage to all timber, trees, and timber growth not covered hereby, and LICENSEE shall cut all trees as close to the ground as practicable, but in no event shall height of stumps exceed _______ inches above the surface of the ground.

10. LICENSEE shall repair all fences or structures damaged by its logging operations and shall leave all roads, fire breaks, property lines and drainage ditches clear of logs, timber, limbs, or debris; and if the repairs are not made or if the debris is not removed and cleared promptly after notice from LICENSOR, LICENSEE shall be liable to LICENSOR for any expense incurred in repairing or removing same.

11. LICENSEE assumes all risk incident to any condition of the land or premises, resulting from any failure of LICENSOR to exercise ordinary care in keeping the premises and approaches safe, or other cause, and covenants and agrees on behalf of LICENSEE and its employees that LICENSOR shall in no way be liable or responsible for any injury or damage done or occasioned by the action and operations of LICENSEE under this agreement, or for any loss or damage occasioned by any condition of the described land or premises, and LICENSEE binds and obligates itself to pay and satisfy any and all claims arising on account of its operations hereunder or on account of any such condition of the land or premises, whether the same be injuries to its employees or others persons, as well as damage to any type of property, and LICENSEE shall indemnify and hold harmless LICENSOR on account of any and all such claims.

12. LICENSEE agrees to pay such severance tax as may now or hereafter be required to be paid by the laws of the State in which the above lands are located, unless specifically prohibited from so doing by law.

13. LICENSEE shall use all reasonable precautions to prevent fires on such lands and to prevent the spreading of any fire that may occur thereon. In the event a fire burns on lands covered by this Agreement, or on adjacent lands that may spread to lands covered hereby, LICENSEE agrees promptly to notify LICENSOR of such fire, if possible, and to have its employees, agents, or assigns, who might be carrying on operations on these lands, control or assist in controlling the said fires. LICENSOR specifically reserves the right to prohibit the making of fires in the woods if it is deemed advisable to do so from a fire protection standpoint, and further reserves the right to stop or interrupt LICENSEE'S operations hereunder if conditions are such that, in LICEN-
SOR'S discretion, continued operations are likely to start forest fires; provided that, in the event such right is exercised, the term of this contract shall be extended by the number of days that such stoppage or interruption continues.

14. LICENSEE further agrees to comply with and abide by all applicable Federal and State laws and regulations in the performance of this agreement and the cutting and removal operations herein contemplated.

15. The violation of any covenant herein by LICENSEE shall give LICENSOR the right to suspend operations of LICENSEE, and in the event the default be not cured within a reasonable length of time, LICENSOR shall have the right to terminate this agreement.

16. This Agreement shall not be assigned by LICENSEE, in whole or in part, without the prior written consent of LICENSOR.

17. The provisions of this Agreement shall inure to the benefit of, and shall be binding upon, the parties, their heirs, successors, representatives, or assigns.

18. It is specifically understood and agreed that this agreement shall be cancellable by Licensor upon thirty (30) days written notice delivered to Licensee or mailed to Licensee at ____________.

19. LICENSEE covenants and obligates himself to carry Vehicle Liability Insurance and Public Liability Insurance including all contractual liability hereunder, with limits not less than $100,000/200,000 personal injury, and $100,000 property damage coverage; and Workmen’s Compensation and Employer’s Liability Insurance fully covering Licensee’s operations hereunder. Evidence of all such Licensee’s insurance, satisfactory to Southwest shall be furnished to Southwest at P.O. Box 2455, Panama City, FL 32401, and all such insurance carried by Licensee shall provide for at least ten (10) days notice to Southwest of cancellation or material change in such insurance policies. If any part of the work to be performed hereunder is subcontracted by Licensee, licensee shall furnish to Southwest evidence, satisfactory to Southwest, that those who perform such work are insured by Vehicle Liability Insurance with limits of not less than $20,000/40,000 personal injury and $5,000 property damage and Workmen’s Compensation and Employer’s Liability Insurance.

IN WITNESS WHEREOF, SOUTHWEST FOREST INDUSTRIES, as Licensor, and__________ as Licensee, have caused this instrument to be duly executed in duplicate originals, by their representatives thereunto duly authorized, on the date first hereinafter written.

WITNESS:

SOUTHWEST FOREST INDUSTRIES
LICENSOR

by

Vice President & Division Manager

VICE PRESIDENT & DIVISION MANAGER

LICENSEE

by

WITNESS:
TIMBER SALE AGREEMENT

THIS Buy AND sell AGREEMENT made this _______ day of ________, 19______,
by and between ________, hereinafter called the Seller,
and ________, hereinafter called the Buyer.

WITNESSETH:

1. Seller agrees to sell and Buyer agrees to buy those trees marked with Blue
tree marking paint at ground line and eye level by representatives of F & W
Forestry Services. This pulpwood being located:

The area from which the pulpwood and timber sold hereunder are to be cut and
removed is more particularly delineated on the attached map prepared by F & W
Forestry Services, Inc., dated ________, 19______, and being marked
Exhibit A. Said map is made a part hereof by this express reference thereto.

2. The Buyer agrees to pay to Seller the sum of $______ for the pulpwood
and timber described above, the receipt of said sum being hereby acknowledged.

3. Buyer agrees to remove all tops and logging debris from all roads, firebreaks,
fields, or other open areas. In the event trees, tops, or other logging debris
does fall into fields, Buyer agrees to immediately remove such trees, tops or
other logging debris.

4. Buyer will cut the stumps as low as feasible, stump height not to exceed six
inches where possible. Buyer will not grant any right, license, or permission
to any of its agents or servants or other persons to hunt or fish on said
property and otherwise will conduct the operation in a modern workmanlike
manner, in accordance with good logging practices.

5. Buyer agrees to prevent damage to trees not designated for cutting and also
agrees to prevent damage to the reproduction. In the event Buyer cuts trees
left undesignated for cutting he agrees to pay $75.00 per cord for those
trees cut and not included within the description of those trees designated
for cutting.

6. The Buyer agrees to avoid damage to fences, roads, firebreaks, crops, and
other improvements located upon the real estate herein described. Buyer
agrees that in the event it or its agents or employees shall damage such
fences, roads, firebreaks, crops, or other improvements that it shall
reasonably compensate Seller therefor, or repair same at election of Seller.

7. The Buyer, his agents, or contractors will not leave trash, bottles, cans, or
other debris in the woods.

8. Buyer agrees to notify F & W Forestry Services, Inc., at the beginning of
the cutting of the pulpwood and timber and in the event cutting is discon-
tinued for more than two weeks, the Buyer agrees to notify F & W Forestry
Services upon resumption of the cutting in order that proper inspections
can be carried out by F & W Forestry personnel.

9. The Buyer is an independent contractor, and as such, will pay all obligations
incurred by it for labor, insurance, and other expenses incurred by it in
cutting and hauling and otherwise dealing with the pulpwood and timber, and
Buyer agrees to save Seller harmless from all claims liens, payments for
damages and expenses or expenditures made in connection with the performance
of this agreement by the Buyer. The Buyer agrees to carry workman's compen-
sation insurance, if applicable, on all its employees.

10. The Buyer agrees to do all things reasonable and proper and everything in
its power to prevent and suppress all forest fires on or threatening the
above-described land. It is further understood and agreed that in case
any fires are caused through the negligence of the Buyer or its agents or
employees then the Buyer agrees to pay to the Seller damages to any of the
pulpwood or timber located on the above-described real estate not sold under
the terms of this agreement. Such damages are to be determined by a qualified
forester chosen by mutual agreement of both parties of this instrument.
11. The term of this contract in which the pulpwood and timber are to be cut and removed shall begin on the ___ day of __________, 19___, and shall terminate at noon ___ months from that date.

12. Seller grants to Buyer all necessary rights of ingress and egress over the real estate of the Seller to carry out the cutting by the Buyer of pulpwood and timber being sold pursuant to the terms of this contract. However, Buyer agrees to use existing roads where possible.

13. Seller for himself and his heirs, executors, and administrators, covenants with the Buyer, its successors and assigns, that Seller has the right to convey the within pulpwood and timber in fee simple, and Seller hereby warrants and will defend the title to said pulpwood and timber against the claims of all persons whomsoever.

IN WITNESS HEREOF, the parties hereto have hereunto set their hands and affixed their seals the day and year first above written.

WITNESS ___________________________ SELLER ___________________________

NOTARY PUBLIC ___________________________

WITNESS ___________________________ BUYER ___________________________

NOTARY PUBLIC ___________________________
SPECIAL CONDITIONS

PURPOSE
The purpose of this bid is to enter into a contract for the purchase of Fuel, Wood, Refined and Densified to be used as a fuel at Florida State Hospital, Chattahoochee, Florida.

ESTIMATED QUANTITIES
It is anticipated that Florida State Hospital will purchase fuel at the rate of 36,500 tons (min), 87,600 (max) per year.

EVALUATION/AWARD
Bids will be evaluated and awarded on a price per ton basis (2000 lbs) FOB Fuel Bin, Florida State Hospital, Chattahoochee, Florida, to the lowest responsive bidder.

DELIVERY
The fuel supplier shall make the initial delivery within (30) days of receipt of written notice from the State of Florida, Department of Health and Rehabilitative Services on or about May, 1982 which is current schedule for completion of facility at Florida State Hospital. The fuel shall be delivered in approximately equal quantities, in bottom unloading trucks that will be compatible with the Florida State Hospital receiving equipment, which will be capable of handling and transferring to bins at a rate of 50 tons per hour. All deliveries to be in weather protected trucks.

Supplier shall agree to comply with all applicable Federal, State of Florida and local Florida laws, ordinances, regulations & Rules in the manufacture, storage, handling, shipping, selling, delivery, and exchange of fuel.

TERM OF CONTRACT
The contract shall be in effect upon execution and shall be for 60 months following notification of first delivery subject to appropriated funds.

For a period of 60 months, upon notification of first delivery, the price of fuels to be delivered during the succeeding twelve (12) months, shall be subject to an increase or decrease by applying the percentage change in the Pulp & Paper and Allied Wood Products Statistics published in the United States Department of Commerce Survey of Current Business in the then current publication of the index. Only one (1) price change will be considered at the anniversary date of first delivery notification and upon each anniversary date thereafter.

CONTRACTOR'S PUBLIC LIABILITY AND PROPERTY DAMAGE INSURANCE
The Contractor shall take out and maintain during the life of this Agreement COMPREHENSIVE GENERAL LIABILITY INSURANCE as shall protect him from claims for damage for personal injury, including accidental death, as well as claims for property damages which may arise from operating under this Agreement whether such operations are by himself or by anyone directly or indirectly employed by him. The minimum limits shall be $300,000 combined single limits. The Contractor shall not commence any work in connection with this Agreement until he has obtained all required insurance and approval granted by the owner. All insurance policies shall be with insurers qualified and licensed to do business in Florida.

LIABILITY
The supplier shall hold and save the State of Florida, its officers, agents, and employees harmless against claims by third parties resulting from the supplier's breach of this contract or the supplier's negligence.

WARRANTIES
The supplier shall warrant that the fuel shall meet the specifications provided herein, and will be free from any defective materials, binders and additives that may cause deleterious effects to the boilers and/or fuel handling system. In the event that the production fuel fails, on the basis of results found by laboratory tests to meet the specifications, the State shall reject the substandard fuel and reduce the quantity required by the State under Paragraph "ESTIMATED QUANTITIES" of special conditions accordingly.

BID NUMBER: 439-405-95-P REBID
ADDITIONAL REQUIREMENTS

A. Each bidder electing to construct a manufacturing plant for the purpose of supplying Refined and Densified Wood Fuel shall submit with his bid the proposed schedule of events with month, day and year indicated for each item. The successful bidder is required to provide within 30 days of award firm dates for all events and verification of an established line of credit sufficient to supplement firm's financial condition for completion of construction. Failure to do so will be grounds for default (See General Condition 13). User will monitor fuel supplier's progress during pre-delivery period, to ascertain compliance with the firm dates for all events. Failure to demonstrate good faith effort to complete the construction according to schedule may be cause for supplier being found in default and the contract terminated. The calendar of events are subject to adjustment by the State for unavoidable or unusual delays due to causes beyond the supplier's control.

1. Plant Site Selection

2. Production Equipment Ordered

3. Plant Construction Permits Obtained

4. Plant Construction Commenced

5. Utility Hook-Ups Completed

6. Raw Material Supplier(s) Selected

7. Plant Construction Completed

8. Test Production Started

9. Delivery Plan Completed (vehicles received or contract executed with transport firm)

10. Operation Readiness (No Later Than May 1982)

B. Each bidder electing to supply Refined and Densified Wood Fuel from a plant already operational must indicate below name of owner and plant location:

   NAME
   LOCATION

C. A certified financial statement must accompany the bid.

Failure to comply with A and C or B and C above will result in rejection of any bid.

POSTING OF BID TABULATIONS

Bid Tabulations with recommended awards will be posted for review by interested parties in the Division of Purchasing, Bureau of Procurement, Room 613, Larson Building, Tallahassee, Florida on or about July 8, 1987, and will remain posted for a period of ten (10) days.

BID NUMBER: 439-405-95-P REBID
Appendix G

WOOD FIRED BOILER EMISSIONS AND CONTROL

by

G.B. Curtis, Senior Research Engineer
M.L. Brown, Research Engineer
Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia
I. INTRODUCTION

This paper discusses the emission products of wood fired combustion systems, the relevant governmental regulations, the various methods of control, and associated owning and operating costs. The 1976 Clean Air Act established or caused to be established rules and regulations that govern the emission of certain materials into the atmosphere. For wood combustion, the emission of most concern is particulate matter related to the ash content of wood. Emission control is an added expense that can be quite substantial both in initial and operating costs. For this reason, it deserves careful attention from the system designer.

Emission control devices cannot be considered in isolation from the other parts of the system. The fuel, the burner, and the boiler design all influence the particulate emission rate. For example, with low turbulence combustion, more of the ash remains in the combustion chamber and does not pass through the boiler. The emphasis must be on system design to provide an installation that will comply with regulation.

II. TYPES OF EMISSION

The primary air pollution concern in the burning of wood is the emission of particulate matter. Particulate from the combustion of wood is composed primarily of ash, unburned char, and condensed droplets. As with any other combustion source, wood furnaces also emit carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulfur (SOx), and unburned hydrocarbons (HC); however, these emissions are either too low to be of concern or are not regulated by law. Because wood is lower in ash and much lower in sulfur than coal, it tends to produce less particulate and almost no sulfur oxides when compared to coal. Thus wood can be an attractive alternative to coal from an emissions viewpoint.
III. EMISSION REGULATIONS

Applicable air pollution standards for emissions vary from state to state. Presently in Georgia the emission criteria to be considered by prospective operators of wood fired boilers are included in "Rules and Regulations of Air Quality Control" published by the Georgia Department of Natural Resources. Figure 1 illustrates the maximum permissible particulate emissions from fuel burning installations. As can be seen, allowable emissions are based on total input in millions of Btu's per hour, beginning on the horizontal scale with 1 million Btu per hour. Again as the requirements can vary from state to state, the applicable regulations should be determined for each location.

"Percent plume opacity" refers to the amount of sunlight blocked by the source plume. An opacity of 100% will theoretically allow no light to pass through, while the background will only be obscured 20% by a plume of 20% opacity. The State of Georgia recently enacted legislation making the general opacity limit 20% or less except for 6 minute-periods within a given hour when 27% opacity is allowed for two minutes to permit soot blowing or system upsets. Wood fired units of moderate to large size will be hard pressed to meet this opacity standard and the accompanying particulate regulation without some form of control equipment.

Companies buying a boiler without help from a design firm should be aware of the appropriate emission control standards. Before constructing a wood fired boiler in Georgia, one should submit form APCS-APC-2 (an application to construct fuel burning equipment) to the Air Quality Control section of the Department of Natural Resources. This form is reviewed and, if in the agency's judgment the source will comply with existing emission control standards, is approved.

There is another regulation that could apply depending on the outcome of a review. To maintain air quality at the current levels, the U.S. EPA promulgated regulations to prevent significant deterioration (PSD) of air that emit above 250 tpy (tons per year) of wood flyash. The 1978 regulations were challenged in U.S. Circuit Court and struck down in the summer of 1979. The final ruling was recently released and as yet the EPA has not
TOTAL INPUT—MILLIONS OF BTU PER HOUR
MAXIMUM PERMISSIBLE EMISSION OF FLY ASH AND OTHER
PARTICULATE MATTER FROM FUEL BURNING INSTALLATIONS

FIGURE 1

FROM RULES AND REGULATIONS FOR AIR QUALITY CONTROL, 1975
promulgated new regulations. Present feeling is that it could be early 1981 before revised PSD regulations will go into effect. Generally for the majority of industrial boilers, PSD regulations will not apply. All sources not regulated by PSD standards will fall under the existing state particulate and opacity rules already presented.

After construction, the owner must file for a permit to operate. If no significant design changes have been made since filing for a permit to construct, a short form to operate may be sufficient. If significant changes have been made, another form APCS-APC-2 may be necessary.*

IV. EXPECTED EMISSIONS

A. Areas Affecting Emissions

Combustion and the formation of emissions is a complicated process controlled by numerous variables. However, the three major areas that affect wood fired boiler emissions are fuel, boiler design, and boiler operation.

- **Fuel.** The importance of fuel size and size consistency cannot be overemphasized. Oversize pieces are difficult to distribute evenly in the furnace and tend to burn slower. Fine particles, on the other hand, are easily entrained in the flue gases especially if any suspension burning occurs. This leads to higher particulate loading. The size of the fuel should be consistent to aid distribution on the bed which assures equitable distribution of the underfire air. Lastly, the cleanliness of the fuel must be considered since whatever foreign matter is picked up during harvest and transport will be fed into the boiler. The ash content of wood itself is low; however, that material lodged in the bark during removal from the forest, or scooped by the loader during handling effectively increases the ash content of the wood.

- **Boiler design.** Wood burning boilers have design specifications that tend to increase the efficiency of combustion and limit emissions. First, designers strive to minimize the gas velocity in the boiler by increasing the grate area. A larger grate area decreases the air flow

*See Appendix B
per unit area which means lower velocities. Lower velocities help reduce emissions by increasing the residence time and decreasing entrainment of fine particles by high speed air. Another factor that can affect emissions is the method by which fuel is introduced into the boiler. Spreader stokers have some suspension burning and generally have higher emissions than methods that burn primarily on the grate. This is because those particles burning in suspension are easily carried out of the boiler. It is a common experience with wood burning that a percentage of the fuel may not completely combust and can be carried out of the boiler unburned and caught in the primary collector. Especially in large size boilers, the unburned carbon can be separated from the flyash by shifting and re-injected into the boiler. Though this practice improves boiler efficiency, re-injecting large char tends to increase the percentage of small particulate. Figure 2 illustrates the effects of re-injection on the particle loading. Note that 100% re-injection is not achievable since this would involve injecting already collected flyash.

- **Boiler Operation.** Boiler operating methods and firing techniques have a direct effect on stack emissions. Unlike most natural gas or light fuel oil fired boilers, wood fueled installations require full time operator attention to achieve maximum efficiency. For example, the rate of flow of combustion air can be automated to the flow of natural gas or oil fuel, but this is not practical with wood systems. If the boiler fireman consistently supplies less air than is needed, unburned fuel will result and smoke may be produced. Excess combustion air will reduce combustion efficiency and will increase the total mass of combustion products. This increased mass results in higher velocities in the combustion zone, which causes the entrainment of particulate matter and reduces the fuel residence time.

In addition to the quantity of combustion air, the method of its introduction can influence emissions. Wood combustion systems are often designed to introduce a percentage of the combustion air from beneath the grates and the remainder above the grate line (under and overfire air). Generally the undergrate air is principally used to combust the fuel on the grates while the overfire air is used to combust the fuel volatile gases. While these
EFFECT OF RE-INJECTION ON PARTICULATE EMISSIONS


FIGURE 2
percentages of over-to-underfire air are a function of boiler design, a good fireman adjusts his air to meet the needs of his particular fuel and operating conditions.

When a boiler is overloaded, a condition similar to that with high excess air develops. As the rated load is exceeded, air flow to the boiler is increased leading to higher velocities and more particle entrainment. Thus higher-than-normal emissions can be expected when a boiler is operated over its rating.

Upsets in the boiler operation can cause temporary excess emissions. Upsets can occur when the load changes rapidly or when the moisture content of the fuel suddenly decreases. Though upsets with wood fired boilers are difficult to eliminate, proper corrective action by the operator can reduce their effect.

B. Emission Factors

Emission factors for particulate emitted from wood waste boilers are presented in Table I. The factors are presented as pound of particulate per ton of fuel burned. The factors for bark and bark mixtures are based on an as-fired moisture content of 50%. The wood fuel considered includes sawdust (5% to 50% moisture), shavings, ends, etc., and no bark. For well designed and operated boilers, use lower emission factors; and in the opposite case, use higher values. The emission factor for wood only is expressed on an as-fired moisture content basis assuming no flyash reinjection.

The U.S. Environmental Protection Agency (EPA) compiles expected emission levels from combustion sources based on pounds of flyash per ton of fuel burned. These factors can only be used for approximate calculations because they do not consider the effects of all the variables mentioned earlier.

C. Emission Characteristics

Several properties of particulate matter from wood combustion are important when considering control equipment. The particle size distribution is a very important factor in control device operation. Smaller particles (less than 10 microns) are very difficult to trap. Gas streams containing large percentages of sub-micron particles will require large
Table I
Particulate Emission Factors for Wood and Bark Combustion in Boilers*

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Emission (lb/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bark</td>
<td></td>
</tr>
<tr>
<td>with re-injection</td>
<td>75</td>
</tr>
<tr>
<td>without re-injection</td>
<td>50</td>
</tr>
<tr>
<td>Wood/Bark Mixtures</td>
<td></td>
</tr>
<tr>
<td>with re-injection</td>
<td>45</td>
</tr>
<tr>
<td>without re-injection</td>
<td>30</td>
</tr>
<tr>
<td>Wood</td>
<td>5-15</td>
</tr>
</tbody>
</table>

energy inputs (that is, pressure drop) to clean. Fortunately, particulate from wood combustion is relatively large in size (Figure 2A).

Particle strength is also a property to be considered in collection. A major problem with carbon particles, like unburned char carryover, is that they break very easily into smaller particles making them more difficult to collect. Therefore, the first stage mechanical collectors used to capture unburned char are designed for low velocities. This helps limit shattering should impact occur.

Particulate resistivity is an important property to consider if an electrostatic precipitator is to be used for collection. Particles must exhibit a relatively high resistivity; that is, ability to accept and hold a charge to be collected effectively. Wood ash generally has a low resistivity rendering it less effective to collection by electrostatic precipitators.

Particles that are adhesive may not be more difficult to collect, but are always more difficult to remove from the collection device. Adhesive particulate tends to clog up collection equipment resulting in decreased effectiveness. Adhesiveness is generally not a problem with particulate from wood ash.

V. CONTROL TECHNIQUES

Many devices are currently available for the control of emissions from combustion sources. The five major control devices in use today are mechanical collectors, baghouses, wet scrubbers, dry scrubbers, and electrostatic precipitators.

A. Mechanical Collectors

The most common control device is a cyclone or the centrifugal dust collector. Cyclones are used primarily to collect heavier dust particles. In the period before the emphasis on emission control, their purpose was to clean the air stream of large particles in order to protect the draft fan against erosion. Particles are removed through the action of a double vortex. The inlet gases spiral downward creating a centrifugal force which pushes the particulates toward the wall (Figure 3). The particulate drops out as the gases change direction and spiral upward to the
SIZE DISTRIBUTION OF WOOD AND COAL FLYASH

(*) FROM "COMPARISON OF FOSSIL AND WOOD FUELS", US ENVIRONMENT PROTECTION AGENCY REPORT EPA-600/2-76-256, MARCH, 1976)

FIGURE 2A
CYCLONE SEPARATOR

CLEAN AIR EXHAUST

ASH LADEN AIR

CENTRIFUGAL ACTION SEPARATES ASH

ASH DISCHARGE

FIGURE 3
exit. Cyclone collectors are best at removing large particles; their efficiency decreases as the mean particle size decreases. An important controlling parameter is the cyclone diameter. As the diameter increases, particles must travel farther to reach the wall; thus, efficiency decreases. This diameter limitation is overcome by using a multi-cyclone which is a series of small diameter cyclones arranged for parallel flow. Multi-clones can handle the same air flow as large diameter singular cyclones at a higher efficiency. The pressure drop that can be expected through a cyclone is 1" to 6" H2O. If a mechanical cyclone collector is insufficient to meet emission standards, it is usually used as the first stage of collection to be followed by an appropriate secondary collector.

B. Baghouse

A baghouse is a container housing rows of cylindrical bags. Air can enter from the top or bottom and as it passes through the bags, particulate matter is trapped. The trapped particles are removed from the bags by reversing air flow, shaking, or impingement of a high velocity air jet. Baghouses are extremely efficient (above 99%) even for submicron particles and have a low pressure drop thus requiring low fan horsepower to operate them.

Historically, baghouses have seen little application in wood fired boiler applications because of the high possibility of spark carryover which creates a fire hazard. Maintenance costs are typically high because the constant flexing action to remove trapped particulate decreases bag life. They generally must be replaced every 18 to 24 months. The bags are temperature limited having an operating limit of 600°F. The bag materials in this temperature range are fiberglass with teflon coating or nomex. A mechanical collector must always be used upstream from a baghouse to remove any large glowing particles. Operating the baghouse at positive pressure to prevent air leakage into the baghouse limits the possibility of fires by keeping oxygen from any glowing char.
C. Wet Scrubbers

Wet scrubbers are designed to develop an interface between a scrubbing liquid and the gas to be cleaned. The particles in the gas are trapped by liquid droplets; then the liquid is collected and removed. There are a variety of wet scrubber designs available--baffle and spray, venturi, and impingement, to name a few. Cross sections of each type are shown in Figures 4, 5, and 6. The type of wet scrubber is chosen based on allowable emissions, particulate size distribution, and gas conditions into the scrubber. In wood applications, usually baffle and spray-on venturi types are used.

Wet scrubbers have the advantage of high efficiency even on small particles, relatively low first and maintenance costs, and resistance to fire damage since glowing sparks are water-quenched. The most obvious disadvantage of a wet scrubber is the problem of water supply and disposal. Wet scrubbers have a high demand for water (usually 5 to 10 gallons per ACFM). Once the liquid has collected the particles, it must be cleaned through the use of a clarifier or settling pond. Also, the energy requirement of a wet scrubber increases as mean particle size to be collected decreases. Most wood applications require a low-to-medium energy scrubber (6" to 15" H₂O).

D. Dry Scrubbers

Dry scrubbers offer an alternative to wet scrubbers in areas where no water supply is available or water pollution presents a problem. Dry scrubbers trap particulate matter in a moving bed of granular material. The trapped particulate material can be removed from the media permitting its recycling. Efficiency and pressure loss are comparable to a wet scrubber, but no water is needed and the overall scrubber is smaller in size. Dry scrubbers have not seen wide application on wood fired boilers. The few locations using dry scrubbers did so because a wet scrubber was not feasible. The major complaint against dry scrubbers on wood fired boilers has been their plugging by tar compounds in the flue gas.
BAFFLE AND SPRAY

GAS Outlet

MESH TYPE MIST SEPARATOR PAD

LIQUID FEED

LIQUID DISTRIBUTION WEIR

BAFFLES

MAKEUP AND LEVEL CONTROL WEIR

GAS INLET

SHELTERED INLET

RECURRENT TANK

CLEAN OUT

PUMP SUCTION

FIGURE 4
VENTURI

MESH TYPE MIST ELIMINATOR PAD FOR DIFFERENTIAL PRESSURES OVER 20" W.G.

STAINLESS STEEL NOZZLE

CONICAL ACCELERATOR SECTION

CYCLONIC SEPARATOR

TANGENTIAL CYCLONE ENTRY

LIQUID DISCHARGE

FIGURE 5
FIGURE 6

IMPINGEMENT SCRUBBER

OUTLET

LIQUID SPRAY MANIFOLD

INLET

INPINGEMENT BAFFLE

DRAIN AND SUPPORT CHANNELS

DRAIN HOLES
E. Electrostatic Precipitation

Electrostatic precipitators operate by ionizing particles as they enter the devices. These charged particles are then attracted to oppositely charged collection plates. The plates are cleaned by periodically "rapping" them mechanically. Dislodged particles are collected in a hopper. The collection efficiency strongly depends on the resistivity of the particles to be collected. If the electrical resistivity of the particles is extremely high or low, the efficiency of an electrostatic precipitator will be adversely affected. Because particulate emissions from wood boilers are generally low in resistivity, they may not be collected effectively.

Electrostatic precipitators have seen wide application in installations where coal is burned and are used in applications where coal/wood mixtures are burned. Because of their uncertain effectiveness and high cost, they have seen almost no use on wood fired boilers.

VI. COSTS

Estimated costs for various emission control systems are presented in Table II. These are approximate installed costs for the above ground structure. These costs are shown as a comparison between various control methods and should not be regarded final since specific costs depend on the characteristics of each individual installation.

<table>
<thead>
<tr>
<th></th>
<th>Installed Cost</th>
<th>ΔP in H₂O</th>
<th>Yearly Energy Cost for fan operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Multi-Cyclone</td>
<td>$2/ckm</td>
<td>2</td>
<td>$4,000</td>
</tr>
<tr>
<td>Double Multi-Cyclone</td>
<td>$4/ckm</td>
<td>4</td>
<td>$8,000</td>
</tr>
<tr>
<td>Spray &amp; Baffle Wet Scrubber</td>
<td>$4/ckm</td>
<td>1-3</td>
<td>$2,800</td>
</tr>
<tr>
<td>Venturi Wet Scrubber</td>
<td>$6/ckm</td>
<td>10</td>
<td>$10,000</td>
</tr>
<tr>
<td>Dry Scrubber</td>
<td>$8/ckm</td>
<td>6</td>
<td>$5,600</td>
</tr>
<tr>
<td>Baghouse</td>
<td>$11/ckm</td>
<td>6</td>
<td>$5,600</td>
</tr>
<tr>
<td>Electrostatic Precipitator</td>
<td>$15/ckm</td>
<td>$</td>
<td>$1,000</td>
</tr>
</tbody>
</table>
The operating cost of an emission control device can be significant. The pressure drop and estimated fan operating costs incurred by each type of device are also shown in Table II. The calculation is based on a 1,000 hp boiler using 3¢/Kwh electricity.

It can be seen in the table that wet scrubbers have the highest associated fan costs with electrostatic precipitators the lowest.

Wet scrubbers use water circulated in a closed-loop system to capture particulate. About 10 gallons of liquid per 1,000 cfm of gas must be pumped through the system of which about 5% is lost by evaporation. (This percentage varies depending on scrubber inlet temperatures). For a 1,000 hp boiler, this cost could be on the order of $3,000 per year depending on local water rates. Some power is required to circulate the liquid, but the associated cost is small (about $500) for the case considered. The yearly maintenance cost for a wet scrubber is estimated to be approximately 1% of the installed cost.

Baghouses have a lower pressure drop, 6 to 8 inches of water, than wet scrubbers so less fan horsepower is required to operate them. One substantial operating cost is the bags. Bags are guaranteed for two years but should last four. For a 1,000 hp boiler with fiberglass bags, the replacement cost is $18,000 plus installation, an average of around $5,000 per year.

Electrostatic precipitators have the lowest associated fan operating costs of any emission control device. Electricity of between 50 to 300 watts/1,000 cfm to charge the plates is the other major operating cost. At 3¢ per kwh, the power required by a 1,000 hp would be about $1,500 per year. Estimated yearly maintenance costs of electrostatic precipitators are $10 to $30 per 1,000 cfm.

VII. SPECIFYING AN EMISSION CONTROL SYSTEM

Because of the many variables associated with emissions from wood fired boilers, the emission control system is never an off-the-shelf item. Generally the design engineering firm works with the boiler manufacturer to arrive at an acceptable system. The three most generally accepted means of controlling wood fired boiler emissions are:

1. Mechanical collectors in series
2. Mechanical collector/partial flow wet scrubber
3. Mechanical collector/full flow wet scrubber
On smaller installations where the grain loading to the collector is relatively low and the emission regulations are not as stringent, two mechanical collectors in series, one after the other, may be sufficient to meet the standard. The first collector removes larger particles while the second collector is equipped with high energy vanes to remove the bulk of the finer material. The overall efficiency of such a system can be as high as 97% to 98%.

System with particulate loading too high to be collected with series mechanical collectors, but low enough not to require the full air flow to be sent through a scrubber can sometimes meet the standard with a selective collector-scrubber system. The full flow goes through a mechanical collector where the dirtiest portion (10% to 20% of the total) is separated out and fed to a wet scrubber. This reduces the size and cost of the wet scrubber to allow emission certification at the most economical cost.

Two different selective flow scrubber systems, shave-off and fractionating, are currently on the market. In the shave-off system, the multi-clone outlet is designed with two outlet tubes instead of one. The inner tube allows the care of cleanest air to pass through. The outer tube shaves off the perimeter of the outlet gases where, due to centrifugal action, the majority of the particulate resides.

The fractionating system approaches the problem by trying to remove the particulate before the airstream reaches the outlet tube. A manifold is attached to the cyclone below the tube sheet allowing a controlled extraction of air from the large cyclone cavity. This extraction aids particle disengagement from the air when it changes direction to go out. The cyclone is under negative pressure due to fan suction and addition of this manifold tends to decrease this negative pressure. The result is two-fold: 1) the increase in pressure creates a force to push particles out of the cyclones and 2) this bleed-off of air tends to sweep the dust from the vessel bottom.

Most large scale operations require a mechanical collector followed by wet scrubber. Due to the tighter emission standards on large boilers, all the flow is sent through the scrubber. This combination should be able to meet even the most stringent emission standard.
The purpose of the selection process is to select the most economical control system which will still meet the regulations. In a turnkey operation where a design engineering firm handles the installation, they usually guarantee meeting emission standards. The design firm and the boiler manufacturer meet and by considering important criteria such as fuel type, boiler size, and emission control labels, arrive at an appropriate design.

Companies who buy boilers without the aid of a consultant firm generally fall into two categories: 1) the small firm which buys a turnkey installation from a boiler contractor and 2) the very large firm where all the engineering is handled in-house. In either case, economics is the most important consideration in the selection of an emission control system. Buy only as much control as required. Consider well what fuel will be used for emission control systems are fuel specific. Knowing the properties of the fuel and proper boiler operating procedures will assure a boiler and emission control system design that meets the regulations as economically as possible.

Estimated cost information for several different size systems is presented in Table III. This price includes the control equipment, connecting ducts, support steel, stacks, controls, settling pond (where applicable) and foundations. In general, emission control requirements are determined during the boiler design phase, and the cost of the necessary devices is included in the boiler package cost.

Table III

<table>
<thead>
<tr>
<th>Boiler Size (lb/hr)</th>
<th>System</th>
<th>Fan Size hp</th>
<th>Installed Cost</th>
<th>Est. Yearly Oper. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,450 (100 bhp)</td>
<td>Multi-cyclone</td>
<td>5</td>
<td>$16,500</td>
<td>$400</td>
</tr>
<tr>
<td>17,250 (500 bhp)</td>
<td>Series Multi-Cyclone</td>
<td>30</td>
<td>$34,500</td>
<td>$4,000</td>
</tr>
<tr>
<td>50,000 (1,450 bhp)</td>
<td>Multiclone/Wet Scrubber</td>
<td>150</td>
<td>$150,000</td>
<td>$41,000</td>
</tr>
<tr>
<td>100,000 (2,900 bhp)</td>
<td>Multiclone/Wet Scrubber</td>
<td>300</td>
<td>$225,000</td>
<td>$82,000</td>
</tr>
</tbody>
</table>
Appendix H

WOOD FUEL STORAGE

by

William S. Bulpitt, Senior Research Engineer
James L. Walsh, Research Engineer
Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia
FUEL HANDLING AND STORAGE

William S. Bulpitt
Senior Research Engineer
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia

James L. Walsh, Jr.
Research Engineer
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia

Abstract

The handling and storage of wood fuels involves a number of problems that are not encountered in coal fired systems. This presentation illustrates the results of a research program conducted by Georgia Tech on one of these problem areas. Outside storage of wood fuel at one of the State of Georgia demonstration sites causes problems when the wet fuel was burned in the boiler. Studies conducted on another part of the program of the effect of covered storage on the available energy and moisture content of the fuel were successful in quantifying the benefit of covered storage to the plant and to other wood energy installations. Additionally the studies supported the development of wood fuel testing standards by the American Society for Testing and Materials (ASTM) which will standardize the techniques used by laboratories to determine fuel properties. The research not only provided a potential solution to the handling and storage problem at a particular plant, but also provided new data to the entire industry.

Introduction

The handling and storage of wood fuels involves a number of problems and considerations that are not commonly found in coal handling systems. Among these problems are those of the reducing size of the fuel to be compatible with both the boiler and the fuel handling systems. The removal of debris such as over-sized pieces, iron and metal or other refuse must also be accomplished before the fuel is put into the system to prevent damage to the fuel handling equipment. The storage of the fuel requires special considerations since the fuel is alive and can also increase in moisture content very readily. Storage, even in enclosed structures, requires special design considerations to permit removal of the fuel at the desired time.

As a part of a two-year wood energy demonstration project, Georgia Tech conducted a special study into a number of these problems. This paper is a report of the findings in one of these areas, namely that of wood fuel storage. Storage of wood using outside storage facilities was found to be a particular problem at the wood energy demonstration plant at the Integrated Products Textile Plant in Aragon, Georgia. Combustion of wood fuel stored on the outside concrete storage pad for a period of time was found to be difficult. The fuel caused problems with black out particularly when the boiler was operating at a low load. Additionally, high fuel consumption rates were experienced since the fuel being burned was wet, and the water must be evaporated before combustion.

The study conducted by Georgia Tech included the construction of a number of test storage piles. The purpose of these piles was to determine the benefits that could be achieved through the use of covered storage in reducing wood moisture content or at least preventing a gain in fuel moisture. The program was designed to obtain quantifiable data which could be used for economic justification for the construction of covered storage. This paper provides some of the results of the test program as well as general discussions of wood fuel storage.

Previous Studies

A number of studies on the effects of storage on wood fuels have been conducted by White and Springer (1,2). The studies by Springer provided a great deal of information on mechanisms associated with wood decay, changes in internal properties and in particular, the changes in temperature experienced in the storage of fuel. Studies by White have quantified some of these changes in temperature, heat of combustion, pH, moisture and other fuel combustion properties. The key findings of these studies, which are summarized in the following paragraphs, were used as a basis for developing the Georgia Tech storage test program as well as comparing data achieved through the program.

All studies have documented the internal temperature rise of wood storage piles. The temperature within piles of bark will rise in some cases to around 190°F during the hotter months of the year. The temperature within chip piles will rise to a lower temperature and piles constructed of
sawdust show the least temperature rise. The primary reason bark piles show a higher temperature rise is that there are more live cells in the bark pile which are biologically more active. The precise mechanism for this temperatures rise is a complex biological chemical reaction.

The temperature rise within piles has both advantages and disadvantages with regard to fuel storage. The rise provides an advantage in that internal sections of the pile will tend to dry out pushing water to the surface. However, the internal temperature rise also can cause potential problems with fires due to spontaneous combustion of the fuels. Care must be taken in the design of the storage mechanism and in many cases bark is not recommended for storage in piles higher than approximately 15 feet.

The moisture content of uncovered wood piles will rise and in most cases will rise very close the theoretical black out point of a boiler or approximately 60% moisture on a wet basis. Sections of the pile near the surface will, of course, experience the highest rise in moisture content with internal zones drying due to temperature rise. However, moisture can percolate to these internal zones with a flat top pile and cause moisture problems with the entire wood storage pile. Piles will exhibit something of a passive solar configuration in that the outer regions of the pile will lose water during dry weather and consequently get wetter during the rainy seasons.

The pH of a pile will decrease and can reach a value as low as 3.0. This acidity associated with piles can cause potential problems if the runoff is allowed to run into a nearby stream. Large piles in particular may exhibit this problem. The acidity of the pile can also cause problems with the construction of storage facilities in that iron structures can be completely eaten away by the acid.

The heat of combustion on a per pound basis has been generally been found to rise over a period of time. The exact mechanism of this phenomena is associated with the change in the concentration of combustible versus noncombustible materials. Studies by White have proposed that this change is due to the decrease in noncombustible materials which are primarily associated with the carbohydrates. However, these studies have also indicated that the rise in heat of combustion is offset by the subsequent rise in moisture content. As a result, the total available energy of the pile will decrease over a period of time.

The ash content within wood piles, particularly those constructed with bark, has been found to increase over a period of time in storage. A number of explanations have been proposed for this increase in ash. Bark may initially have more ash particularly if it is located in sandy areas where sand may be impacted in the bark by wind or the logging mechanism drags the bark through dirt before harvesting. Even with these increases in the ash content during storage the percentage of ash is still significantly lower than coal.

Georgia Tech Storage Test Program

The previous studies conducted have not been able to determine two key properties. One of these properties is the change in total available energy in the pile. The determination of total available energy requires a knowledge of the internal packing density of the pile. With a precise knowledge of volume, density, internal heat value, and moisture, the total available energy in the pile can be computed.

Additionally, a detailed comparison between covered versus uncovered storage has not been conducted. The objective of the Tech program was to provide data on the relative benefits of covered versus uncovered storage. This data could then be used by a plant engineer as economic justification to determine the paybacks and life cycle costing associated with a new indoor storage facility. The test would also quantify the differences in moisture content using covered and uncovered storage.

The Georgia Tech program constructed four test storage piles on the outdoor storage pad at the Integrated Products Textile Plant in Aragon, Georgia. Two of the piles were constructed with wood waste or sawdust which is the normal fuel for the plant’s boilers. Two other piles were constructed using whole tree chips obtained from a local supplier. The chips consisted of mixed hardwoods and softwoods. One of the chip piles and one of the waste piles were covered, and the second chip and second waste piles were left uncovered.

Covering for the piles was fabricated using a canvas tarp extended over a wood frame support. The support was essentially a tee-ppee which allowed ventilation along the sides of the pile to the top. A hole was cut in the canvas at the top and a hat placed over the hole to permit ventilation of the pile without allowing rain into the covered pile. The tarp itself was light blue in color and thus the effects of a solar heater system were somewhat negated. The intent was to simulate a metal building.

Each of the piles constructed was approximately eight feet high and was built using the outdoor storage conveyor at the plant. During construction of the piles four thermocouples were inserted at two-
foot levels throughout the pile. Additionally, two-inch nominal diameter PVC pipes were inserted in the piles. The purpose of these pipes was to allow the traverse of a radioactive source in nuclear probe which would be used for experimental determination of bulk density and moisture content. The construction of the sawdust piles was completed in early July of 1981 and the construction of the wood chip piles was completed in early August of 1981.

Data was taken on the piles approximately every 30 days after completion of construction. Data gathering consisted of using the nuclear probe in the PVC traverses to determine bulk density and moisture at two-foot intervals. Six samples were removed from each pile and these samples were later analyzed in the laboratory. Additionally, the thermocouple data was read and recorded.

The samples removed from each pile were analyzed at the Georgia Tech fuels testing laboratory. The samples were analyzed for moisture content, volatile content, ash content, fixed carbon content, and gross calorific value.

The moisture and volatile content were analyzed using standards newly developed by the American Society for Testing and Materials (ASTM). These standards were developed as another part of the Georgia Tech wood demonstration program, and the fuel storage testing provided significant data on their use and accuracy. The lack of standardized testing procedures for determining wood fuel combustion properties have hindered the expansion of the use of wood energy systems.

Storage Test Program Results

The key results of the storage test program conducted by Georgia Tech agreed very closely with previous work conducted by White. The temperature within the piles was found to increase and follow the changes in ambient temperature. Likewise, moisture in both of the uncovered piles increased very close to the blackout point of the pile.

A comparison of the moisture content differences between the covered and uncovered piles is shown in Figure 1. The figure very graphically illustrates the benefits that could be obtained with a covered storage facility. There is a significant difference in the moisture content for both chips and waste in covered versus uncovered storage. The uncovered storage piles approach the theoretical boiler blackout point of approximately 60% moisture as discussed in the previous paragraph. The covered storage piles have dried significantly since the construction of the pile.

The successful drying of the covered storage piles indicates that the type of construction used could possibly be used for passive drying of wet outdoor piles. The comparison of sample data taken at various distances from the edge of the pile indicates that the center zones showed almost no drying. Thus it is anticipated that a system similar to that used could dry approximately the first five to six feet of the pile surface. Thus the pile could theoretically be dried a layer at a time. As discussed earlier, piles are generally not as wet in the interior due to internal temperature rises. Thus after the first two to three layers of the pile are dried it is possible that the pile could be completely burned.

The available energy in a pile can be determined by evaluating the changes in the low heat value of the fuel. The low heat value is a measure of the energy which can be obtained from a fuel for heating after the moisture and other losses in the fuel combustion are accounted for. For purposes of these tests the hydrogen concentration was assumed to remain constant at five percent of the dry weight of the fuel. The moisture changes were computed to determine the approximate reduction in low heat values due to gains or losses in moisture. The results of this analysis are shown in Figure 2.

As can be seen in Figure 2 there is an approximate fourteen percent difference in the low heat value of the covered versus the uncovered waste piles and a thirteen percent difference in the covered and uncovered chip piles. This difference was realized in approximately three months of storage. This data can be used as the basis for an economic comparison of the covered versus uncovered storage.

This economic computation, however, does not give the complete picture of the advantage of covered storage. As was shown in Figure 1 the moisture content of uncovered piles can approach the blackout point of the boiler, thus making the energy from the pile immediately go to zero since the fuel cannot be burned in its present state. Thus while using the differences in the low heat values for determination of paybacks, a plant engineer must also consider the potential that the value of the uncovered pile could potentially drop to zero.

SUMMARY

The results of the storage test program provided quantitative data on a potential solution to the problem at not only the demonstration site, but at other wood energy installations as well. Data from low heat value comparisons can be used for economic analysis. Data from moisture
**FIGURE 1**
CHANGE IN PILE AVERAGE MOISTURE CONTENT WITH TIME

- Uncovered Waste
- Covered Waste
- Uncovered Chips
- Covered Chips

**FIGURE 2**
PERCENTAGE CHANGE OF TOTAL PILE LOW HEAT VALUE WITH TIME

- Uncovered Waste
- Covered Waste
- Uncovered Chips
- Covered Chips
content comparisons can be used to illustrate the potential for increasing the moisture content past the blackout point with uncovered piles and for drying wet piles with covered storage. The program addresses only one of many problems associated with handling and storage, but the results are extremely important in the design of a wood energy installation.

References


Appendix I

WOOD HARVESTING

by W.S. Bulpitt

"A Feasibility Study for Wood Energy Utilization in the Southeast," Final Report on Project A-2140, Georgia Tech Engineering Experiment Station, Atlanta, Georgia, December 1979
FUELWOOD HARVESTING AND TRANSPORTATION

Introduction

Substantial research and development has been conducted in the last twenty years on mechanization of wood harvesting, resulting in many time-honored techniques and beliefs becoming obsolete. Much of the activity in machinery improvement has been concentrated on developments in equipment to harvest the traditional forest crops in the South -- sawtimber and pulpwood. However, these developments have been accompanied by other new machines that are particularly suited to the harvest of energy wood. In this chapter, the state-of-the-art of harvesting techniques and the economic viability of harvesting wood for fuel will be considered.

Harvesting Concepts

There are few virgin timber stands left in the Southeast -- most areas have been cut over at least once, and many areas have been cut over several times since the colonies were settled. Today in Georgia there are many areas that have been "high-graded" over the years. That is, the choice timber for pole and sawtimber production has been removed and inferior trees remain. In other areas, trees are packed in the forest so densely that no tree can grow as productively as would be possible with less intense competition for the soil, water, and sunlight.

The Coastal Plains areas of Georgia and the other southeastern states are particularly suited for the growing of softwoods such as pine, while the higher elevations are presently covered mostly with hardwoods. Hardwoods are prized for furniture production and sawtimber production in some areas, while large softwoods are also used for sawtimber. The largest and use of softwoods continues to be in the pulp and paper industry, however.

Traditional logging practices have dictated selective thinning of the prime wood or clearcutting of large tracts of timber for harvest at one time. Clearcutting can be a wasteful practice since it is usually only the main trunk of the tree that is of interest to the logger, and the tops and limbs are only a nuisance. Many years ago clearcutting was accomplished
by hand, but today the most widely used implement is the gasoline powered chain saw. After the tree is felled, the tops and limbs are removed and left to rot on the forest floor. In order for replanting to be accomplished successfully, this residue must be removed. To the small landowner, this site preparation can be a considerable expense (up to $100 per acre) and he may be reluctant to make the investment (1). As a result, forest management suffers and the land is not used to its full potential.

In recent years, however, the concept of "total tree chipping" has been established, and it is this concept that greatly enhances the possibilities of utilizing wood for energy.

An overall view of the total tree chipping concept is shown in figure 3-1. This figure clearly shows the sources of energy wood -- tops, limbs, dead trees, undesirable or "cull" trees, and victims of insect kills and fire. This timber is not considered "merchantable" wood by the logger and may be left standing or left to rot. Site preparation for new planting would traditionally involve raking the residue into piles and burning it in open fires. This is, of course, a great waste of potential energy source and an undesirable practice environmentally since local air pollution problems are created and the fires may spread to neighboring stands of good timber.

With the new equipment shown in figure 3-1, it is possible to collect the tops, limbs, and culls and chip them into small pieces with a portable total tree chipper. These chips are blown into trucks for transport to the point of final utilization. This final point could be an industrial plant using the wood residue for fuel. It has been estimated that up to 50 tons per acre could be collected for fuel wood following a clearcutting operation, since such an operation may leave 40% of the tree's biomass lying in the field (2).

**Harvesting Equipment**

The production of fuelwood for industrial use requires the following operations:
Figure 3-1
Residue Fuel Flow Concepts
(Reference 2)

Forest Residue
- Ground: Tops and limbs, cull logs, dead and down, wind blown, road construction
- Standing: Diseased, insect infested, fire damaged, precommercial thinning, stagnated stand, dead and standing, urban removals

Harvesting
- Fell and bunch, residue collection

In Woods Processing
- Chipping, other preparation

Transport
- Truck, rail, barge

In Plant Processing
- Size reduction, dry, clean

Combustion
- Boiler (large/packaged), special combustor

Emission Control

Process Energy
• Felling
• "Forwarding" or retrieval
• Loading
• Transport

Felling

The felling operation involves the actual cutting of the trees. This can be done with the traditional chain saw, but more modern methods are now available. These methods involve the use of a "feller-buncher" machine which is a piece of equipment that can shear a tree (up to 20 inches in diameter) off at ground level, grasp the trees several at a time, and carry the stems to a convenient area for accumulation where they are laid down horizontally. This method is positive, the desired trees are removed, the direction of fall is always known, and no unnecessary damage to surrounding trees results. This equipment is particularly useful in thinning operations where the good timber can be left standing and the "junk wood" and cull timber can be removed for use as energy wood. The trees left behind have more room to grow and will develop more fully. Of course, this equipment also can be used for straight clearcutting.

There are a wide variety of feller-bunchers available, covering a wide range of sizes and concepts. At the small end of the scale are the "Bobcats," which are actually small front-end loaders with a shear and bunching apparatus mounted on the front of the machine in place of the usual bucket. Feller-buncher attachments are also available for larger tractors and front-end loaders, both rubber tired and tracked. The largest feller-bunchers available are fitted to crawler tractor-type power shovels. Thus, the prices for such machines vary widely, from about $40,000 to about $110,000. Terrain and methods of operation will determine which piece of equipment is best suited for the job at hand. A closer look at a typical feller-buncher is included in figure 3-2.
Forwarding

Feller-bunchers will accumulate substantial stacks of trees in short order, and these have to be moved to a chipping area rapidly. This task is usually performed by a "skidder," a tracked or rubber-tired vehicle specially built for pulling bunches of logs through the forest. The two major types of skidders are the cable skidder and the grapple skidder. The cable skidder wraps a steel cable around the logs, while the grapple skidder grasps several stems at once with a hydraulic grapple. This piece of equipment will cost in the $40,000 to $60,000 range. (A typical grapple skidder is shown in figure 3-3).

Forwarding also can be accomplished by other machines that actually load the trees on a bed with a hydraulic boom for transport, but this generally requires delimming and would not be particularly appropriate for the production of energy wood.

Loading

The loading of energy wood for transport is accomplished using the total-tree chipper. This machine can be portable (mounted on a semi-trailer) or installed in a more or less permanent location. The total tree chipper will pull an entire tree into the chipping blades and reduce it to small pieces which are blown into a waiting truck. The chipper is generally powered by a diesel engine and is available in sizes capable of chipping trees approximately 10 inches in diameter up to 20 inches in diameter. These machines are manufactured by several companies (see Appendix B), but the corporation that has gained the most recognition in the field is Morbark Industries in Winn, Michigan. Morbark has reportedly sold more than 400 of these machines in the past ten years.

Some whole tree chippers can separate a portion of the foreign material (dirt, bark, pine needles, etc.) from the good portion of the chips, with the result being the production of a relatively high quality chip. Some of these chips can be used by paper mills, so that total-tree chipping operations in Georgia today supply chips
for pulp and paper and for energy. There are approximately 30 active total tree chipping operations in the state of Georgia today (1).

Energy wood could be produced with several scenarios using total tree chippers. Feller-bunchers can be used to thin out a stand of timber, and the trees removed could be used for energy wood. Another approach might be to clearcut an area for sawtimber or pulp and paper, and while the logs are being loaded onto pole trailers, the limbs, tops, and culls could be chipped and loaded into vans for energy use. A third approach would be a clearcutting operation followed by complete total tree chipping for energy wood.

Total tree chipping equipment is quite expensive. A typical current (July 1979) price for a chipper to handle 12-inch diameter trees is $50,000, for 18-inch diameter trees the price is $80,000, and for 22-inch diameter trees the price would be $160,000. Operating and maintenance costs will include oil, diesel fuel, chipper knives and parts, and miscellaneous mechanical repairs. Since this machinery is costly, it will be necessary to keep the machines active on a busy chipping schedule to make them pay for themselves. A typical total tree chipper is shown in more detail in figure 3-4.

There are pros and cons to the total tree chipping concept and they can be summarized as follows:

**Pros**

- Total tree chipping increases the total wood yield per acre.
- Chipping requires fewer men to harvest the same timber.
- Chipping is safer than conventional logging (due to the use of feller-bunchers and due to the lack of large log loading).
- Chipping reduces preparation for replanting.
- Chipping provides a use for unmerchantable lumber.

**Cons**

- Total tree chipping requires a large initial expense.
- Total tree chipping requires a fairly large fleet of trucks.
- Total tree chipping does not produce chips that are completely "clean".

Transport

With a total tree chipping operation, the energy chips must be loaded into trucks that are suitable for the transport of chips. The types of trailers available will be considered in more detail in Chapter 4, but most chip transport is done with lightweight semi-trailer van bodies, which may or may not be self-unloading. The cost of trucking today in Georgia is about $1.30 to $1.80 per mile for a typical load of chips (20 to 25 tons). This charge is paid only when the truck is loaded. If the truck returns empty, no additional charges are paid.

Alternative Harvesting Methods

Other methods have been developed for the harvesting of wood in different areas, but for the harvest of energy wood in the Coastal Plains, the total tree chipping concept should be feasible in most locations. The strongest factor affecting feasibility of the method will be weather, since rubber-tired vehicles can become almost useless under severely wet conditions.

Cable harvesting is an important method used in areas where slopes are quite steep, as in West Virginia and the Pacific Northwest (3). In cable harvesting, felling of the trees is done with chain saws, and the logs are pulled up steep slopes by steel cables connected to stationary engines or tractors equipped with cable drums. This practice eliminates the need for skidding equipment and reduces the requirements for the building of logging roads.

Another method that has gained more acceptance in particularly inaccessible areas is helicopter logging. With this practice, helicopters hover over the area where trees have been felled (and usually delimbed as well), and the saw logs are flown out to areas where they can be loaded on trucks for transport to their final destination. This can be expensive but may be the only viable alternative for logging on extremely steep slopes.
Another alternative harvesting method involves large power shovel-type equipment that physically pulls up whole trees by their roots using a large vibrator to help shake the dirt out of the root system. This practice could conceivably have major impacts on soil erosion and may result in high levels of sand and soil in chips produced for fuel by total-tree chippers (chipping the roots and all). It is thus doubtful that this method will have a major impact on energy wood harvesting.

Companies interested in wood harvesting are developing other methods for total tree harvesting. Georgia-Pacific is developing a large machine which it calls a "biomass harvesting machine" which will cut a swath through undergrowth and small trees (up to 8 inches in diameter) producing fuel chips which are unloaded periodically into trucks (4). This machine is still under development.

**Equipment Costs Summary**

Depending on the level of effort to be mounted by a company engaged in the harvest of fuelwood, the necessary investment can quickly become quite large when the purchase prices of all the machines are totalled. Purchase prices for various types of harvesting machinery were collected by the Georgia Forestry Commission in 1978, and these are given for reference in Table 3-1. Operating costs also are estimated.

**Economics of Total-Tree Chipping**

Because in-field, whole-tree chipping is feasible in much of the Coastal Plains Region, it is assumed that a fully mechanized system of harvesting wood chips will be employed. Further, this analysis assumes a 50-week operation, working 40 hours per week, with a productivity of 62.5 tons of green wood chips per hour loaded into chip vans. A chip van contains 25 tons per load, or 10 cords per load at 5,000 lbs. per cord of green wood chips.

There are several variables which have major effects on the costs of harvesting and transporting wood chips. Assuming whole-tree chipping eliminates one variable. Another variable is the type of harvesting: clearcutting, selective thinning, timber stand improvement, etc.
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Purchase Cost</th>
<th>Years Life</th>
<th>Fixed</th>
<th>Operating</th>
<th>Total</th>
<th>Utilization or Availability %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chain saw - Straight Blade</td>
<td>$ 440</td>
<td>1</td>
<td>$ --</td>
<td>$ 2.40</td>
<td>$ 2.40 hr.</td>
<td>50</td>
</tr>
<tr>
<td>Chain saw - Bow Blade</td>
<td>$ 490</td>
<td>1</td>
<td>--</td>
<td>3.05</td>
<td>3.05 hr.</td>
<td>50</td>
</tr>
<tr>
<td>Bob Truck - Single Axle</td>
<td>$11,000</td>
<td>3</td>
<td>.20</td>
<td>.38</td>
<td>.58 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Bob Truck - Dead Tandem</td>
<td>$11,800</td>
<td>3</td>
<td>.22</td>
<td>.38</td>
<td>.60 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Bob Truck - Live Tandem</td>
<td>$19,000</td>
<td>4</td>
<td>.24</td>
<td>.40</td>
<td>.64 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Big Stick Loader</td>
<td>$2,500</td>
<td>5</td>
<td>1.97</td>
<td>1.40</td>
<td>2.37 hr.</td>
<td>90</td>
</tr>
<tr>
<td>Shortwood Hydraulic Loader</td>
<td>$24,000</td>
<td>5</td>
<td>7.74</td>
<td>10.05</td>
<td>17.79 hr.</td>
<td>65</td>
</tr>
<tr>
<td>Longwood Hydraulic Loader</td>
<td>$34,000</td>
<td>4</td>
<td>10.80</td>
<td>10.25</td>
<td>21.05 hr.</td>
<td>64</td>
</tr>
<tr>
<td>Uniloader (diesel)</td>
<td>$13,500</td>
<td>3</td>
<td>3.77</td>
<td>3.75</td>
<td>7.52 hr.</td>
<td>60</td>
</tr>
<tr>
<td>Front End Loader</td>
<td>$49,000</td>
<td>5</td>
<td>8.85</td>
<td>5.60</td>
<td>14.45 hr.</td>
<td>60</td>
</tr>
<tr>
<td>Cable Skidder</td>
<td>$36,000</td>
<td>3</td>
<td>11.55</td>
<td>7.63</td>
<td>19.18 hr.</td>
<td>67</td>
</tr>
<tr>
<td>Grapple Skidder</td>
<td>$54,000</td>
<td>3</td>
<td>14.16</td>
<td>6.02</td>
<td>20.20 hr.</td>
<td>67</td>
</tr>
<tr>
<td>Shortwood Prehauler</td>
<td>$38,500</td>
<td>4</td>
<td>10.10</td>
<td>5.50</td>
<td>15.60 hr.</td>
<td>64</td>
</tr>
<tr>
<td>Longwood Prehauler</td>
<td>$50,000</td>
<td>4</td>
<td>13.11</td>
<td>8.68</td>
<td>21.79 hr.</td>
<td>64</td>
</tr>
<tr>
<td>G.I. 6 x 6 &quot;used&quot; gas</td>
<td>$7,000</td>
<td>5</td>
<td>1.66</td>
<td>2.13</td>
<td>3.79 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Single Axle Gas Truck-Tractor</td>
<td>$11,000</td>
<td>3</td>
<td>.14</td>
<td>.48</td>
<td>.62 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Tandem Gas Truck-Tractor</td>
<td>$19,500</td>
<td>4</td>
<td>.11</td>
<td>.44</td>
<td>.55 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Single Axle Diesel Truck-Tractor</td>
<td>$28,500</td>
<td>5</td>
<td>.11</td>
<td>.30</td>
<td>.41 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Tandem Diesel Truck-Tractor</td>
<td>$41,000</td>
<td>5</td>
<td>.12</td>
<td>.36</td>
<td>.48 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Pole Trailer</td>
<td>$6,700</td>
<td>8</td>
<td>.05</td>
<td>.04</td>
<td>.09 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Frame Trailer</td>
<td>$6,500</td>
<td>8</td>
<td>.05</td>
<td>.04</td>
<td>.09 mi.</td>
<td>--</td>
</tr>
<tr>
<td>Chip Vans</td>
<td>$10,500</td>
<td>8</td>
<td>.05</td>
<td>.05</td>
<td>.10 mi.</td>
<td>--</td>
</tr>
</tbody>
</table>
Table 3-1 (Continued)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Purchase Cost</th>
<th>Years Life</th>
<th>Cost/Mile - Hour</th>
<th>Utilization or Availability %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixed</td>
<td>Operating</td>
</tr>
<tr>
<td>D-4 with Shear</td>
<td>$60,000</td>
<td>5</td>
<td>$12.00</td>
<td>$6.12</td>
</tr>
<tr>
<td>D-4 with Blade</td>
<td>55,000</td>
<td>5</td>
<td>9.16</td>
<td>6.02</td>
</tr>
<tr>
<td>Drott Feller-Buncher</td>
<td>110,000</td>
<td>5</td>
<td>22.00</td>
<td>9.68</td>
</tr>
<tr>
<td>Bobcat Feller-Buncher</td>
<td>39,000</td>
<td>3</td>
<td>9.70</td>
<td>9.30</td>
</tr>
<tr>
<td>Hydro-Axe 311 Feller-Buncher</td>
<td>54,000</td>
<td>4</td>
<td>7.76</td>
<td>5.68</td>
</tr>
<tr>
<td>Hydro-Axe 511 Feller-Buncher</td>
<td>69,000</td>
<td>4</td>
<td>10.00</td>
<td>7.56</td>
</tr>
<tr>
<td>Franklin 170 Feller-Buncher</td>
<td>52,000</td>
<td>4</td>
<td>7.48</td>
<td>6.38</td>
</tr>
<tr>
<td>Half-Ton Pickup</td>
<td>4,300</td>
<td>3</td>
<td>.08</td>
<td>.08</td>
</tr>
<tr>
<td>Pallets</td>
<td>190</td>
<td>8</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Three Pallet Frame</td>
<td>2,300</td>
<td>5</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Mobile Chipper 22&quot;</td>
<td>160,000</td>
<td>5</td>
<td>21.30</td>
<td>12.49</td>
</tr>
<tr>
<td>Mobile Chipper 12&quot;</td>
<td>44,400</td>
<td>5</td>
<td>6.80</td>
<td>8.18</td>
</tr>
<tr>
<td>Slasher</td>
<td>6,850</td>
<td>3</td>
<td>2.85</td>
<td>.63</td>
</tr>
</tbody>
</table>

Source: Georgia Forestry Commission
These will have effects on the productivity rates of the operation because the feller-bunchers and skidders will have greater distances to travel to collect a "turn" or bundle of logs; when these distances become too great, the chipper must be moved to another central location. Both of these systems reduce productivity. A third variable is the size of the operation, both machinery and labor. The size of the chipper will serve as the guide to how many feller-bunchers, skidders, and tractor/chip vans are required. The optimal size operation should keep the chipper in operation approximately 65% of the time. The final variable, of course, is the timber stand itself. The density and average d.b.h. of the trees determine the volume of wood which can be collected and chipped in a given period.

Because of the range and importance of the variables discussed above, the productivity and unit costs of harvesting are very site-specific. There are computer simulations which "create" harvesting environments representative of other areas of the country. There are no existing computer simulations for the Southeast at this time. Therefore, we have compiled a "representative" case which is a combination of data received from the Georgia Forestry Commission, some private companies, some independent loggers, and published reports. Other than a computer simulation, no published data has treated all of the variables mentioned above; rather, they have dealt with a particular side, a particular method of harvesting, or a specific total output (tons per year) of chips required for some purpose, such as fueling a wood-fired steam boiler.

Estimated Costs of Harvesting and Transporting Wood Chips

The following is a breakdown of the unit costs of a harvesting, chipping, and transporting operation utilizing clearcut, in-field, whole-tree chipping.

**Productivity:** 62.5 tons/hour; 125,000 tons/year

**Equipment:** (Fixed and operating costs, excluding labor, $/ton)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Bobcat Feller-Bunchers</td>
<td>0.61</td>
</tr>
<tr>
<td>2 Grapple Skidders</td>
<td>0.70</td>
</tr>
</tbody>
</table>
1 Mobile Chipper  0.58
Support equipment (2 pickup trucks, crew truck, chainsaws,  .95
  backup skidder, tractorcrawler, knife
  grinder)

Transportation: (20 loads, 50 miles one-way, per day,  2.84
  $0.67/mile) 5 to 6 Tandem diesel truck
  tractors plus chip vans
Labor:  6 drivers @ $250/week, 7 loggers @ $250/week  1.58
  2 foremen @ $350/week

Workmen's Compensation:  .28
Insurance:  .40
Benefits:  .40
Overhead:  .88

Profits and Taxes( 20% of equipment, transportation, labor)  1.42
Subtotal  $10.48/ton
Stumpage\(^1\) (low-high range)  $4.44 to 8.89/ton
TOTAL  $14.92 to 19.37/ton

\(^1\)Stumpage prices based on pine (softwood prices).

Note that the transportation costs shown are for a logging/chipping operation that owns its tractors and chip vans. If the operation, rather than owning the tractor-vans, used a common carrier, the transportation charges would be subject to various state public service commissions, the Southern Motor Carriers Rate Conference, and the Interstate Commerce Commission, depending upon the points of origin and destination. For example, an intrastate shipment of chips (points of origin and destination within the state) in Georgia would be subject to the Georgia Motor Trucking Association (GMTA) Tariff 5-D, specific commodity rates. These are specific point-of-origin to point-of-destination rates which supersede the intrastate general commodity rates. If a large volume of chips are to be harvested in a location and shipped to one or more specific locations, a point-to-point rate can be applied for through the GMTA and Georgia Public Service Commission (intrastate). These point-to-point rates are lower than the general commodity rates between the same points and over the same routes. These rates are also carrier-specific, but an example of such an operation is displayed. Note that the labor unit
costs will be lower than the above example because drivers are not needed; naturally, the transportable costs are different because of the use of a regulated common-carrier rather than ownership of tractors and vans.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment:</td>
<td>2.84</td>
</tr>
<tr>
<td>Transportation: (@ 0.29/cwt)</td>
<td>5.80</td>
</tr>
<tr>
<td>Labor:</td>
<td>.98</td>
</tr>
<tr>
<td>Workmen's Compensation:</td>
<td>.17</td>
</tr>
<tr>
<td>Insurance:</td>
<td>.40</td>
</tr>
<tr>
<td>Benefits:</td>
<td>.24</td>
</tr>
<tr>
<td>Overhead:</td>
<td>.88</td>
</tr>
<tr>
<td>Profits and Taxes:</td>
<td>1.92</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$13.23/ton</td>
</tr>
</tbody>
</table>

In this example, the case where the logging operation owns its tractor-vans works out to be approximately $2.75 per ton cheaper than the regulated carrier case. It is likely that this would be true in all larger operations; if the scale was not large enough, however, the economics of ownership would not be present and it would be advisable to use the regulated or contract carriers.
REFERENCES

1. Preston, Druid, Georgia Forestry Commission, personal communication to W.S. Bulpitt, May 1978.


Appendix J

WOOD FUEL HANDLING

by

G.B. Curtis, Senior Research Engineer
M.L. Brown, Research Engineer
B.S. Dixit, Senior Research Engineer
Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia
1979
I

INTRODUCTION

The purpose of this report is to provide general background information for industrial plant engineering and management personnel on the practical design, operation, and costs of on-site wood fuel handling systems. The work is not a detailed design manual, but will aid in the preparation of feasibility studies.

The wood handling system is important in that it is a costly component of a wood-fired plant, and its design can directly affect the plant's success. A well-designed system can result in lower operating cost and fewer interruptions. The space and equipment requirements of the solid fuel handling system is the most visible difference in a wood boiler plant compared to a natural gas or oil boiler plant.

The actual detailed design of a wood handling system can be performed by company engineering personnel provided the necessary time can be allocated. Certainly the larger installations should consider using professional consulting engineering assistance.

This report has six topics: Wood Fuel Properties, Receiving, Storage, Transport, Preparation, and Typical System Designs.
II
WOOD FUEL PROPERTIES

The purpose of this section is to give a general description of the characteristics of wood that affect its use as a fuel. There are relatively few varying characteristics of wood that are significant in its use for fuel. The principal ones are its moisture content and size.

Wood fuel can be a waste product of lumber or furniture manufacturing. It can come from waste generated by conventional harvesting techniques or it can be directly harvested from the forest. The largest quantities of wood fuel are green. Dry wood fuel is waste from manufacturing that uses kiln dried lumber such as furniture operations. The choice between dry or green wood fuel for a particular location is decided on the basis of availability and cost. A consideration is that combustion equipment for green fuel can also burn dry fuel, but the reverse is seldom true. It is believed that most systems will be based on green fuel which may burn dry fuel should it become available.

The physical size of wood fuel is important and affects handling, storage, on-site fuel preparation, combustion systems, and emissions. There are presently no official standards for wood fuel. Current practice is to analyze local availability and design the plant system accordingly. General classifications are sawdust up to 1/16 inch, chips up to 2 inches, and wood waste, a mixture of sizes from sawdust to pieces several feet long. Corresponding combustion systems are sawdust burners, stoker systems, and pile burning designs. Sawdust burners can only handle fine material, and in some designs, the material must be dry. Stoker systems normally are for material in the range of 2 to 4 inches maximum while pile burning designs will handle any size material deliverable to the pile. For nonforest industry plants, stoker-fired systems are likely to be the most efficient and economical. These can burn sawdust and chips. Wood waste may require size reduction. This can be accomplished by purchasing prehogged material or, in the instance of large systems, by hogging on-site as a part of the plant's fuel handling system.

Another general classification of wood fuel that is available in certain areas is "bark and shavings," which is derived from debarking of logs. Depending upon the maximum size of the bark and shavings, this type of wood fuel may require size reduction.
Wood fuel for industry can be purchased on several bases, but the common method is by ton weight. As the wood fuel industry progresses, it is expected that standards will evolve that reflect actual heat content. This lack of standards is not unusually critical in that the various green wood materials range plus or minus 5% of 4,000 Btu per pound. For dry wood more care must be exercised because the percentage of drying affects the heat content. For example, kiln dried material may have a 10% moisture level and will contain nearly 8,000 Btu per pound.

Wood ash content ranges around 1%. Coal ash can range from 8% to 14%. This low ash content makes ash disposal a relatively easily-managed problem. It is expected that there will be few, if any, restrictive environmental concerns. Some studies indicate that the ideal disposal is to return the ash to the forest land. In practical terms, the ash content can be greatly increased by soil from harvesting or handling techniques. It is important that this foreign material be minimized: it can interfere with the combustion process, cause heat exchanger erosion, increase the particulate emissions, and increase wear of fuel handling equipment.

Prepared wood fuel for industrial use in certain applications may become available. The most promising technique that currently has limited commercial distribution is densification. Wood is dried, reduced to small particle size, and then densified by extrusion. This process produces a product in the form of pellets or cubes. The bulk density is about 35 lb/ft³ compared to about 23 lb/ft³ for wood chips. The uniform product will allow storage, handling, and combustion equipment to be designed to its specific characteristics. Combustion thermal efficiency can be 15% higher than obtainable with green wood, and the capital cost of the combustion equipment can be reduced. However, the costs of densification are significant, so the place of prepared wood fuel is not clear at this time.

The heat content of wood is related to its moisture content more directly than to the species of wood. Typical completely dry softwoods have a heating value around 9,000 Btu per pound while hardwoods average 8,400 Btu per pound. In practice, little completely dry wood is available for fuel wood; and even wood that is called dry (kiln dried) has some moisture. Table II-1 gives some average values for typical wood fuel.
Table II-1
WOOD FUEL PROPERTIES

<table>
<thead>
<tr>
<th>Wood Fuel</th>
<th>Moisture Content, wet basis</th>
<th>Higher Heating Value, Btu per lb</th>
<th>Bulk Density lbs/ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Tree Chips</td>
<td>50%</td>
<td>4,000</td>
<td>24.0</td>
</tr>
<tr>
<td>Green Sawdust</td>
<td>50%</td>
<td>4,500</td>
<td>20.0</td>
</tr>
<tr>
<td>Dry Planer Shavings</td>
<td>13%</td>
<td>7,800</td>
<td>6.0</td>
</tr>
<tr>
<td>Dry Sawdust</td>
<td>13%</td>
<td>7,800</td>
<td>11.5</td>
</tr>
<tr>
<td>Wood Pellets</td>
<td>10%</td>
<td>8,100</td>
<td>35.0</td>
</tr>
</tbody>
</table>

The calculations for determining the quantity of fuel required are given by the formula

\[
\text{Wood Quantity} = \frac{\text{Boiler Output}}{\text{Wood Btu} \times \text{Combustion Efficiency}}
\]

For a 100 hp boiler burning green wood chips at 65% combustion efficiency, the calculation would be

\[
\text{Wood Requirement} = \frac{100 \text{ hp} \times 34.5 \text{ lbs steam/hp} \times 1000 \text{ Btu/lbs steam}}{4000 \text{ Btu/lb} \times 65\% \times 2000 \text{ lb/ton}}
\]

\[
= 0.67 \text{ tons per hour}
\]

For some commonly used industrial boilers, Table II-2 is calculated using green wood chips as the fuel and a boiler combustion efficiency of 65%. This table can also assist in calculations necessary for sizing the wood fuel handling and storage facilities.
### TABLE II-2

**WOOD FUEL QUANTITY REQUIREMENTS**

<table>
<thead>
<tr>
<th>Boiler Hp</th>
<th>Steam Output lb/hr</th>
<th>WOOD CONSUMPTION</th>
<th>Truckloads/day 23 tons/load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tons/hr</td>
<td>Tons/24 hrs</td>
</tr>
<tr>
<td>100</td>
<td>3,450</td>
<td>0.67</td>
<td>16.08</td>
</tr>
<tr>
<td>200</td>
<td>6,900</td>
<td>1.35</td>
<td>32.16</td>
</tr>
<tr>
<td>300</td>
<td>10,350</td>
<td>2.01</td>
<td>48.24</td>
</tr>
<tr>
<td>400</td>
<td>13,800</td>
<td>2.70</td>
<td>64.32</td>
</tr>
<tr>
<td>500</td>
<td>17,250</td>
<td>3.35</td>
<td>80.40</td>
</tr>
<tr>
<td>600</td>
<td>22,500</td>
<td>4.02</td>
<td>96.48</td>
</tr>
<tr>
<td>700</td>
<td>24,150</td>
<td>4.69</td>
<td>112.56</td>
</tr>
<tr>
<td>800</td>
<td>27,600</td>
<td>5.40</td>
<td>128.64</td>
</tr>
<tr>
<td>900</td>
<td>31,050</td>
<td>6.03</td>
<td>144.72</td>
</tr>
<tr>
<td>1,000</td>
<td>34,500</td>
<td>6.70</td>
<td>160.80</td>
</tr>
</tbody>
</table>

**Notes:**
1. Fuel is green wood chips.
2. Boiler combustion efficiency assumed to be 65%.
III
RECEIVING

The purpose of this section is to describe the usual methods that wood fuel can be received and unloaded at an industrial plant. There is no one accepted method so it is necessary to evaluate specific conditions at each site. The capabilities of prospective wood fuel suppliers can also influence the decision. Certainly economics is a major consideration, and the lowest cost method that meets the particular needs should be selected.

Figure III-1 illustrates four receiving methods that are widely used, and Table III-1 shows estimated costs per year.

- **Live Bottom Van.** The live bottom van is a self-unloading trailer with a chain conveyor incorporated into the floor. A typical van is 40 ft long, 8 ft wide, and 13 ft 6 in. high and will transport about 23 tons of material per load. The chain conveyor travels at the rate of six feet per minute, permitting the van to be unloaded in under 10 minutes. Live bottom vans cost approximately $24,000 which is twice the cost of standard open top trailers of the same size. The increased cost of labor to operate the van is reflected by increased transportation charges on the order of 10% to 15%. The advantage to fuel purchases via live bottom van deliveries is that no costly unloading device is required on site. During discussions with companies presently in the waste wood business, several expressed the opinion that the live bottom van will be the method of choice for many industrial plants that require six deliveries per day or less.

- **Truck Dumps.** Truck dumps are devices installed at the plant site that elevate and unload trailers. Most are hydraulically operated. They come in two sizes—one size handles both tractor and trailer and the other handles the tractor only. A truck dump with a 40-foot platform to handle a standard trailer costs about $20,500, a dump with a 60-foot platform to handle both the tractor and trailer costs around $50,000. A complete installation including a live bottom receiving hopper can exceed $100,000. The major advantage of a truck dump is that it can quickly unload widely available standard 40-foot vans. Turn-around time can be 20 minutes or less. Truck dumps are most practical for larger installations that require more than 10 deliveries per day.
## TABLE III-1

**COMPARISONS BETWEEN UNLOADING ALTERNATIVES**

**Estimated Cost Per Year**

<table>
<thead>
<tr>
<th>Boiler Size 1b/hr</th>
<th>Tons/yr</th>
<th>Live Bottom Van¹</th>
<th>Truck Dump²</th>
<th>Front Eng Loader³</th>
<th>Scoop Roveyor ⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>(100 hp) 3,450</td>
<td>4,900</td>
<td>$1,000</td>
<td>$13,000</td>
<td>$4,950</td>
<td>$9,350</td>
</tr>
<tr>
<td>(1000 hp) 34,500</td>
<td>49,000</td>
<td>$10,000</td>
<td>$14,000</td>
<td>$20,260</td>
<td>$12,950</td>
</tr>
<tr>
<td>100,000</td>
<td>142,000</td>
<td>$29,000</td>
<td>$16,000</td>
<td>$51,260</td>
<td>$20,450</td>
</tr>
<tr>
<td>250,000</td>
<td>355,000</td>
<td>$73,000</td>
<td>$33,567*</td>
<td>---</td>
<td>$46,400*</td>
</tr>
</tbody>
</table>

*Note: Interest rates are assumed to be 10%*

¹/ Haul is 30 miles one-way, 22 tons per load, live bottom vans add $.15/mile
²/ Installed cost of truck dump is $110,000, life is 15 years, unloading time is 15 minutes.
³/ Cost of loader is $20,000, unloading time is 45 minutes, labor is $5/hr, operating costs are $5/hr, tractor life is 10 years.
⁴/ Cost of Scoop-Roveyor is $55,000, life is 10 years, unloading time is 15 minutes, labor is $5/hr, and operation is $2/hr.

*Two unloading devices required*
IV

STORAGE OF WOOD FUEL

The storage of wood fuel is one of the first considerations in the design of a wood fuel facility. Often a significant land area is required, and the location of available storage area relative to the burner location affects the fuel handling system design and associated costs.

The size and type of wood storage required varies with the requirements of a particular plant. Among the factors that need to be considered are:

- Heat energy requirements of the plant
- Land area available and its location
- Moisture content of fuel
- Fuel preparation requirements
- Reliability of wood fuel supply system
- Weather severity

All of these factors should be evaluated and considered in the storage system. The actual storage is usually accomplished by open storage, covered storage, or by silos. Figure IV-1 provides schematic views of typical storage methods.

- Open storage. Open storage is storage area that is not covered for protection from rain or other precipitation. It can be the only storage needed, but is most often used for a 10 to 30 day supply to handle interruptions in the normal fuel delivery system such as inclement weather or strikes. The quantity of material storable on a given site is limited to the height obtainable by the stacking and retrieval equipment.

It is recommended that the open storage area be paved, preferably with concrete, to prevent the accidental scraping up of dirt with the fuel which can cause problems with the burning equipment. The area should be pitched to allow for drainage and should not be located in a flood prone area.

The maximum storage time for wood fuel before significant deterioration begins is not well established. It may be as short as six months, but from the evidence now available, one year appears to be the maximum recommended.
• Railroad Delivery. Receiving wood fuel by railroad is practical under the right circumstances. Railroad shipment can be the lowest cost transportation when shipping distances exceed 70 miles. If a railroad siding is available and the local area wood fuel is in short supply, then railroad shipment needs to be evaluated.

• Dump Trucks. Dump trucks are sometimes used for wood fuel delivery. Though usually of smaller capacity than standard 40-foot vans, they can be utilized in specific circumstances for short haul situations.

• Other. One semi-automatic method of truck unloading is the "Scoop-Roveyor" device by Morbark of Winn, Michigan. A "Scoop-Roveyor" resembles a coal seam miner and actually digs its way into the rear of a chip van emptying the wood in 10 to 15 minutes. An operator to control it is stationed at the collection end. The cost of this device is from $50,000 to $55,000 depending on options and capacity. Scoop-Roveyors may be the economical unloader for plants of medium size.

Small installations not having specialized unloading devices could employ a front end loader for this purpose. Front end loaders can unload trailers in around 30 to 45 minutes. When the tractor operation and labor costs are considered, this method can be justified economically only in a few small-size operations. Unless the operator is skilled, damage to the trailer can occur.
FIGURE IV-1

STORAGE METHODS

COVERED

OPEN

SILO

BIN
Like storage time, the effect of rain or other precipitation on the heat content of openly stored wood fuel is not well known. There is some evidence that rain has minor effects on long term storage (most of it runs off or evaporates), but using wood fuel immediately after it has received rain will hamper or prevent its combustion.

As stated, the storage volume per unit area is determined by pile height, and the total weight is obtainable by multiplying the volume by the specific weight of the particular wood fuel. As an example, if whole tree chips at 23 lbs/ft$^3$ are stacked to an average height of 12 ft, then 138 tons can be stored per thousand square feet of area. The cost of paved open storage depends upon local conditions (amount of area preparation necessary), but an average cost of $1.30 per sq ft can be used for preliminary estimating purposes.

- **Covered storage.** Wood storage systems frequently contain a covered storage area using an open-sided metal building located adjacent to the burning equipment. It is sized for a three or four day storage capacity. Many of the same considerations considered under the discussion of open storage apply to covered storage.

  Fuel to be immediately burned is taken from this area. The cover prevents soaking by rain. Under normal operation, most of the fuel can be delivered to the covered storage area and consumed without going through the open storage area.

  Covered storage is also necessary for fuel that is dry. This could be fuel from kiln dried lumber or from prepared densified wood fuel. For estimating, Figure IV-2 shows storage capacities for whole tree chips and the typical costs of covered storage sheds.

- **Silos.** Silos are used to store wood fuel under certain conditions. For the nonforest industry, it is expected that silos will be considered when

  a) Fuel requirements are relatively small, about one fuel delivery per day or less

  b) Automated fuel feed is highly desirable

  c) Site location presents the use of open storage
Figure IV-2

Covered Storage Costs

Storage Capacity - Chips -

Costs

$ / sq. ft.

Tons

6' depth

1000 sq. ft.

5

10

20

30

40

50

5

10

20

30

40

50

3000

2000

1000

0
Silos come in a variety of diameters, heights, and volumes; and they can be manufactured of metal, poured concrete, or staved concrete.

Wood fuel as a class has poor flow characteristics, and this must be considered in the silo design. Wood fuel may not be free flowing in silo storage; therefore, silos require active mechanical retrieval systems. These are manufactured in several designs and can include a chain flail or screw auger. Wood fuel in silo storage can bridge over. Under certain conditions, the collapse of this bridge can create outward thrust and/or vacuum conditions severe enough to cause structural failure to the silo.

There are a number of successful wood fuel silo storage systems now in operation. If properly designed, they can achieve full automation except for loading. Typical system designs are given in Section VII of this report.

Tables IV-3 and IV-4 present some typical steel and poured concrete silos showing size, storage capacity, and approximate installed costs.

### TABLE IV-3

**POURED CONCRETE SILOS WITH UNLOADER**

<table>
<thead>
<tr>
<th>Storage Capacity ft(^3)</th>
<th>Weight of Wood Fuel Stored</th>
<th>= Silo Size dia. x height</th>
<th>= Installed Cost Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green Wood Chips Tons</td>
<td>Wood Pellets Tons</td>
<td></td>
</tr>
<tr>
<td>10,000</td>
<td>100 - 120</td>
<td>175</td>
<td>20' x 56'</td>
</tr>
<tr>
<td>15,000</td>
<td>150 - 180</td>
<td>263</td>
<td>20' x 72'</td>
</tr>
<tr>
<td>20,000</td>
<td>200 - 240</td>
<td>350</td>
<td>24' x 68'</td>
</tr>
<tr>
<td>30,000</td>
<td>300 - 360</td>
<td>525</td>
<td>30' x 72'</td>
</tr>
<tr>
<td>40,000</td>
<td>400 - 480</td>
<td>700</td>
<td>30' x 88'</td>
</tr>
</tbody>
</table>

Notes:
1) Silos are constructed with flat roof and an unloader. Cost of foundation is included.

2) The bulk density of wood chips is assumed to be 23 lbs/ft\(^3\).
   The bulk density of pellets is assumed to be 35 lbs/ft\(^3\).
## TABLE IV-4

STEEL SILOS WITH UNLOADER

<table>
<thead>
<tr>
<th>Storage Capacity ft³</th>
<th>Weight of Wood Fuel Stored</th>
<th>= Silo Size dia. x height</th>
<th>= Installed Cost Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>50 - 60</td>
<td>88</td>
<td>15' x 38'</td>
</tr>
<tr>
<td>10,000</td>
<td>100 - 120</td>
<td>175</td>
<td>21' x 33'</td>
</tr>
<tr>
<td>15,000</td>
<td>150 - 180</td>
<td>263</td>
<td>21' x 48'</td>
</tr>
<tr>
<td>20,000</td>
<td>200 - 240</td>
<td>350</td>
<td>21' x 60'</td>
</tr>
<tr>
<td>25,000</td>
<td>250 - 300</td>
<td>438</td>
<td>27' x 50'</td>
</tr>
<tr>
<td>30,000</td>
<td>300 - 360</td>
<td>526</td>
<td>27' x 58'</td>
</tr>
<tr>
<td>35,000</td>
<td>350 - 420</td>
<td>613</td>
<td>27' x 67'</td>
</tr>
</tbody>
</table>

Notes:  
1) Silos are constructed of steel with fused glass.  
2) Height is from floor to top.  
3) Bulk density of wood is assumed to be 23 lbs/ft³.  
   Bulk density of pellets is assumed to be 35 lbs/ft³.
V

TRANSPORT

This section describes the various methods commonly employed in the transport of wood fuel at a plant site. After delivery, the wood may be transported to long or short term storage, to fuel preparation equipment, or to the boiler hopper. A key design criteria of wood handling systems is to minimize the amount of transport required to keep costs down. The choice of quality transport equipment, properly applied, will insure reliable operation and reduce operating costs.

For the nonforest industrial plant, viable transport methods include

- Belt conveyors
- Chain conveyors
- Augers
- Front end loaders

In addition, there is limited application of pneumatic conveying, vibrating conveyors, and bucket elevators.

The demarcation between various transport methods is not always clear and their recommended uses can overlap. Careful attention is necessary at final design to select the system that will provide good service at reasonable cost with low maintenance. Figure V-1 illustrates four transport methods.

- Belt conveyors. Belt conveyors are widely used for conveying wood fuel. They are used to convey sawdust, bark, wood chips, and unhogged wood waste. They can handle large capacities and are especially useful for conveying wood fuel over long distances. Belts operate best under uniform loading. They are not satisfactory for retrieving material from storage where the material may be many feet in depth over the belt. Usually belts are limited to an incline of 15° to prevent slippage of material. Belts are available with flights and flexible sidewalls which increase the transport angles. The belts come in various sizes, widths, and lengths from a few feet up to hundreds of feet.
- **Drag chains.** Drag chain conveyors are widely used where the transport distance is relatively short. Though construction details differ, they essentially consist of one or more metal chains connected with pusher barrels or drag bars that run in troughs. They can be installed in parallel to create live bottoms. They are used to transport sawdust, bark, wood chips and unhugged wood pieces of moderate size.

Drag chains are rugged in construction and can handle heavy non-uniform loads. They are especially suited for reclaiming wood pieces from receiving hoppers, storage piles, and for feeding boiler hoppers. They are relatively easy to operate and maintain. Broken links can be replaced or welded by plant personnel.

- **Augers.** Augers or screw conveyors consist of a helical blade mounted on a shaft enclosed by troughs or covers that hold the material to be transported. They are commonly used in feeders to the burners and as part of the retrieval equipment in silos or bins. They can transport material horizontally or on inclines with reduced capacity. With variable speed drives, they can be used as metering devices. They can handle hogged wood and wood chips. Augers are inexpensive and easy to operate.

- **Front end loaders.** Front end loaders are very useful machines for wood fuel handling. For many installations, the machine can be the principal fuel handling method. For installations that use systems such as drag chains and belt conveyors, the front end loader is useful in cleaning up spills and serving as backup for equipment breakdown.

There are two basic types—the agricultural tractor and the construction tractor. These units differ primarily in their design duty. The agricultural tractor is lightweight and is not expected to maintain a heavy duty cycle; whereas construction units often are of articulated design for maneuverability. For wood fuel use, the standard buckets should be replaced with larger volume buckets. Wood fuel at less than 25 lb/ft$^3$ can be easily handled using high volume buckets known in the trade as snow buckets or loose material buckets.

As a size selection aid, Table V-2 has been prepared. The table is based on the loader being able to move twice the required weight of fuel per hour—that is, the completion of two cycles of scoope, move, dump, and
<table>
<thead>
<tr>
<th>Type</th>
<th>Bucket Size (yd³)</th>
<th>Applications</th>
<th>Tractor Wt (lb)</th>
<th>Estimated Fuel Consumption (gal/hr)</th>
<th>Engine (hp)</th>
<th>Approx. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>1 1/2</td>
<td>600 hp or 21,700 lb/hr</td>
<td>6,300</td>
<td>1.0</td>
<td>45</td>
<td>$16,000</td>
</tr>
<tr>
<td>Agricultural</td>
<td>3</td>
<td>1000 hp or 34,500 lb/hr</td>
<td>7,800</td>
<td>1.5</td>
<td>64</td>
<td>$22,000</td>
</tr>
<tr>
<td>Construction</td>
<td>5</td>
<td>3333 hp or 115,000 lb/hr</td>
<td>21,000</td>
<td>11.5</td>
<td>80</td>
<td>$57,000</td>
</tr>
<tr>
<td>Construction</td>
<td>12</td>
<td>6666 hp or 230,000 lb/hr</td>
<td>37,000</td>
<td>23.5</td>
<td>170</td>
<td>$120,000</td>
</tr>
</tbody>
</table>
return. Taking into account their more substantial design, a 75% duty cycle is applied to the construction loader while a 25% duty cycle is applied to the agricultural loader.

● Other. Among other wood fuel transport methods are pneumatic conveyors, vibrating conveyors, and bucket elevators. Pneumatic conveyors are used in the lumber and furniture manufacturing industries to pick up sawdust for transport to central storage. As their operating costs are relatively higher than belt conveying, limited use is expected in the nonforest industry. Vibrating conveyors have certain special applications, but are not widely used. Bucket elevators are modified chain conveyors with bucket attached and are useful where vertical lift is required.
VI

PREPARATION OF WOOD FUEL

The preparation of wood fuel at a nonforest industry plant may be necessary to facilitate handling and to meet the requirements of the burning system. It is normally limited to size reduction and to the removal of foreign objects. In some instances, pre-drying may be appropriate where waste heat is available or where higher flame temperatures are required such as calcining. Many nonforest industries purchase their fuel in a form such that no on-site preparation is required.

Size reduction is required when the wood fuel has dimensions too large to pass through the burner feed system or to combust properly. For example, two inches may be the maximum dimension desired. If any of the wood fuel exceeds this dimension, it can be reduced to proper size by passing through a machine commonly called a "hog" (knife hog or hammermill).

As a general statement, on-site preparation of wood fuel should be kept to a minimum consistent with the needs of the combustion system. This statement implies that prior to the purchase of a particular unit, the availability of suitable wood fuel should be evaluated. For example, some wood burning units require dry or partially dried wood. If only green fuel wood is available locally at reasonable cost, then only systems that are capable of using green wood should be considered.

Figure VI-1 illustrates the arrangement of a typical size reduction system utilizing waste wood. The unhogged material first passes under a magnetic metal separator that removes tramp iron or steel. There are several designs of magnetic separation devices, but they all work on the principal of the magnetic attraction of iron. The material then passes onto the top of the disk screen. The disk screen consists of a series of disks rotating on parallel shafts. The spacing of the disks is such that material under a certain size (e.g. 2") will pass down across the top of the disk screen and drop into the hog. The hog will then reduce the larger pieces to the required size (e.g. 2"). The purpose of the screen is to reduce the horsepower requirements of the hog by screening out the material that is of proper size. In the usual design, the material that passes through the screen and the hog is rejected on a conveyor and transported to storage. Costs of some typical screens, hogs, and hammermills are listed in Table VI-1.
### TABLE VI-1

**SCREEN COSTS**

<table>
<thead>
<tr>
<th></th>
<th>Capacity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Disc</td>
<td>40 tons/hr</td>
<td>$20,000</td>
</tr>
<tr>
<td>Large Disc</td>
<td>250 tons/hr</td>
<td>$50,000</td>
</tr>
<tr>
<td>Small Shaker</td>
<td>10 tons/hr</td>
<td>$5,500</td>
</tr>
<tr>
<td>Large Shaker</td>
<td>40 tons/hr</td>
<td>$20,000</td>
</tr>
<tr>
<td>Revolving Drum</td>
<td>40 tons/hr</td>
<td>$45,000</td>
</tr>
</tbody>
</table>

**COSTS OF HOGS AND HAMMER MILLS**

<table>
<thead>
<tr>
<th></th>
<th>Capacity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Knife Hog</td>
<td>10 tons/hr</td>
<td>$12,000</td>
</tr>
<tr>
<td>Large Knife Hog</td>
<td>32 tons/hr</td>
<td>$38,000</td>
</tr>
<tr>
<td>Small Hammermill</td>
<td>3 tons/hr</td>
<td>$10,500</td>
</tr>
<tr>
<td>Large Hammermill</td>
<td>8 tons/hr</td>
<td>$24,000</td>
</tr>
</tbody>
</table>
The decision on whether to purchase preparation equipment is based on the amount of fuel used and the cost differential between prepared and unprepared fuel. Figure VI-2 illustrates the effect of yearly wood usage on the fuel preparation equipment payback period for different differential costs. Preparation equipment cost was assumed to be $75,000.

As indicated previously, pre-drying of green fuel may be desirable in limited instances. If there is a quantity of waste heat from a manufacturing process, this heat could be used to dry the green fuel prior to introduction into the furnace. Dryers that are suitable in design for drying wood fuel are now used in particleboard manufacturing. They are of horizontal rotary direct fired construction.

The net effect of pre-drying on the combustion of wood is that dry wood is more easily burned and flame temperatures at 2300°F to 2500°F can be obtained instead of 1800°F expected from green wood. Also, the overall thermal efficiency of a boiler can be increased by several percent.

Another fuel preparation method that may be useful in some instances is wood fuel densification. It is expected that in the usual instance, fuel densification benefits will not be justified at an individual plant.
PREPARED-UNPREPARED COST DIFFERENCE

- $1/ton differential between prepared and unprepared fuel
- $2/ton differential between prepared and unprepared fuel
- $4/ton differential between prepared and unprepared fuel

1. Preparation equipment includes screen, hog, and metal separator which cost $75,000.
VII

TYPICAL DESIGNS OF WOOD FUEL FACILITIES

The purpose of this section is to present three conceptual designs for wood fuel facilities that address the needs of nonforest related industrial plants. The designs can be adapted to meet the requirements for any size plant. Keep in mind that an actual design should be site specific and should account for local conditions.

Three basic systems are described. The first is based on the silo for storage and uses prepared fuel (fuel which requires no on-site beneficiation). The second type is also based on prepared fuel but uses both outdoor and covered storage. The third system is based on wood waste material and contains a fuel preparation section. It also utilizes open and covered storage.

The silo based system (Figure VII-1) is a very commonly used design for the moderate size plant and for locations where storage area is limited. This system is also indicated where the wood fuel is dry and protection is needed from precipitation. The silo can be of steel, poured concrete, or staved concrete construction and may be almost completely automated. It requires little attention or maintenance.

Silos are subject to fuel flow interruptions from bridging of the fuel in the silo. For this reason, most silos include a device for breaking up the bridging to assure fuel flow. There are several devices of this kind. The drawing indicates a frequently used unit which consists of a motor-driven vertical shaft with chain flails. The flow problem limits the size of the material. Large pieces will not pass through the silo and conveying system so the wood fuel is limited to pieces 2" and smaller. These systems are often designed for three days' storage. With this limited storage, a reliable fuel supplier is imperative.

The next system (Figure VII-2) consists of open and covered storage with wood handling by a front end loader. For a given size, this design represents the lowest capital cost. No conveying equipment is specified, though for a particular installation, conveying equipment may be desirable.

The open storage is a concrete slab designed to hold a 30-day supply of wood fuel. The slab has a slight pitch to aid in rainwater runoff. The
covered storage is designed to hold three days of fuel and consists of a concrete slab with an open-sided metal building. The building should be a minimum of 30 feet in width to accommodate two trailer vans. In practice, the covered storage is the active area with the outdoor storage serving as a reserve holding area to allow for special purchases and to provide fuel during periods when the regular supply may be interrupted.

No fuel preparation is included as it is anticipated that the fuel will be purchased sized to the requirements of the burning system. A truck receiving unloading system may have to be included depending upon the type of fuel delivery.

The last system (Figure VII-3) illustrates the components that are usually necessary for the larger systems. The fuel is received from a hydraulic truck dump into a live bottom pit. The material is conveyed up through a station where it is passed over a magnetic separation belt to remove tramp metal. The fuel is then conveyed to a disc screen and hog where any oversized pieces are reduced to proper size. From the hog, the material is transported by conveyors to the covered storage. Not shown but generally included in a system of this size is an open storage area. After passing through the disc screen and hog, the conveying system is so arranged that the fuel can be transported to covered storage or to an open storage area. A front end loader is a necessary piece of equipment to handle special transport problems and to handle spills.
Appendix K

GENERAL COMMENTS ON BOILERS AND WOOD USE

by W.S. Bulpitt

from

"A Feasibility Study for Wood Energy Utilization in the Southeast," Final Report on Project A-2140, Georgia Tech Engineering Experiment Station, Atlanta, Georgia, December 1979
Wood Combustion Equipment and Steam Generation Equipment

Wood Use in the Forest Products Industry

The processing of wood into usable products can be quite energy intensive, as any visitor to a large pulp and paper mill soon realizes. Unfortunately, during the production of usable goods from wood, much of the tree is often wasted, resulting in a solid waste disposal problem for the industrial plant. In the production of sawtimber, for example, the clear-cutting operation and removal of tops and limbs may leave 50% of the tree as waste on the forest floor, and the actual sawing of the wood into usable lumber may result in a further waste of 40% of the wood harvested. Some of the waste from the sawing operations may be usable as pulp chips, but a large part of it may be usable only as a fuel. In the past nearly every sawmill viewed this wood waste as a disposal problem and either incinerated it in a "teepee" burner or transported it to a landfill for burial. This was done in spite of the fact that other operations in the sawmill depended directly on the combustion of fossil fuels to produce heat. After sawing, lumber must be dried properly in kilns before shipment to dealers, and most often these kilns were also fired with oil or natural gas, or with steam heat generated by oil or natural gas boilers. It is still possible to find sawmills using fossil fuels exclusively for drying operations, but they are rapidly disappearing.

Similarly, the production of plywood and other forms of veneer results in approximately 40% of the input log material being wasted. Veneer dryers in a plywood mill consume large amounts of energy which could be provided by the accumulated waste. The production of particleboard also requires drying, although in this instance, the wood to be used for fuel becomes more difficult to separate from the product.

Another class of wood users includes the wood manufacturing plants where raw wood is made into furniture, cable reels, pellets, or a host of other products. Each of these plants also generates large amounts of wood waste, principally dry material which consists of planer shavings and sawdust. Again, this material has posed a disposal problem for some plants in the past.
Recently, however, there has been a trend toward the use of wood waste as an energy source in the forest products industry, particularly due to the skyrocketing prices paid for fossil fuels. In many instances, the amount of wood waste generated still contains more energy than the plant requires, and again a waste disposal problem results. This residue then becomes a fuel source that can be sold or given to another plant.

Large pulp and paper mills produce wood residues on very large scales, principally bark as a product of the debarking operation. The amount of bark thus generated can be hundreds of tons per day and landfilling or transport from the plant becomes out of the question. The bark is burned in large (up to 500,000 lb/hr of steam) combination boilers which can also be fired with oil or gas. The steam generated is used to produce electricity for the mill and for the paper processing operations. In recent years, many mills have come to consider bark more of a windfall fuel supply than a disposal problem and many have installed extra boilers to ensure that all the bark can be burned. Some have even contracted with sawmills and other residue producers to supply the paper mill with additional fuel. Many power plant superintendents have made it a personal goal to cut down on fossil fuel use for boilers as much as possible while expanding the capacities of bark boilers and liquor recovery boilers.

Wood Use in the Non-Forest Products Industries

In spite of this recent enlightenment, in some industries there still exists an ample supply of wood residue in many locations. If the demands of the forest products industry are not sufficient, this residue becomes a potential fuel for non-forest products industries. Thus far in the U.S., relatively few non-forest industries have taken advantage of wood fuel as an energy source. Two notable exceptions in the South have been the conversion of a textile mill steam plant to the use of wood residue (replacing fuel oil) in Alabama and the firing of brick kilns in Georgia and North Carolina with dry wood waste.

Many opportunities exist for the use of wood waste in non-forest products industries in the South, but industry in general seems reluctant to change, possibly because of misgivings about the supply picture. Any industrial plant with a steam plant can easily convert to wood use today with the
hardware available. Major constraints involve first cost of the equipment, a more complicated fuel handling system, and the need for a larger storage area. It is conceivable that wood or wood gas could eventually act as an energy source for textile drying, carpet drying, the firing of lime kilns, the firing of large mineral dryers, space heating, the drying of paper products and, of course, the production of steam. The remainder of this section will deal more explicitly with the hardware that is available today for the production of steam and heat energy from wood.

General Comments on Boilers and Wood Use

Since steam power began to be an important source of energy in the 1700's, there has been a gradual evolution in hardware to the point we find ourselves today. Many talented engineers and scientists met with failure and bodily harm while developing the state-of-the-art of steam power. Early efforts were relatively crude, producing only low steam pressure and unreliable operation, while a modern fossil-fuel-fired power plant is enormously complex and represents a high water mark in the development of mechanical systems. Steam pressures in excess of 3,000 lb/in^2 are in use today, and steam temperatures are pushing the limits of metallurgical science.

The original fuel for steam production in this country was, of course, wood. Early industrial plants and early locomotives all ran on wood and coal did not begin to make serious encroachments on the use of wood fuel until the late 19th century. As coal technology developed, the use of wood became almost a lost art. In the 1930's, 1940's, and 1950's coal also fell victim to the cleanliness and ease of operation of fuel oil and natural gas. This brings us to the present, and the plight the U.S. is in with regard to foreign fuel supplies. Coal continued to be used through the times when oil and natural gas gained widespread acceptance, and coal burning technology continued to evolve, albeit at a much slower pace than during the early 1900's. Recent mandates by the Federal government and the skyrocketing prices of oil and natural gas have dictated a swing back to coal for use by utilities and industries. New processes are being developed to make coal gas, to clean
coal to solve pollution problems, and to burn coal in fluidized beds.

The evolution of wood burning hardware has continued, but this evolu-
tion has not received nearly as much publicity as developments in coal
burning. Indeed, applications of new boilers and new combustion systems
for wood have often spun off from similar developments for handling coal.

Again, the industry that has done most to develop the art and science
of wood burning has been the pulp and paper industry. The past 50 years
have seen the gradual development of wood burning boilers from rather prim-
itive pile burners to units that are capable of producing 400,000 to 500,000
lb/hr of steam at pressures that rival the steam pressures found in central
utility plants. This survey is not concerned primarily with these very
large units, however, but is concerned more with the smaller boilers and
combustors that could find widespread application in the non-forest pro-
ducts industries. For this reason the emphasis was placed on collecting
information on systems capable of producing 100,000 lb/hr or less of steam,
except for those larger units that could be used for cogenerating up to 25
megawatts of electric power in an industrial environment.

Boilers may be divided into two general classes – firetube boilers and
watertube boilers. As the designations indicate, in the firetube design
the fire actually travels through steel tubes passing through a water tank,
while in the watertube design the water being heated passes through steel
tubes which are heated on the outside by the hot gases from the combustion
process. Today many people have the tendency to dismiss the firetube boiler
as an "old-fashioned" design, but this is not always the case. There are
many applications where the firetube unit has distinct advantages over a
watertube unit, particularly in light and medium industrial applications.
The firetube boiler can be cheaper to purchase initially and it can be more
forgiving in terms of routine maintenance, particularly with regard to water
treatment. Its limitations begin to become apparent in the 20,000 to 40,000
lb/hr range, particularly when pressures exceed 300 psi. Larger shell dia-
meters require thicker plates to withstand the pressure and temperature stresses.
Temperature differentials in the boiler create high stresses, and these stresses
combined with the effects of precipitates and other deposits, have caused boiler
explosions in the past. Because of its smaller component sizes and ability to accommodate expansion, the steel watertube boiler is more suitable for large capacities and high pressure.

Besides the firetube and watertube classifications, boiler designations can be made in another manner: boilers can be "package" boilers or "field-erected" boilers. These designations can cause some confusion since virtually all wood burning units require some field erection. A package boiler generally can be shipped over the land with normal transportation methods bed truck or railcar. The major boiler components are in one assembly and can often be lifted right on to a simple foundation and piped in to an existing system. As a result, the package boiler requires far less labor before start-up than a field-erected unit. The field-erected unit often requires individual welding of boiler tubes and the entire fabrication of a steel framework. In other words, the boiler is completely built up at the job site from all the component parts, while the package boiler is nearly complete when it leaves the factory. Package boilers in the 100,000 lb/hr range have been shipped for gas/oil firing, but the larger combustion volumes necessary for wood units generally limit the top size for a wood fired package boiler to less than 50,000 lb/hr. As one might expect, field-erected boilers cost more than package boilers, and construction times are significantly longer; more will be said about these plants later.

Classification of Combustion Systems

Some types of systems for burning wood waste have been in use for many years, but recently many new pieces of hardware have entered the market and it has become difficult to place all these systems in particular classes, but an attempt will be made in this section to do so. The following breakdown of systems will be used:

- Wood Fired Package Boilers
- Suspension and Cyclone Burners
- Fluidized Bed Combustors
- Pyrolysis Systems
- Gasification Systems
- Other Systems
- Field-Erected Boilers

Wood-Fired Package Boilers

There are many manufacturers in the wood package boiler field today. In general, it can be said that the larger and perhaps better known boiler manufacturers (Babcock and Wilcox, Combustion Engineering, Riley Stoker, Foster-Wheeler, etc.) are not really interested in building small (less than 50,000 lb/hr) boilers for light- and medium-sized commercial and industrial operations. This gap has been filled by a number of smaller manufacturers, and, as wood energy use has grown, the market has become more and more competitive. The products of some of these companies are considered in greater detail below.

Industrial Boiler Company

The Industrial Boiler Company of Thomasville, Georgia, has installed over 40 wood fired boilers over the last several years throughout the country. The company's primary product for the wood industry is an HRT type firetube boiler which is available in sizes from approximately 77 hp to 1,000 hp in single boiler installations. The main boiler components are factory-made and erected in the field. Depending on the customer's fuel requirements and desires, different options are available for grate designs and furnaces. Some installations use dutch ovens which require more refractory work. Operating pressures range up to 300 psi, and most installations have been able to meet local pollution codes with strictly mechanical equipment. The company will install turnkey jobs which include complete wood handling and storage systems and all controls and air pollution equipment. The manufacturer claims a thermal efficiency of 60%, and these units can burn wood waste up to a moisture content of 60%.
Advantages of the Industrial Boiler units include simplicity of design and associated low maintenance costs. Replacement of boiler tubes is a straightforward operation, and the largest single maintenance items probably will involve refractory repairs. The smaller Industrial Boiler units are semi-automatic and require little operator attention. A representative Industrial Boiler Co. installation is shown in figure 4-35.

Ray Burner Company

The Ray Burner Company of San Francisco, California, offers a packaged boiler for wood use which is similar to many gas/oil fired boilers in appearance. The Ray unit is a three pass dry-back firetube boiler available in sizes from 100 to 500 hp. Wood waste is dropped into the combustion chamber from above and burns partially in suspension and partially on the stationary grate. Auxiliary oil/gas firing is available and is used for start-up or instances of wood fuel interruption.

The fuel must be 20% moisture content or less, which makes this unit ideal for furniture or finished lumber plants, but predrying of the fuel would be necessary for the combustion of green chips or wet wood waste. The manufacturer claims a thermal efficiency of 80% and also claims that additional cleanup equipment (besides the cyclone system supplied with the boiler) is rarely required to meet air pollution codes. The manufacturer lists more than ten successful installations to date.

An advantage of the Ray Burner units is the total package design which allows the easy installation of the unit in place of a gas/oil boiler. A cross-section of a typical Ray Burner wood boiler is shown in figure 4-36.

The Bethlehem Corporation

The Boiler Division of the Bethlehem Corporation in Easton, Pennsylvania, markets a package boiler for burning wood waste that
Figure 4-35

HRT BOILER FOR WOOD FIRING
(Courtesy Industrial Boiler Co.)
Figure 4-36

FIRETUBE WOOD BOILER
(Courtesy Ray Burner Co.)
is based on coal burning technology developed in England by G.W.B. Ltd. in the 1950's. The Bethlehem boiler is a three pass firetube boiler of a "wetback" configuration. The wetback design is reported to give greater flexibility to the pressure parts which lowers maintenance requirements and eliminates part of the refractory.

Fuel is introduced into the boiler through the top of the combustion chamber with a pneumatic conveying system. The fuel is thus spread over the burning bed. Integral with the boiler, a mechanical flue gas cleaner is provided which allows for recirculation of the collected flyash to the combustion chamber. Ash removal from the combustion chamber is accomplished manually, and when wood is being burned, the manufacturer claims this can be done once per shift.

Bethlehem supplies multifuel boilers in sizes up to 30,000 lb/hr of steam. A turndown ratio of 3/1 is claimed for wood fuel, and the boilers have a thermal efficiency of up to 83% on coal, so they can be expected to be slightly less efficient on wood, depending on the moisture content. The manufacturer claims that wood waste with a moisture content of up to 25% can be burned in the boiler.

A picture showing the configuration of a typical Bethlehem installation is included in figure 4-37.

**CNB Tri-Fuel Boiler**

The CNB Tri-Fuel Boiler is manufactured by the Combustion Service & Equipment Company in Pittsburgh, Pennsylvania. It was originally marketed as a boiler able to fire coal as well as oil and gas, but several successful installations have been made using wood as a solid fuel. The boiler is a firetube firebox of three-pass wetback design and is available in sizes from 100 to 700 boiler horsepower and in a high pressure (up to 200 psi) or low pressure (15 psi or hot water) configuration.

The CNB boiler is equipped with an underfed stoker for handling wood waste, wood pellets, or coal. A gas/oil integral fan burner is also provided for standby and load swing control.
THREE-PASS WOOD WASTE BOILER
(Courtesy Bethlehem Corp.)
The manufacturer claims a thermal efficiency of 80% for this boiler firing wood waste. Air pollution regulations are met with no additional collectors, and the boiler is reportedly capable of burning 100% wood waste with a moisture content of 30%. Wetter material can be burned if auxiliary fuel is also used. A picture of a typical Tri-Fuel boiler illustrating the overall design is shown in figure 4-38.

Wellons Boilers

Another approach to the wood burning boiler concept is taken by Wellons, Inc., of Sherwood, Oregon. At present, more than 60 wood boilers have been started up by this company, and it is also well known for its lumber dry kilns and wood storage bins. The size range available for their boilers is 3,000 lb/hr of steam to 60,000 lb/hr of steam, with larger systems possible using multiple boilers.

Wellons uses a pile burning system company officials call the "cyclo-blast furnace," which they report is capable of burning wood up to 50% in moisture content with a maximum particle size of 3". The furnace is a refractory chamber which allows complete combustion of the fuel, but reportedly limits turndown ratios although the manufacturers claim 5/1. Load response due to the pile burning design is probably slower than some other configurations.

The Wellons furnace is a watertube design and is equipped with combustion air preheating. Air pollution requirements are met with a multi-cyclone mechanical collector and the furnaces are operated balanced draft with I.D. and F.D. fans. Figure 4-39 gives an overall view of a typical Wellons system.

Deltak Corporation

The Deltak Corporation of Minneapolis, Minnesota, offers several boilers suitable for firing wood and other solid fuels. These boilers are all shop assembled for shipment by conventional means. The "Cub" is produced in sizes for firing wood in the 15,000 to 30,000 lb/hr range.
Figure 4-38

THREE-PASS WOOD BOILER
(Courtesy Combustion Service & Equipment Co.)
Figure 4-39

WOOD FIRED PACKAGE BOILER SYSTEM
(Courtesy Wellons Inc.)
The "Coyote" is built for 30,000 to 150,000 lb/hr, and the "Condor" is built for 40,000 to 100,000 lb/hr.

The Cub contains the furnace and convection sections in a single module, the Coyote is shipped in two or three modules and assembled into a single furnace and convection section, and the Condor contains three basic modules - two separate furnaces and a single convection section.

These boilers are designed for fuel to be fed by any of the conventional wood stokers, such as those systems supplied by Auburn Stoker and McBurney Stoker. The boiler can be auxiliary fired with fossil fuel allowing wet wood fuel to be burned. The manufacturer claims that wood waste with a moisture content up to 55% can be burned, and that boiler efficiencies are in the range of 60% to 70%.

A typical Deltak boiler installation is shown in figure 4-40.

Weiss Boiler Company

The Gebr. Weiss Company of Fronhausen, West Germany, has been supplying boilers to the woodworking industry in Europe for many years and has begun to install its units in this country over the past several years. Their installations tend to be more custom-built in nature than those of some of the other suppliers, particularly since the entire boiler assemblies are shipped from Germany pre-assembled.

Weiss manufactures a line of watertube boilers called the "Compact" series which are available in many configurations ranging in size from 2,400 lb/hr to 50,000 lb/hr of steam. These become very much custom installations depending upon the customer's needs and are available with shaft furnaces, inclined grates, or steam grates. Auxiliary firing of oil or gas is provided with most of these units. Depending on the fuel and the regulations, most of these units can meet particulate standards with mechanical collectors. A typical Weiss "Compact" installation is shown in figure 4-41.

Weiss also supplies large field-erected radiant boilers in capacities up to 140 million Btu/hr.
Figure 4-40

MODULAR WOOD FIRED PACKAGE BOILER
(Courtesy Deltak Corporation)
Figure 4-41

"COMPACT" WOOD WASTE BOILER
(Courtesy Energy Control Engineering Corp.)
There are several other manufacturers of wood fired package boilers that will not be considered here, but are included in the list of manufacturers to be found in Appendix B. The systems offered by these suppliers are similar to one or more of the systems already discussed.

The first cost of wood burning package boilers can be quite high, as shown in figure 4-42. The cost curves in this figure are based on typical "turnkey" jobs installed by various boiler manufacturers and include fuel metering, controls, a limited amount of wood handling equipment, and air pollution control devices. The less expensive range of boilers are generally the ones with the least flexibility with regard to the quality of fuel that may be burned. As with suspension wood burners, even the smallest package boilers require a given amount of solids handling equipment and control systems so that the system cost per pound of steam is much higher for the smaller systems. As can be seen from figure 4-42, a given size of wood package boiler will generally have a first cost of three to four times that of a comparable gas/oil boiler.

It may be difficult to retrofit an existing steam plant with a wood fired package boiler due to space limitations. Wood systems generally require a greater area for wood handling and storage, and the combustion volumes are much greater than gas or oil, dictating a larger physical size for a given steam output.

The major conclusion to be drawn about wood fired package boilers is that as a class they represent a system that is considered fully commercial. Depending on the type of wood waste to be used, an industrial customer should be able to receive at least several bids on a complete wood burning system. The cost will be substantially higher than the traditional gas/oil package boiler, but the payback time due to fuel cost savings can be attractive.

In general, it can be said that most wood-fired package boilers on the market today are automated or nearly automated. Many systems require only infrequent operator attention, and most of the system malfunctions will occur in the wood handling system. Most package boilers will require some kind of collection devices to meet local air pollution codes, and the prospective industrial customer would do well to check out all the local regulations before signing a contract. In addition, the contract should ensure that the boiler manufacturer or builder will guarantee compliance with the air pollution regulations.
Figure 4-42

COST OF WOOD ENERGY SYSTEMS

Wood Fired Package Boiler Systems

Field Erected Wood-Fired Boilers

Wood Gasifier Retrofits

Oil/Gas Package Boilers

10,000 lbs steam/hr

100,000

100 300 500 1000

Boiler Horse Power

Capital Cost (dollars/lb/hr of steam)
As with most large purchases of this type, the customer should visit a working installation similar to what his will become, if possible. Most boiler manufacturers will be glad to help arrange such a visit.
Appendix L

WOOD TRANSPORTATION BY WATER
January 12, 1983

Mr. Dave Harris
Georgia Tech University
EES-TAL
O'Keefe Building - Room 217
Atlanta, Georgia 30332

Dear Dave:

As per your request, here is a summary of my findings of the economics of barging biomass from Columbus, Georgia to St. Marks, Florida. You indicated that the movement would require approximately 2300 net tons of material per day and would stow at a factor of 23 - 25 pounds per cubic foot. Basis a potential truck rate of approximately $6.00 to $6.50 per net ton, I found no barging scenario that would enable us to come close to being competitive. The problem is compounded by the fact that in most cases, the material handling requirements for barge movements (to load and unload) would be higher than for truck movements.

As we discussed, the greater the distance, the more competitive the barge mode becomes vis-a-vis truck and rail. Movements originating on the Gulf Intracoastal Canal or a larger waterway, such as the Warrior - Tombigbee would in all likelihood improve the competitive aspects of a potential barge movement.

Parker Towing Company has been in the barge and towing business for over forty years and our current fleet consist of fifteen (15) towboats, 135 hopper barges and four (4) tank barges.

I'll be glad to work with you and your associates on this project if you so desire.

Sincerely,

Tim Parker, Jr.

TPJr/b

Enclosures
January 5, 1983

Mr. David Harris
Georgia Tech.
Atlanta, Georgia, 30332

Dear Mr. Harris:

Your inquiry concerning the movement of wood chips from Chattahoochee, Florida to St. Marks, Florida has been studied and we have resolved the following for your consideration.

1. The equipment required would entail the use of two tug boats. One push boat for the rivers, and one model bow tug for the open water portion of the voyage.

2. To move the volume of material requested, on a daily basis, as we see it, could require 12 "load line" barges.

3. Per our telephone conversation of January 4, 1983, the figure of approximately $3.75 per ton is a figure you should use in preliminary computations only. Please bear in mind that this number cannot be binding since the availability and quantity of load line equipment has not been fully investigated. To maximize the efficiency required for a job of this magnitude, several combinations of barges could be used, ie, 50' X 250', 195' X 35', one giant load line barge for open water, all of which will result in cost changes that cannot be estimated at this point in time.

As your needs become more clear, we will be glad to put a total transportation package together for your consideration.

Sincerely,

Don Childress
December 28, 1982

Mr. David Harrison
% Georgia Tech E.E.S. - TAD
Okeefe Bldg. Room 217
Atlanta, Georgia 30332

Re: Biomass transportation
Apalachicola to St. Marks,
Florida

Dear David,

In response to our conversation of 17 Dec. I have the following responses and suggestions to make.

Enclosed is a drawing of a standard hopper (open) barge and their dimensions. A regular river barge 195x35 (outside dimensions) usually has an inside dimension of 155-165 Ft. long 26.5 to 28 Ft. in width (inside) so from this you can figure your cubic and tonnage.

My suggestion, in order to increase tonnage per barge would be to build extensions above the hopper comings to give increased capacity up to the stability recommendations and to a 7 foot maximum draft on the barge. A 7 foot draft would be a nominal draft that we could work with on the Apalachicola River. There are two factors to take into consideration by building cage extensions on these barges. Would rain water or salt water spray from crossing the Gulf have any effect? If any of these would be detrimental, then we could revert to a covered barge with limited capacity.

Part II Cost:
Marine equipment; barges, boats etc. cost more when chartered for short term periods and when barges can be chartered yearly or longer you can attain better rates. For example:

<table>
<thead>
<tr>
<th>Barge Type</th>
<th>Daily</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>195x35 open hopper</td>
<td>$120 - 140 plus Ins.</td>
<td>$50,00 plus Ins.</td>
</tr>
<tr>
<td>Push boat (1400)</td>
<td>$240 Fully Paid</td>
<td>$1850.00 FF</td>
</tr>
</tbody>
</table>
Part III  Operation Time:
I estimate that on a yearly average we can figure being able to run 6 out of 7 days. The lost day can be attributed to waiting on suitable weather to cross the open water between Apalachicola and St. Marks.

My suggestion on the number of barges (195x35) would be 2, we could make better running time and decrease our exposure in the Gulf with a two barge tow as compared to 4 barges.

David, I hope that answers most of your questions on this movement. As I expressed the other day, P&S would like to participate in a trial movement, so we could pinpoint our cost, running time and give you a chance to check on loading and discharge times. We would do this at a rate of $1950.00 per day on the tug and whatever the cost of chartering barges and insurance, we would just pass this on at our cost.

If I can be of any further assistance to you in this matter please call me at anytime.

Wishing you a Happy New Year, I remain,

Respectfully,

Charles E. (Bud) Smith, Jr.
Vice President
P&S Marine Builders & Repair Co.
HOPPER BARGES

Hoppers are usually of double-hull construction, wherein the sides and bottom of the cargo hold are separated from the hull by void spaces. These barges are designed for efficient transport of commodities in bulk, such as grain, coal, sugar, ore, steel, aggregates, timber products and numerous other cargos.

Hopper barges have a boxed, semi-raked, or double-raked hull configuration. The hoppers may be covered or open. Covers provide protection of cargos from outside elements. Covers may be roll-top (telescoping), or lift-off (stacking) type.

<table>
<thead>
<tr>
<th>McDONOUGH BARGE SIZE</th>
<th>APPROXIMATE SHORT TON CARGO CAPACITY AT FREEBOARDS OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>175' x 35' x 11'</td>
<td>1' 2 3 4</td>
</tr>
<tr>
<td>195' x 35' x 11'</td>
<td>1800 1000 800 500</td>
</tr>
<tr>
<td>195' x 35' x 12'</td>
<td>1840 1100 840 600</td>
</tr>
<tr>
<td>200' x 35' x 12'</td>
<td>1910 1210 1100 910</td>
</tr>
</tbody>
</table>

These sketches show the typical configurations of hopper barges.
January 31, 1983

Mr. David Harris
Wood Energy Division
Engineering Experiment Station
Room 222, O'Keefe Building
Georgia Institute of Technology
Atlanta, Georgia

Dear David:

As requested, I've enclosed the wood price information from the December Timber Mart-South. All prices have been converted to a per ton basis. Whether you use stumpage and add logging and transportation or use the delivered price, the cost of loading the barges will need to be added.

I spoke with Calvin on Friday, and discussed with him the changes he wanted. I will be working on these this week and hope to have the finished product to you shortly thereafter.

Sincerely,

Charles H. Houder, III

Enclosure
## Prices for Stumpage and Wood Delivered to Ports Within the St. Marks Barge Area
(Dollars per Green Ton)

<table>
<thead>
<tr>
<th></th>
<th>Pensacola</th>
<th>Tampa</th>
<th>Columbus</th>
<th>Mobile</th>
<th>New Orleans</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stumpage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hdw. pulpwood</td>
<td>1.61</td>
<td>1.25</td>
<td>1.52</td>
<td>1.96</td>
<td>1.61</td>
</tr>
<tr>
<td>Pine pulpwood</td>
<td>7.93</td>
<td>7.57</td>
<td>6.13</td>
<td>6.49</td>
<td>5.41</td>
</tr>
<tr>
<td>Hdw. sawtimber</td>
<td>5.59</td>
<td>4.82</td>
<td>5.80</td>
<td>7.06</td>
<td>5.06</td>
</tr>
<tr>
<td><strong>Delivered</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hdw. pulpwood*</td>
<td>11.61</td>
<td>10.71</td>
<td>10.00</td>
<td>11.43</td>
<td>13.21</td>
</tr>
<tr>
<td>Pine pulpwood*</td>
<td>18.02</td>
<td>15.86</td>
<td>16.04</td>
<td>18.02</td>
<td>16.40</td>
</tr>
<tr>
<td>Hdw. whole-tree</td>
<td>-</td>
<td>11.00</td>
<td>-</td>
<td>-</td>
<td>11.00</td>
</tr>
<tr>
<td>Pine whole-tree</td>
<td>-</td>
<td>13.00</td>
<td>12.00</td>
<td>11.50</td>
<td>12.50</td>
</tr>
<tr>
<td>Hdw. clean chips</td>
<td>-</td>
<td>14.50</td>
<td>14.00</td>
<td>15.50</td>
<td>14.00</td>
</tr>
<tr>
<td>Pine clean chips</td>
<td>23.50</td>
<td>23.00</td>
<td>23.50</td>
<td>24.00</td>
<td>24.75</td>
</tr>
<tr>
<td>Hdw. sawtimber</td>
<td>10.00</td>
<td>11.18</td>
<td>11.47</td>
<td>14.71</td>
<td>13.18</td>
</tr>
</tbody>
</table>

*F.O.B. Woodyard